

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
<u>11 prel</u> A measurement system comprising:	Without conceding that the preamble of Claim 11 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, measurement systems, either literally or under the doctrine of equivalents. For example, Samsung provides a system including a Galaxy Watch Ultra, a Samsung smartphone or tablet, and Samsung Cloud (“system”) for measuring a user’s heart rate, blood oxygen level, and electrocardiogram (“ECG”). 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 transfers the information to an Accused Phone/Tablet and to the Accused Cloud.

¹ 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. 10,874,304 (the “’304 Patent”)

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

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

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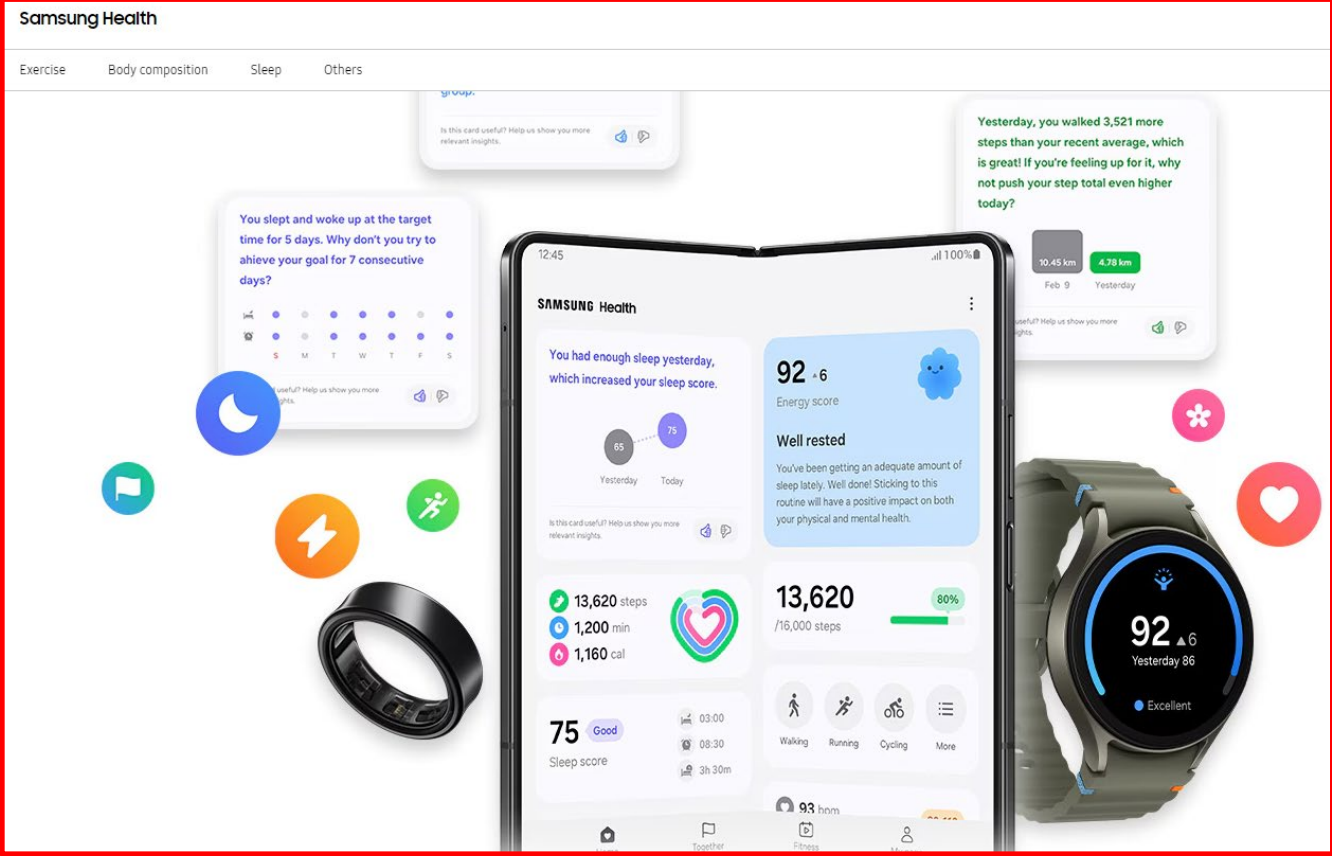
“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'304 Patent Claim	Samsung Accused System ¹
	Medical Health & wearables AFE4490 PPG-2 LED, 1 PD 110 dB dynamic range AFE4403 PPG-3 LED, 1 PD 110 dB dynamic range AFE4400 PPG-2 LED, 1 PD 95 dB dynamic range AFE4460 PPG-32 LED, 4 PD 115 dB signal-to-noise ratio AFE4432 PPG-4 LED, 3 PD 115 dB signal-to-noise ratio AFE44S30 PPG-8 LED, 4 PD 108 dB signal-to-noise ratio AFE44I30 PPG-6 LED, 4 PD 108 dB signal-to-noise ratio Optical biosensing Multimodal biosensing Biopotential Heartrate & SpO₂ ECG or EEG ECG & Respiration ECG, Respiration & Pace

Source: <https://www.ti.com/data-converters/integrated-special-function/medical-afes/biosensing-afes/overview.html>

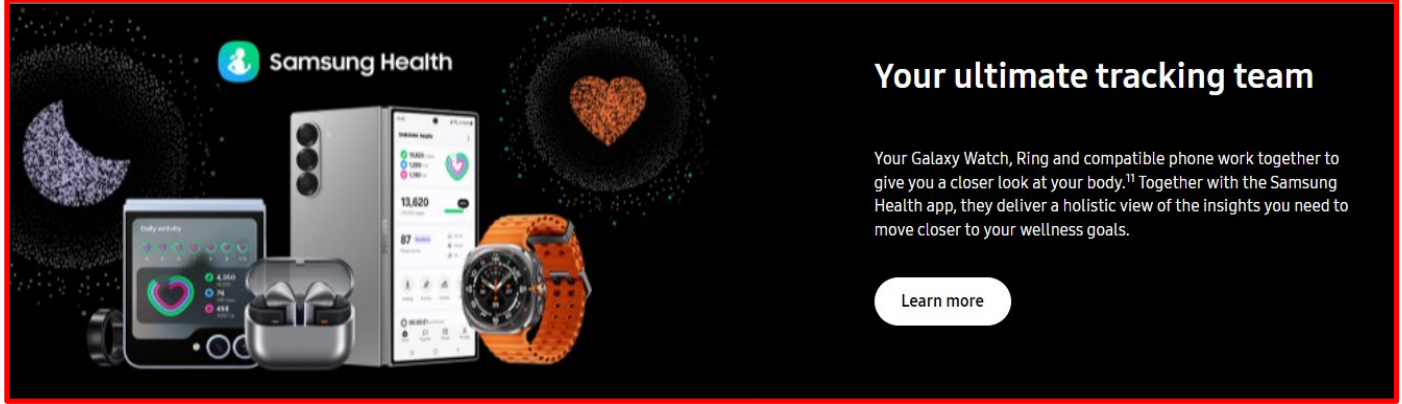
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	The image shows a screenshot of the Samsung Health app interface. At the top, there are tabs for 'Exercise', 'Body composition', 'Sleep', and 'Others'. Below these, there are several health-related cards and icons. A card on the left says 'You slept and woke up at the target time for 5 days. Why don't you try to achieve your goal for 7 consecutive days?'. Another card in the center says 'You had enough sleep yesterday, which increased your sleep score.' and shows a sleep score of 75. To the right, there's a card about walking steps: 'Yesterday, you walked 3,521 more steps than your recent average, which is great!'. Below these, there's a section for 'Energy score' showing 92 and 'Well rested' status. Further down, it displays '13,620 steps' and '1,200 min' of activity. At the bottom, there's a 'Sleep score' of 75 and a '7h 30m' sleep duration. To the right of the app interface is a Samsung Watch displaying a large '92' on its screen. Various health icons like a heart, a person running, and a light bolt are scattered around the app interface. 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/

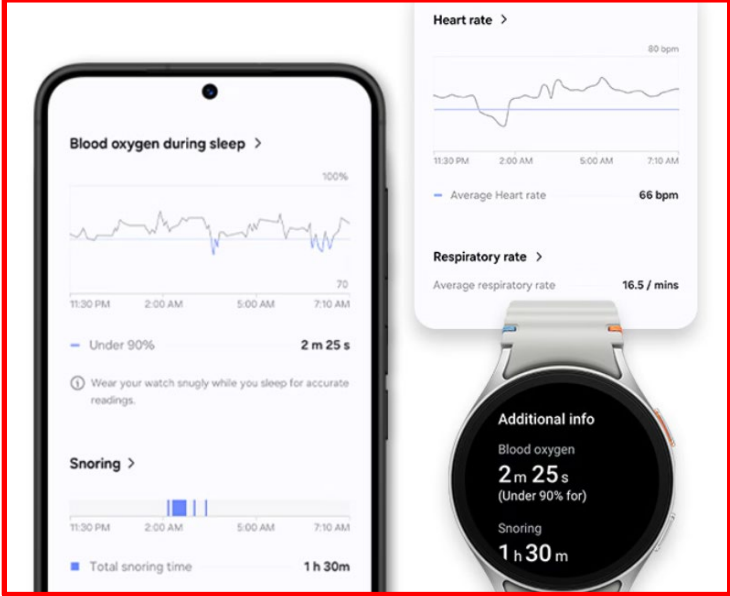
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'304 Patent Claim	Samsung Accused System ¹
	Pairs well with Experience a smarter life with a Galaxy that'll keep up with you.  Galaxy Watch Ultra  Galaxy Z Fold6  Galaxy Z Flip6 Source: https://www.samsung.com/us/apps/samsung-health/

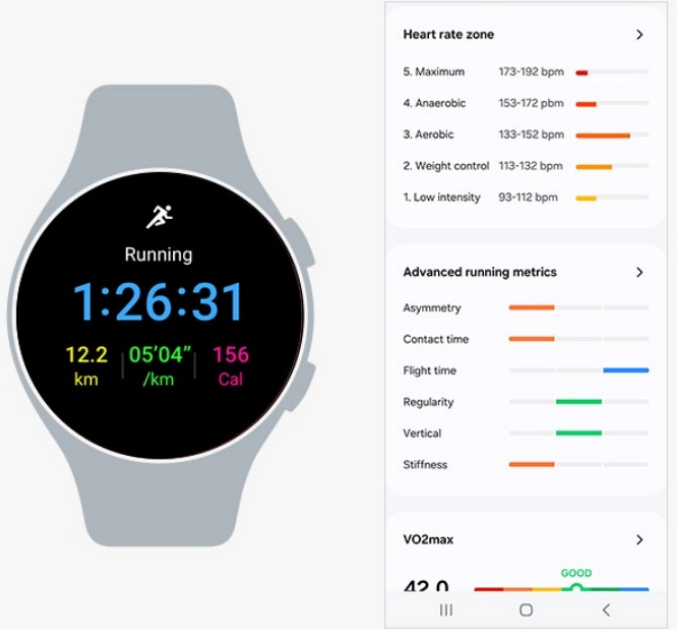
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'304 Patent Claim	Samsung Accused System ¹
	 The image shows a smartphone screen and a Samsung Watch displaying sleep-related data from the Samsung Health app. The smartphone screen displays 'Blood oxygen during sleep' with a line graph showing oxygen levels over time (11:30 PM to 7:10 AM). It also shows 'Snoring' with a bar chart and 'Total snoring time' of 1 h 30m. The Samsung Watch displays 'Additional info' including 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. A red box highlights the smartphone screen and the watch. Source: https://www.samsung.com/us/apps/samsung-health/

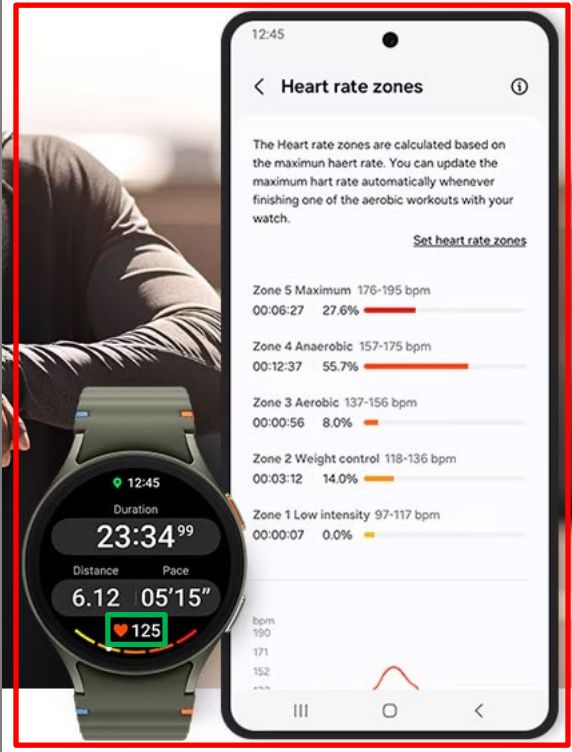
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'304 Patent Claim	Samsung Accused System ¹
	Monitor your workout results on your watch or smartphone.  Source: https://www.samsung.com/us/apps/samsung-health/

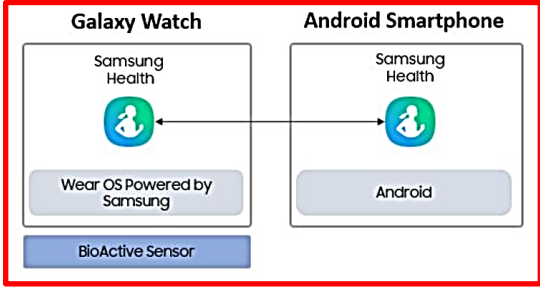
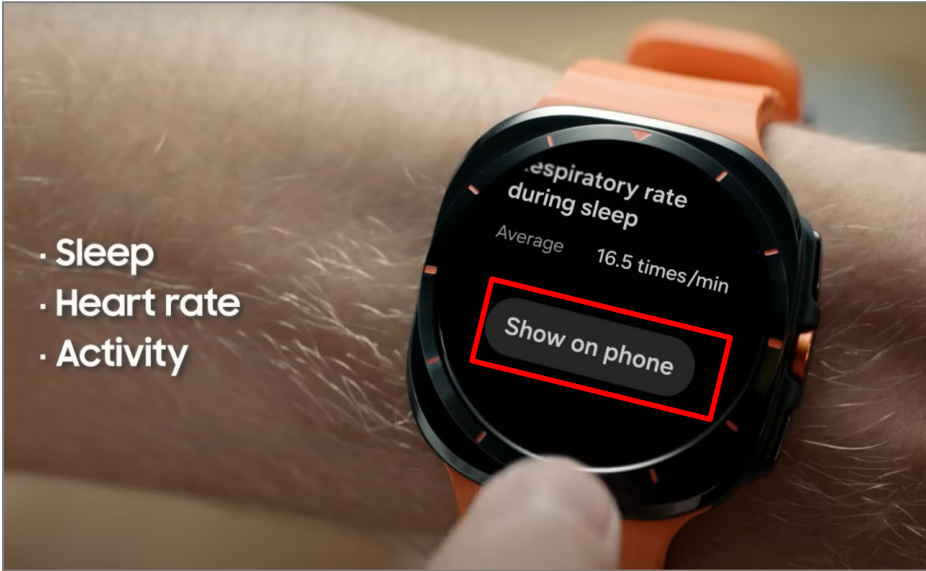
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	 Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life

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'304 Patent Claim	Samsung Accused System ¹
	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.  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/ <u>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.</u> 1 Navigate to and open the Samsung Health app. Tap More options (the three vertical dots), and then tap Settings. 2 <u>Tap Sync with Samsung Cloud, and then tap the switch at the top of the screen.</u> 3 Additionally, you can tap Sync using to select Wi-Fi only or Wi-Fi and mobile data. 4 <u>Tap Sync now to immediately sync your Samsung Health data.</u> 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/
11[a] a wearable measurement device for measuring one or more physiological	The Accused System comprises a wearable measurement device for measuring one or more physiological parameters, including a light source comprising a plurality of semiconductor sources.

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parameters, including a light source comprising a plurality of semiconductor sources	For example, the Accused Smartwatch (“wearable measurement device”) is worn on the wrist of the user for measuring the user’s heart rate.  Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

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'304 Patent Claim	Samsung Accused System ¹
	 More precise <u>Heart Rate Tracking</u> Zero in on more precise readings during workouts using Heart Rate Tracking^{3, 4, 5} with Galaxy AI² that filters out the physical movements of your body. Insights are collected by your Watch and analyzed on your phone. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

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	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ The Accused Smartwatch includes a light source comprising multiple light emitting diodes (“LEDs”), such as a green LED, a red LED, and an infrared LED, each of which includes a “semiconductor source.” 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

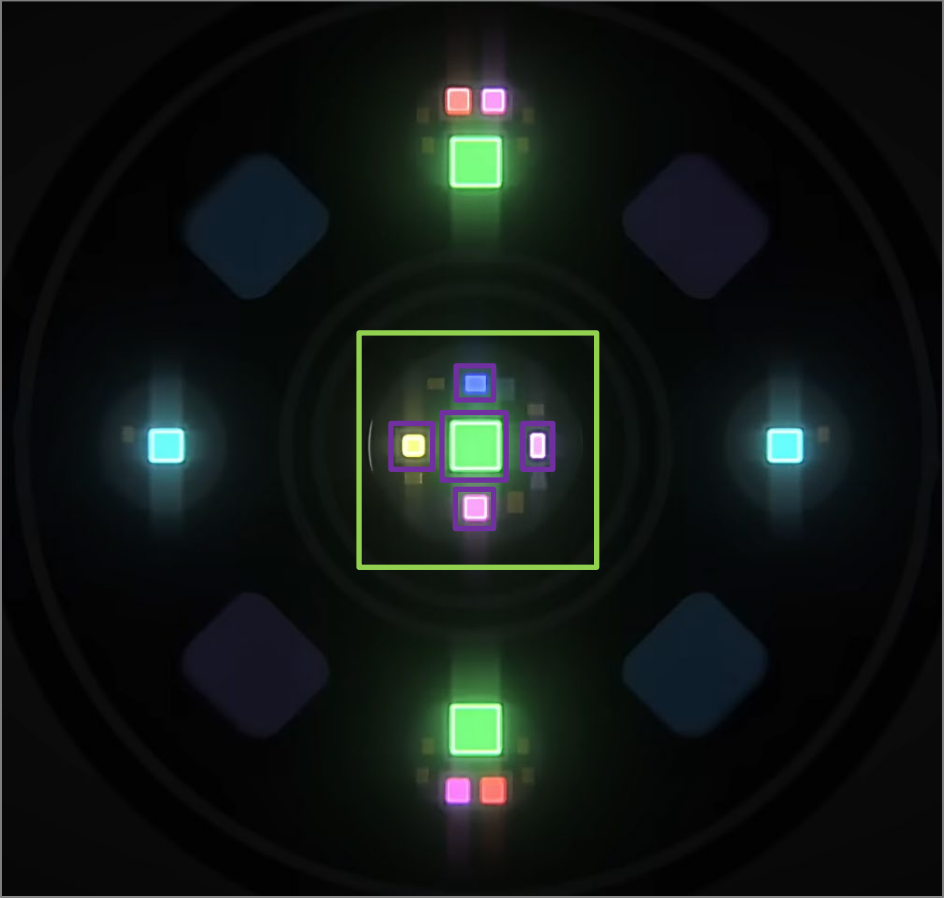
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	Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor Samsung further states that “[t]he optimal allocation of Green, Red and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure, blood oxygen levels and stress levels. Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor  The diagram shows the back of a black Samsung Galaxy Watch. Four labels with dashed lines point to specific features: 'Quick Button' points to a small orange button at the top; 'Dynamic Lug System' points to a white circular feature on the right side; 'Dual-Frequency GPS' points to a white circular feature on the bottom left; and 'BioActive Sensor' points to a white circular feature on the bottom right. The watch is shown with orange straps.

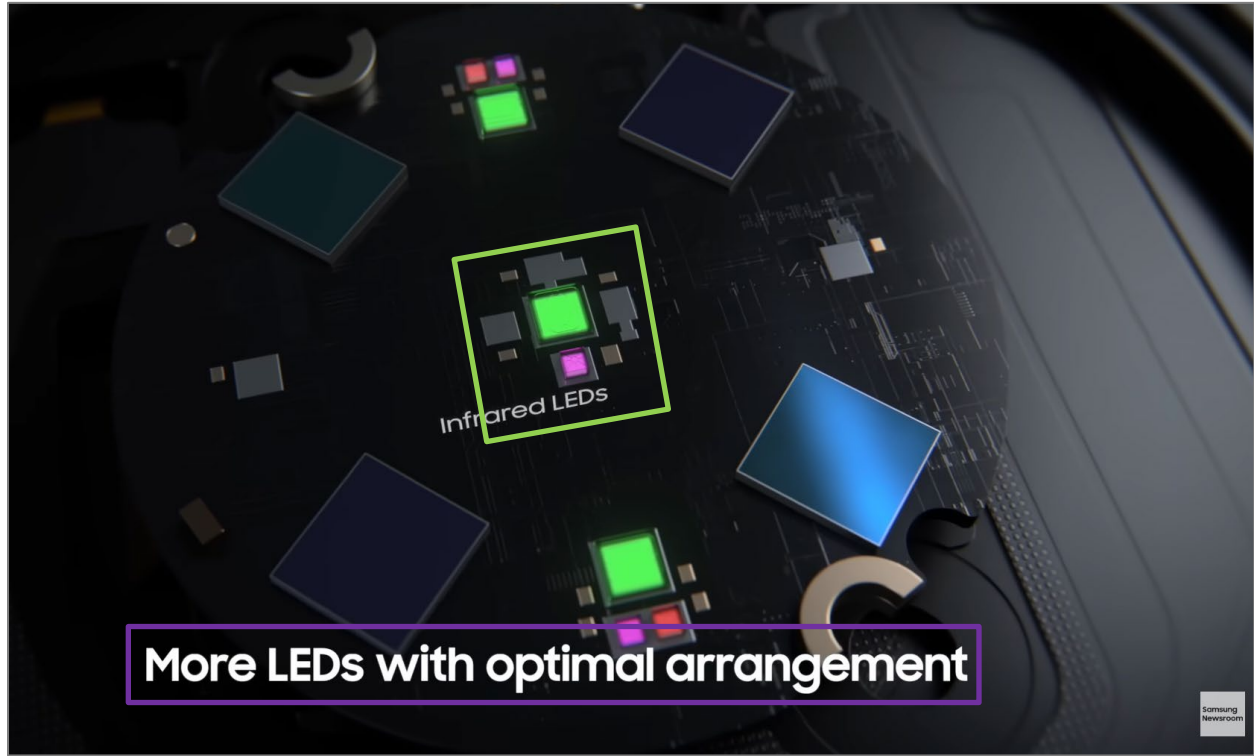
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	Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/  Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

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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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’304 Patent Claim	Samsung Accused System ¹
	Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327
11[b] that are configured to generate an output optical beam with one or more optical wavelengths;	In the Accused Smartwatch, the plurality of semiconductor sources are configured to generate an output optical beam with one or more optical wavelengths. For example, the Accused Smartwatch includes multiple LEDs (“semiconductor sources”), such as a green LED, a red LED, and an infrared LED. Different color LEDs and infrared LEDs each generate an output optical beam with one or more optical wavelengths. 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

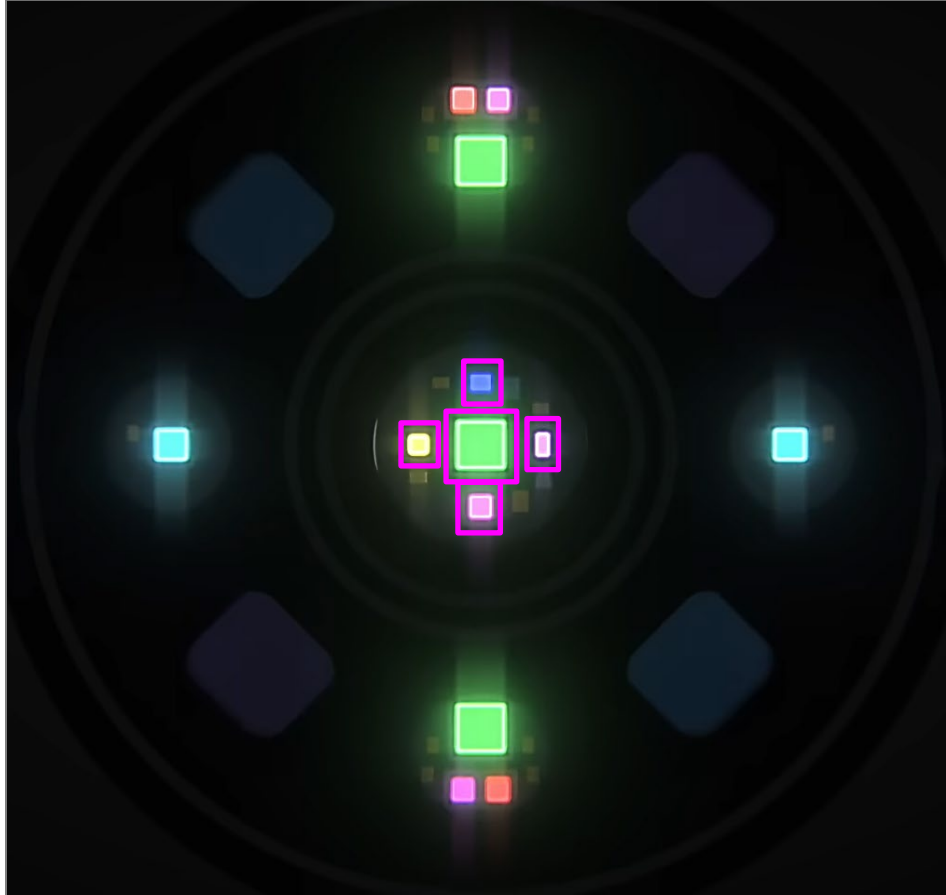
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	Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor The following data types are supported by the Samsung Privileged Health SDK: <table border="1" data-bbox="506 467 1524 889"><tr><td data-bbox="506 467 978 605">PPG green</td><td data-bbox="978 467 1524 605">Raw data from PPG <u>green</u> LED. Provided as a batching event.</td></tr><tr><td data-bbox="506 605 978 760">PPG IR</td><td data-bbox="978 605 1524 760">Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 760 978 889">PPG red</td><td data-bbox="978 760 1524 889">Raw data from PPG <u>red</u> LED. 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	PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.	PPG IR	Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.	PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.
PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.						
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PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.						

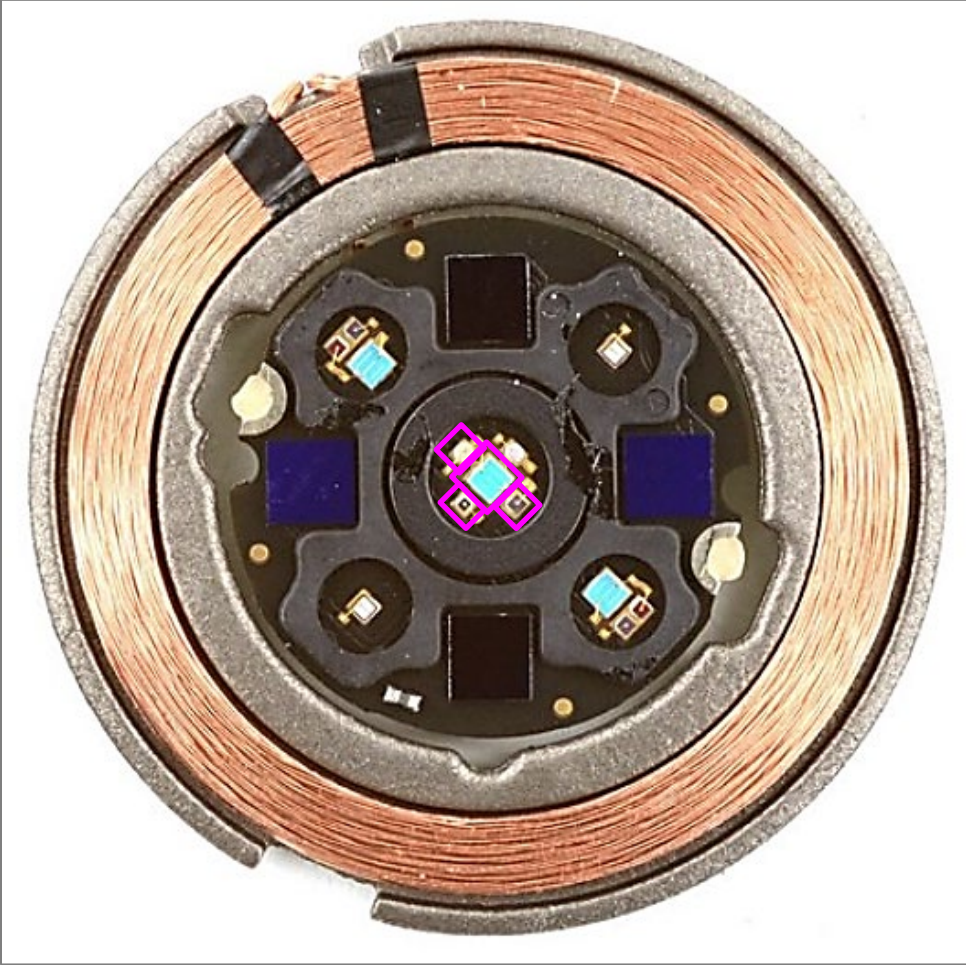
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	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

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

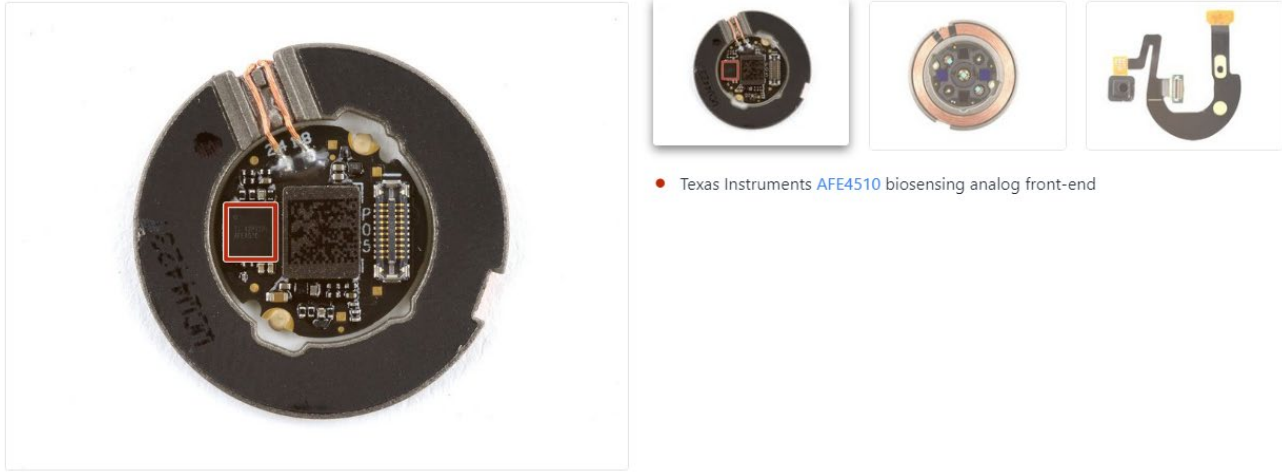
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	LEDs outputting light at different colors do so at different optical wavelengths. For example, a green LED, a red LED, and an infrared LED all output light at different optical wavelengths: <table border="1" data-bbox="510 358 1495 1156"> <thead> <tr> <th data-bbox="510 410 905 464">LED Wavelength (Color)</th><th data-bbox="905 410 1495 464">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="510 464 905 518">410–420 nm (Violet)</td><td data-bbox="905 464 1495 518">Skin therapy</td></tr> <tr> <td data-bbox="510 518 905 571">430–470 nm (Blue)</td><td data-bbox="905 518 1495 571">Dental curing instruments</td></tr> <tr> <td data-bbox="510 571 905 625">470 nm (Blue)</td><td data-bbox="905 571 1495 625">White LEDs using phosphor</td></tr> <tr> <td data-bbox="510 625 905 678">520–530 nm (Green)</td><td data-bbox="905 625 1495 678">Green traffic signal lights</td></tr> <tr> <td data-bbox="510 678 905 732">580–590 nm (Amber)</td><td data-bbox="905 678 1495 732">Amber traffic signal lights</td></tr> <tr> <td data-bbox="510 732 905 786">630–640 nm (Red)</td><td data-bbox="905 732 1495 786">Red signal lights</td></tr> <tr> <td data-bbox="510 786 905 839">660 nm (Deep Red)</td><td data-bbox="905 786 1495 839">Blood oximetry</td></tr> <tr> <td data-bbox="510 839 905 893">680 nm (Deep Red)</td><td data-bbox="905 839 1495 893">Blood analysis</td></tr> <tr> <td data-bbox="510 893 905 946">800–850 nm (Near-IR)</td><td data-bbox="905 893 1495 946">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="510 946 905 1000">850–940 nm (Near-IR)</td><td data-bbox="905 946 1495 1000">Photoelectric controls</td></tr> <tr> <td data-bbox="510 1000 905 1053">940 nm (Near-IR)</td><td data-bbox="905 1000 1495 1053">Covert illumination CCD-based systems</td></tr> </tbody> </table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706	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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11[c] the light source configured to increase signal-to-noise ratio by	In the Accused Smartwatch, the light source is configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources.																								

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increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources;	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 the peak SNR, the sensor is configured to increase the LED current (“light intensity”) of the LEDs (“semiconductor sources”). Step 6 Bio Sensor Assembly  Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsItd=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.

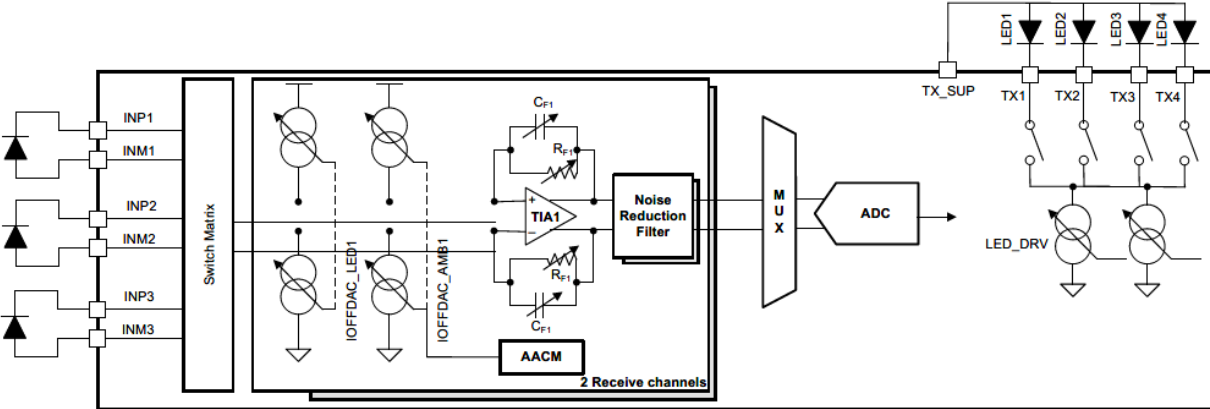
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	3 Description The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bio-impedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver 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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	Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-4, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf. 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, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

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	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, available at https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	“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. “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, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor <pre> graph LR Watch[BioActive Sensor Watch] --> SD[Sensor Data] SD --> SDK[Samsung Privileged Health SDK] SDK -- "Tracking Raw / Processed Health Sensor Data" --> App[Wear OS Application] </pre>

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

'304 Patent Claim	Samsung Accused System ¹
	“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
11[d] the wearable measurement device configured to receive a portion of the output optical beam and to deliver an analysis output beam to a sample;	The Accused System comprises a wearable measurement device 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 (“wearable measurement device”) comprises one or more lenses positioned between LEDs and the wrist of a user when worn by the user. The lenses receive a portion of the output optical beam from the LEDs and deliver the analysis output beam to a tissue sample of the user (e.g., skin, blood vessels, veins).

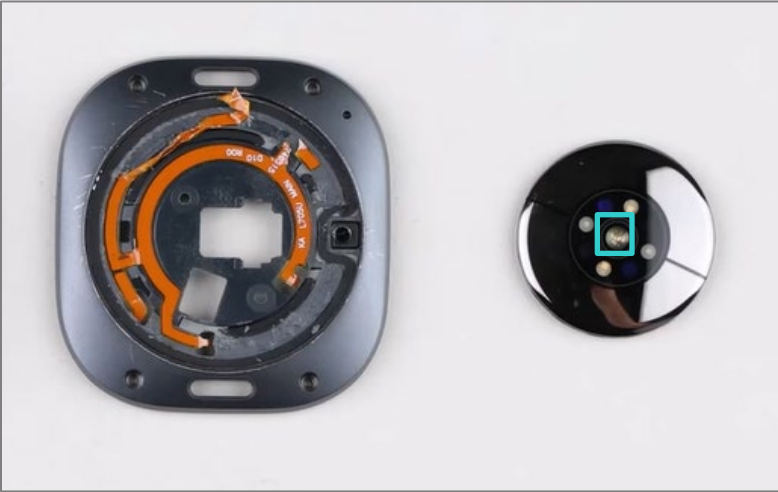
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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’304 Patent Claim	Samsung Accused System ¹
	 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 (“lens output light to tissue”).

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’304 Patent Claim	Samsung Accused System ¹
	 Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0  Source: https://www.youtube.com/watch?v=jlW0i7u4FVk

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’304 Patent Claim	Samsung Accused System ¹
	Additionally, in a technical paper, Samsung engineers and pixel designers for photoplethysmography (“PPG”) sensors explained “applying micro lenses” and using “micro lens focusing” techniques to enhance the delivery of infrared (“IR”) light sources. J. Lim et al., “A single chip PPG sensor with enhanced IR sensitivity for low power and small size,” 2021 IS&T Int’l Symp. Elec. Imaging, at 2-3, <i>available at</i> https://library.imaging.org/admin/apis/public/api/ist/website/downloadArticle/ei/33/7/art00002. 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. The Accused Smartwatch (“wearable measurement 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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	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:

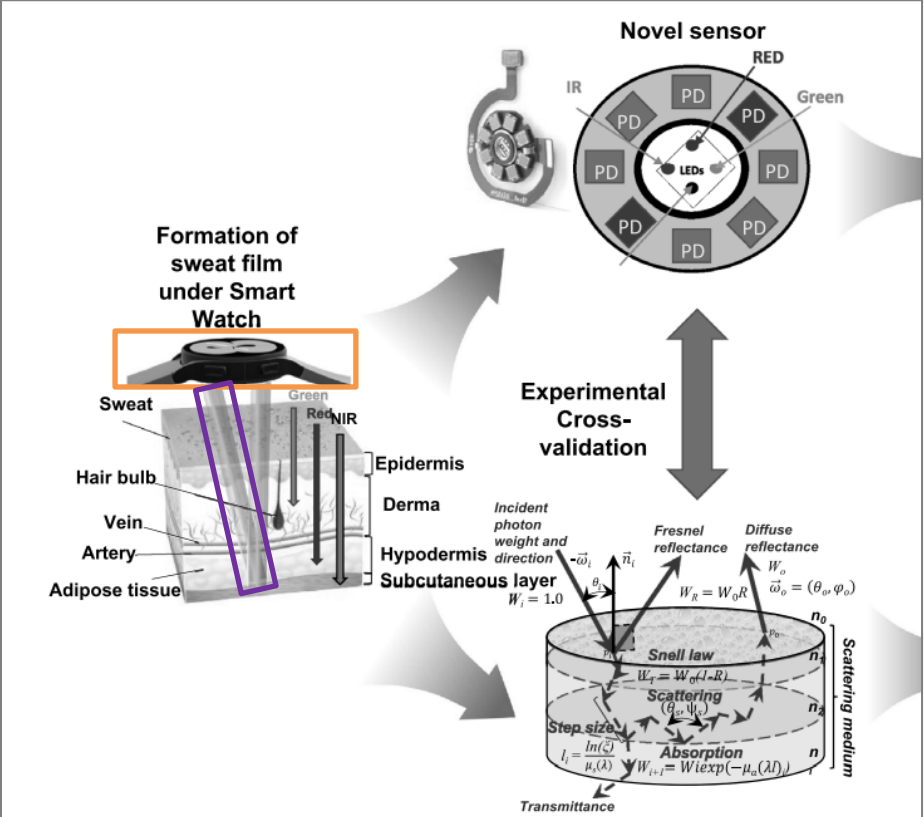
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’304 Patent Claim	Samsung Accused System ¹
	Application <i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate.</i> For a healthy individual, the heart pumps blood to all parts of the body 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.

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'304 Patent Claim	Samsung Accused System ¹
	Additionally, the following scientific report authored by multiple Samsung engineers further shows an analysis output beam being delivered to a tissue sample 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.

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11[e] the wearable measurement device further comprising a receiver configured to: receive and process at least a portion of the analysis output beam reflected or transmitted from the sample, generate an output signal representing at least in part a non-invasive measurement on blood contained within the sample,	The wearable measurement device of the Accused System further comprises a receiver configured to: receive and process at least a portion of the analysis output beam reflected or transmitted from the sample and generate an output signal representing at least in part a non-invasive measurement on blood contained within the sample. For example, the BioActive Sensor in the Accused Smartwatch (“wearable measurement device”) comprises a receiver that: (a) receives and processes a portion of the analysis output beam reflected or transmitted from the tissue sample, and (b) generates an output PPG signal representing at least in part a non-invasive measurement on blood contained within the tissue sample. The diagram shows a side view of a smartwatch with a circular face and a strap. Various components are labeled with lines pointing to them: 'Optical bio-signal sensor' (on the back of the case, highlighted with a red box), 'Microphone' (on the side), 'Speaker' (on the side), 'Electrical bio-signal sensors' (on the back of the case), 'Band release button' (on the side), 'Band' (the strap), 'Pressure vent' (on the back of the case), and 'Infrared temperature sensor' (on the back of the case). 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.

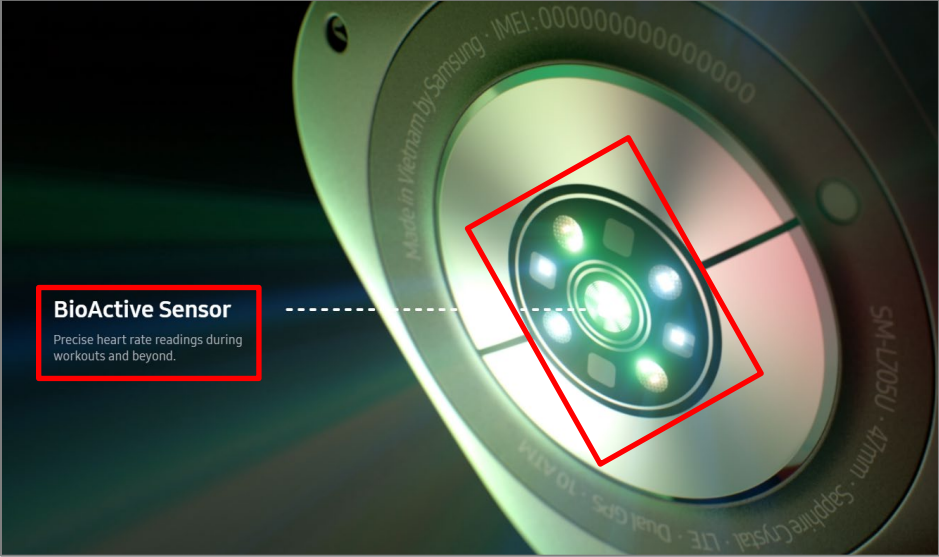
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	 The diagram shows the back of a Samsung Galaxy Watch Ultra with a black case and a brown leather strap. Four features are labeled with dashed lines pointing to them: 'Quick Button' at the top center, 'Dynamic Lug System' at the top right, 'Dual-Frequency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

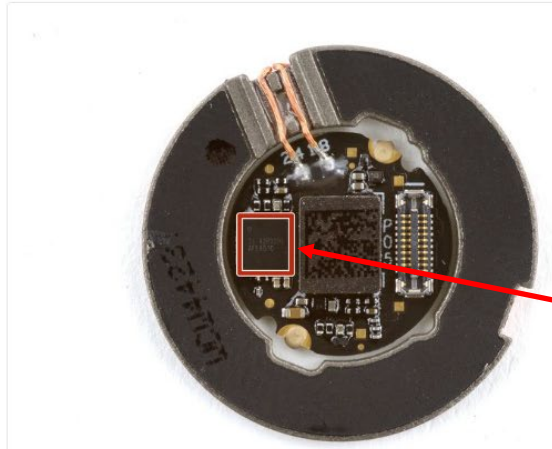
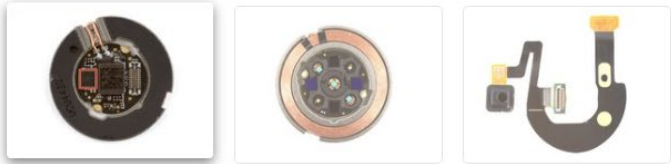
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'304 Patent Claim	Samsung Accused System ¹
	 BioActive Sensor Precise heart rate readings during workouts and beyond. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

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'304 Patent Claim	Samsung Accused System ¹
	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 The AFE4510 specification (excerpts shown below) describes a PPG signal receiver, a PPG signal transmitter, and PPG signal acquisition functionality for receiving and processing at least a portion of the analysis output beam 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.

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	 TEXAS INSTRUMENTS AFE4510 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

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Simplified Schematic

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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	The BioActive Sensor (“receiver”) in the Accused Smartwatch is configured to receive and process at least a portion of the analysis output beam that is reflected from a body tissue sample of the user and to generate an 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:

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’304 Patent Claim	Samsung Accused System ¹
	<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 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). 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.

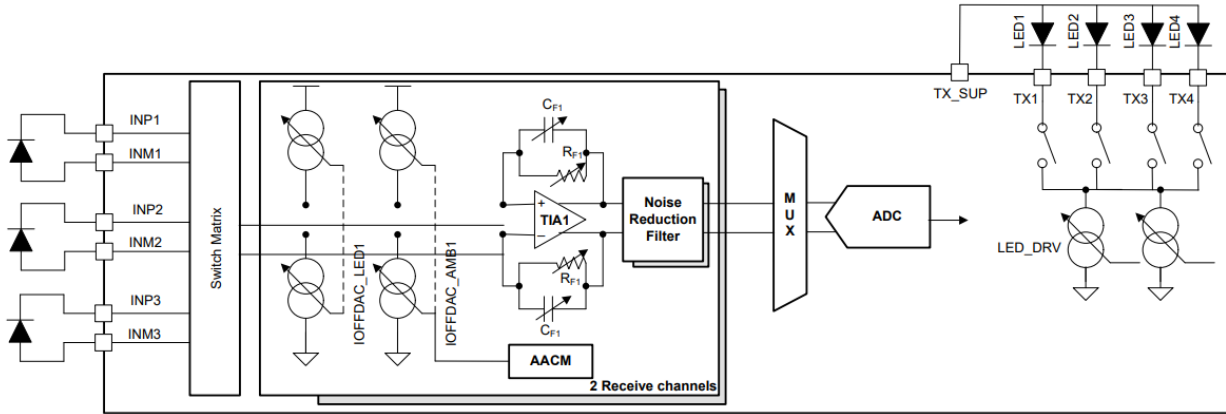
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'304 Patent Claim	Samsung Accused System ¹
	Figure 1. Heart Rate Monitoring on a Wearable Device Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf. An exemplary “PPG signal chain” for a TI AFE biosensor (shown below) further illustrates how the BioActive Sensor (“receiver”) of the Accused Smartwatch is configured to receive and process at least a portion of the analysis output beam that is reflected from a body tissue sample of the user and to generate an output PPG signal.

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	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 receiver configured to receive and process at least a portion of the analysis output beam that is reflected from a body tissue sample of the 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

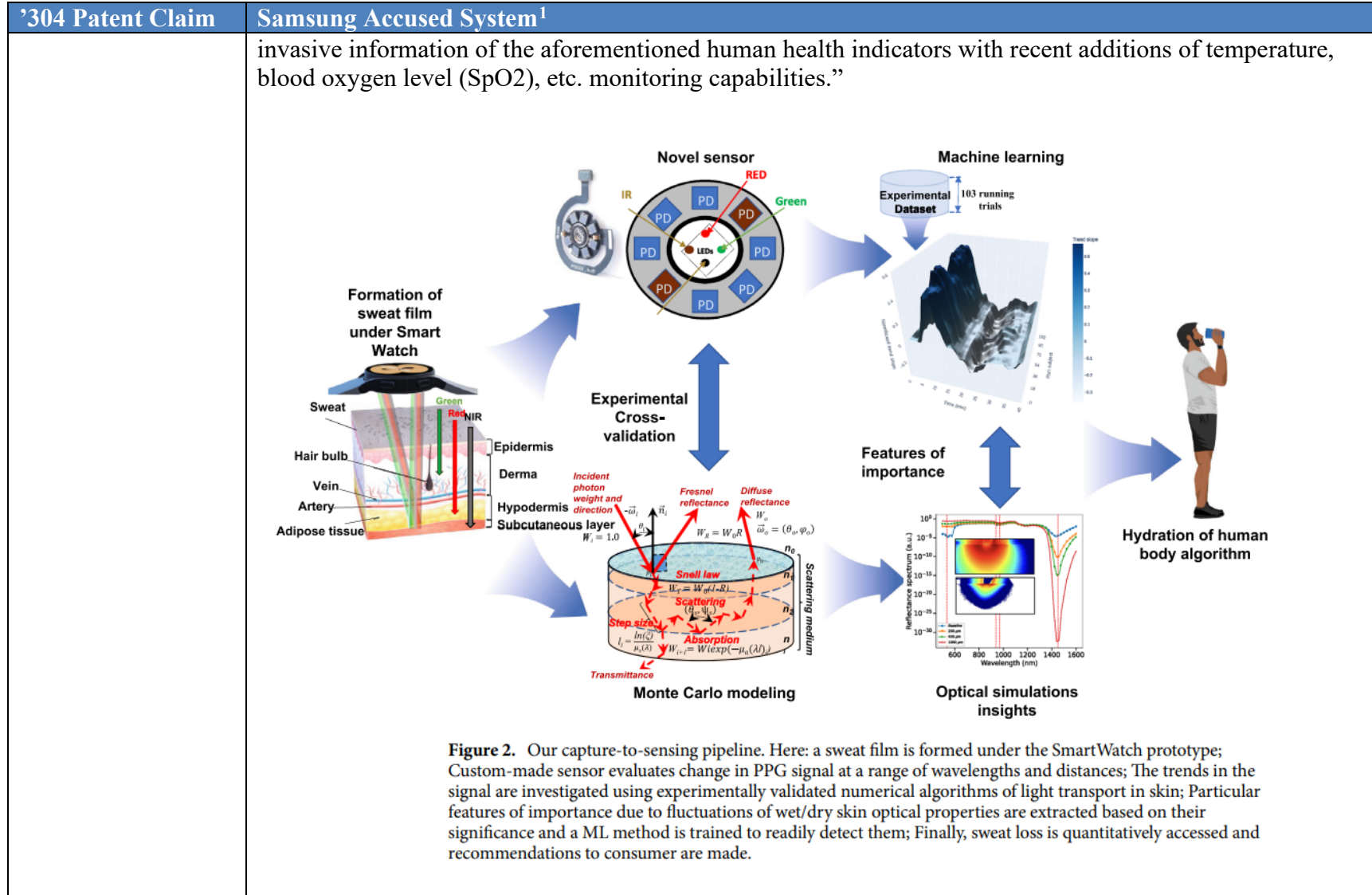
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	absorption by the blood vessel is changed in synchronization with the heart rate. A sensor measures, transmitted or reflected signal represented in Amplitude Modulation It has been used for a long time as a medical tool to measure oxygen saturation (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 2-3, <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-

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	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. The receiver of the Accused Smartwatch has been detailed in other technical documents as well. For example:

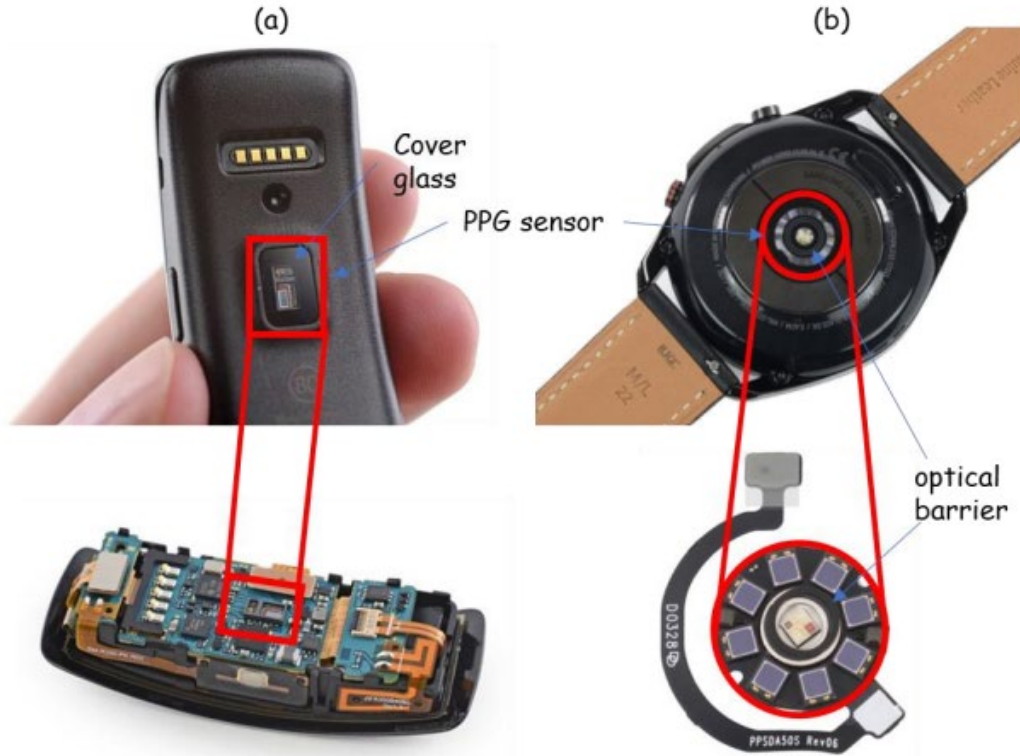
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	Figure 3. Conceptual diagram of a PPG sensor module with an embedded LED–PD pair. The diagram illustrates two scenarios: (a) when the integrated sensor module is in direct contact with the wrist and (b) when the sensor module is embedded in a device 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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	 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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	 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.
11(f) synchronize to the light source,	The Accused Smartwatch comprises a receiver configured to synchronize to the light source.

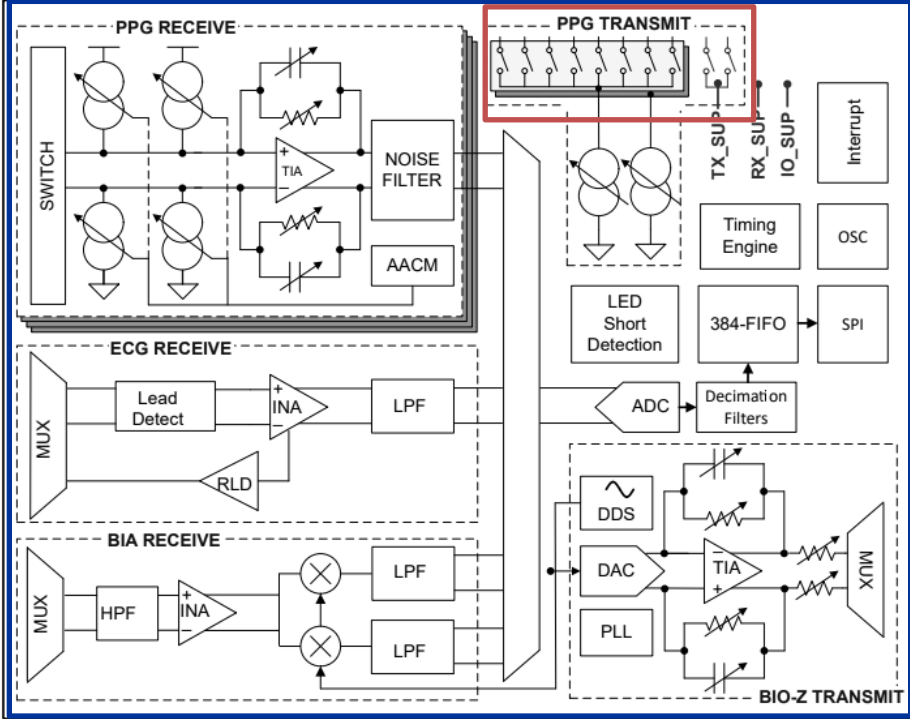
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	For example, the BioActive Sensor (“receiver”) is connected to the light source containing multiple LEDs. It is configured to synchronize with the light source by controlling the LED current (light intensity) and the pulse rate of the LEDs using LED drivers. To measure heart rate, for example, green LEDs are used with a 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>

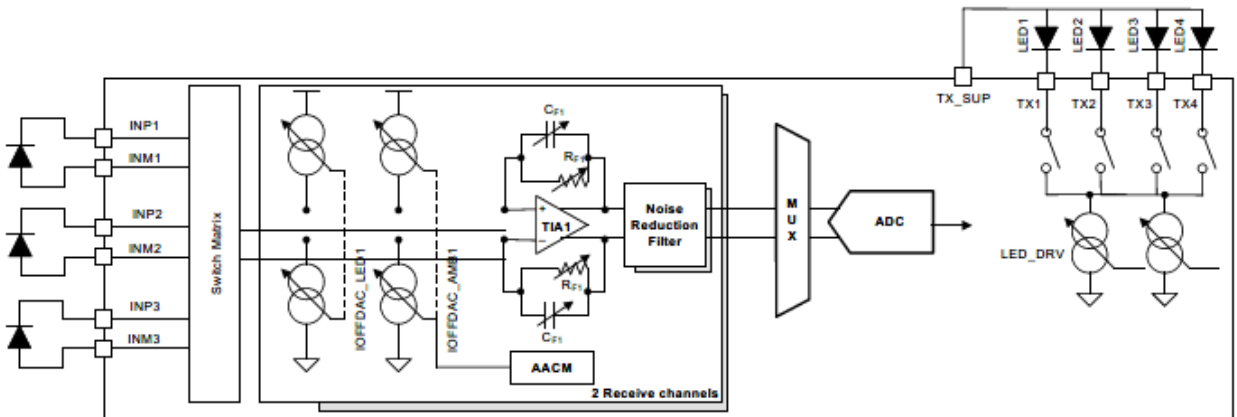
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	 The diagram is a 'Simplified Schematic' of the AFE4510 system. It is divided into three main sections: PPG RECEIVE, ECG RECEIVE, and BIA RECEIVE, all connected to a central ADC and Decimation Filters. The PPG RECEIVE section includes a SWITCH, TIA, NOISE FILTER, and AACM. The ECG RECEIVE section includes a MUX, Lead Detect, INA, LPF, and RLD. The BIA RECEIVE section includes a MUX, HPF, INA, LPF, and two multipliers. The PPG TRANSMIT section (highlighted with a red box) includes a current driver for LEDs, TX_SUP, RX_SUP, IO_SUP, and an Interrupt. The BIO-Z TRANSMIT section includes a DDS, DAC, PLL, TIA, and a MUX. Other components include a Timing Engine, OSC, 384-FIFO, SPI, and LED Short Detection. 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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'304 Patent Claim	Samsung Accused System ¹
	 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.

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	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, available at https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.

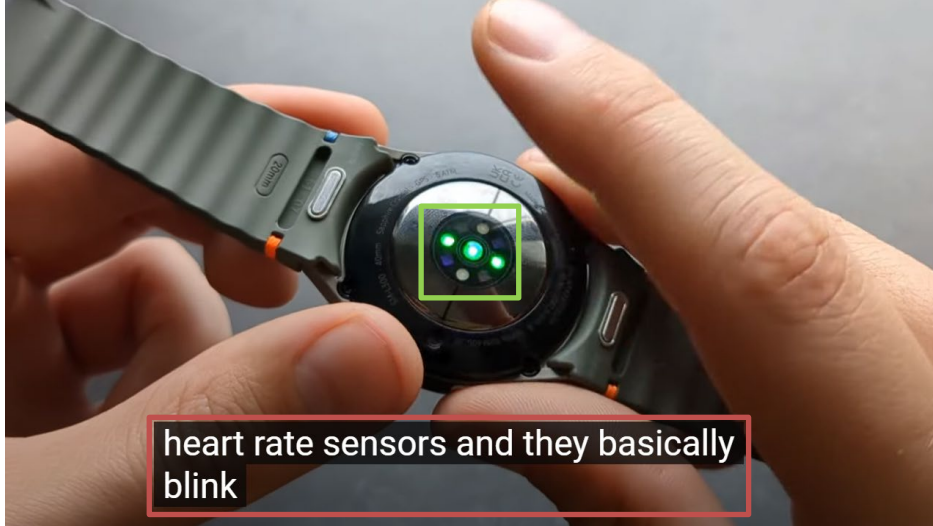
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	“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.

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	 heart rate sensors and they basically blink 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=JG9pGlqmgcs&t=23s.

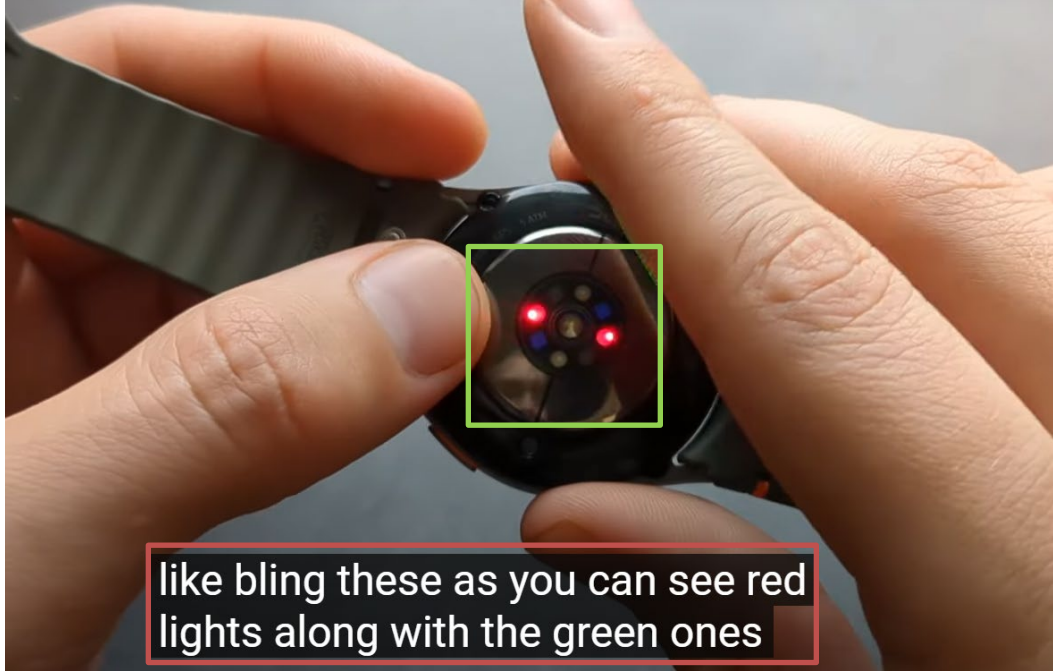
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	 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/JG9pGlmges?si=IrcplcEOdHE3cB3l&t=37

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	 Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:53, https://youtu.be/JG9pGlmges?si=xMBhD11dBJQoADTO&t=53

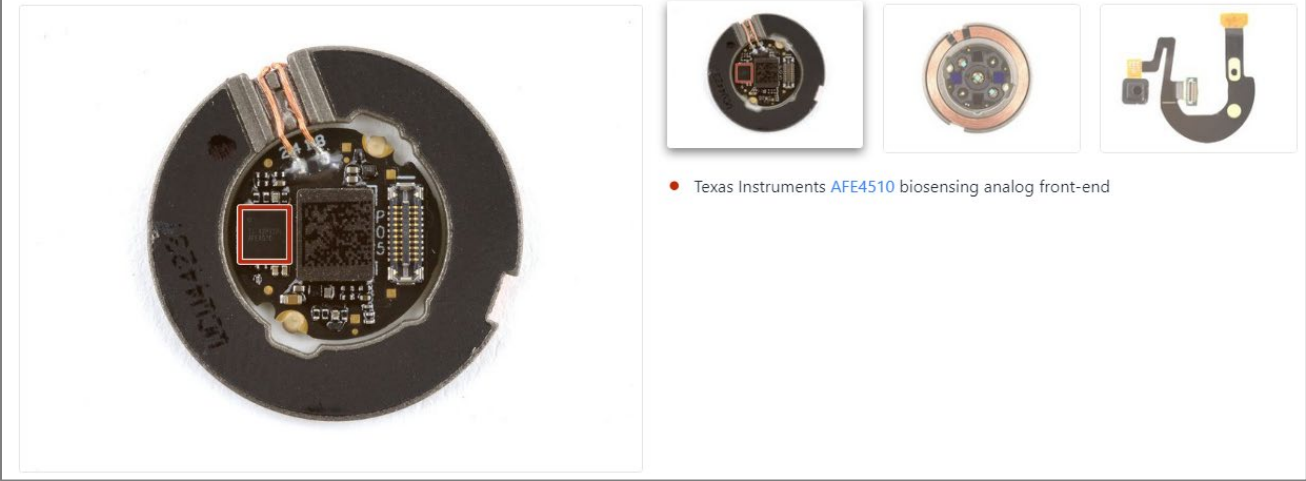
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	 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/JG9pGlqmgcs?si=YV8CQ6yVqkvL7ITZ&t=53
11[g] capture light while the semiconductor sources are off and convert the captured light into a first signal, capture light while at least one of the semiconductor	The Accused Smartwatch comprises a receiver configured to capture light while the semiconductor sources are off and convert the captured light into a first signal and capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a part of the at least a portion of the analysis output beam reflected or transmitted from the sample. For example, the BioActive Sensor includes a PPG sensor that operates in multiple phases, including (1) Ambient (when the LEDs, or “semiconductor sources,” are off) and (2) LED (when the LEDs, or “semiconductor sources,” are on). During the Ambient phase, the sensor receives light with the LEDs off

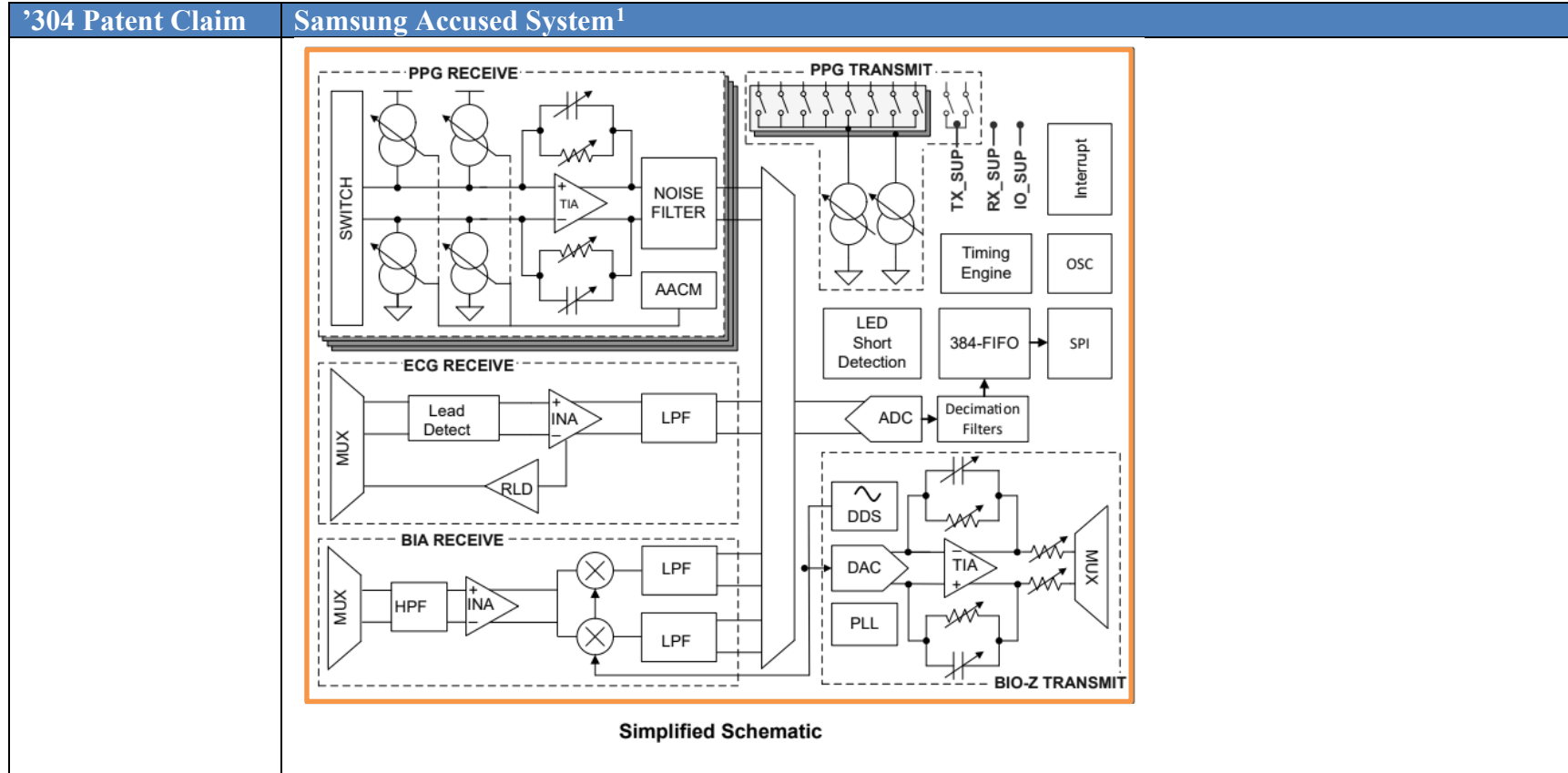
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
sources is on and convert the captured light into a second signal, the captured light including at least a part of the at least a portion of the analysis output beam reflected or transmitted from the sample,	and generates a first signal. In the LED phase, the sensor receives light from the LEDs and generates a second signal. Step 6 Bio Sensor Assembly  Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srsId=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	PPG signal acquisition: – Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19μA for the Receiver 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 Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.

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		5.1 PPG Configuration 5.1.1 Phase Definition This sheet is used to specify number of phases, timing, signal chain parameters associated with each phase, and the LED/PD association for each phase. The phase type is selected from the drop down menu (<u>Ambient</u> and <u>LED</u>) and the appropriate parameters for the phase type are automatically shaded in blue. Specify only the parameters that show up in the Blue boxes. Manually fill each cell using the drop down boxes (do not cut and paste values across cells). Also, fill only the boxes that show up in blue. Do not modify the cream- colored boxes.																																																																																																																																																																																																																																																																																																																																																																						
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		Figure 5-1. PPG per-phase configuration																																																																																																																																																																																																																																																																																																																																																																						

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'304 Patent Claim

Samsung Accused System¹

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S			
3		ILED_SAMP	0	us (LED ON start to SAMP start)			1 No data written into FIFO		Single or Dual TIA										Single		
4							2 Phase [N] - Phase [N-1]		PPG Decimation Factor: PPG_DEC_F										2		PPG Decimation: EN_PPG_DEC
5	Phase parameter table						3 Phase [N-1] - Average(Phase [N], Phase [N-2])														
							4 Phase[N] - Phase [N-2]														
6	Phase	Phase type	LED drv1 connects to	LED drv2 connects to	NUMAV	Stagger LED?	Fractional masking	FIFO data word	SAMP time (us)	Filter BW Selection	Connect PD4?	Connect PD3?	Connect PD2?	Connect PD1?	Rf (kOhm)	Cf (pF)	IOFFDAC_TIA1 (uA)	AACM TYPE			
7	1	Ambient			2	0	Never mask	1	115	Set1				1	100	20	0	ANA AACM			
17	2	LED	TX5	TX5	2	0	Never mask	1	115	Set1				1	100	20	0	LED DC Cancel			
27	3	Ambient			2	0	Never mask	3	115	Set1				1	100	20	0	ANA AACM			
37																					
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97																					
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117																					

Figure 5-1. PPG per-phase configuration

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

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

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'304 Patent Claim	Samsung Accused System ¹
	The top section shows two system-level diagrams. The left diagram, labeled 'Heart Rate Monitoring', shows a hand with a sensor emitting green light (LED) and receiving reflected light (PD). The signal path goes through an IPD, an Analog Front End (AFE), and a Heart Rate Extraction (MCU). The right diagram, labeled 'SpO₂ Monitoring', shows a hand with a sensor emitting red light (LED) and receiving reflected light (PD). The signal path goes through an IPD, an Analog Front End (AFE), and an SpO₂ Calculation Algorithm. The bottom section is a 'Block Diagram' of the receiver. It shows a Switch Matrix connected to multiple inputs (INP1, INM1, etc.). The signal passes through a Receiver section containing a TIA, a Noise Reduction Filter, and DC Cancellation blocks for Ambient and LED. The output goes through a MUX, an ADC, and Decimation. Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, available at https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F. A technical paper authored by Samsung engineers further explains a PPG signal receiver for use in wearable measurement devices configured to operate in an Ambient and LED phase:

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

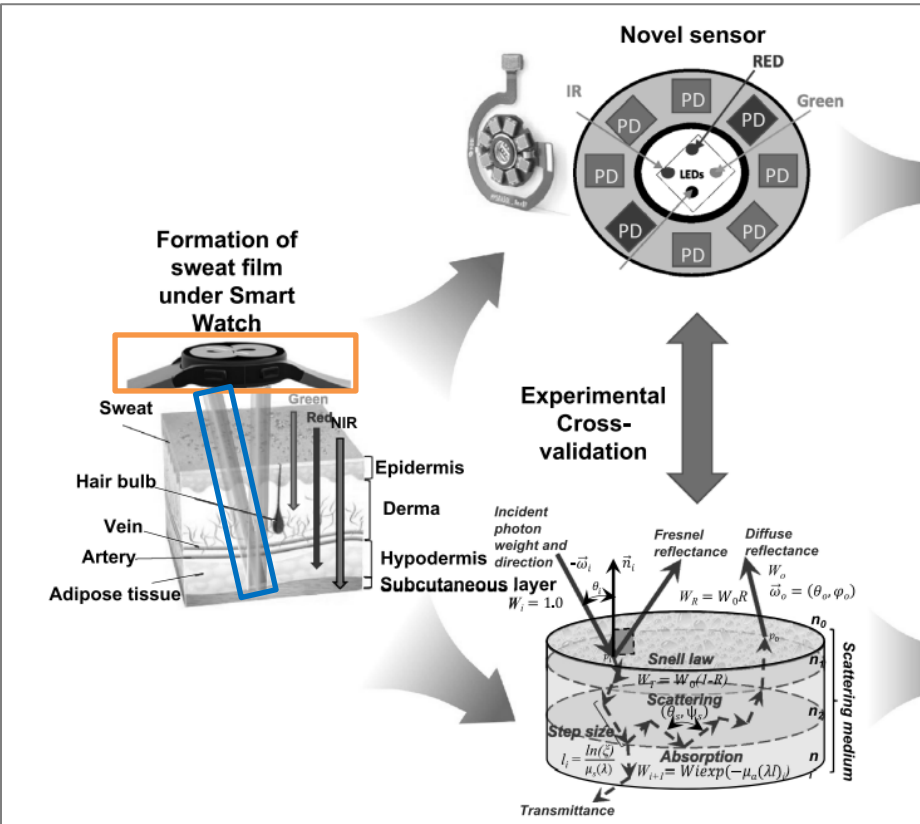
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'304 Patent Claim	Samsung Accused System ¹
	Ambient Light Cancellation(ALC) Block Figure 2. Detailed architecture of the ambient light cancellation (ALC) block. Source: J. Kim et al., “Ambient light cancellation in photoplethysmogram application using alternating sampling and charge redistribution technique,” 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), at 6441-42. 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

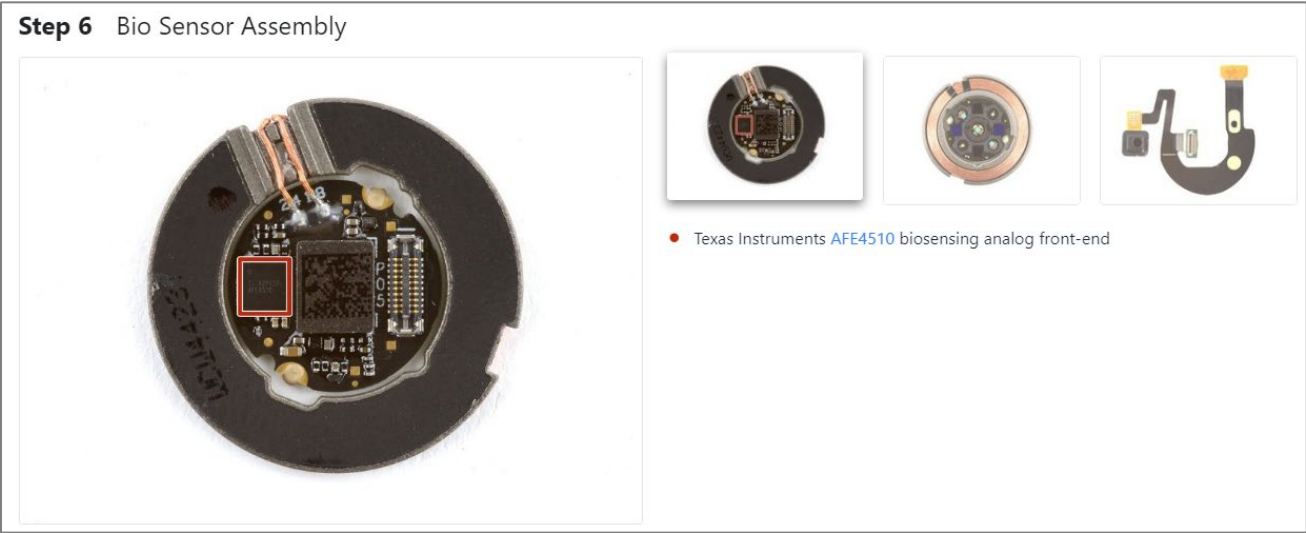
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'304 Patent Claim	Samsung Accused System ¹
	of the sensor on the body, and other end-user interactions.” Samsung Galaxy Watch7 Watch Ultra User Guide, at p. 42, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf. Additionally, the following scientific report authored by multiple Samsung engineers further shows an analysis output beam being delivered to a tissue sample of the user: 

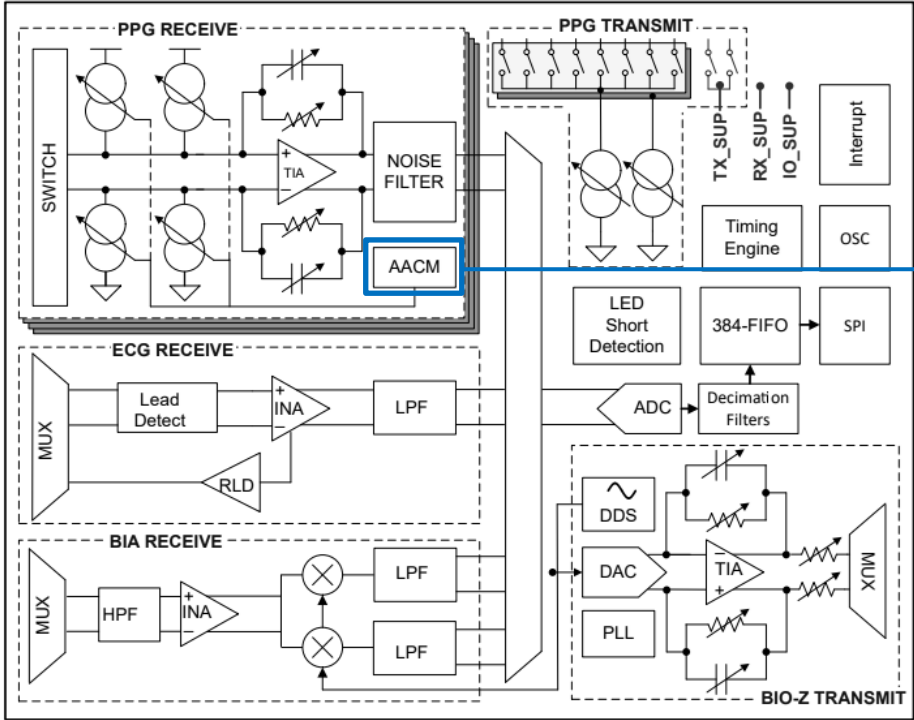
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	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, <i>available at</i> https://www.nature.com/articles/s41598-023-40339-7.pdf.
11[h] wherein the measurement system is further configured to improve the signal-to-noise ratio by differencing the first signal and the second signal;	The Accused System is configured to improve the signal-to-noise ratio by differencing the first signal and the second signal. For example, ambient light is considered as noise in PPG sensors. Therefore, the presence of ambient light decreases the SNR of PPG sensors. Ambient light cancellation is performed to cancel out the ambient light noise, thereby increasing the SNR. The BioActive Sensor of the Galaxy Watch Ultra performs ambient light cancellation (also referred to as “Digital Ambient Subtraction”), to increase the SNR, by comparing the measured signal when the LED sources are off (“first signal”) and the measured signal when the LED sources are on (“second signal”). Step 6 Bio Sensor Assembly 

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'304 Patent Claim	Samsung Accused System ¹
	Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327?srltid=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.  Simplified Schematic

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	PPG signal acquisition: – Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19µA for the Receiver 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 – <u>Digital Ambient Subtraction at ADC Output</u> Source: Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf. “To save power, the LED is pulsed at the PRF rate, turning on for a short window in each PRF cycle. Each turning on of the LED results in one sample in the digital data stream. . . . Input offset cancellation DAC cancels DC from both ambient and LED, and allows a high TIA gain setting for the best noise performance.” Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

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

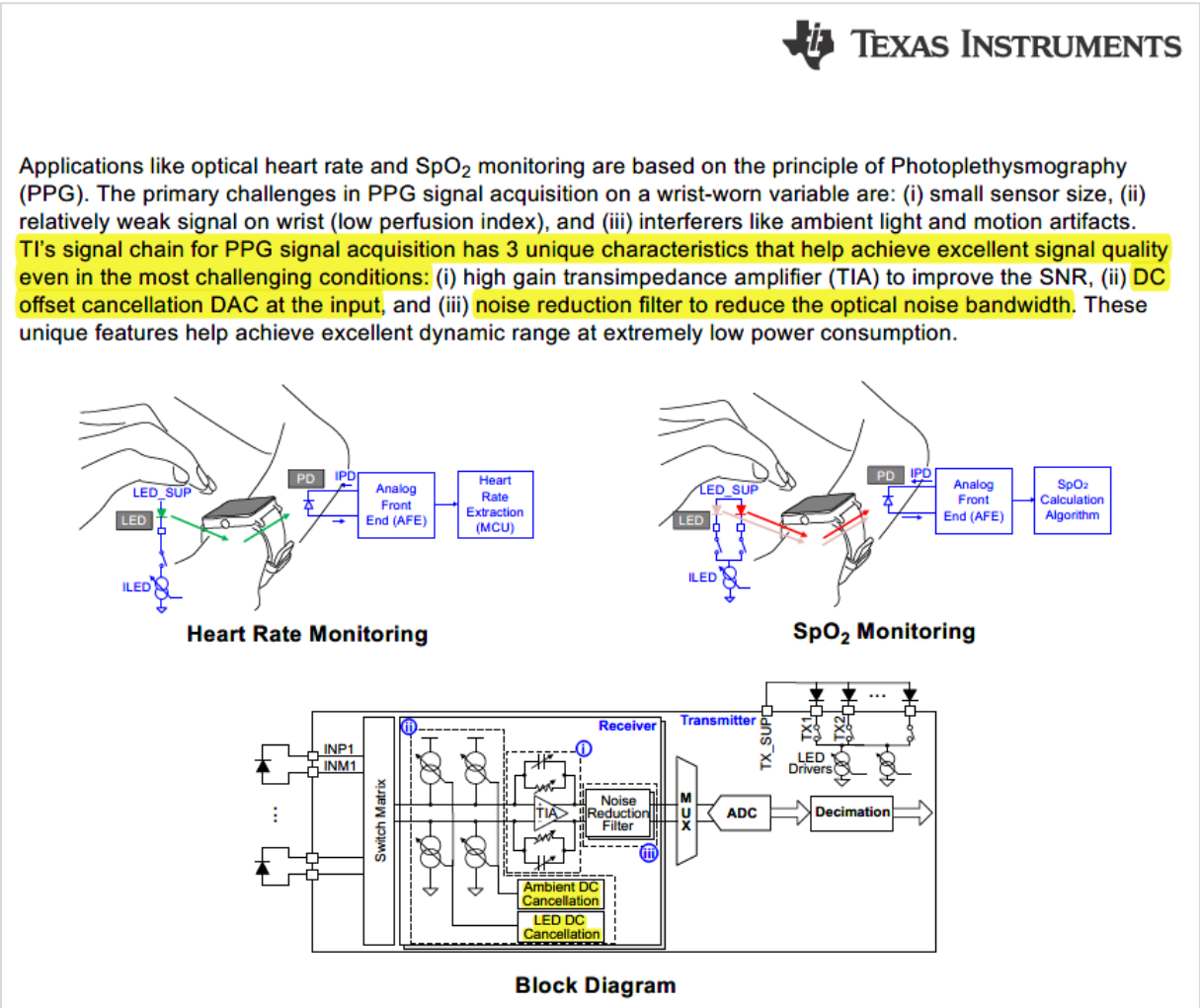
Figure 3 shows the PPG signal chain in AFE4432.

Figure 3. PPG Signal Chain in AFE4432

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

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	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.  The diagram shows the Texas Instruments logo at the top right. Below it, a paragraph describes the challenges in PPG signal acquisition and the unique characteristics of TI's signal chain. The signal chain for Heart Rate Monitoring includes an LED, LED_SUP, ILED, PD, IPD, Analog Front End (AFE), and Heart Rate Extraction (MCU). The signal chain for SpO₂ Monitoring includes an LED, LED_SUP, ILED, PD, IPD, Analog Front End (AFE), and SpO₂ Calculation Algorithm. A block diagram at the bottom shows the internal components of the system, including a Switch Matrix, Receiver, Transmitter, LED Drivers, TX_SUP, M, X, C, ADC, and Decimation.

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	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. 5 AFE4500 Register Generation Excel The AFE4500_Register_Generation_v*.xlsm will be given by TI. This configuration file will be in the EVM software installation directory. Default file location: C:\Program Files\Texas Instruments\Bio-Sensing\AFE4500EVM\Register config\AFE4500_Register_Generation_v*.xlsm By default the EVM ships in LDO enable mode with following configuration • Clocking : Internal oscillator • PPG configuration – PPG output data rate: 50 Hz – 3 Phases (Phase1, Phase2, Phase3) are defined for PPG: AMB1, LED, AMB2 – PPG Phases are sampled from Green PD of sensor board – TX1 (connected to Green LED on sensor board) is used to LED Phase. – TIA Gain (i.e. Rf): 250 kΩ – Sampling width: 117 μS – Noise reduction filter: 2.5 KHz – ANA AACM: Enabled to cancel ambient signal from all Phases – DIG AACM: Enabled to cancel the DC in LED Phase. • ECG Configuration – ECG output data rate: 500 Hz – ECG INA Gain: 21 Source: Texas Instruments, AFE4500 EVM User Guide, SBAU370 – April 2021, at 23, <i>available at</i> https://www.manualslib.com/download/2652772/Texas-Instruments-Afe4500evm.html.

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

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'304 Patent Claim	Samsung Accused System ¹
	Figure 2. Detailed architecture of the ambient light cancellation (ALC) block. Source: J. Kim et al., “Ambient light cancellation in photoplethysmogram application using alternating sampling and charge redistribution technique,” 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), at 6441-42.
11[i] a smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a microphone, a	The Accused System comprises a smart phone or 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.

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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 (“smart phone”). The Galaxy Z Fold6 includes Wi-Fi connectivity, which requires the smart phone to include both a wireless receiver and a wireless transmitter.  Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/

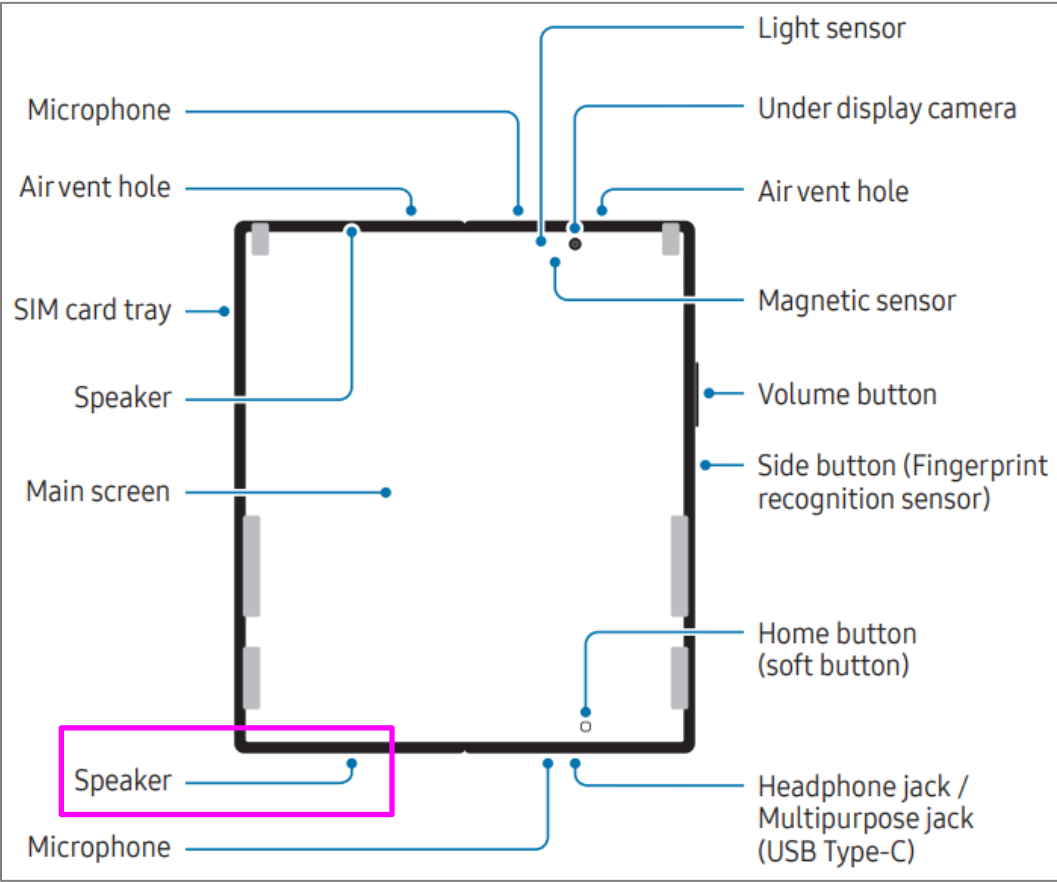
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'304 Patent Claim	Samsung Accused System ¹						
	Connectivity Wi-Fi Connectivity 802.11a/b/g/n/ac/ax 2.4GHz+5GHz+6GHz, HE160, MIMO, 1024-QAM Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/ The Galaxy Z Fold6 (“smart phone”) 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					

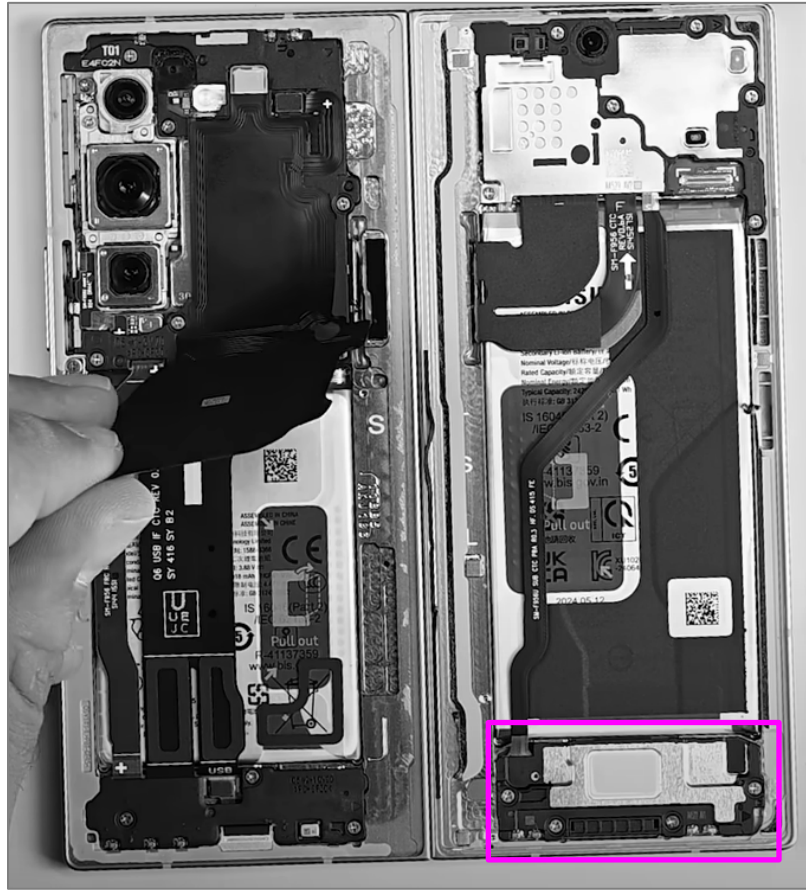
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'304 Patent Claim	Samsung Accused System ¹
	 The diagram shows a top-down view of a smartphone with various components labeled with leader lines. A pink rectangular box highlights the bottom-left corner of the device, specifically the area containing a speaker and a microphone. The labels are as follows: - Microphone (top-left) - Air vent hole (top-left) - SIM card tray (left) - Speaker (left, inside the pink box) - Main screen (center) - Light sensor (top-right) - Under display camera (top-right) - Air vent hole (top-right) - Magnetic sensor (right) - Volume button (right) - Side button (Fingerprint recognition sensor) (right) - Home button (soft button) (bottom-right) - Headphone jack / Multipurpose jack (USB Type-C) (bottom-right) - Speaker (bottom-left, inside the pink box) - Microphone (bottom-left) Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]

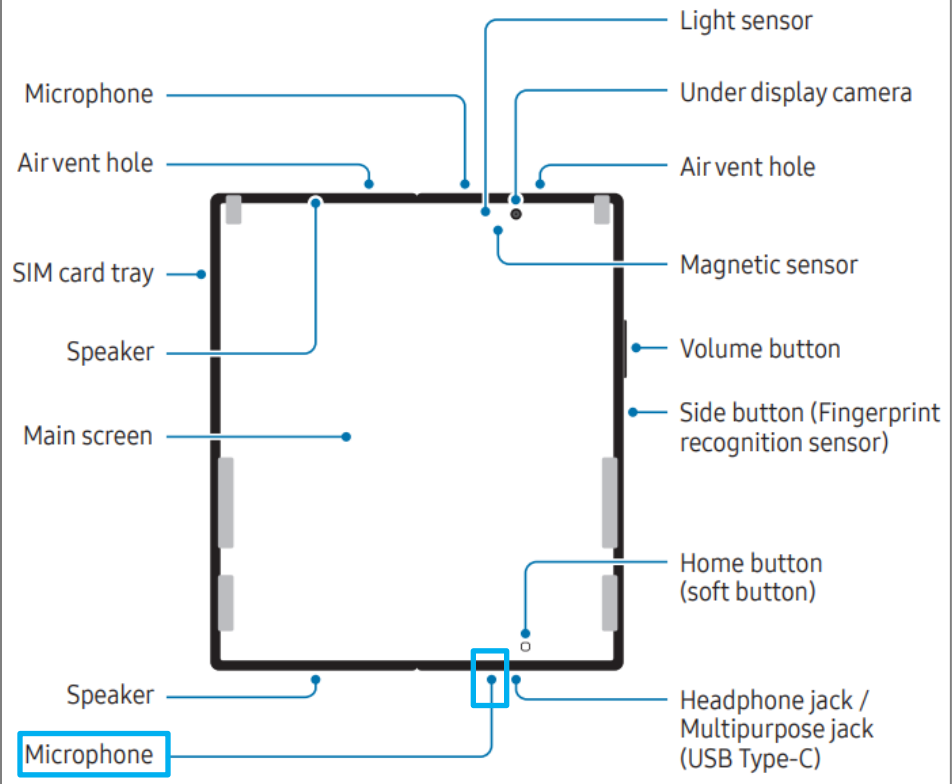
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’304 Patent Claim	Samsung Accused System ¹
	 Source: https://www.youtube.com/watch?v=xYIe5uDVDWI

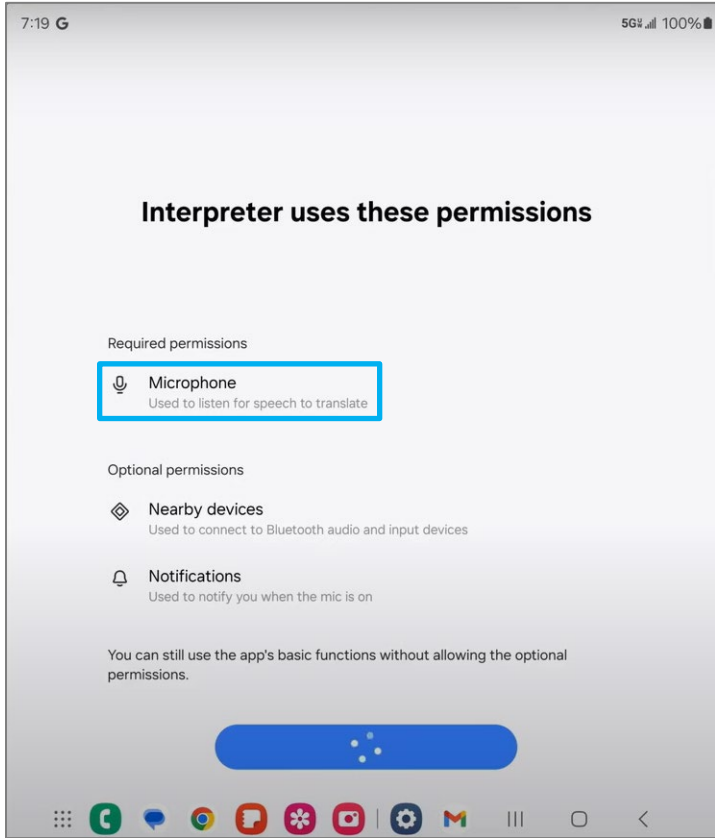
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	 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]

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'304 Patent Claim	Samsung Accused System ¹
	 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.

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

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'304 Patent Claim	Samsung Accused System ¹
	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/

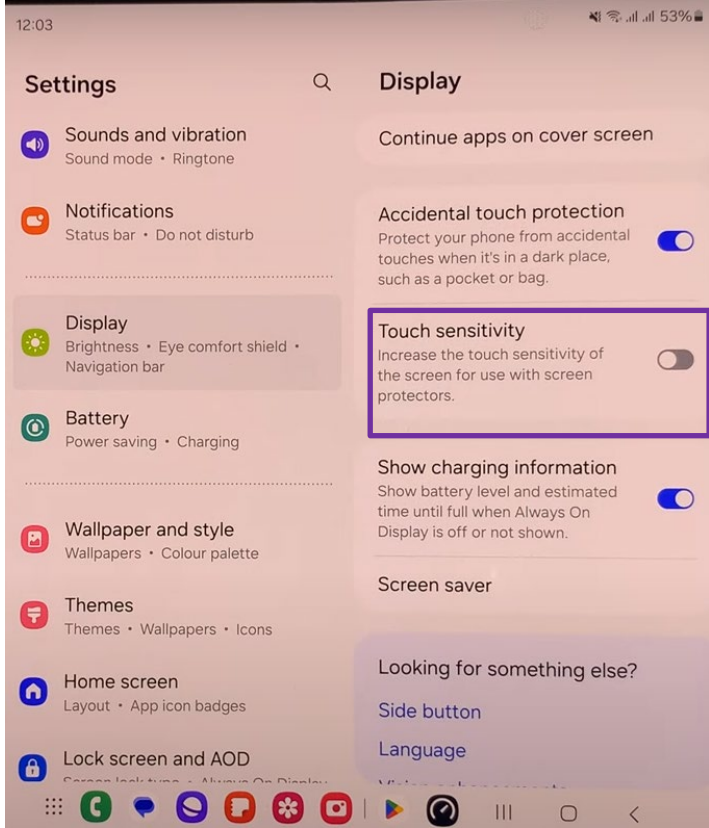
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’304 Patent Claim	Samsung Accused System ¹
	CPUName: Qualcomm® Kryo™Architecture: 64-bitClock Speed: Up to 3.4 GHz¹ Source: https://www.qualcomm.com/products/mobile/snapdragon/smartphones/snapdragon-8-series-mobile-platforms/snapdragon-8-gen-3-mobile-platform

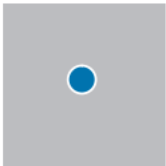
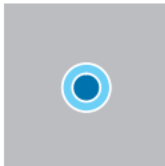
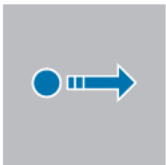
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	 The screenshot shows the Samsung Settings app. The 'Display' section is expanded, showing options like 'Continue apps on cover screen', 'Accidental touch protection', 'Touch sensitivity', 'Show charging information', and 'Screen saver'. The 'Touch sensitivity' option is highlighted with a red box. The text for 'Touch sensitivity' reads: 'Increase the touch sensitivity of the screen for use with screen protectors.' The toggle switch is currently turned off. Source: https://www.youtube.com/watch?v=cn2UQ6Fr4hM

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'304 Patent Claim	Samsung Accused System ¹
	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]
11[i] the smart phone or tablet configured to	The Accused Phone/Tablet is configured to receive and process at least a portion of the output signal, to store and display the processed output signal, and to transmit a portion of the processed output signal over a wireless transmission link.

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’304 Patent Claim	Samsung Accused System ¹
receive and process at least a portion of the output signal, to store and display the processed output signal, and to transmit a portion of the processed output signal over a wireless transmission link; and	For example, the Galaxy Z Fold6 (“the smart phone”) receives the output signal from the BioActive Sensor via the Samsung Health app, processes the signal (<i>e.g.</i>, generates Heart Rate Zones, in addition to other health and wellness metrics and reports), and then stores and displays the Heart Rate Zones (“processed output signal”). “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 (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.

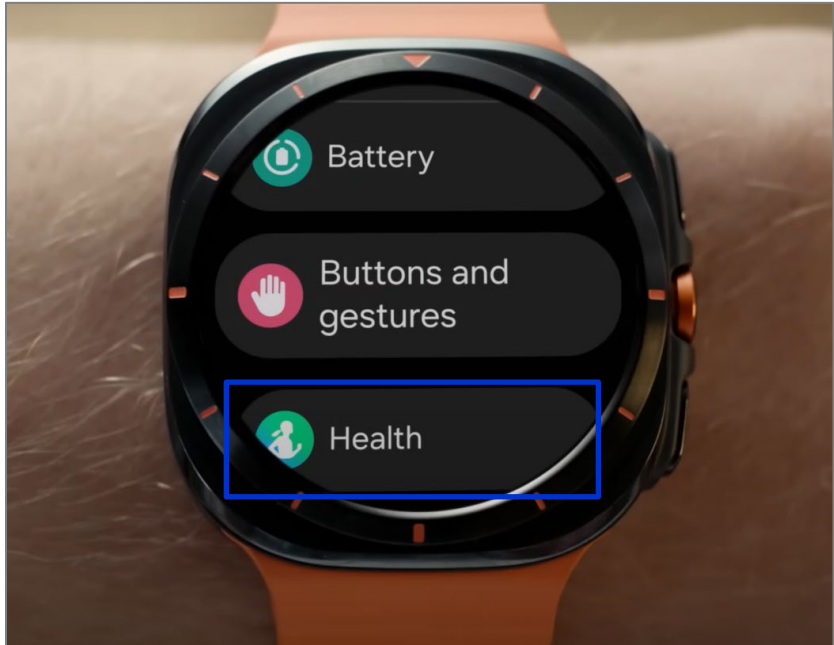
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	An advertisement for the Samsung Health ecosystem. At the top center is the Samsung Health logo, which consists of a green circle with a white person icon and the text "Samsung Health". Below the logo, a collection of Samsung devices is displayed: a Galaxy Z Fold smartphone in the center, a Galaxy Watch 4 on the right, a Galaxy Buds Pro earbuds case in the foreground, and a Samsung Health Monitor on the left. The background features two large, stylized heart shapes composed of dots, one purple on the left and one orange on the right. The smartphone screen shows the Samsung Health app interface with various health metrics like steps, heart rate, and sleep score. The watch face also displays health data. The entire scene is set against a white background with a subtle pattern of dots. Source: https://www.samsung.com/us/apps/samsung-health/.

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

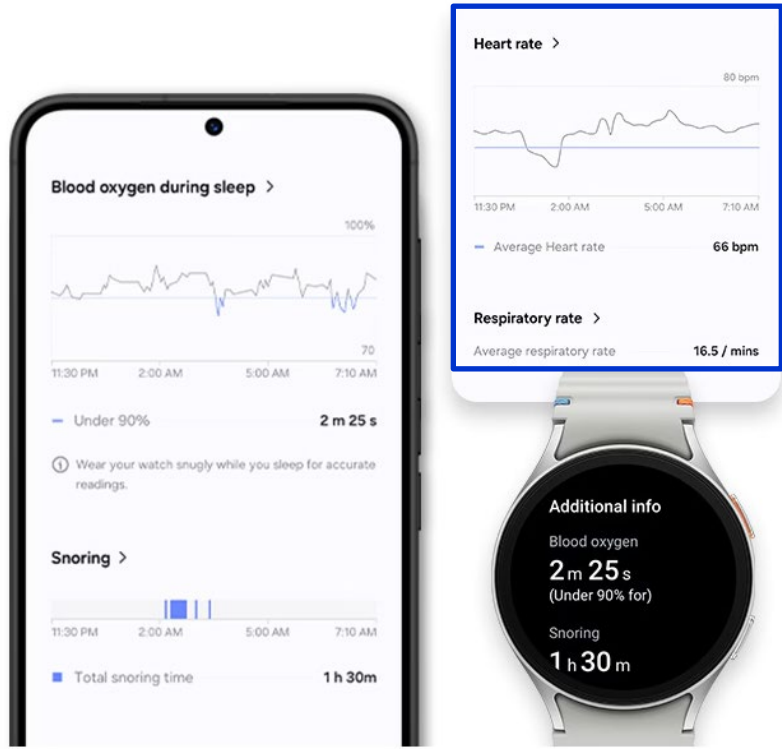
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'304 Patent Claim	Samsung Accused System ¹
	 . Sleep . Heart rate . Activity Respiratory rate during sleep Average 16.5 times/min Show on phone Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3Pro,” July 24, 2024, https://www.youtube.com/watch?v=VQW-ZpdAm5M

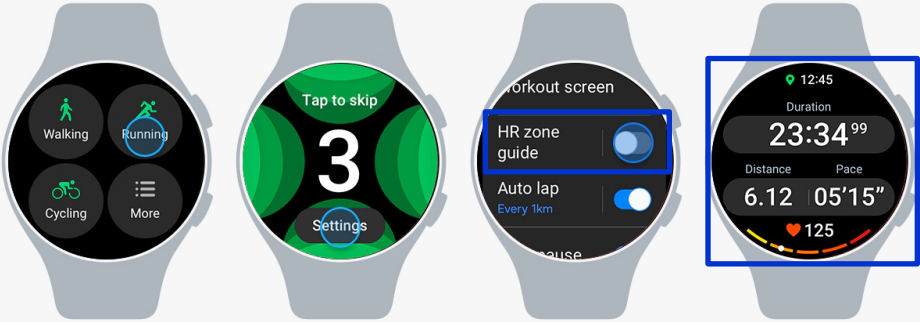
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'304 Patent Claim	Samsung Accused System ¹
	 The image displays the Samsung Health app interface on a smartphone and a smartwatch. The smartphone screen shows the 'Blood oxygen during sleep' graph with a peak at 100% and a trough at 70% between 11:30 PM and 7:10 AM. Below this, it indicates 'Under 90%' for 2 m 25 s. A note states: 'Wear your watch snugly while you sleep for accurate readings.' The 'Snoring' section shows a bar chart with a total snoring time of 1 h 30 m. The smartwatch displays 'Additional info' including 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. A separate inset shows 'Heart rate' and 'Respiratory rate' graphs with an average heart rate of 66 bpm and an average respiratory rate of 16.5 / mins. Source: https://www.samsung.com/us/apps/samsung-health/

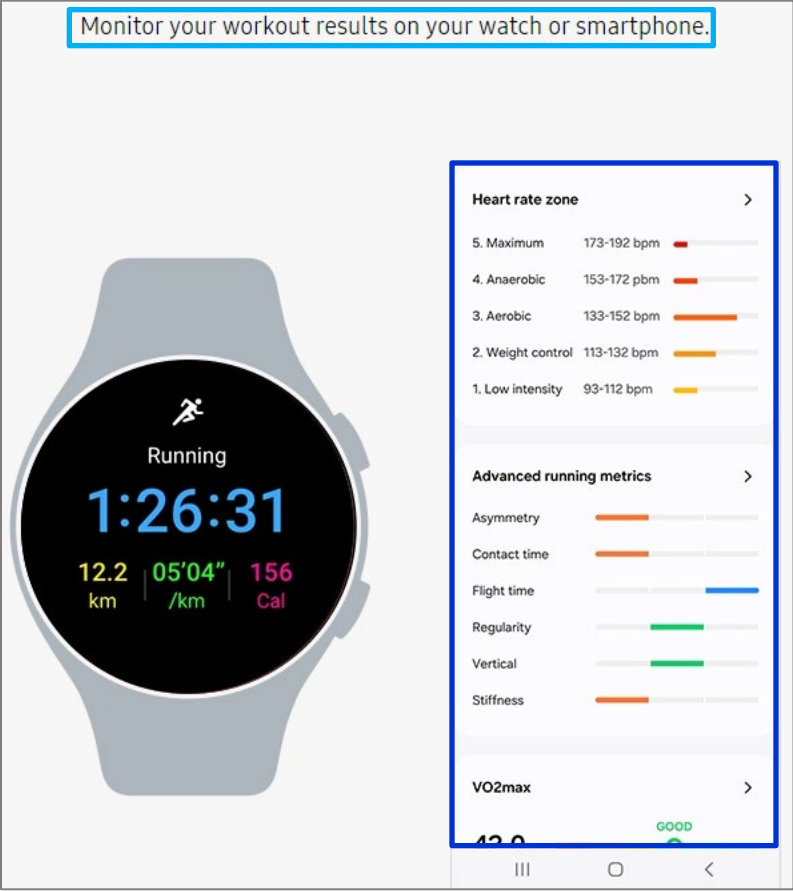
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	Check your Heart Rate Zone with Galaxy Watch Choose your preferred workout type and initiate by tapping 'Settings' when the countdown begins. Activate the HR Zone guide and engage in a 10-minute run within the exercise mode.  Source: https://www.samsung.com/us/apps/samsung-health/ 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. 

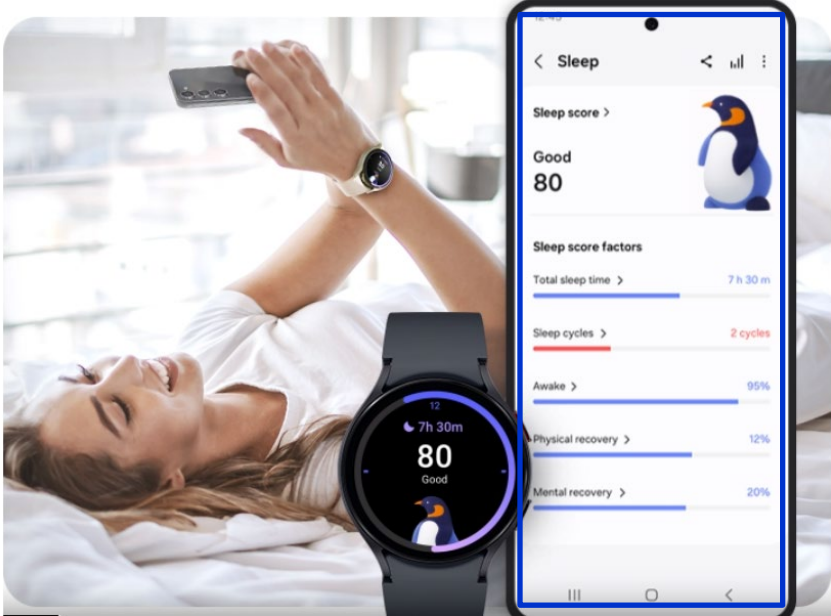
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'304 Patent Claim	Samsung Accused System ¹
	Source: https://www.samsung.com/us/apps/samsung-health/ Monitor your workout results on your watch or smartphone.  The screenshot displays the Samsung Health app interface. On the left is a smartwatch face showing 'Running' with a time of 1:26:31, 12.2 km, 05'04"/km, and 156 Cal. On the right is a smartphone screen showing a 'Heart rate zone' chart with five levels: 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, 'VO2max' is shown as 42.0 with a 'GOOD' status. Source: https://www.samsung.com/us/apps/samsung-health/

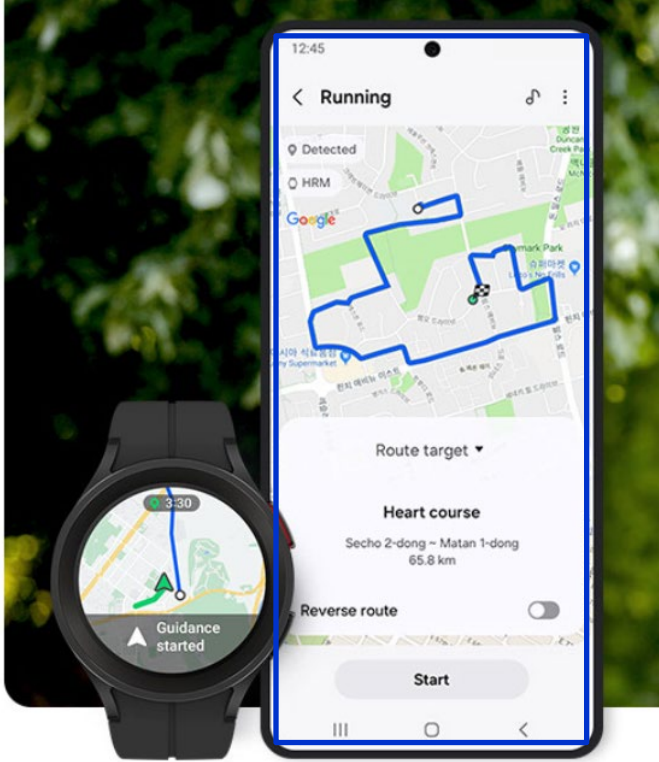
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	 Source: https://www.samsung.com/global/galaxy/apps/samsung-health/

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’304 Patent Claim	Samsung Accused System ¹
	 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, <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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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

’304 Patent Claim	Samsung Accused System ¹
	“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. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	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/.
11[k] a cloud configured to receive over the wireless transmission link an output status comprising the at	The Accused System comprises a cloud configured to receive over the wireless transmission link an output status comprising the at least a portion of the processed output signal, to process the received output status to generate processed data, and to store the processed data, and wherein the cloud is capable of storing a history of at least a portion of the received output status over a specified period of time.

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

’304 Patent Claim	Samsung Accused System ¹
least a portion of the processed output signal, to process the received output status to generate processed data and to store the processed data, and wherein the cloud is capable of storing a history of at least a portion of the received output status over a specified period of time.	For example, the Accused Cloud receives data from the Samsung Health app over a Wi-Fi connection (“wireless transmission link”). It processes the Samsung Health app data and stores it as a backup (“processed data”), enabling future restoration 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. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	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. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	<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. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	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.

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	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/ <i>See also</i> 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/.

U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
14. The measurement system of claim 11, wherein the plurality of semiconductor sources comprises at least one of: light emitting diodes (LEDs), laser diodes (LD's), tunable LD's, and super-luminescent laser diodes (SLDs), and the measurement system further comprising a reflective surface to receive and redirect at least some of the at least a portion of the analysis output beam reflected or transmitted from the sample.	The Accused System comprises a plurality of semiconductor sources that comprise at least one of: light emitting diodes (LEDs), laser diodes (LD's), tunable LD's, and super-luminescent laser diodes (SLDs) and a reflective surface to receive and redirect at least some of the at least a portion of the analysis output beam reflected or transmitted from the sample, literally or under the doctrine of equivalents. For example, the Accused System comprises light emitting diodes (LEDs) and a reflective surface on at least the underside of the Accused Smartwatch that receives and redirects at least some of the analysis output light beam that is reflected from the user's skin. The Accused Smartwatch includes a light source comprising multiple light emitting diodes (“LEDs”), such as a green LED, a red LED, and an infrared LED, each of which includes a “semiconductor source.” 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 broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure, blood oxygen levels and stress levels. Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

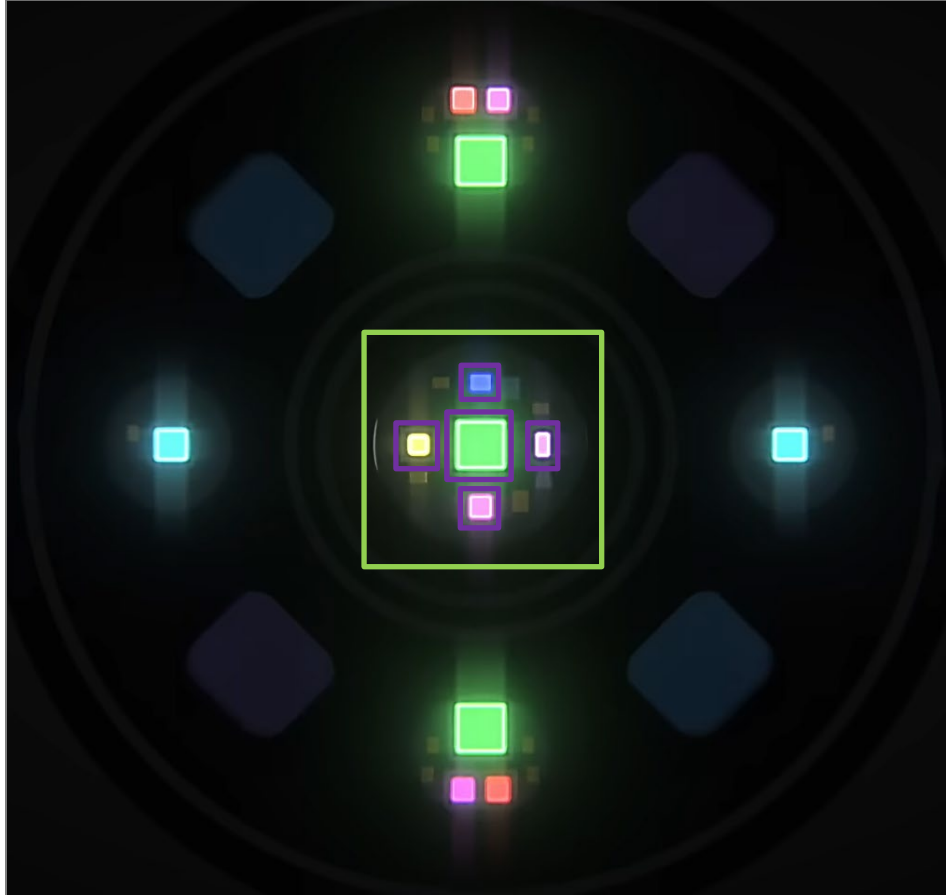
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'304 Patent Claim	Samsung Accused System ¹
	A top-down view of the Samsung Galaxy Watch Ultra. The watch has a black case with two large, dark, rectangular buttons on the left and right sides. In the center is a circular crown with a white ring. On the right side of the case, there is a small, circular, white sensor. The watch is shown with a brown, textured strap. Four dashed lines point from labels to specific features: 'Quick Button' points to the crown, 'Dynamic Lug System' points to the right side of the case, 'Dual-Frequency GPS' points to the bottom left of the case, and 'BioActive Sensor' points to the bottom right of the case. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

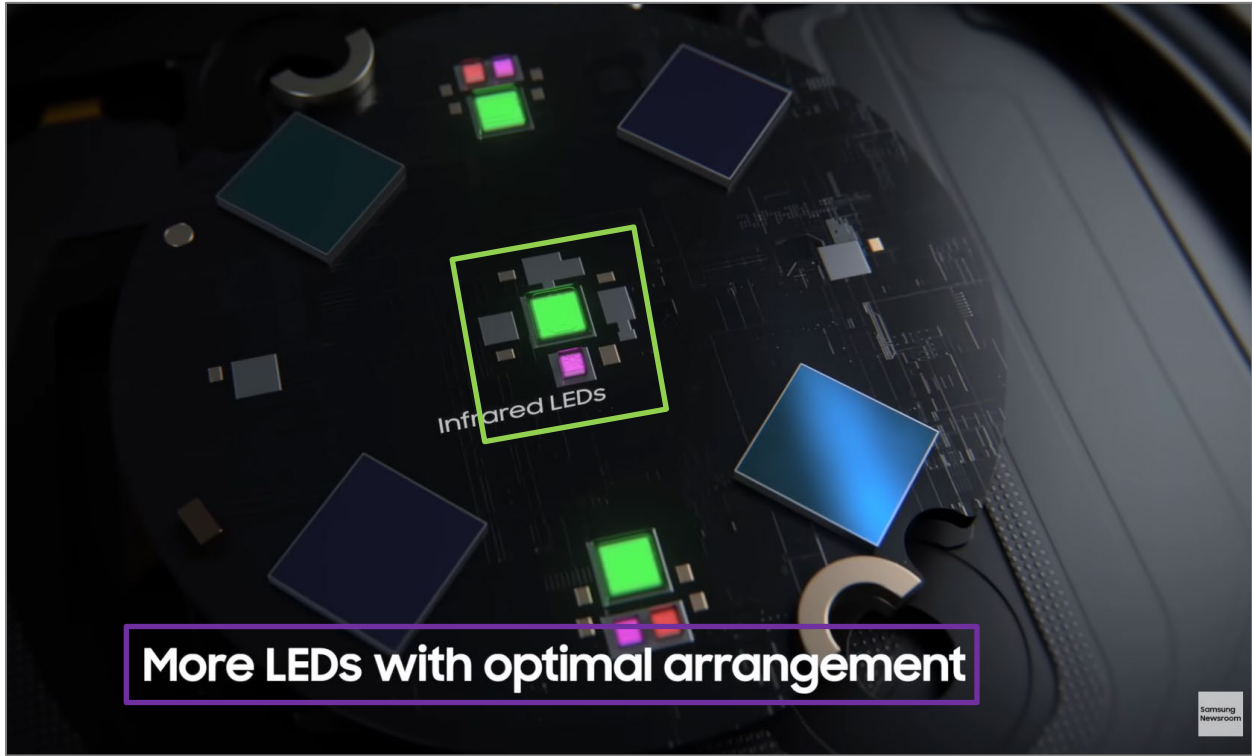
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

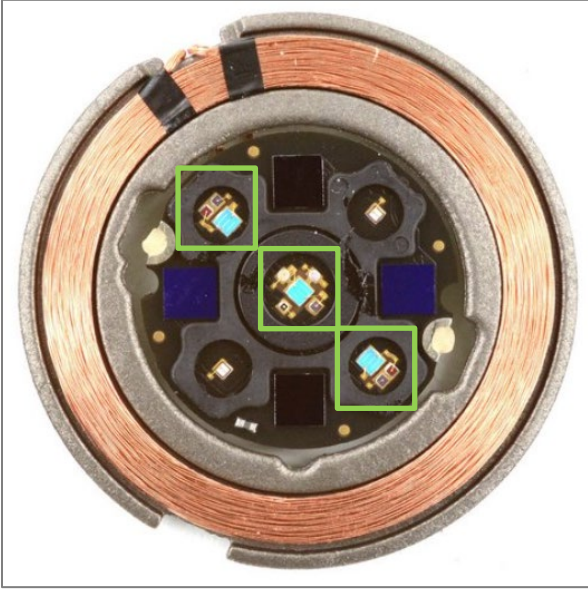
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

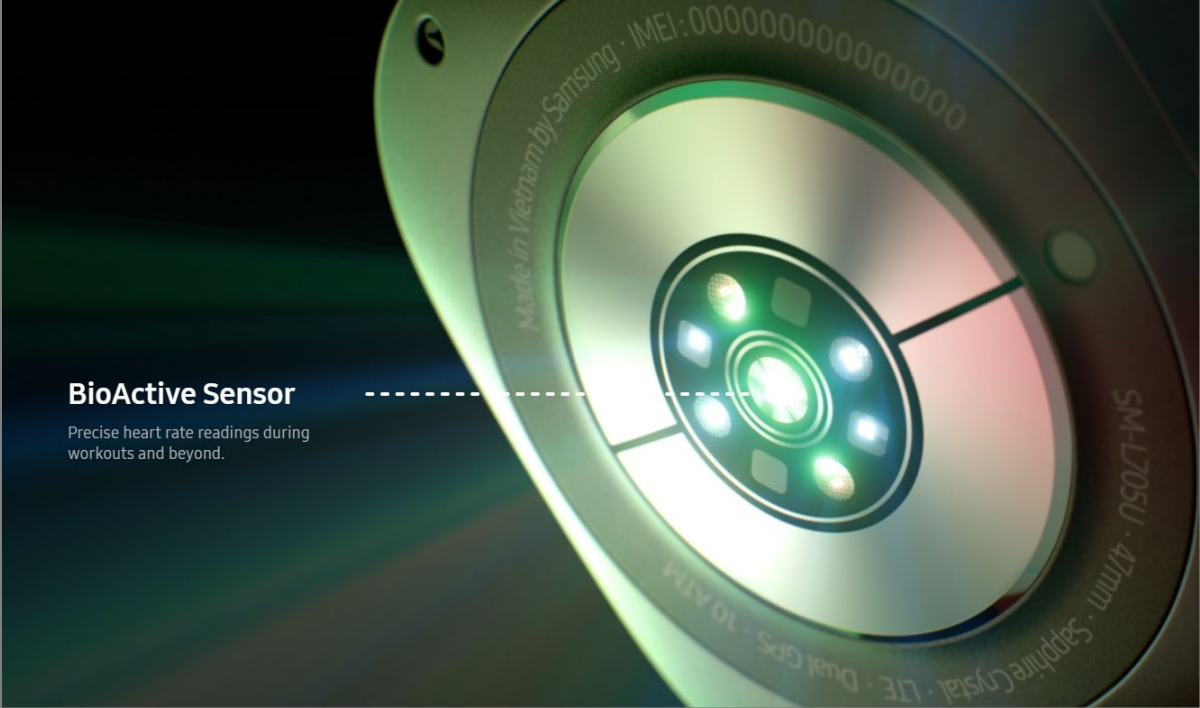
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

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

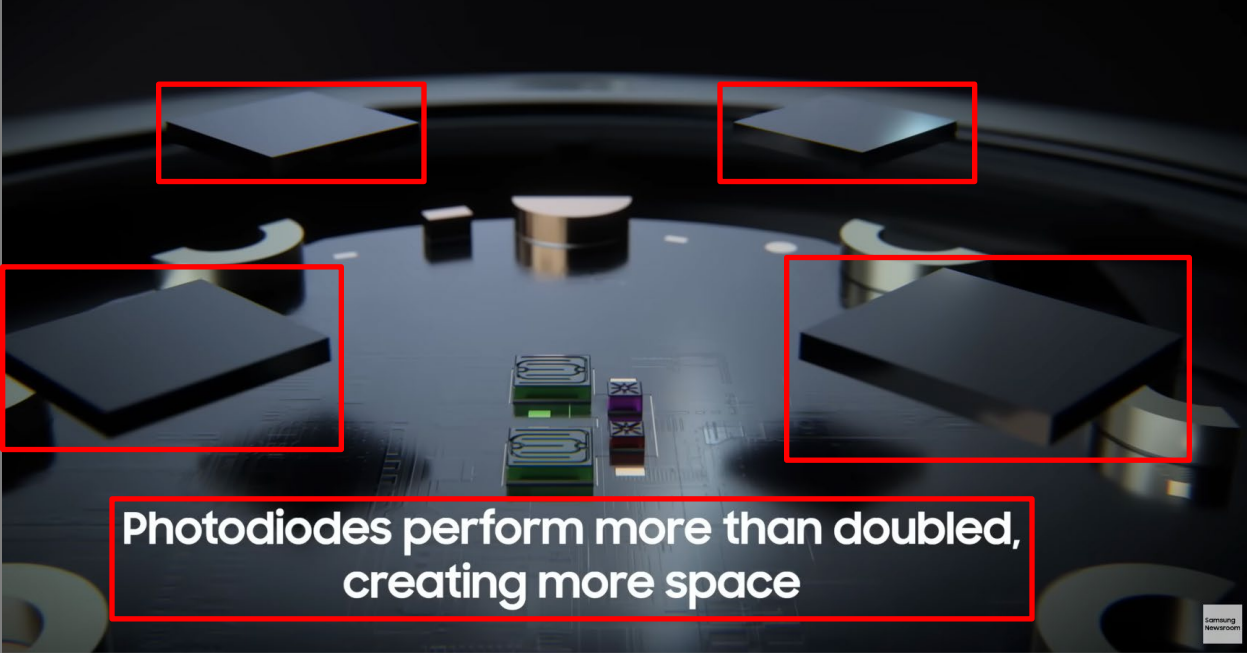
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	 BioActive Sensor Precise heart rate readings during workouts and beyond. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/
15. The measurement system of claim 11, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor	The Accused System’s receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc that is offset from the first arc. For example, the Accused Smartwatch contains multiple LEDs ("semiconductor sources") and multiple photodiodes ("detectors"). The photodiodes are arranged along a first arc, while the LEDs are arranged along a second, distinct arc, with both arcs following different circular paths ("offset").

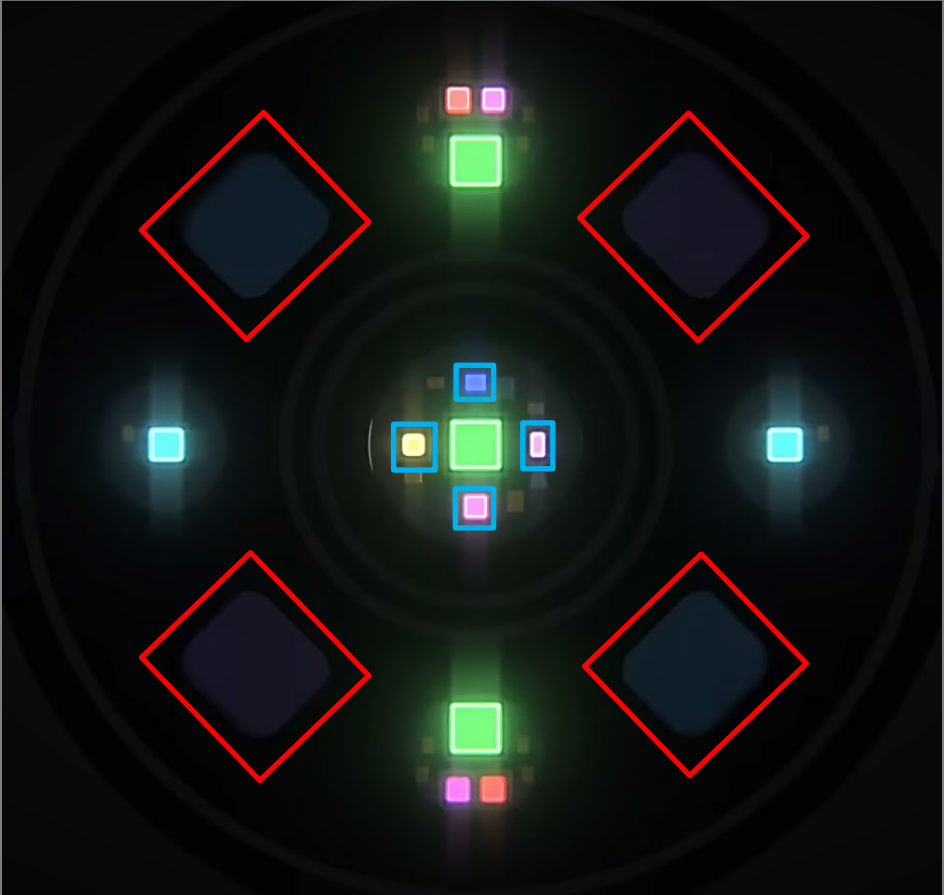
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
sources are arranged along a second arc that is offset from the first arc.	 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

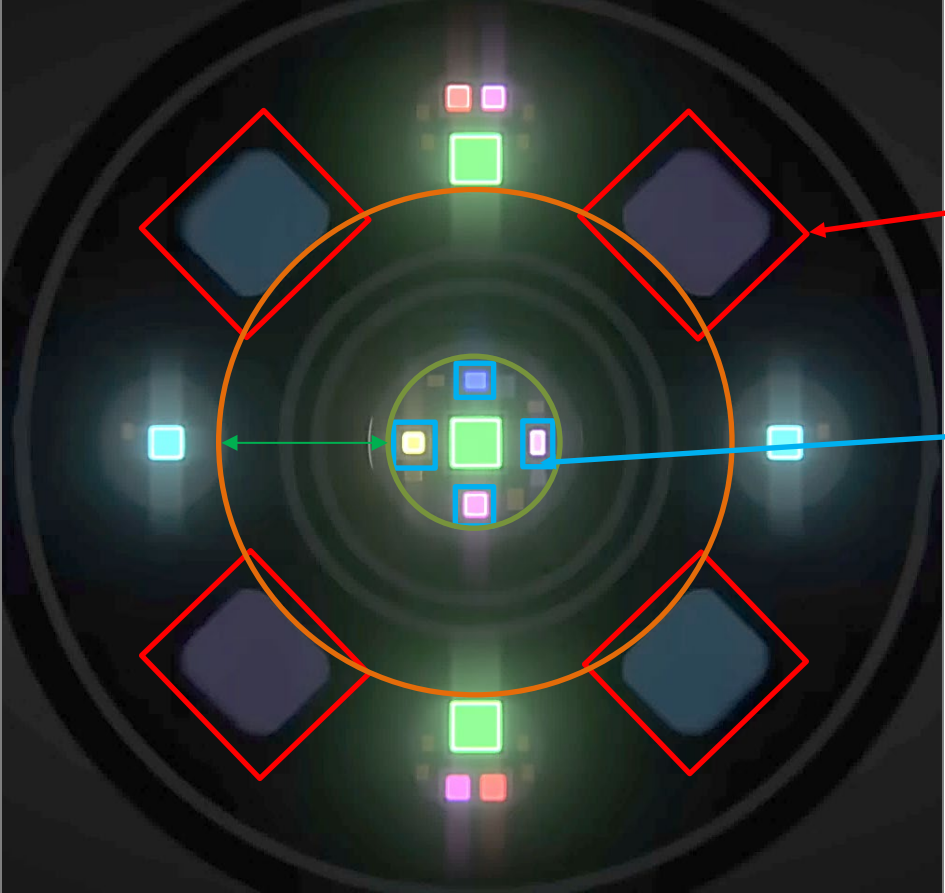
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

’304 Patent Claim	Samsung Accused System ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

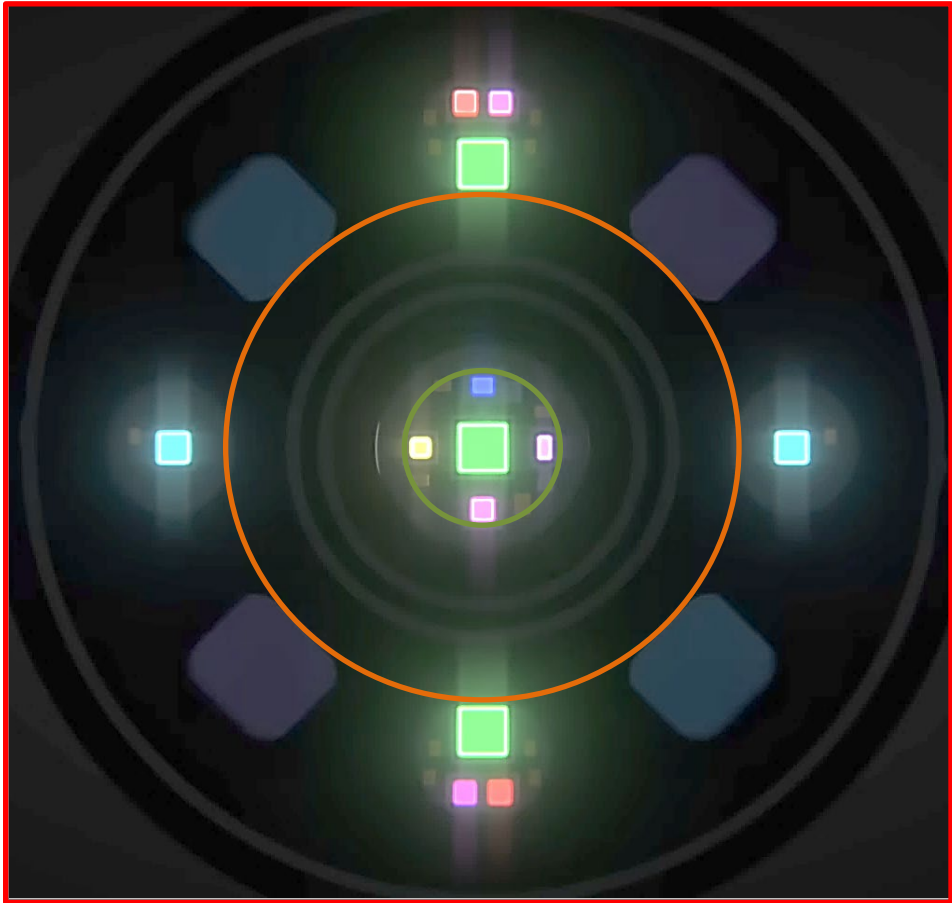
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor
16. The measurement system of claim 15, wherein	The Accused Smartwatch contains multiple LEDs and multiple photodiodes. The photodiodes are arranged along a first concentric arc, while the LEDs are arranged along a second concentric arc.

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'304 Patent Claim	Samsung Accused System ¹
the first arc and the second arc are concentric.	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor
19[Pre] A wearable device for use with a smart phone or	Samsung has made, used, offered to sell, sold in the United States, and/or has imported into the United States, and/or, continues to make, use, offer to sell, and sell within the United States, and/or import into the United

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'304 Patent Claim	Samsung Accused System ¹
tablet, the wearable device comprising:	States, a wearable device for use with a smart phone or tablet, either literally or under the doctrine of equivalents. For example, Samsung provides a system including a Galaxy Watch Ultra, a Samsung smartphone or tablet, and Samsung Cloud (“system”) for measuring a user’s heart rate, blood oxygen level, and electrocardiogram (“ECG”). 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 transfers the information to an Accused Phone/Tablet and to the Accused Cloud. Source: https://news.samsung.com/global/galaxy-history-%E2%91%A2-evolution-of-the-galaxy-watch-series-reimagining-the-watch

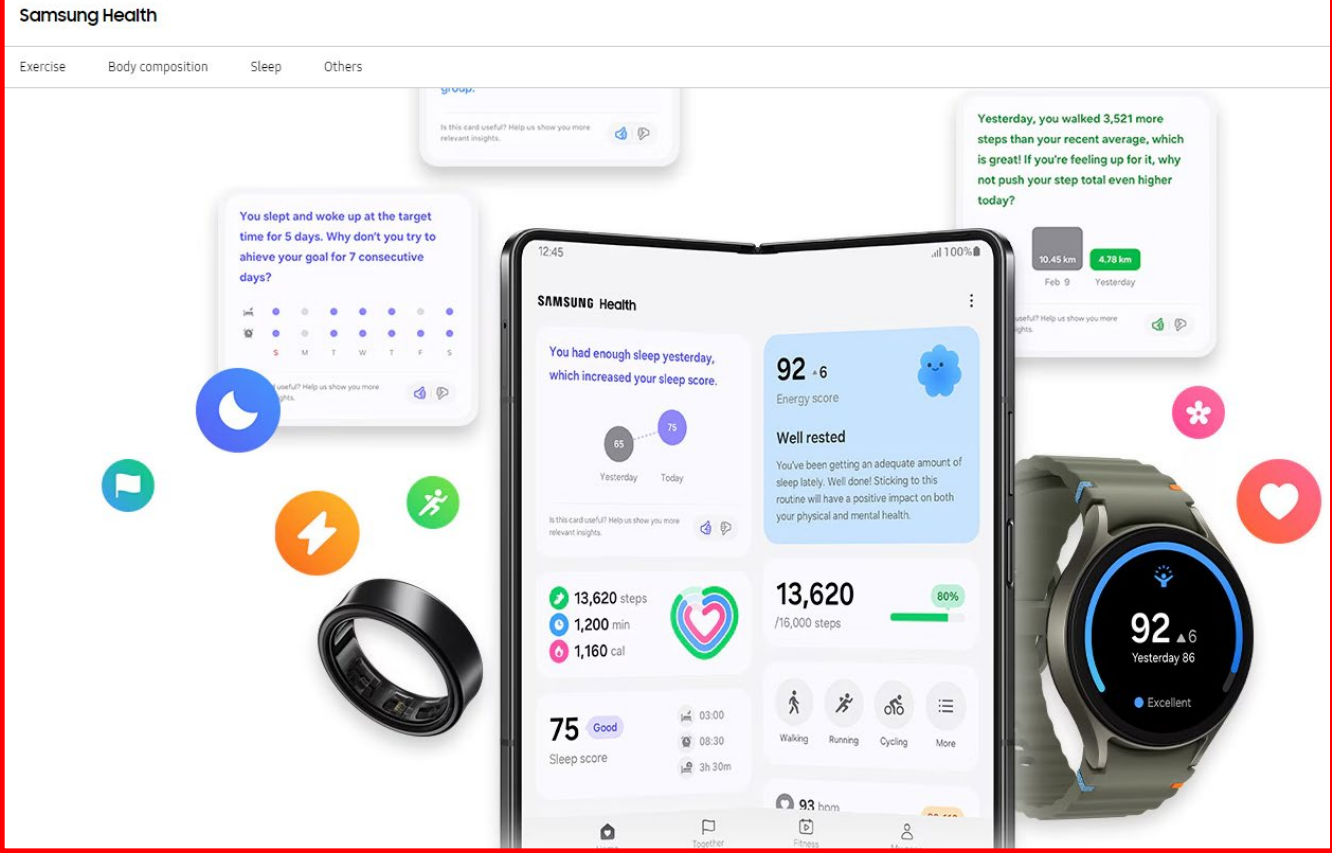
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	Medical AFE4490 PPG-2 LED, 1 PD 110 dB dynamic range AFE4400 PPG-2 LED, 1 PD 95 dB dynamic range AFE4403 PPG-3 LED, 1 PD 110 dB dynamic range AFE4960P PPG-4 LED, 4 PD 1/2-ch ECG ADS1298R/6R/4R/2R 24-bit 8/6/4/2-ch ECG, Respiration ADS1299/-6/-4 24-bit 8/6/4-ch EEG AFE4960 24-bit 1/2-ch ECG ADS1298/6/4/2/1 24-bit 8/6/4/2/1-ch ECG Health & wearables AFE4460 PPG-32 LED, 4 PD 115 dB signal-to-noise ratio AFE44S30 PPG-8 LED, 4 PD 108 dB signal-to-noise ratio AFE4432 PPG-4 LED, 3 PD 115 dB signal-to-noise ratio AFE44I30 PPG-6 LED, 4 PD 108 dB signal-to-noise ratio AFE4500 PPG-8 LED, 4 PD BIA, EDA, 1-ch ECG AFE4950 PPG-8 LED, 4 PD 1-ch ECG AFE49I30 PPG-6 LED, 4 PD 1-ch ECG Optical biosensing Multimodal biosensing Biopotential Heartrate & SpO₂ ECG or EEG ECG & Respiration ECG, Respiration & Pace Source: https://www.ti.com/data-converters/integrated-special-function/medical-afes/biosensing-afes/overview.html

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'304 Patent Claim	Samsung Accused System ¹
	The image shows a screenshot of the Samsung Health app on a smartphone. The app displays various health metrics and a Samsung Watch. The metrics include: Sleep score (75, Good), Energy score (92, Well rested), Steps (13,620), Distance (10.45 km), and Calories (1,160). The watch face shows the Energy score (92) and a 'Excellent' status. The app interface includes tabs for Exercise, Body composition, Sleep, and Others. There are also several floating cards with motivational messages and icons for different activities like walking, running, and cycling. Source: https://www.samsung.com/us/apps/samsung-health/

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'304 Patent Claim	Samsung Accused System ¹
	 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/

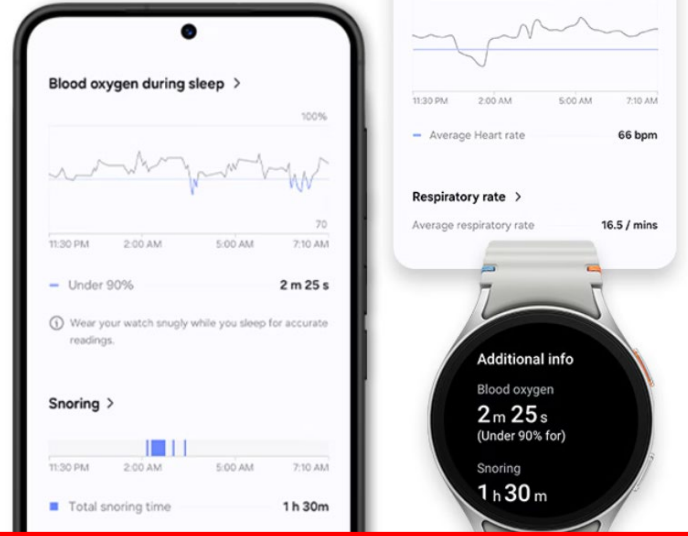
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	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/

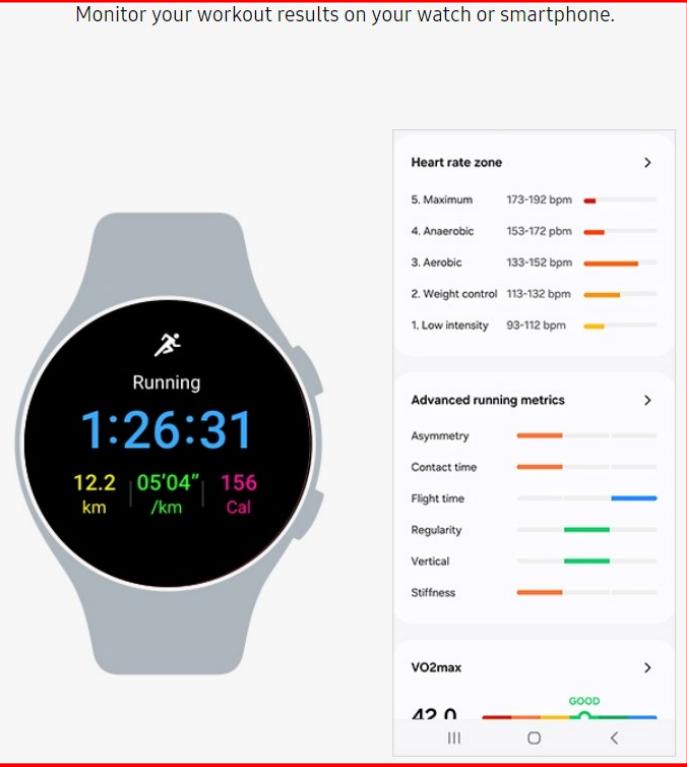
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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’304 Patent Claim	Samsung Accused System ¹
	A screenshot of the Samsung Health app interface. The screen is divided into several sections. At the top, 'Blood oxygen during sleep' shows a line graph of oxygen levels over time (11:30 PM to 7:10 AM) with a peak at 100% and a low at 70%. Below this, 'Heart rate' shows a line graph of heart rate over the same period, with an average heart rate of 66 bpm. 'Respiratory rate' shows an average respiratory rate of 16.5 / mins. 'Snoring' shows a bar chart of snoring events over time, with a total snoring time of 1 h 30m. A smartwatch is shown at the bottom right, displaying 'Additional info' with 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. The entire screenshot is enclosed in a red rectangular border. Source: https://www.samsung.com/us/apps/samsung-health/

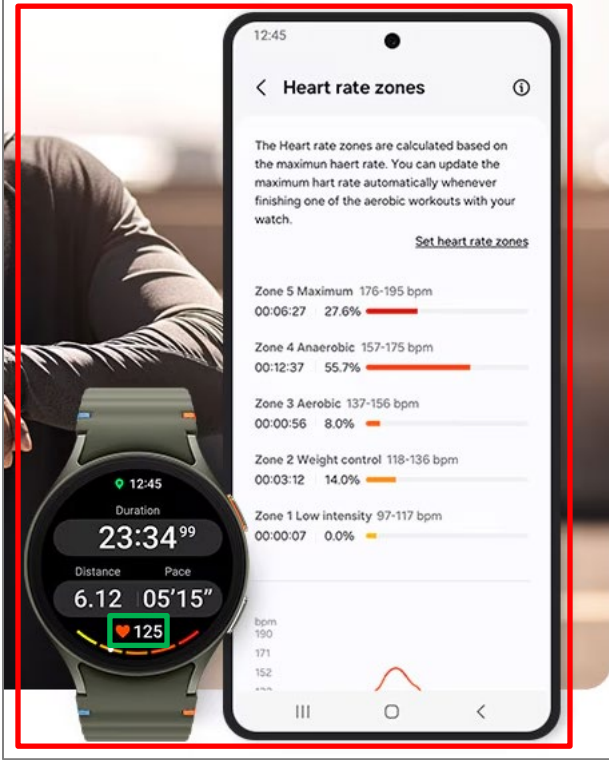
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'304 Patent Claim	Samsung Accused System ¹
	Monitor your workout results on your watch or smartphone.  Source: https://www.samsung.com/us/apps/samsung-health/

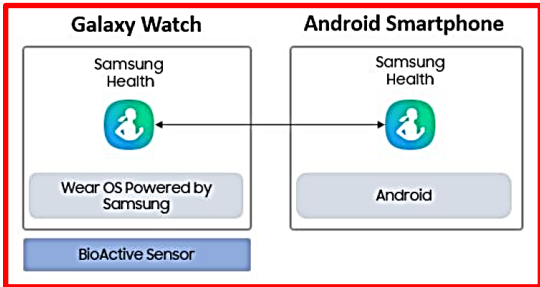
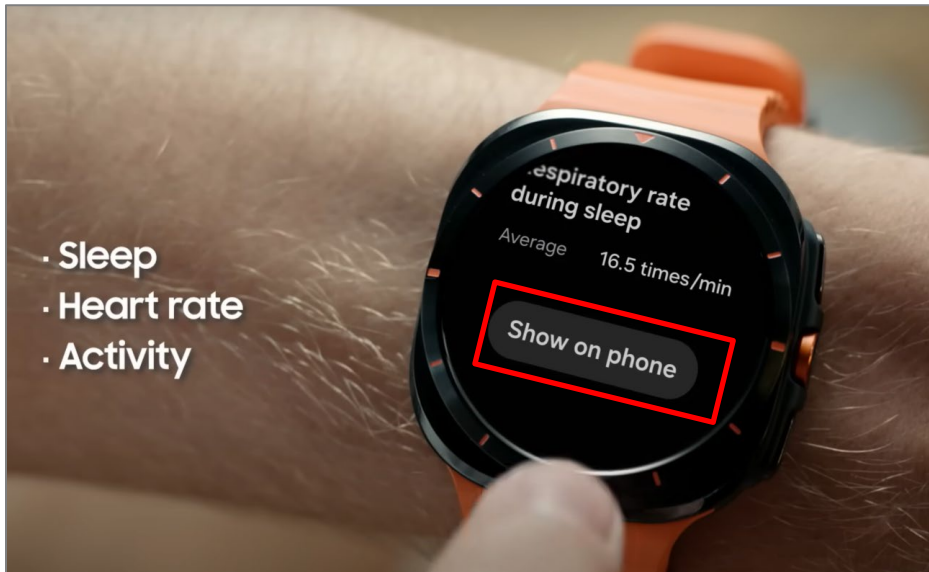
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’304 Patent Claim	Samsung Accused System ¹
	 Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life

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'304 Patent Claim	Samsung Accused System ¹
	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.  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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'304 Patent Claim	Samsung Accused System ¹
	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/ <u>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.</u> 1 Navigate to and open the Samsung Health app. Tap More options (the three vertical dots), and then tap Settings. 2 <u>Tap Sync with Samsung Cloud, and then tap the switch at the top of the screen.</u> 3 Additionally, you can tap Sync using to select Wi-Fi only or Wi-Fi and mobile data. 4 <u>Tap Sync now to immediately sync your Samsung Health data.</u> 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/
19[a] a measurement device including a light source	The Accused Smartwatch is a measurement device including a light source comprising a plurality of semiconductor sources for measuring one or more physiological parameters, literally or under the doctrine of equivalents.

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’304 Patent Claim	Samsung Accused System ¹
comprising a plurality of semiconductor sources for measuring one or more physiological parameters, the measurement device configured to:	For example, the Accused Smartwatch is worn on the wrist of the user for measuring the user’s heart rate. A Samsung Galaxy Watch Ultra smartwatch is shown. It has a black circular face with multiple sub-dials and a white bezel. The watch is attached to a bright orange, perforated, flexible strap. The watch is positioned diagonally within a thin orange rectangular border. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

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'304 Patent Claim	Samsung Accused System ¹
	 More precise <u>Heart Rate Tracking</u> Zero in on more precise readings during workouts using Heart Rate Tracking^{3, 4, 5} with Galaxy AI² that filters out the physical movements of your body. Insights are collected by your Watch and analyzed on your phone. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

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

'304 Patent Claim	Samsung Accused System ¹
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ The Accused Smartwatch includes a light source comprising multiple light emitting diodes (“LEDs”), such as a green LED, a red LED, and an infrared LED, each of which includes a “semiconductor source.” 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

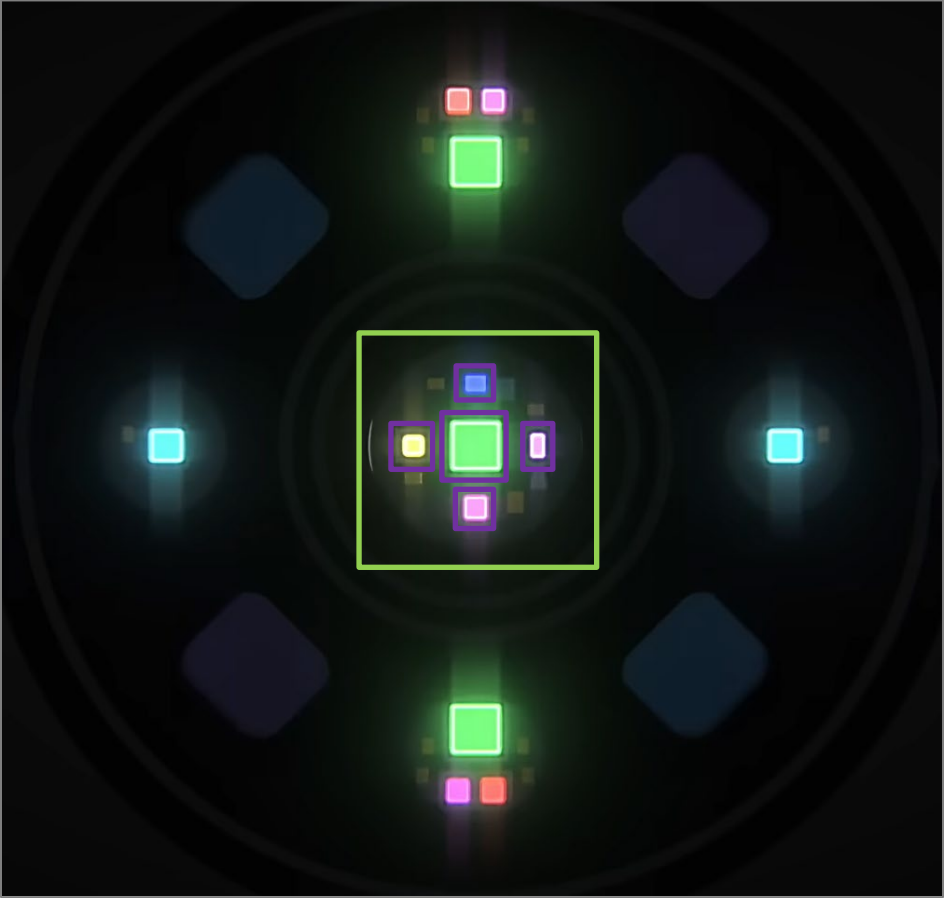
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
	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 broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood pressure, blood oxygen levels and stress levels. Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor 

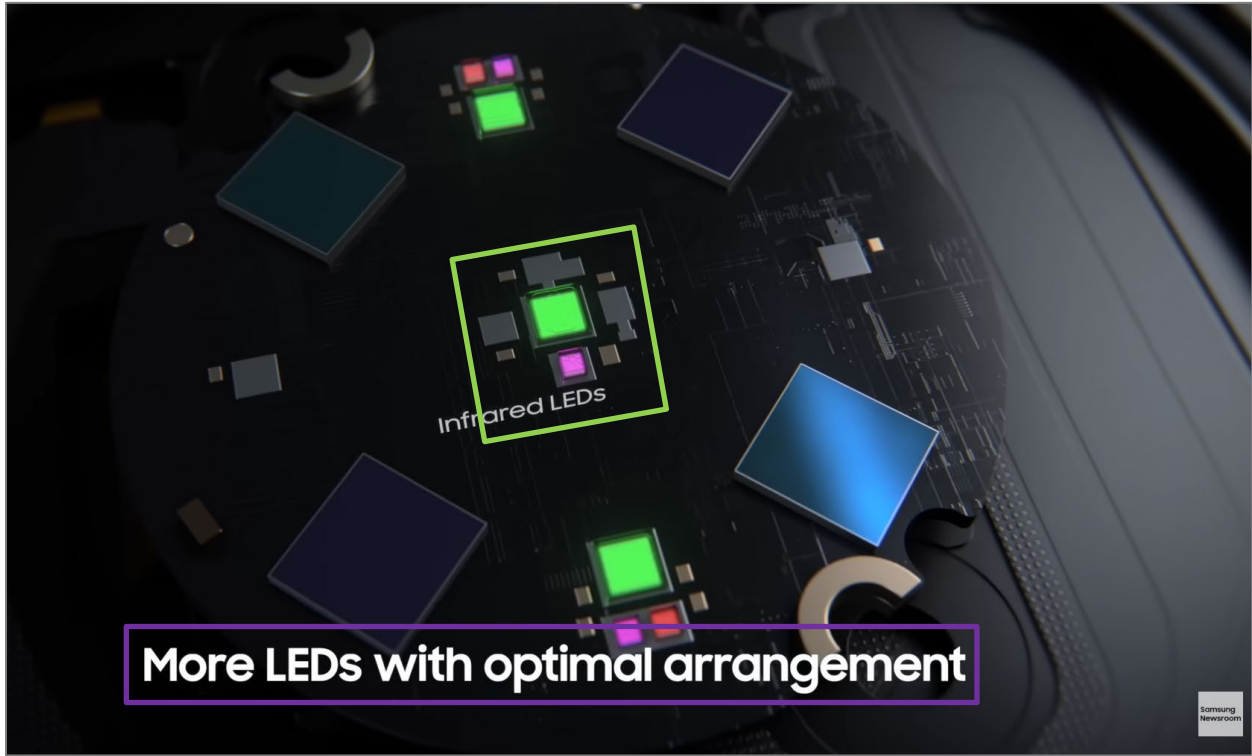
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	Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/  Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

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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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'304 Patent Claim	Samsung Accused System ¹
	Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327
19[b] generate, by modulating at least one of the semiconductor sources having an initial light intensity, an input optical beam having one or more optical wavelengths, and	In the Accused Smartwatch, the semiconductor sources are configured to generate, by modulating at least one of the semiconductor sources having an initial light intensity, an input optical beam having one or more optical wavelengths, literally or under the doctrine of equivalents. For example, the Accused Smartwatch includes multiple LEDs (“semiconductor sources”), such as a green LED, a red LED, and an infrared LED. Different color LEDs and infrared LEDs each generate an output optical beam with one or more optical wavelengths. 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

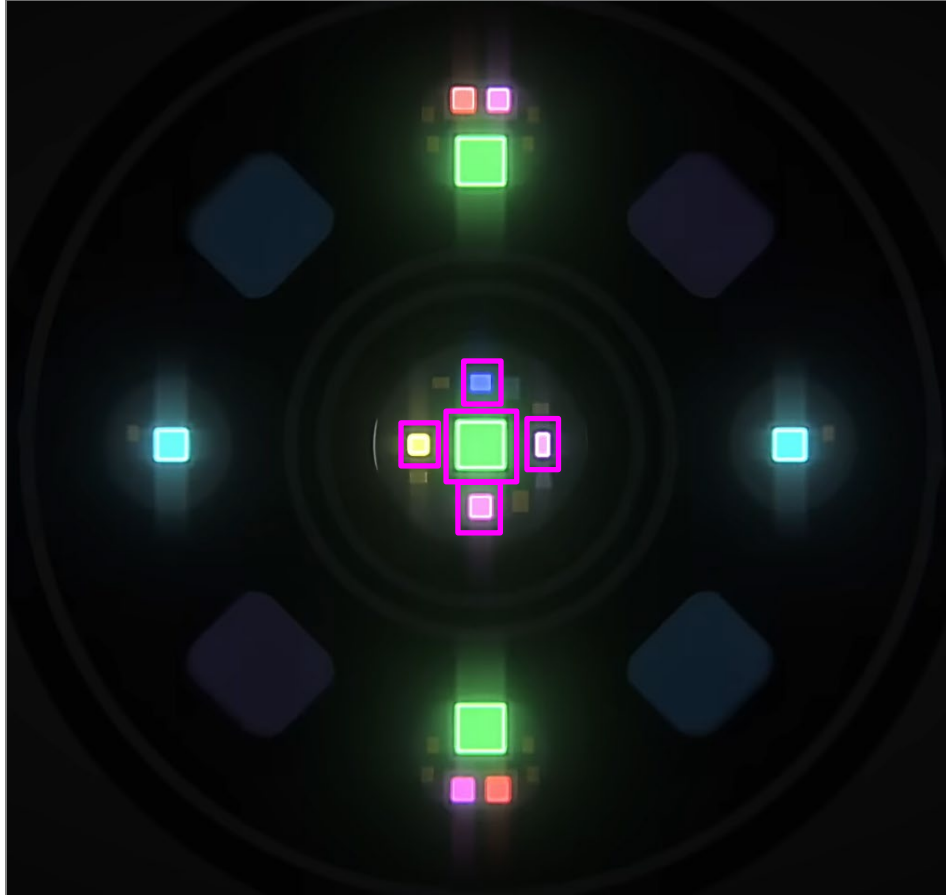
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	heart rate during intensive workouts is 30% more accurate compared to its predecessor.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor The following data types are supported by the Samsung Privileged Health SDK: <table border="1" data-bbox="506 501 1526 924"><tr><td data-bbox="506 501 976 641">PPG green</td><td data-bbox="976 501 1526 641">Raw data from PPG <u>green</u> LED. Provided as a batching event.</td></tr><tr><td data-bbox="506 641 976 794">PPG IR</td><td data-bbox="976 641 1526 794">Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 794 976 924">PPG red</td><td data-bbox="976 794 1526 924">Raw data from PPG <u>red</u> LED. 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	PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.	PPG IR	Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.	PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.
PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.						
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PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.						

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

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	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: <table border="1" data-bbox="510 355 1495 1154"> <thead> <tr> <th colspan="2" data-bbox="510 407 905 459">Table 1. LEDs – Wavelengths and Applications</th></tr> <tr> <th data-bbox="510 459 905 511">LED Wavelength (Color)</th><th data-bbox="905 459 1495 511">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="510 511 905 563">410–420 nm (Violet)</td><td data-bbox="905 511 1495 563">Skin therapy</td></tr> <tr> <td data-bbox="510 563 905 615">430–470 nm (Blue)</td><td data-bbox="905 563 1495 615">Dental curing instruments</td></tr> <tr> <td data-bbox="510 615 905 667">470 nm (Blue)</td><td data-bbox="905 615 1495 667">White LEDs using phosphor</td></tr> <tr> <td data-bbox="510 667 905 719">520–530 nm (Green)</td><td data-bbox="905 667 1495 719">Green traffic signal lights</td></tr> <tr> <td data-bbox="510 719 905 771">580–590 nm (Amber)</td><td data-bbox="905 719 1495 771">Amber traffic signal lights</td></tr> <tr> <td data-bbox="510 771 905 823">630–640 nm (Red)</td><td data-bbox="905 771 1495 823">Red signal lights</td></tr> <tr> <td data-bbox="510 823 905 875">660 nm (Deep Red)</td><td data-bbox="905 823 1495 875">Blood oximetry</td></tr> <tr> <td data-bbox="510 875 905 927">680 nm (Deep Red)</td><td data-bbox="905 875 1495 927">Blood analysis</td></tr> <tr> <td data-bbox="510 927 905 979">800–850 nm (Near-IR)</td><td data-bbox="905 927 1495 979">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="510 979 905 1031">850–940 nm (Near-IR)</td><td data-bbox="905 979 1495 1031">Photoelectric controls</td></tr> <tr> <td data-bbox="510 1031 905 1083">940 nm (Near-IR)</td><td data-bbox="905 1031 1495 1083">Covert illumination CCD-based systems</td></tr> </tbody> </table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706	Table 1. LEDs – Wavelengths and Applications		LED Wavelength (Color)	LED Applications	410–420 nm (Violet)	Skin therapy	430–470 nm (Blue)	Dental curing instruments	470 nm (Blue)	White LEDs using phosphor	520–530 nm (Green)	Green traffic signal lights	580–590 nm (Amber)	Amber traffic signal lights	630–640 nm (Red)	Red signal lights	660 nm (Deep Red)	Blood oximetry	680 nm (Deep Red)	Blood analysis	800–850 nm (Near-IR)	Night-vision illuminators and beacons for use with night-vision goggles or CCDs	850–940 nm (Near-IR)	Photoelectric controls	940 nm (Near-IR)	Covert illumination CCD-based systems
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19[c] receive and to deliver a portion of the input optical beam to tissue,	The Accused Smartwatch is configured to receive and to deliver a portion of the input optical beam to tissue, wherein the tissue reflects at least a portion of the input optical beam delivered to the tissue, literally or under the doctrine of equivalents.																										

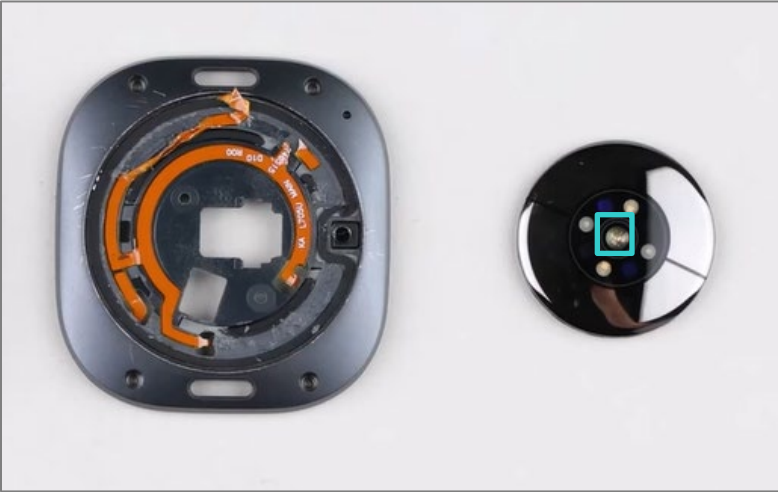
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wherein the tissue reflects at least a portion of the input optical beam delivered to the tissue;	For example, the Accused Smartwatch comprises one or more lenses positioned between LEDs and the wrist of a user when worn by the user. The lenses receive a portion of the output optical beam from the LEDs and deliver the analysis output beam to a tissue sample of the user (<i>e.g.</i>, skin, blood vessels, veins).  Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0 Samsung states that “[t]he Galaxy Watch uses light sensors that operate within the limits set by the IEC62471 safety regulations. However, people with photosensitive skin may have adverse reactions to light, such as skin discoloration or a rash.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor. Thus, the one or more lenses in the Accused Smartwatch delivers light that is output from the LEDs to skin of the user (“lens output light to tissue”).

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	 Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0  Source: https://www.youtube.com/watch?v=jlW0i7u4FVk

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	Additionally, in a technical paper, Samsung engineers and pixel designers for photoplethysmography (“PPG”) sensors explained “applying micro lenses” and using “micro lens focusing” techniques to enhance the delivery of infrared (“IR”) light sources. J. Lim et al., “A single chip PPG sensor with enhanced IR sensitivity for low power and small size,” 2021 IS&T Int’l Symp. Elec. Imaging, at 2-3, <i>available at</i> https://library.imaging.org/admin/apis/public/api/ist/website/downloadArticle/ei/33/7/art00002. 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. The Accused Smartwatch (“wearable measurement 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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	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:

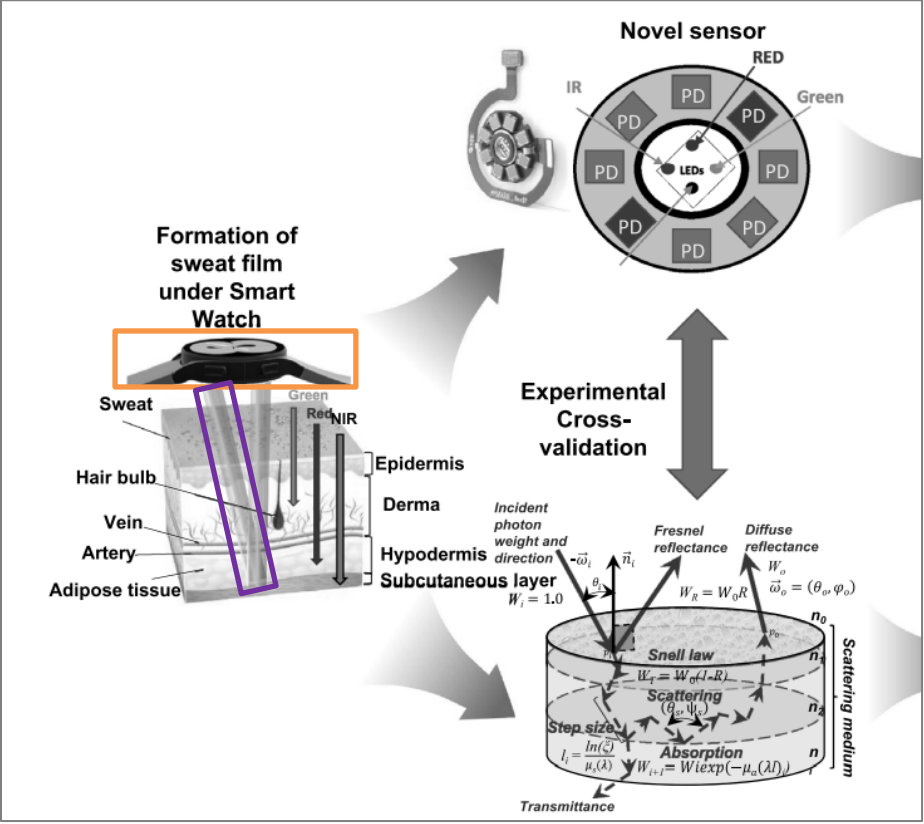
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	Application <i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate.</i> For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume 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.

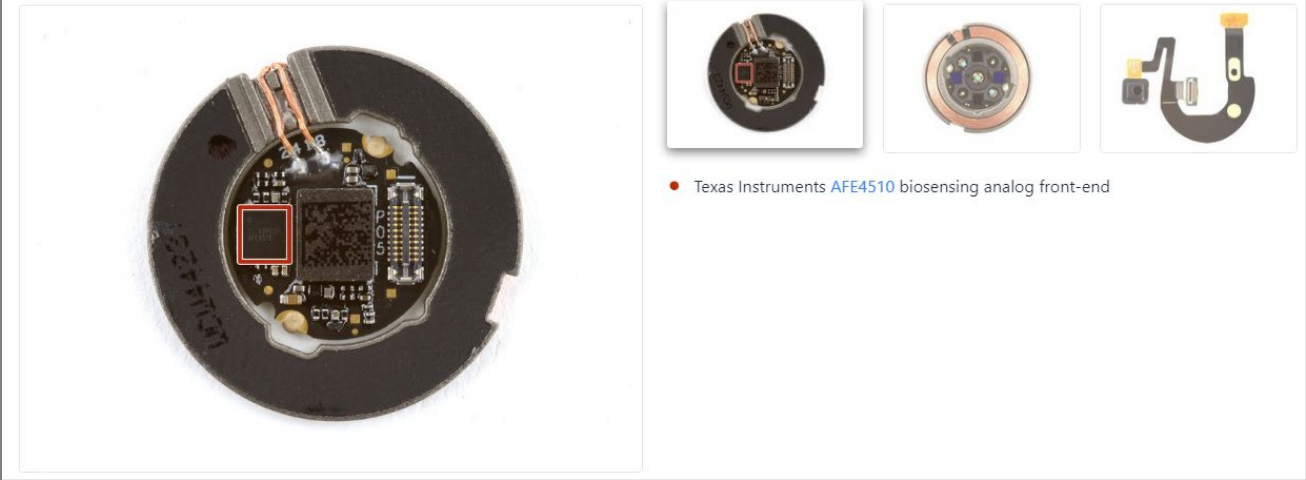
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	Additionally, the following scientific report authored by multiple Samsung engineers further shows an analysis output beam being delivered to a tissue sample of the user:  Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in 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.

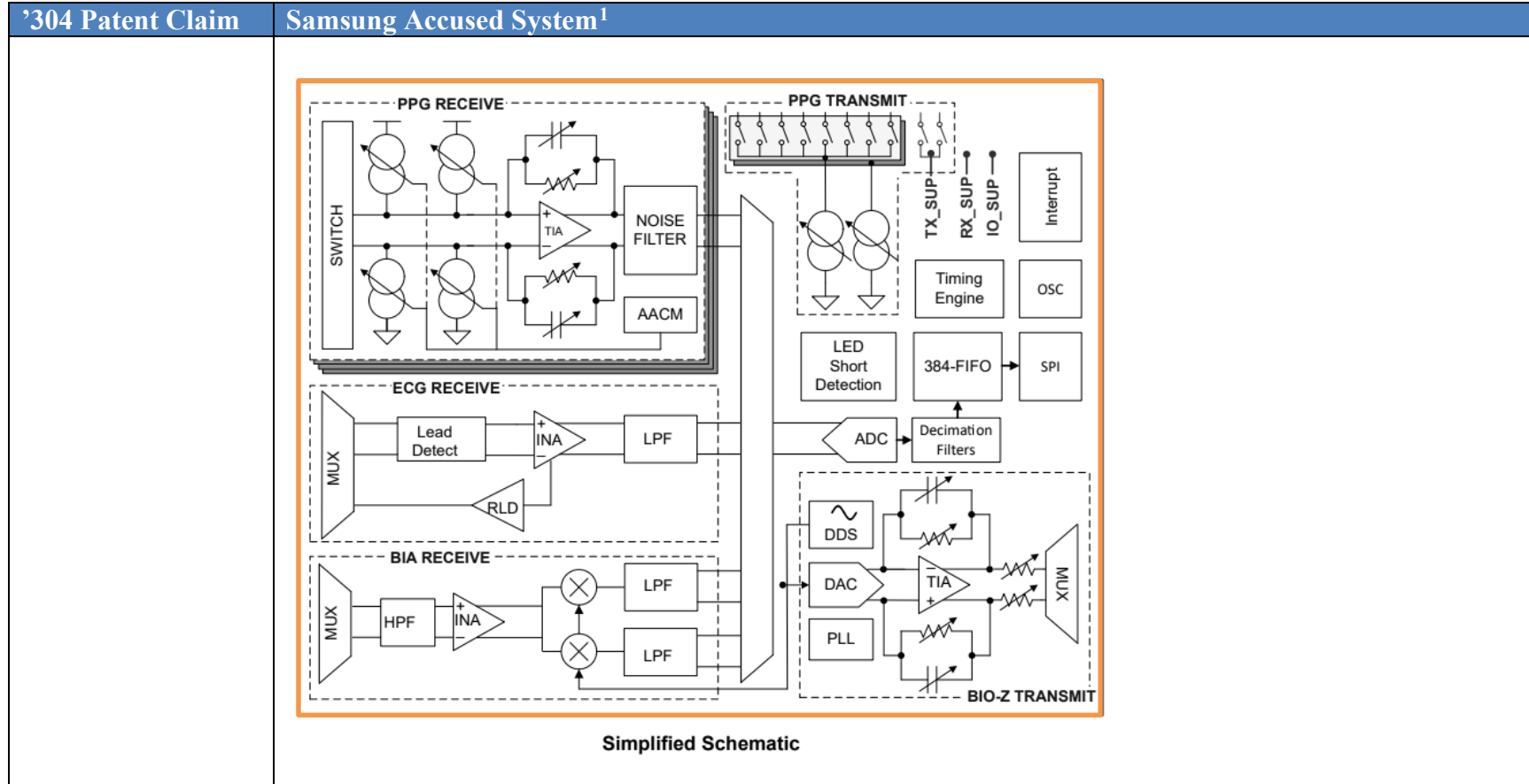
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19[d] the measurement device further comprising a receiver configured to: capture light while the semiconductor sources are off and convert the captured light into a first signal, and capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a portion of the input optical beam reflected from the tissue;	The Accused Smartwatch is configured to capture light while the semiconductor sources are off and convert the captured light into a first signal, and capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a portion of the input optical beam reflected from the tissue, either literally or under the doctrine of equivalents. For example, the BioActive Sensor includes a PPG sensor that operates in multiple phases, including (1) Ambient (when the LEDs, or “semiconductor sources,” are off) and (2) LED (when the LEDs, or “semiconductor sources,” are on). During the Ambient phase, the sensor receives light with the LEDs off and generates a first signal. In the LED phase, the sensor receives light from the LEDs and generates a second signal. 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=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.

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	PPG signal acquisition: – Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19μA for the Receiver 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 Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.

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		5.1 PPG Configuration 5.1.1 Phase Definition This sheet is used to specify number of phases, timing, signal chain parameters associated with each phase, and the LED/PD association for each phase. The phase type is selected from the drop down menu (<u>Ambient</u> and <u>LED</u>) and the appropriate parameters for the phase type are automatically shaded in blue. Specify only the parameters that show up in the Blue boxes. Manually fill each cell using the drop down boxes (do not cut and paste values across cells). Also, fill only the boxes that show up in blue. Do not modify the cream- colored boxes.																																																																																																																																																																																																																																																																																																																																																																						
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'304 Patent Claim

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	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
3		ILED_SAMP	0	us (LED ON start to SAMP start)			1	No data written into FIFO						Single or Dual TIA			Single	
4							2	Phase [N] - Phase [N-1]						PPG Decimation Factor: PPG_DEC_F		2	PPG Decim: EN_PPG_DEC	
5	Phase parameter table						3	Phase [N-1] - Average(Phase [N], Phase [N-2])						TIA1				
							4	Phase[N] - Phase [N-2]										
6	Phase	Phase type	LED drv1 connects to	LED drv2 connects to	NUMAV	Stagger LED?	Fractional masking	FIFO data word	SAMP time (us)	Filter BW Selection	Connect PD4?	Connect PD3?	Connect PD2?	Connect PD1?	Rf (kOhm)	Cf (pF)	IOFFDAC_TIA1 (uA)	AACM TYPE
7	1	Ambient			2	0	Never mask	1	115	Set1				1	100	20	0	ANA AACM
17	2	LED	TX5	TX5	2	0	Never mask	1	115	Set1				1	100	20	0	LED_DC Cancel
27	3	Ambient			2	0	Never mask	3	115	Set1				1	100	20	0	ANA AACM
37																		
47																		
57																		
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77																		
87																		
97																		
107																		
117																		

Figure 5-1. PPG per-phase configuration

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

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

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	The top section shows two system-level diagrams. The 'Heart Rate Monitoring' diagram illustrates a hand with a sensor (LED, ILED, PD) connected to an Analog Front End (AFE) and a Heart Rate Extraction (MCU). The 'SpO₂ Monitoring' diagram shows a similar setup but with an additional SpO₂ Calculation Algorithm block. The bottom section is a detailed 'Block Diagram' of the receiver. It features a Switch Matrix connected to multiple input channels (INP1, INM1, etc.). The signal path includes a Receiver section with a TIA (Transimpedance Amplifier) and a Noise Reduction Filter, followed by Ambient DC Cancellation and LED DC Cancellation blocks. The output goes through a MUX (Multiplexer), an ADC (Analog-to-Digital Converter), and Decimation before being sent to the Transmitter section, which includes TX SUP, TX1, TX2, and LED Drivers. Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, available at https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F. A technical paper authored by Samsung engineers further explains a PPG signal receiver for use in wearable measurement devices configured to operate in an Ambient and LED phase:

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

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	Ambient Light Cancellation(ALC) Block Figure 2. Detailed architecture of the ambient light cancellation (ALC) block. Source: J. Kim et al., “Ambient light cancellation in photoplethysmogram application using alternating sampling and charge redistribution technique,” 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), at 6441-42. 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

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of the sensor on the body, and other end-user interactions.” Samsung Galaxy Watch7 | Watch Ultra User Guide, at p. 42, *available at* https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf.

Additionally, the following scientific report authored by multiple Samsung engineers further shows an analysis output beam being delivered to a tissue sample of the user:

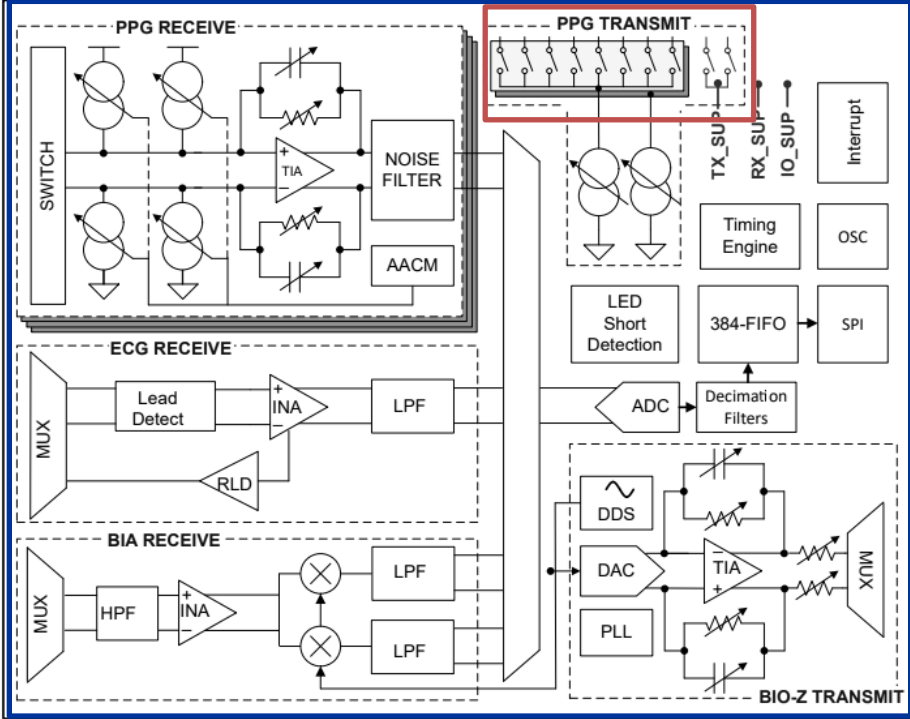
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	Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in situ continuous monitoring of human skin hydration and body sweat loss,” Scientific Reports (2023), at 3, <i>available at</i> https://www.nature.com/articles/s41598-023-40339-7.pdf.
19 e synchronize to the modulation of the at least one of the semiconductor sources;	The Accused Smartwatch comprises a receiver configured to synchronize to the modulation of the at least one of the semiconductor sources, literally or under the doctrine of equivalents. 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 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>

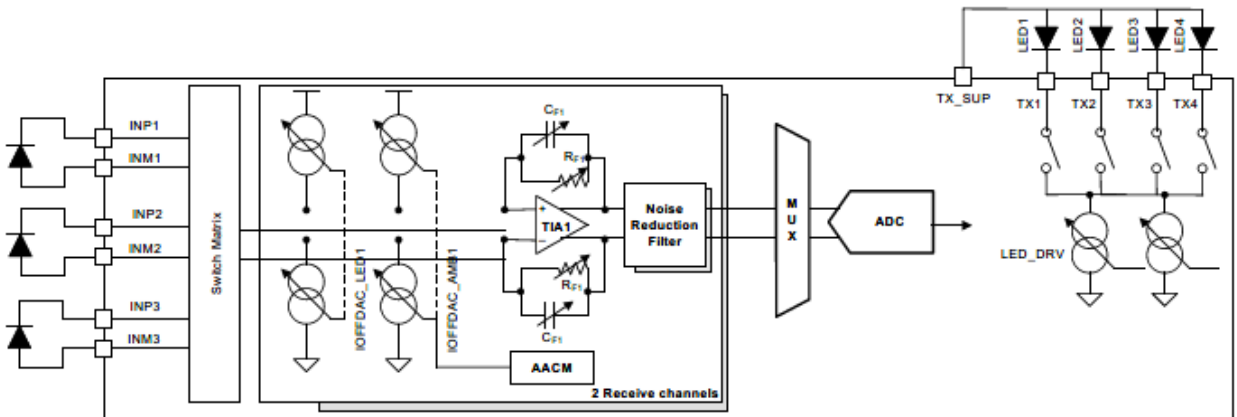
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	 The diagram is a block-level schematic of the AFE4510 system. It is divided into three main functional blocks: PPG RECEIVE, ECG RECEIVE, and BIA RECEIVE, all connected to a central ADC and Decimation Filters. The PPG RECEIVE block includes a SWITCH, 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 border, includes a current driver for LEDs, TX_SUP, RX_SUP, and IO_SUP pins, and an Interrupt pin. The BIO-Z TRANSMIT block includes a DDS (Direct Digital Synthesizer), a DAC (Digital-to-Analog Converter), a PLL (Phase-Locked Loop), a TIA, and a MUX. Other blocks include a Timing Engine, OSC (Oscillator), 384-FIFO, SPI, and LED Short Detection. The entire system is labeled 'Simplified Schematic'. 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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	 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, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

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	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.

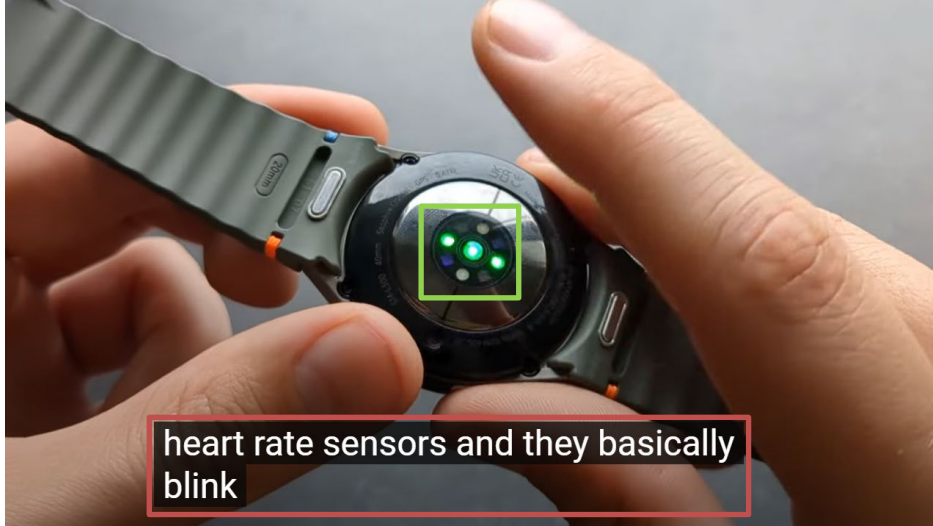
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	“The BioActive sensor has three sensors integrated inside. Apart from body composition, it can measure heart rate, ECG, and blood pressure. . . . It is one of the common uses of the BioActive sensor on your Galaxy Watch. The sensor relies on built-in 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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'304 Patent Claim	Samsung Accused System ¹
	 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=JG9pGlqmgcs&t=23s.

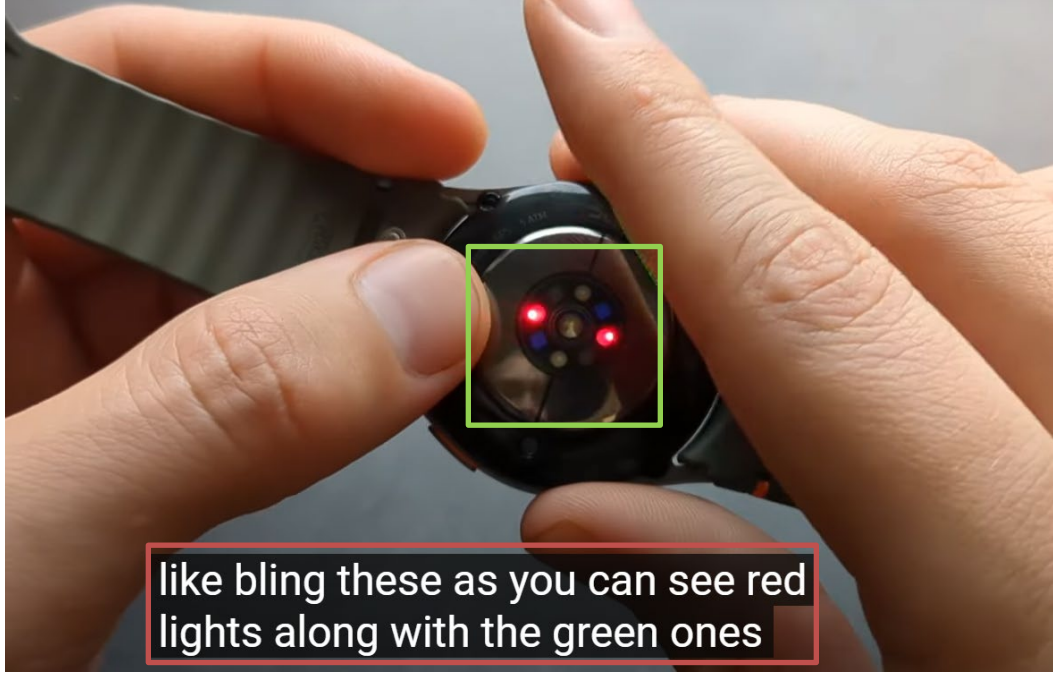
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'304 Patent Claim	Samsung Accused System ¹
	 Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:37, https://youtu.be/JG9pGlmges?si=IrcplcEOdHE3cB3l&t=37

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’304 Patent Claim	Samsung Accused System ¹
	 Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:53, https://youtu.be/JG9pGlmges?si=xMBhD11dBJQoADTO&t=53

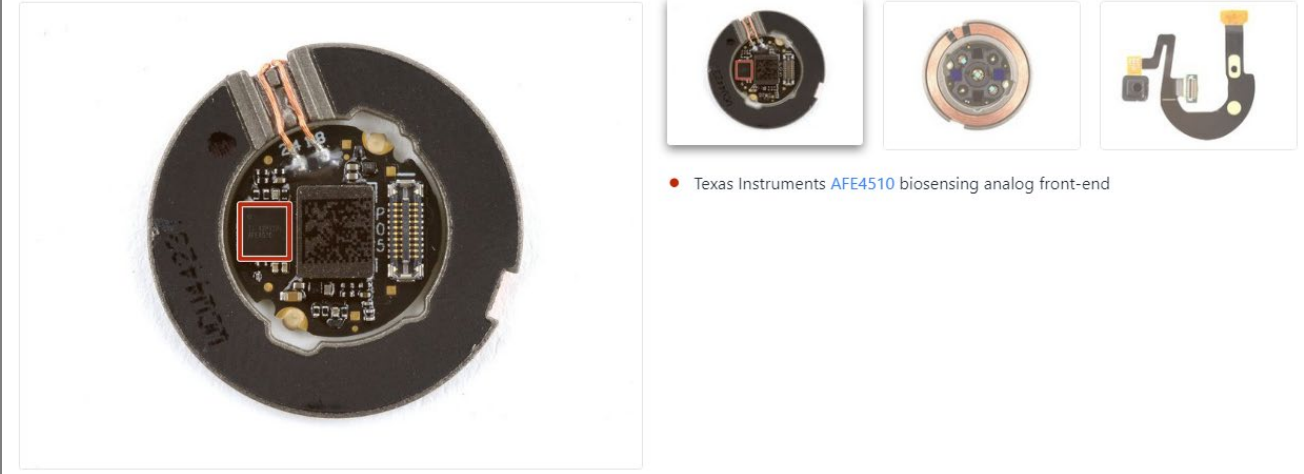
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“Semiconductor source based near infrared measurement device with improved signal-to-noise ratio”

'304 Patent Claim	Samsung Accused System ¹
	 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/JG9pG1qmgcs?si=YV8CQ6yVqkvL7ITZ&t=53
19[f] the measurement device further configured to improve a signal-to-noise ratio of the input optical beam reflected from the tissue by:	The Accused Smartwatch is configured to improve the signal-to-noise ratio by differencing the first signal and the second signal. For example, ambient light is considered as noise in PPG sensors. Therefore, the presence of ambient light decreases the SNR of PPG sensors. Ambient light cancellation is performed to cancel out the ambient light noise, thereby increasing the SNR. The BioActive Sensor of the Galaxy Watch Ultra performs ambient light cancellation (also referred to as “Digital Ambient Subtraction”), to increase the SNR, by comparing the measured signal when the LED sources are off (“first signal”) and the measured signal when the LED sources are on (“second signal”).

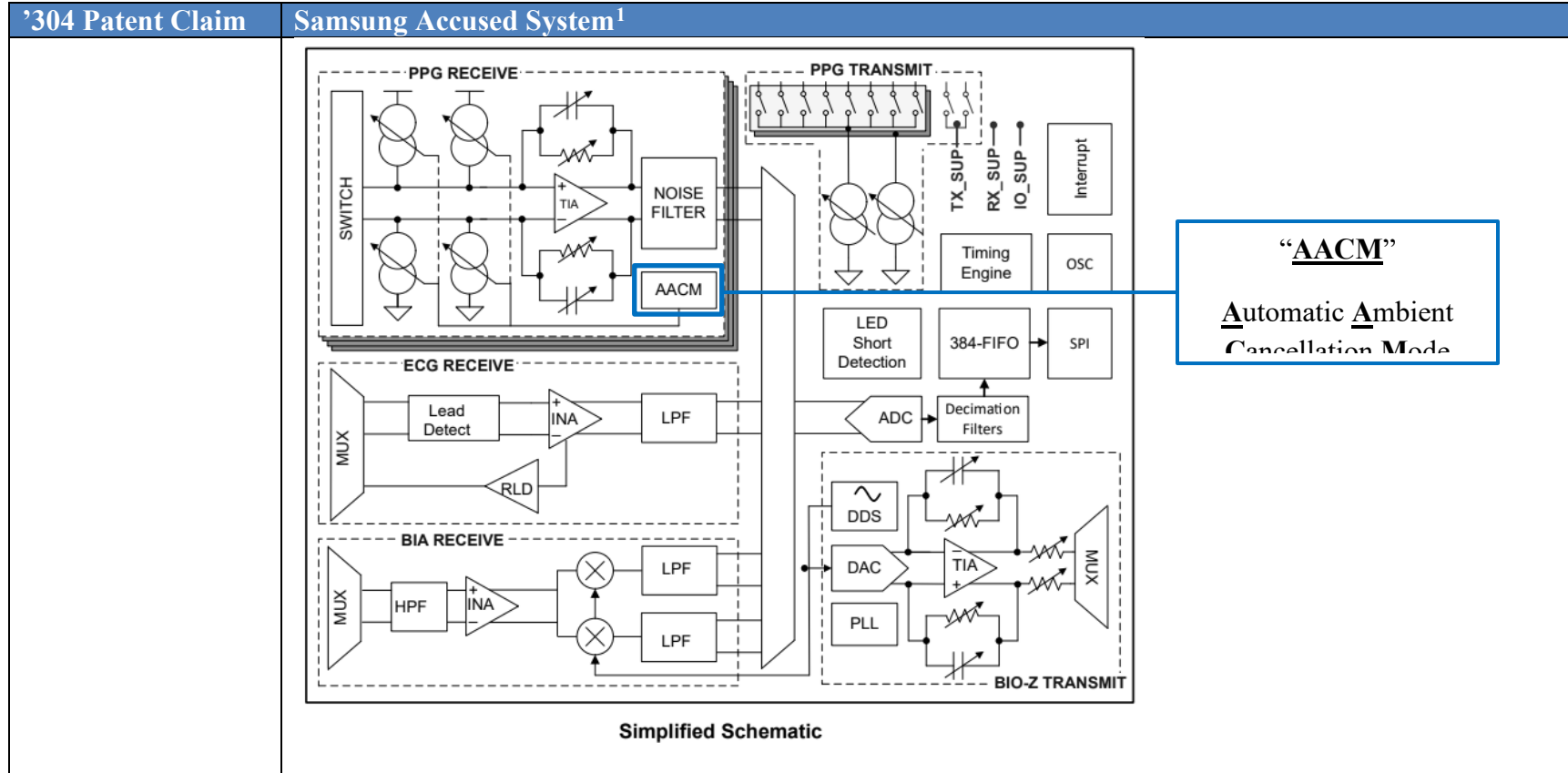
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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

'304 Patent Claim	Samsung Accused System ¹
differencing the first signal and the second signal, and	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.

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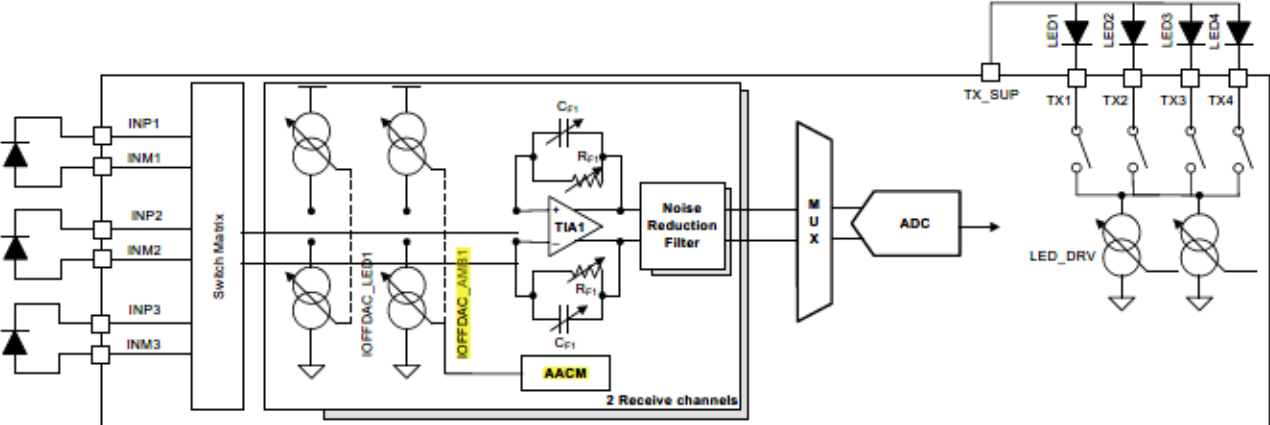
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	PPG signal acquisition: – Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19µA for the Receiver 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 – <u>Digital Ambient Subtraction at ADC Output</u> Source: Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf. “To save power, the LED is pulsed at the PRF rate, turning on for a short window in each PRF cycle. Each turning on of the LED results in one sample in the digital data stream. . . . Input offset cancellation DAC cancels DC from both ambient and LED, and allows a high TIA gain setting for the best noise performance.” Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 1, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

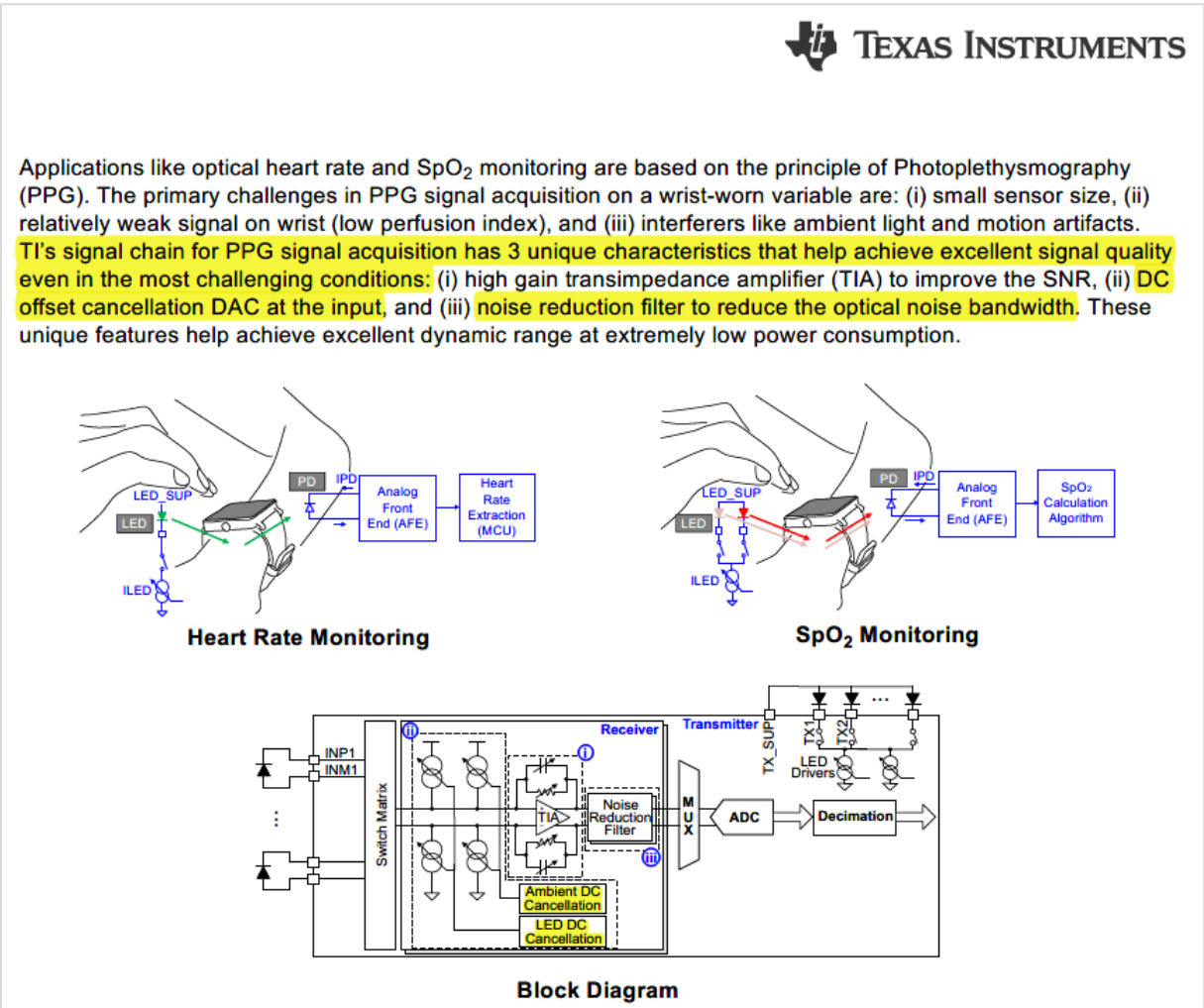
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹																		
Table 1. Specifications for OHRM on Wearables <table><tr><th>System Specifications</th><th>AFE4432</th><th>Comments</th></tr><tr><td>Multi-sensor support</td><td>4 LEDs, 3 PDs</td><td>Combining signals from multiple PDs and LEDs helps mitigate motion artifacts</td></tr><tr><td>Sampling rate</td><td>1 Hz–1 kHz</td><td>A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM</td></tr><tr><td>Current consumption</td><td>12 μA</td><td>For the receiver at 25 Hz PRF</td></tr><tr><td>Peak SNR</td><td>115 dB over 10-Hz bandwidth</td><td>Important consideration to achieve good accuracy in low perfusion cases.</td></tr><tr><td>Ambient rejection</td><td>> 70 dB up to 160 Hz</td><td>Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting</td></tr></table>		System Specifications	AFE4432	Comments	Multi-sensor support	4 LEDs, 3 PDs	Combining signals from multiple PDs and LEDs helps mitigate motion artifacts	Sampling rate	1 Hz–1 kHz	A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM	Current consumption	12 μA	For the receiver at 25 Hz PRF	Peak SNR	115 dB over 10-Hz bandwidth	Important consideration to achieve good accuracy in low perfusion cases.	Ambient rejection	> 70 dB up to 160 Hz	Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting
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	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.  The diagram shows the Texas Instruments logo and the title "Optical Heart Rate Monitoring (OHRM) on Wearables". Below the title, it states: "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." Two block diagrams illustrate the signal chains for Heart Rate Monitoring and SpO₂ Monitoring. Both start with a sensor on a wrist receiving light from an LED and reflecting it back to a photodiode (PD). The signal then passes through an Analog Front End (AFE) and an MCU for Heart Rate Monitoring, or an SpO₂ Calculation Algorithm for SpO₂ Monitoring. A detailed Block Diagram shows the internal components: a Switch Matrix, a Receiver with a TIA and Noise Reduction Filter, a Transmitter with TX Drivers, and an ADC. It also highlights "Ambient DC Cancellation" and "LED DC Cancellation" blocks.

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	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. 5 AFE4500 Register Generation Excel The AFE4500_Register_Generation_v*.xlsm will be given by TI. This configuration file will be in the EVM software installation directory. Default file location: C:\Program Files\Texas Instruments\Bio-Sensing\AFE4500EVM\Register config\AFE4500_Register_Generation_v*.xlsm By default the EVM ships in LDO enable mode with following configuration • Clocking : Internal oscillator • PPG configuration – PPG output data rate: 50 Hz – 3 Phases (Phase1, Phase2, Phase3) are defined for PPG: AMB1, LED, AMB2 – PPG Phases are sampled from Green PD of sensor board – TX1 (connected to Green LED on sensor board) is used to LED Phase. – TIA Gain (i.e. Rf): 250 kΩ – Sampling width: 117 μS – Noise reduction filter: 2.5 KHz – ANA AACM: Enabled to cancel ambient signal from all Phases – DIG AACM: Enabled to cancel the DC in LED Phase. • ECG Configuration – ECG output data rate: 500 Hz – ECG INA Gain: 21 Source: Texas Instruments, AFE4500 EVM User Guide, SBAU370 – April 2021, at 23, <i>available at</i> https://www.manualslib.com/download/2652772/Texas-Instruments-Afe4500evm.html.

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

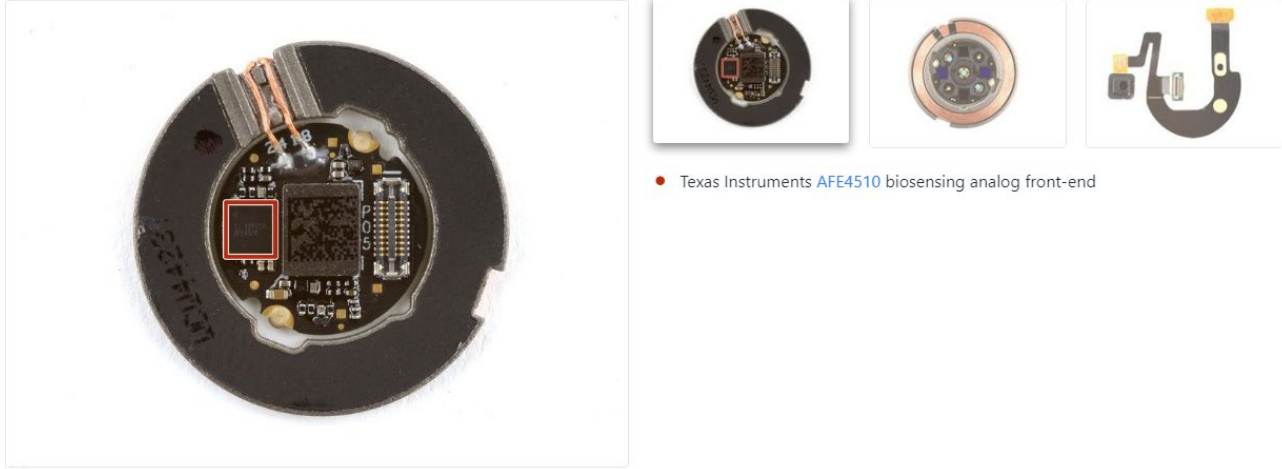
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	Ambient Light Cancellation(ALC) Block Figure 2. Detailed architecture of the ambient light cancellation (ALC) block. Source: J. Kim et al., “Ambient light cancellation in photoplethysmogram application using alternating sampling and charge redistribution technique,” 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), at 6441-42.
19[g] increasing the light intensity relative to the initial light intensity from at least one of the	The Accused Smartwatch is configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources, 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

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'304 Patent Claim	Samsung Accused System ¹
semiconductor sources;	the general output SNR is lower than this peak value. To achieve the peak SNR, the sensor is configured to increase the LED current (“light intensity”) 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=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.

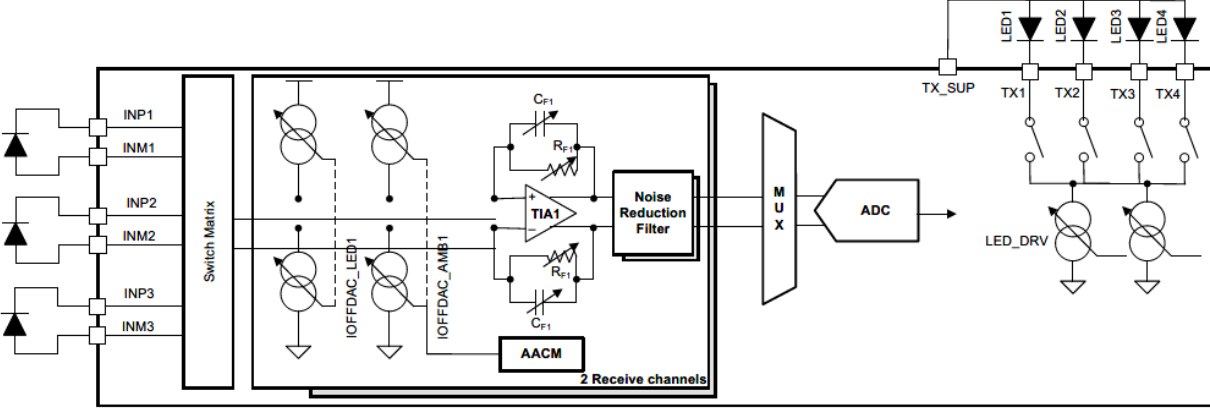
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	3 Description The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bio-impedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that senses the signal from PDs. An ECG receiver 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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	Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-4, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf. 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, <i>available at</i> https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

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'304 Patent Claim	Samsung Accused System ¹
	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, available at https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F.

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'304 Patent Claim	Samsung Accused System ¹
	“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. “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, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor The diagram illustrates the BioActive Sensor system architecture. On the left, a Galaxy Watch displays 'Heart Rate 71' and 'SpO2 96%'. A green 'MEASURE' button is at the bottom. To the right, a flowchart shows 'Sensor Data' (represented by a circular icon) feeding into the 'Samsung Privileged Health SDK' (a blue rounded rectangle). This SDK then feeds into 'Tracking Raw / Processed Health Sensor Data' (a blue rounded rectangle), which finally feeds into the 'Wear OS Application' (a white rounded rectangle). The entire flow is set against a dark blue background.

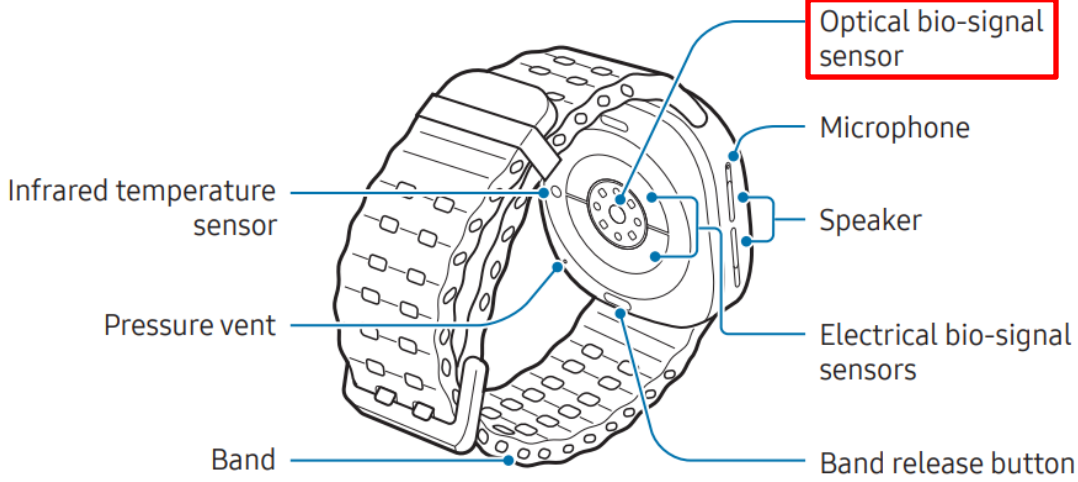
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	“The SDK supports an improved health tracking capability to allow your applications to track the user’s health data accurately with the accelerometer, raw ECG (Electrocardiogram), PPG (Photoplethysmogram), and heart rate including inter-beat interval. 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
19[h] the measurement device further configured to generate an output signal representing at least in part a non-invasive measurement on blood contained within the tissue;	The Accused Smartwatch is further configured to generate an output signal representing at least in part a non-invasive measurement on blood contained within the tissue, literally or under the doctrine of equivalents. For example, the BioActive Sensor in the Accused Smartwatch (“wearable measurement device”) comprises a receiver that: (a) receives and processes a portion of the analysis output beam reflected or transmitted from the tissue sample, and (b) generates an output PPG signal representing at least in part a non-invasive measurement on blood contained within the tissue sample.

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	 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.

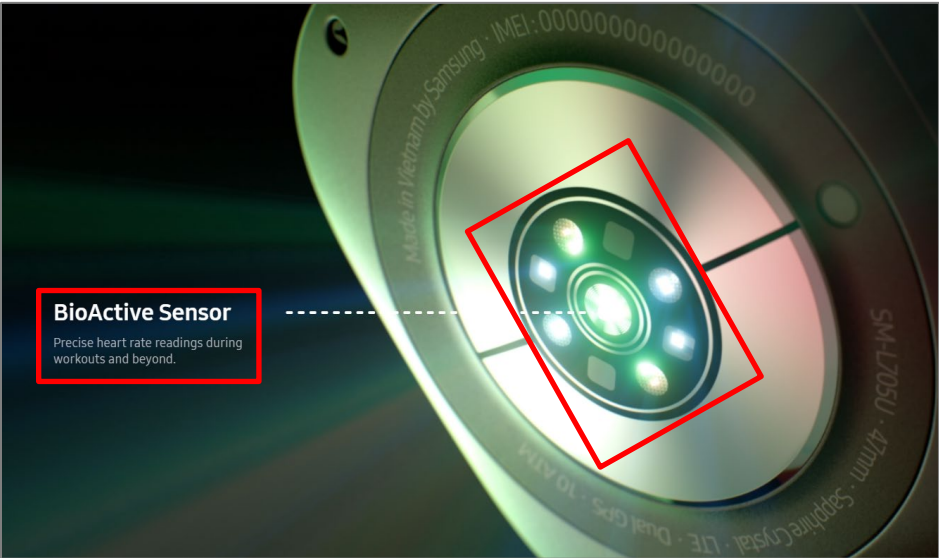
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	 The diagram shows the back of a Samsung Galaxy Watch Ultra with a black case and a brown leather strap. Four components are labeled with dashed lines pointing to them: 'Quick Button' at the top center, 'Dynamic Lug System' at the top right, 'Dual-Frequency GPS' at the bottom left, and 'BioActive Sensor' at the bottom right. The 'BioActive Sensor' label is enclosed in a red rectangular box. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

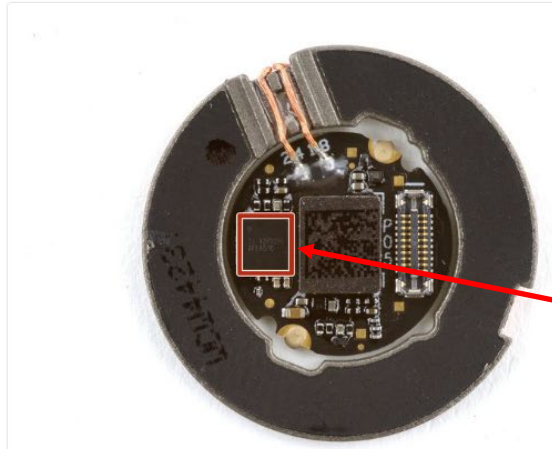
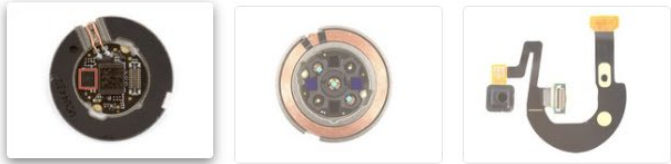
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	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

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	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 The AFE4510 specification (excerpts shown below) describes a PPG signal receiver, a PPG signal transmitter, and PPG signal acquisition functionality for receiving and processing at least a portion of the analysis output beam 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.

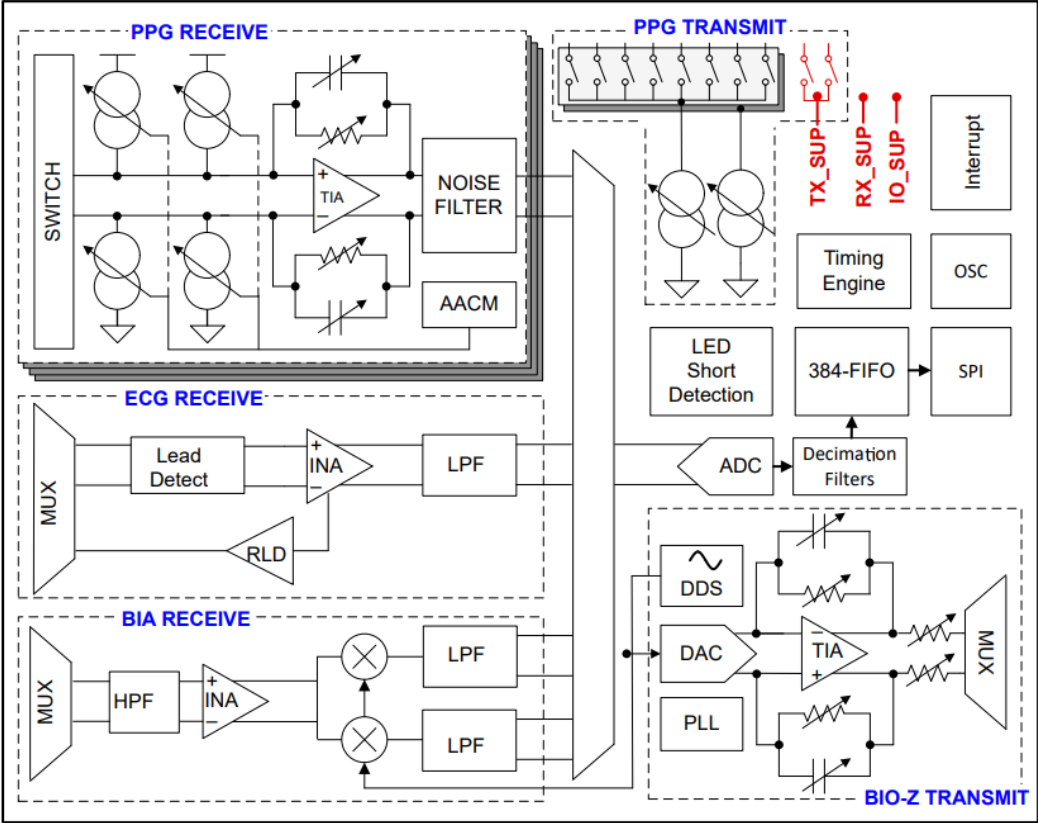
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	 TEXAS INSTRUMENTS AFE4510 SBASB19 – MARCH 2024 AFE4510 Ultra Small, Integrated AFE for Bio Impedance Analysis, Electrical Bio Sensing & Optical Bio Sensing • PPG signal acquisition: – Acquisition of 24 PPG signal sets (LED, AMB) – Supports PPG sensors 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

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	 Simplified Schematic The schematic illustrates the internal components of the Samsung Accused System, organized into several functional blocks: PPG RECEIVE: This block contains a SWITCH, two photodiodes, a TIA (Transimpedance Amplifier), a NOISE FILTER, and an AACM (Analog-to-Digital Converter). PPG TRANSMIT: This block includes a multi-channel switch, two photodiodes, and three output lines labeled TX_SUP, RX_SUP, and IO_SUP. ECG RECEIVE: This block features a MUX (Multiplexer), a Lead Detect circuit, an INA (Instrumentation Amplifier), an RLD (Right Leg Drive) circuit, and an LPF (Low Pass Filter). BIA RECEIVE: This block includes a MUX, an HPF (High Pass Filter), an INA, two multipliers (X), and two LPFs. BIO-Z TRANSMIT: This block contains a DDS (Direct Digital Synthesizer), a DAC (Digital-to-Analog Converter), a PLL (Phase-Locked Loop), a TIA, and a MUX. Central Processing: The system includes an ADC (Analog-to-Digital Converter), Decimation Filters, a 384-FIFO, and an SPI (Serial Peripheral Interface). Other Components: The system also includes an LED Short Detection block, a Timing Engine, an OSC (Oscillator), and an Interrupt block.

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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’304 Patent Claim	Samsung Accused System ¹
	The BioActive Sensor (“receiver”) in the Accused Smartwatch is configured to receive and process at least a portion of the analysis output beam that is reflected from a body tissue sample of the user and to generate an 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:

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	<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 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). 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.

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'304 Patent Claim	Samsung Accused System ¹
	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, <i>available at</i> 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 (“receiver”) of the Accused Smartwatch is configured to receive and process at least a portion of the analysis output beam that is reflected from a body tissue sample of the user and to generate an output PPG signal.

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	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 receiver configured to receive and process at least a portion of the analysis output beam that is reflected from a body tissue sample of the 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

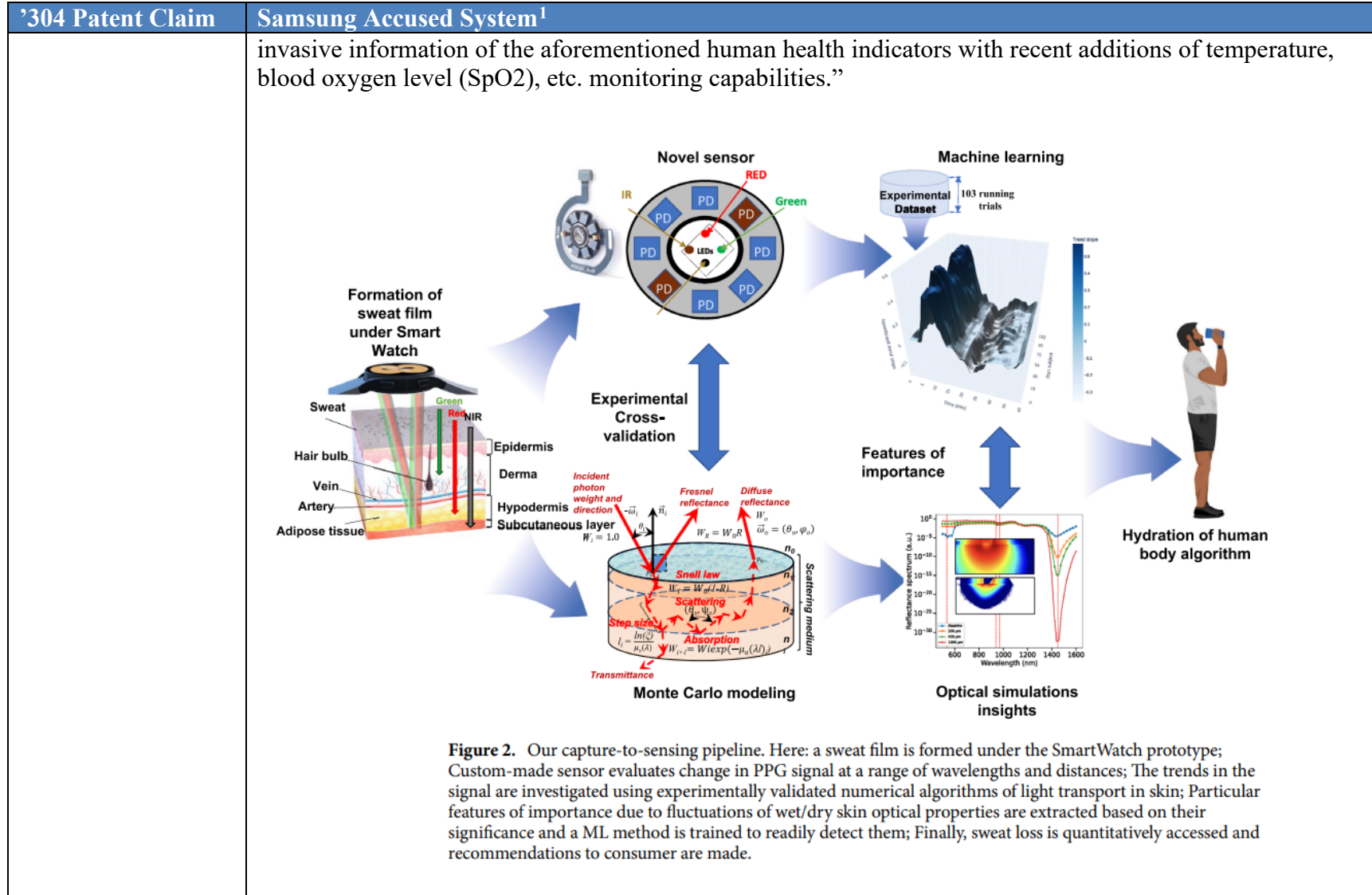
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	absorption by the blood vessel is changed in synchronization with the heart rate. A sensor measures, transmitted or reflected signal represented in Amplitude Modulation It has been used for a long time as a medical tool to measure oxygen saturation (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 2-3, <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-

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	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. The receiver of the Accused Smartwatch has been detailed in other technical documents as well. For example:

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	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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	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.

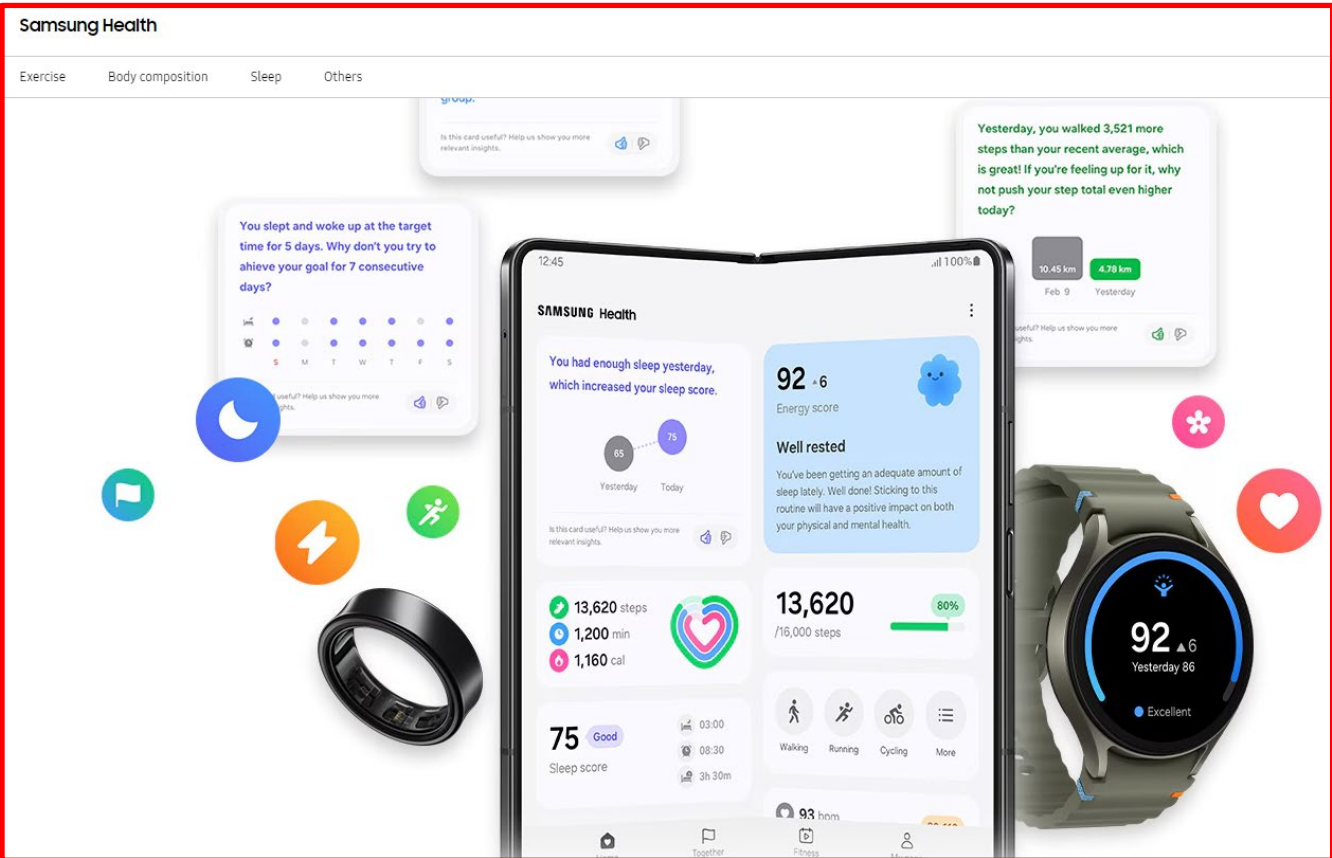
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	Figure 5. Examples of PPG sensor configurations that use multiple LEDs and PDs, and their application to commercial smartwatches. (a–d) illustrate different PPG sensor structures, while (e) through (h) present examples of these structures in use: (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.

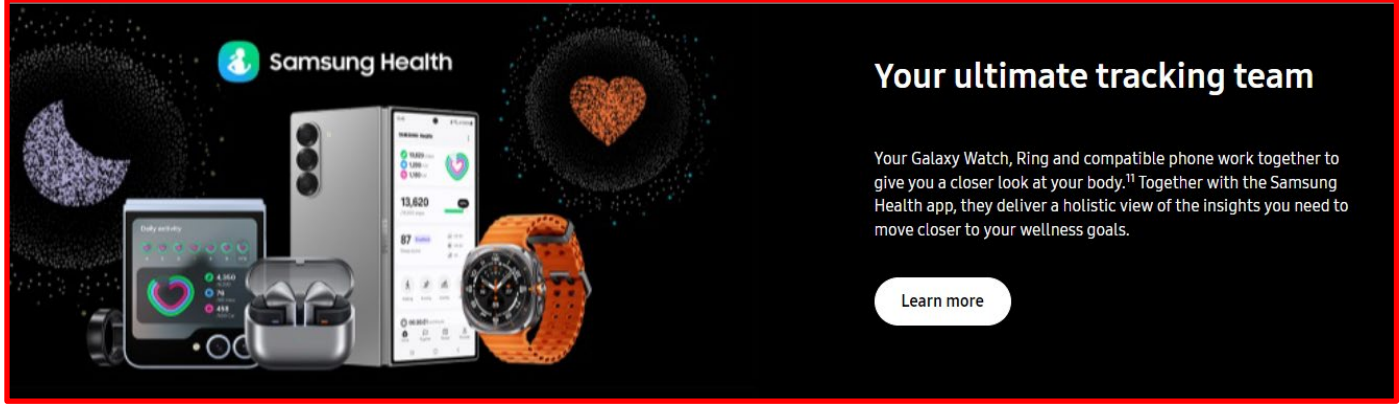
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19<u>ii</u> the wearable device configured to communicate with the smart phone or tablet, the smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a voice input module, a speaker, and a touch screen; and	The Accused Smartwatch is configured to communicate with the smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a voice input module, a speaker, and a touch screen, literally or under the doctrine of equivalents.  The image shows a promotional graphic for the Samsung Health ecosystem. In the center is a smartphone displaying the Samsung Health app interface. The app shows a 'Sleep score' of 92 (up from 86 yesterday), an 'Energy score' of 92 (up from 86 yesterday), and a step count of 13,620 (80% of the 16,000 goal). It also displays a 'Well rested' status and a 'Good' sleep score of 75. Surrounding the phone are other Samsung wearable devices: a Samsung Watch with a black strap and a Samsung Ring. The background features various health-related icons like a heart, a person running, and a lightbulb. Source: https://www.samsung.com/us/apps/samsung-health/

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	A promotional image for Samsung Health. It features a Samsung Galaxy Z Fold6 smartphone displaying the Samsung Health app interface with various health metrics like heart rate, steps, and sleep. Next to it is a Samsung Galaxy Watch Ultra with an orange strap. In the foreground, there's a pair of Samsung wireless earbuds in their charging case. The background is dark with some abstract light patterns. The text 'Your ultimate tracking team' is prominently displayed on the right side of the image. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ For example, the Galaxy Watch Ultra pairs with the Galaxy Z Fold6 (“smart phone”). The Galaxy Z Fold6 includes Wi-Fi connectivity, which requires the smart phone to include both a wireless receiver and a wireless transmitter.

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	 Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/

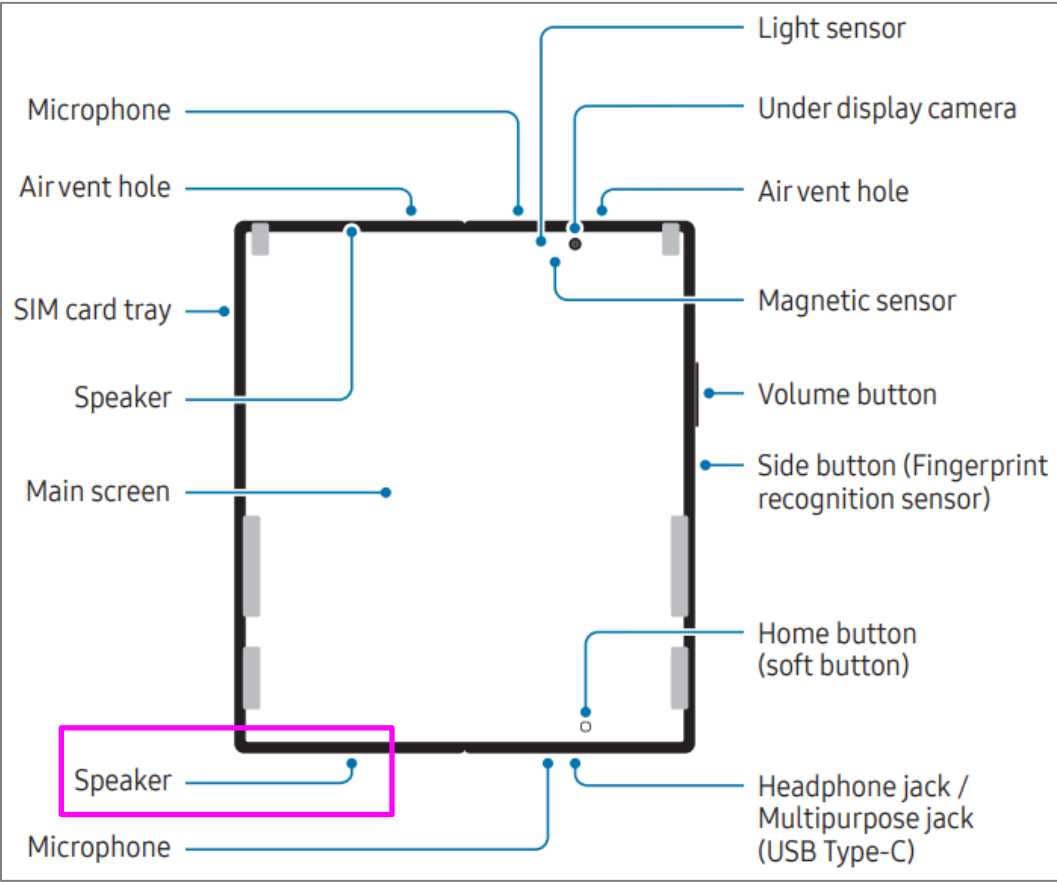
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	Connectivity Wi-Fi Connectivity 802.11a/b/g/n/ac/ax 2.4GHz+5GHz+6GHz, HE160, MIMO, 1024-QAM Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/ The Galaxy Z Fold6 (“smart phone”) further 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					

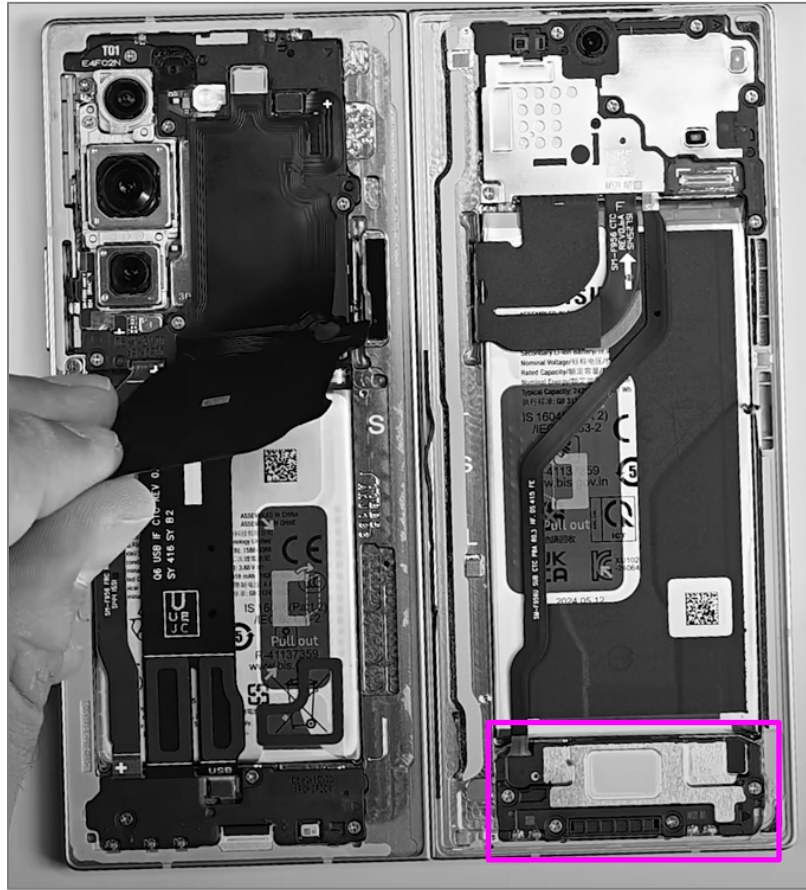
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	 The diagram shows a top-down view of a smartphone with various components labeled with lines pointing to their locations: Microphone (top left) Air vent hole (top left, below microphone) SIM card tray (left side) Speaker (left side, below SIM card tray) Main screen (center) Light sensor (top right) Under display camera (top right) Air vent hole (top right) Magnetic sensor (right side) Volume button (right side) Side button (Fingerprint recognition sensor) (right side) Home button (soft button) (bottom center) Headphone jack / Multipurpose jack (USB Type-C) (bottom right) Speaker (bottom left, highlighted with a pink box) Microphone (bottom left, below the pink box) Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]

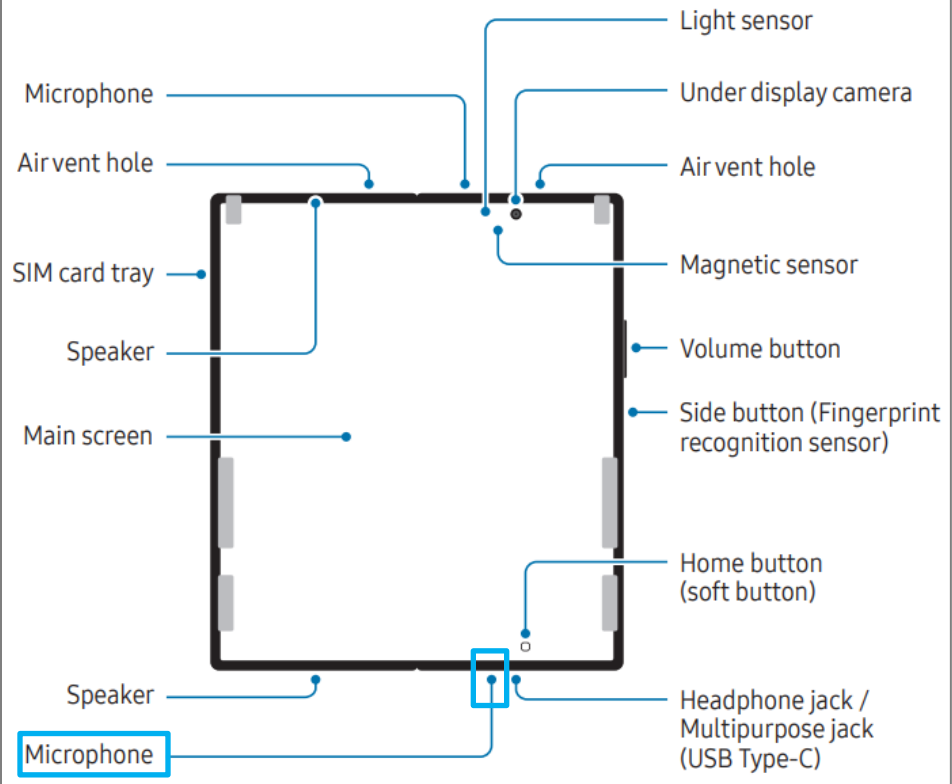
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'304 Patent Claim	Samsung Accused System ¹
	 Source: https://www.youtube.com/watch?v=xYIe5uDVDWI

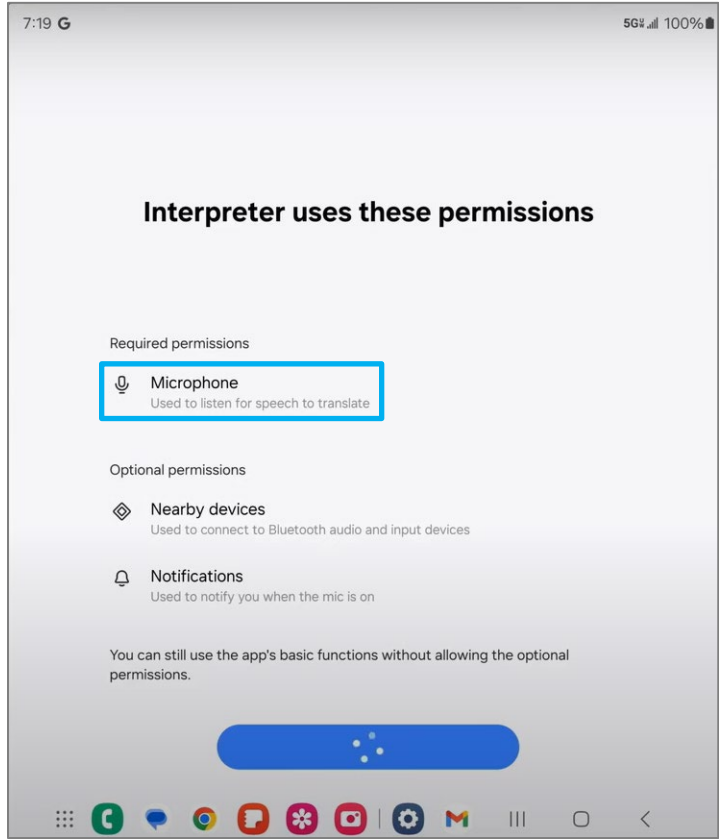
U.S. Patent No. 10,874,304 (the “’304 Patent”)

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'304 Patent Claim	Samsung Accused System ¹
	 The diagram shows a top-down layout of a smartphone. Labeled components include: 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 blue 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), and Headphone jack / Multipurpose jack (USB Type-C) (bottom right). Blue lines connect the labels to their respective locations on the device. Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]

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'304 Patent Claim	Samsung Accused System ¹
	 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.

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	 Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/

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'304 Patent Claim	Samsung Accused System ¹
	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  Snapdragon 8 Gen 3 FOR GALAXY The fastest Snapdragon on a Galaxy smartphone^{19,21} Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/

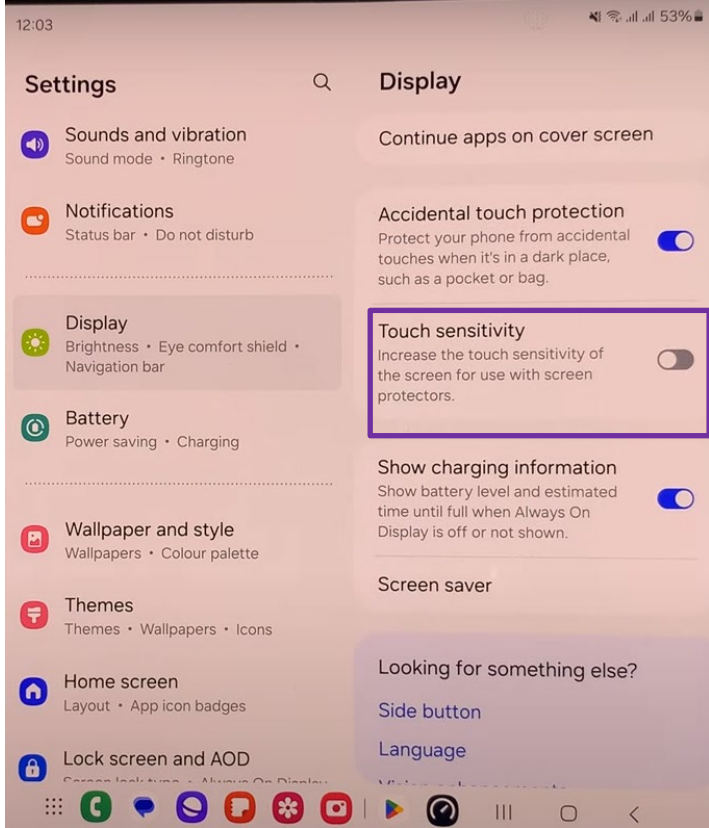
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’304 Patent Claim	Samsung Accused System ¹
	CPUName: Qualcomm® Kryo™Architecture: 64-bitClock Speed: Up to 3.4 GHz¹ Source: https://www.qualcomm.com/products/mobile/snapdragon/smartphones/snapdragon-8-series-mobile-platforms/snapdragon-8-gen-3-mobile-platform

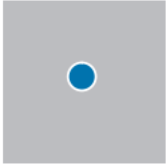
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’304 Patent Claim	Samsung Accused System ¹
	 The screenshot shows the Samsung Settings app. The 'Display' section is expanded, showing options like 'Continue apps on cover screen', 'Accidental touch protection', 'Touch sensitivity', 'Show charging information', and 'Screen saver'. The 'Touch sensitivity' option is highlighted with a red box. The text for 'Touch sensitivity' reads: 'Increase the touch sensitivity of the screen for use with screen protectors.' The toggle switch is currently turned off. Source: https://www.youtube.com/watch?v=cn2UQ6Fr4hM

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'304 Patent Claim	Samsung Accused System ¹
	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]
19[i] the smart phone or tablet configured to:	The Accused Phone/Tablet is configured to receive and process at least a portion of the output signal, to store and display the processed output signal, and to transmit a portion of the processed output signal over a wireless transmission link, literally or under the doctrine of equivalents.

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’304 Patent Claim	Samsung Accused System ¹
receive and to process at least a portion of the output signal, store and display the processed output signal, and transmit at least a portion of the processed output signal over a wireless transmission link.	For example, the Galaxy Z Fold6 (“the smart phone”) receives the output signal from the BioActive Sensor via the Samsung Health app, processes the signal (<i>e.g.</i>, generates Heart Rate Zones, in addition to other health and wellness metrics and reports), and then stores and displays the Heart Rate Zones (“processed output signal”). “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 (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.

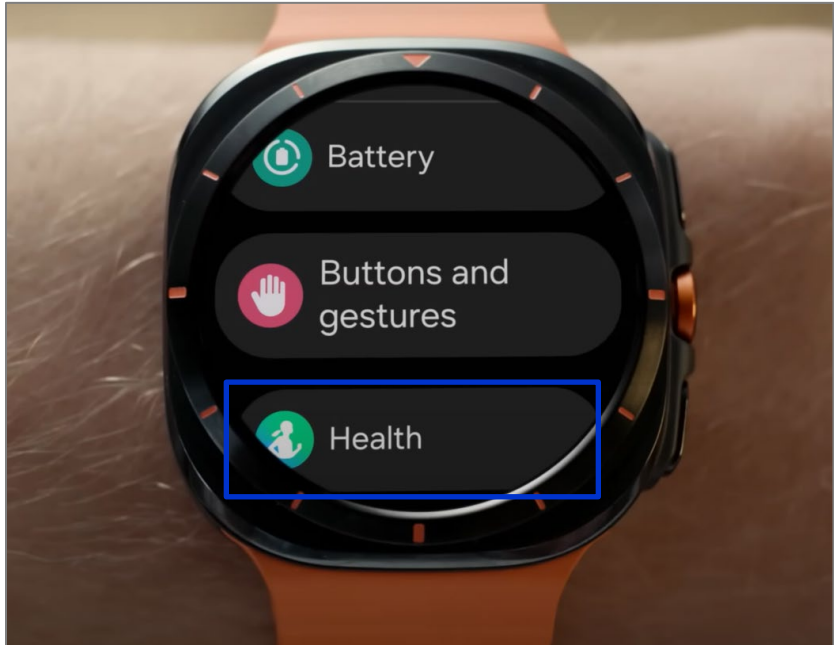
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'304 Patent Claim	Samsung Accused System ¹
	An advertisement for the Samsung Health ecosystem. At the top center is the Samsung Health logo, which consists of a green circle with a white person icon and the text "Samsung Health". Below the logo, a collection of Samsung devices is displayed: a Galaxy Z Fold smartphone in the center, a Galaxy Watch 4 on the right, a Galaxy Buds Pro earbuds case in the foreground, and a Samsung Health monitor on the left. The background features two large, stylized heart shapes composed of dots, one purple on the left and one orange on the right. The smartphone screen shows the Samsung Health app interface with various health metrics like steps, heart rate, and sleep score. The watch face also displays health data. The entire scene is set against a white background with a subtle pattern of dots. Source: https://www.samsung.com/us/apps/samsung-health/.

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

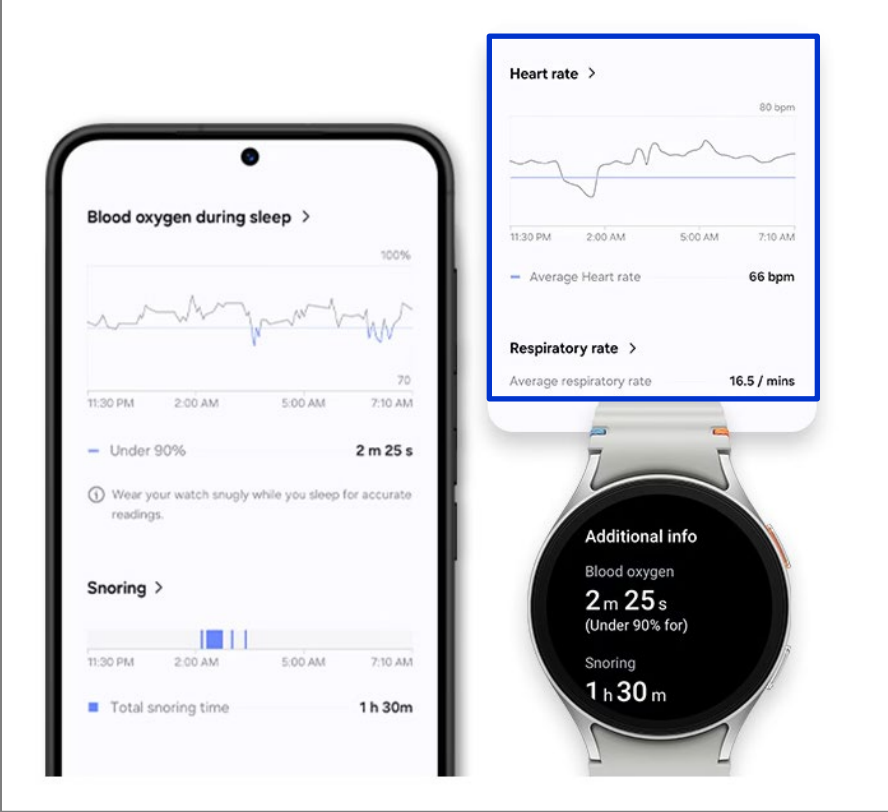
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'304 Patent Claim	Samsung Accused System ¹
	 · Sleep · Heart rate · Activity Source: Samsung, “A friendly guide to Galaxy Watch Ultra, Watch7 and Buds3Pro,” July 24, 2024, https://www.youtube.com/watch?v=VQW-ZpdAm5M

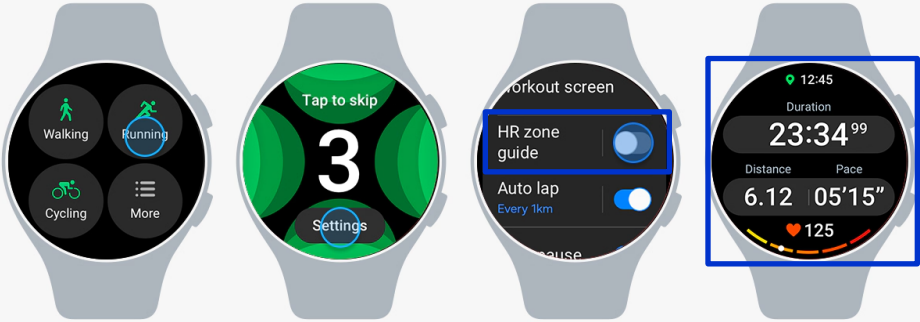
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	 The image displays the Samsung Health app interface on a smartphone and a smartwatch. The smartphone screen shows the 'Blood oxygen during sleep' graph with a peak at 100% and a trough at 70% between 11:30 PM and 7:10 AM. Below this, it indicates 'Under 90%' for 2 m 25 s. A note states: 'Wear your watch snugly while you sleep for accurate readings.' The 'Snoring' section shows a bar chart with a total snoring time of 1 h 30 m. The smartwatch displays 'Additional info' including 'Blood oxygen 2 m 25 s (Under 90% for)' and 'Snoring 1 h 30 m'. A separate inset shows 'Heart rate' and 'Respiratory rate' graphs with an average heart rate of 66 bpm and an average respiratory rate of 16.5 / mins. Source: https://www.samsung.com/us/apps/samsung-health/

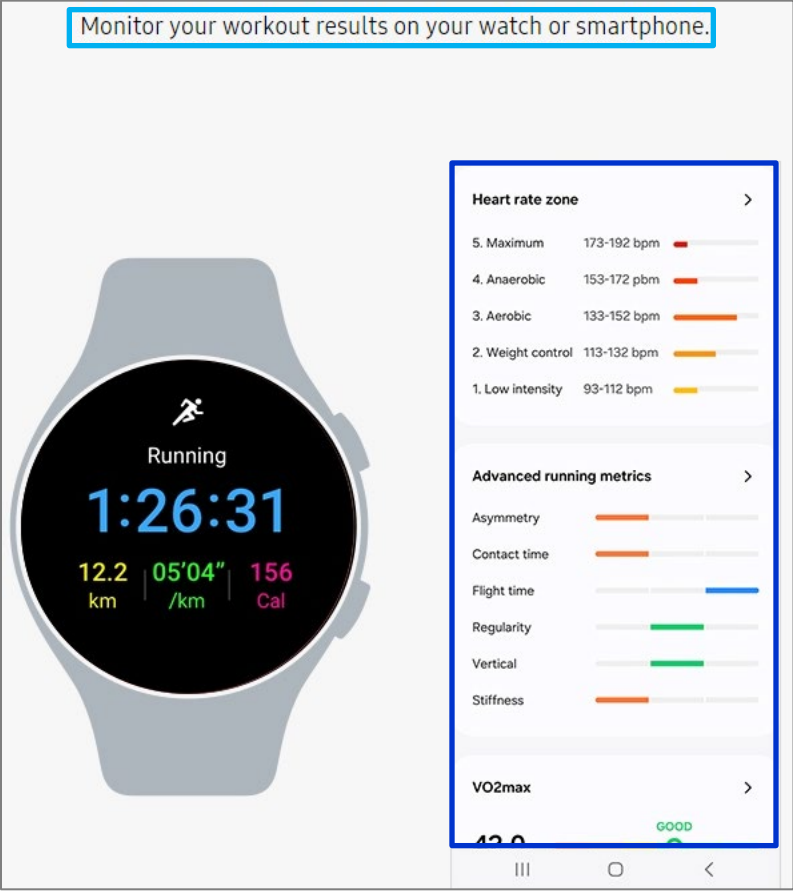
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	Check your Heart Rate Zone with Galaxy Watch Choose your preferred workout type and initiate by tapping 'Settings' when the countdown begins. Activate the HR Zone guide and engage in a 10-minute run within the exercise mode.  Source: https://www.samsung.com/us/apps/samsung-health/ 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. 

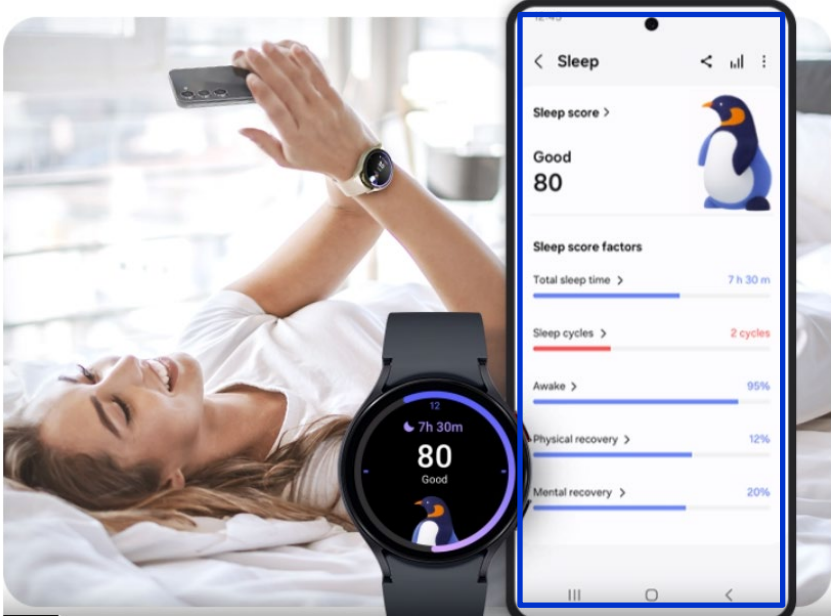
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'304 Patent Claim	Samsung Accused System ¹
	Source: https://www.samsung.com/us/apps/samsung-health/ Monitor your workout results on your watch or smartphone.  The screenshot displays the Samsung Health app interface. On the left is a smartwatch face showing 'Running' with a time of 1:26:31, distance of 12.2 km, pace of 05'04"/km, and calories of 156. On the right is a detailed metrics screen with a blue border. This screen includes a 'Heart rate zone' section with five levels (Maximum, Anaerobic, Aerobic, Weight control, Low intensity) and their corresponding heart rate ranges and progress bars. Below this is an 'Advanced running metrics' section with bars for Asymmetry, Contact time, Flight time, Regularity, Vertical, and Stiffness. At the bottom, it shows 'VO2max' with a 'GOOD' status and a value of 42.0. Source: https://www.samsung.com/us/apps/samsung-health/

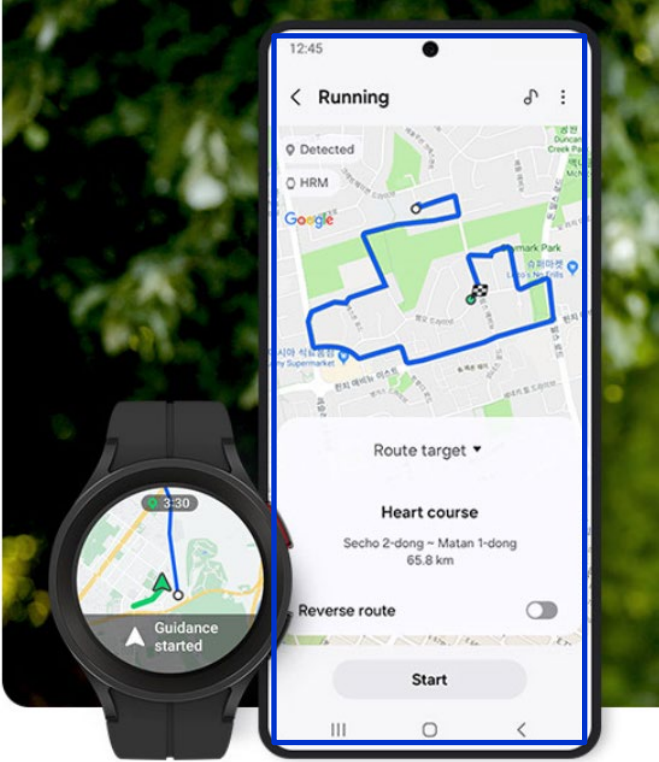
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’304 Patent Claim	Samsung Accused System ¹
	 Source: https://www.samsung.com/global/galaxy/apps/samsung-health/

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’304 Patent Claim	Samsung Accused System ¹
	 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, <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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’304 Patent Claim	Samsung Accused System ¹
	“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.”

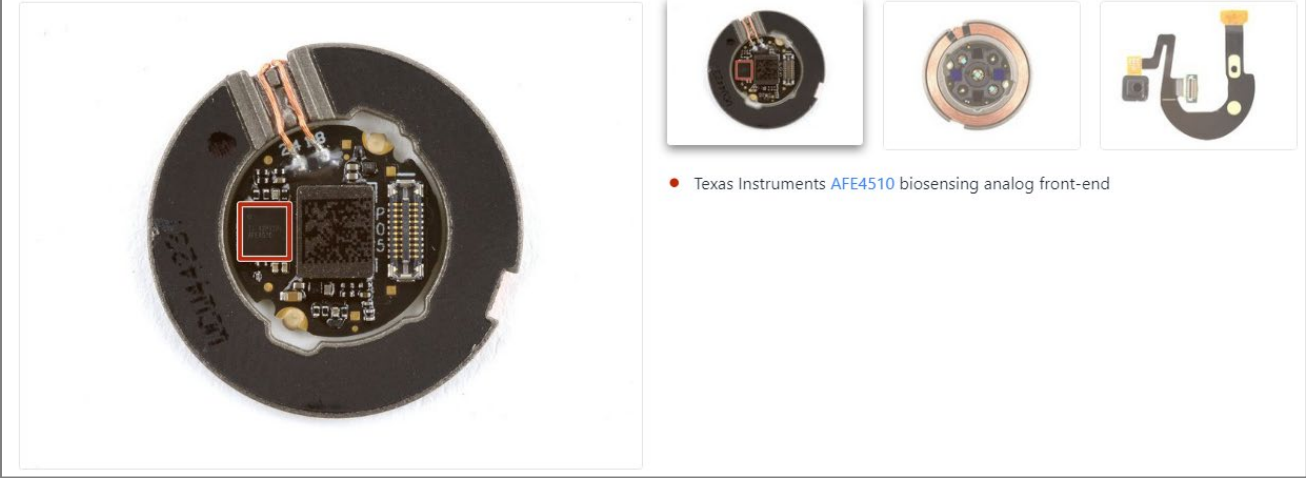
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	Adjust the sync options  Before you can get your health and workout data onto another device, you'll need to sync information from your Samsung account to Samsung Health. If you're worried you'll forget, you can even sync information automatically. 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/.
20. The wearable device of claim 19, wherein the light source is configured to further improve the signal-to-noise ratio of the input	The Accused Smartwatch is configured to further improve the signal-to-noise ratio of the input optical beam reflected from the tissue by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate, 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

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optical beam reflected from the tissue by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.	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=AfmBOoriU1zDb_SwZ7O5CP4JIQFSWUnKHWqSe9g6SXYqF3F-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>  TEXAS INSTRUMENTS Application Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or 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).

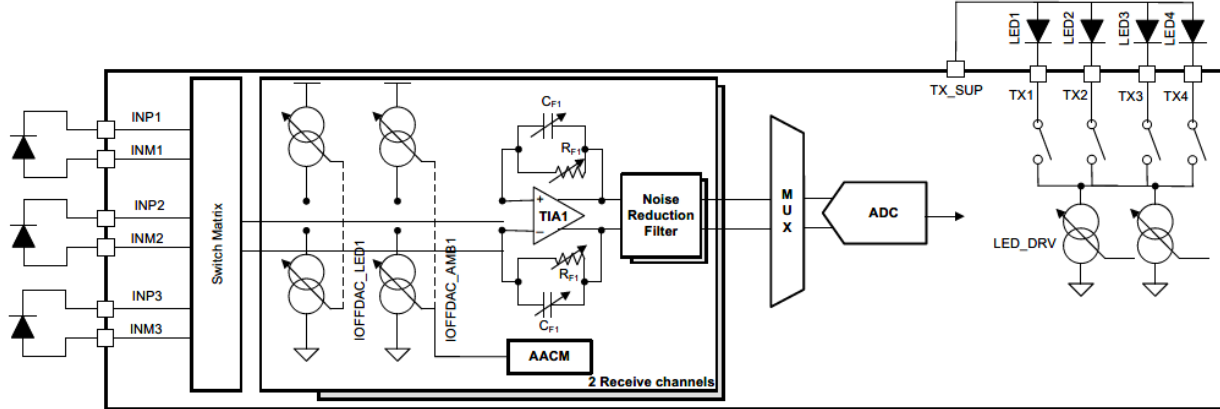
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	To save power, the LED is pulsed at the PRF rate, turning on for a short window in each PRF cycle. Each turning on of the LED results in one sample in the digital data stream. Differentiation • Signal chain has wide adaptability (LED current, transimpedance 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 1. Specifications for OHRM on Wearables <table><tr><th>System Specifications</th><th>AFE4432</th><th>Comments</th></tr><tr><td>Multi-sensor support</td><td>4 LEDs, 3 PDs</td><td>Combining signals from multiple PDs and LEDs helps mitigate motion artifacts</td></tr><tr><td>Sampling rate</td><td>1 Hz–1 kHz</td><td>A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM</td></tr><tr><td>Current consumption</td><td>12 μA</td><td>For the receiver at 25 Hz PRF</td></tr><tr><td>Peak SNR</td><td>115 dB over 10-Hz bandwidth</td><td>Important consideration to achieve good accuracy in low perfusion cases.</td></tr><tr><td>Ambient rejection</td><td>> 70 dB up to 160 Hz</td><td>Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting</td></tr></table>	System Specifications	AFE4432	Comments	Multi-sensor support	4 LEDs, 3 PDs	Combining signals from multiple PDs and LEDs helps mitigate motion artifacts	Sampling rate	1 Hz–1 kHz	A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM	Current consumption	12 μA	For the receiver at 25 Hz PRF	Peak SNR	115 dB over 10-Hz bandwidth	Important consideration to achieve good accuracy in low perfusion cases.	Ambient rejection	> 70 dB up to 160 Hz	Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting
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	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.

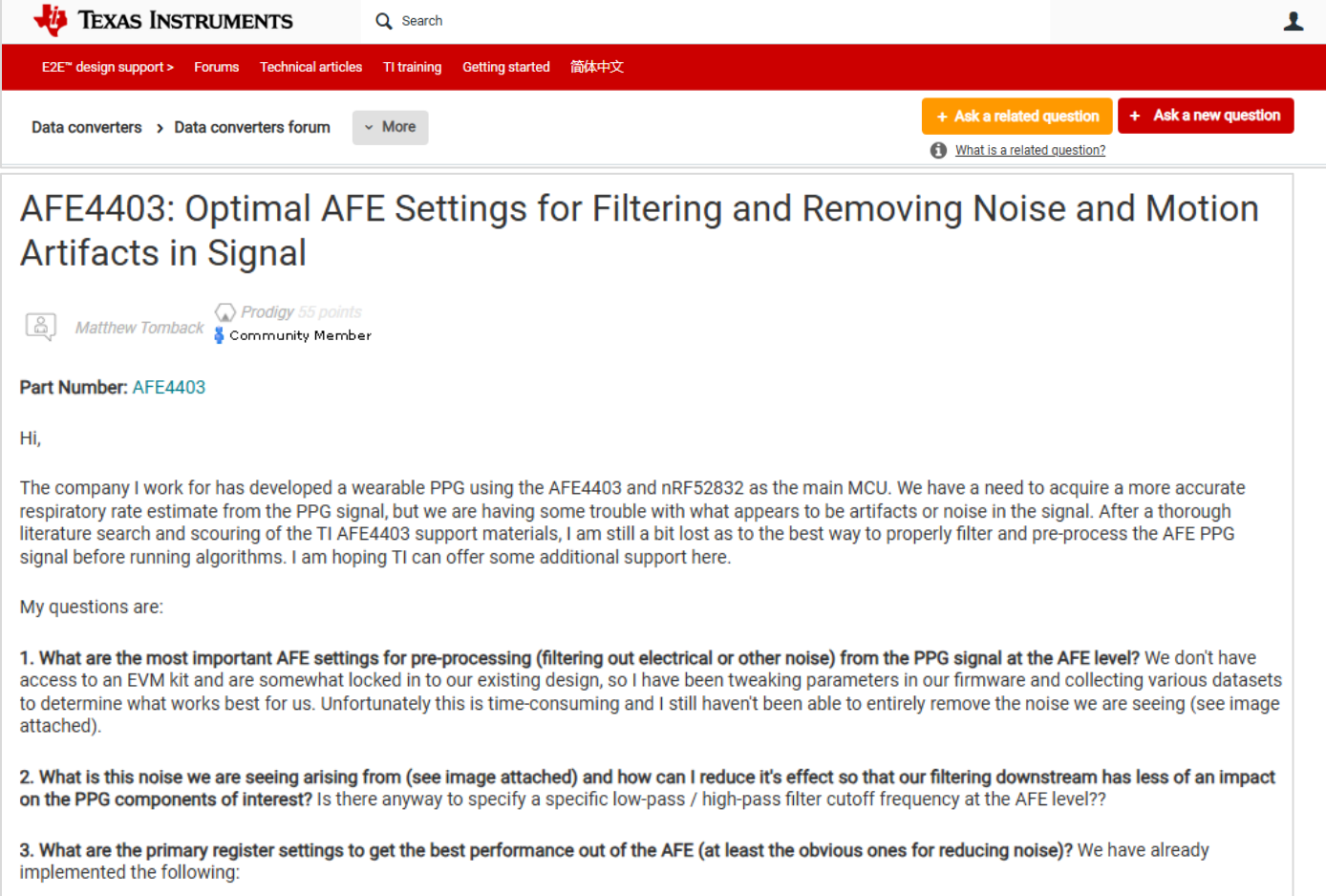
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	“However, increasing the LED current gives better signal quality from the SNR perspective. The optimal AFE configuration settings are completely dependent on the application. This includes the separation of LED and PD, location of the sensor, and 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%	
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT																																																								
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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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	 The screenshot shows a forum post on the Texas Instruments website. The post is titled "AFE4403: Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal" and is authored by Matthew Tomback, a community member with 55 Prodigy points. The post discusses the challenges of filtering noise from a PPG signal using the AFE4403 and nRF52832 MCUs. The author asks three specific questions: 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? 2. What is this noise we are seeing arising from (see image attached) and how can I reduce its effect so that our filtering downstream has less of an impact on the PPG components of interest? 3. What are the primary register settings to get the best performance out of the AFE (at least the obvious ones for reducing noise)?

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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 <i>Getting Started Guide</i> TIDA-00301 <i>Miniaturized Pulse Oximeter Reference Design</i> <i>HealthTech</i>

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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. The level of the PPG signal may be proportional to the intensity of light emitted by the light emitter and the intensity of light collected by the light detector. The intensity of light emitted by the light emitter may be proportional to the intensity of a current applied to the light emitter. The light detector may amplify the collected light according to a predetermined gain value. 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 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 the current rather than raising the gain may be advantageous in maximizing the SNR of a heart rate signal included in the PPG signal. 15

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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

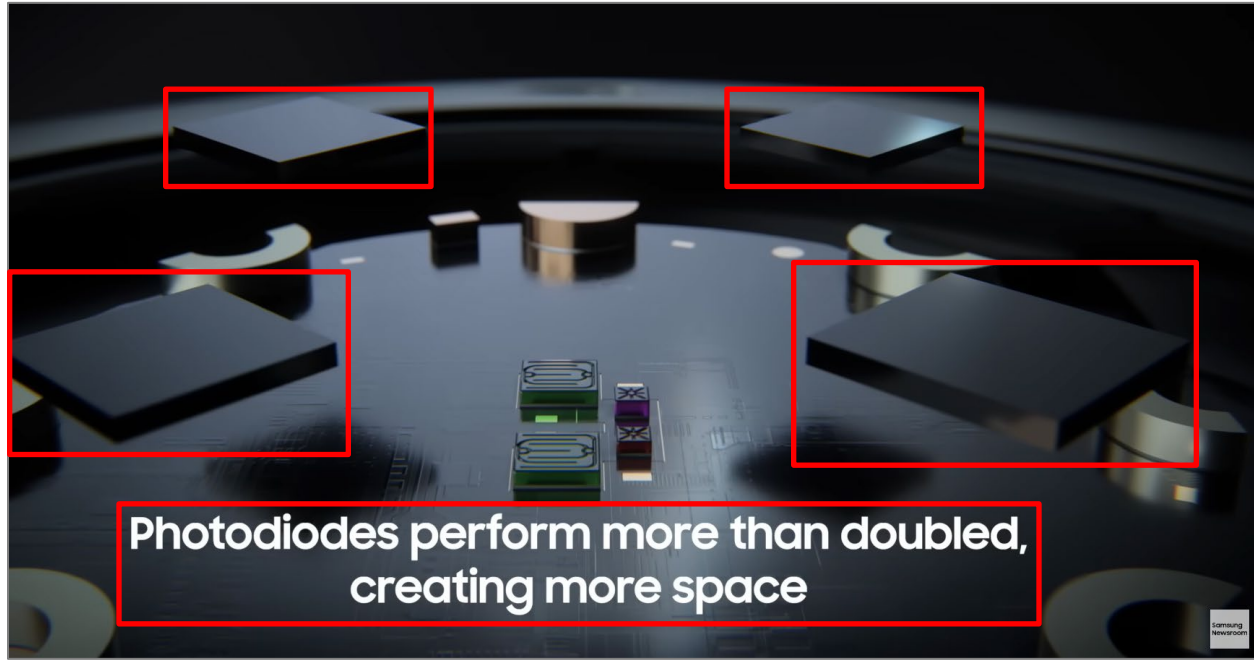
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'304 Patent Claim	Samsung Accused System ¹
	<pre> graph LR Watch[BioActive Sensor] --> SD[Sensor Data] SD --> SDK[Samsung Privileged Health SDK] SDK -- "Tracking Raw / Processed Health Sensor Data" --> App[Wear OS Application] </pre> “The SDK supports 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
21. The wearable device of claim 20, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor	The receiver in the Accused Smartwatch comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc that is offset from the first arc, literally or under the doctrine of equivalents. For example, the Accused Smartwatch contains multiple LEDs ("semiconductor sources") and multiple photodiodes ("detectors"). The photodiodes are arranged along a first arc, while the LEDs are arranged along a second, distinct arc, with both arcs following different circular paths ("offset").

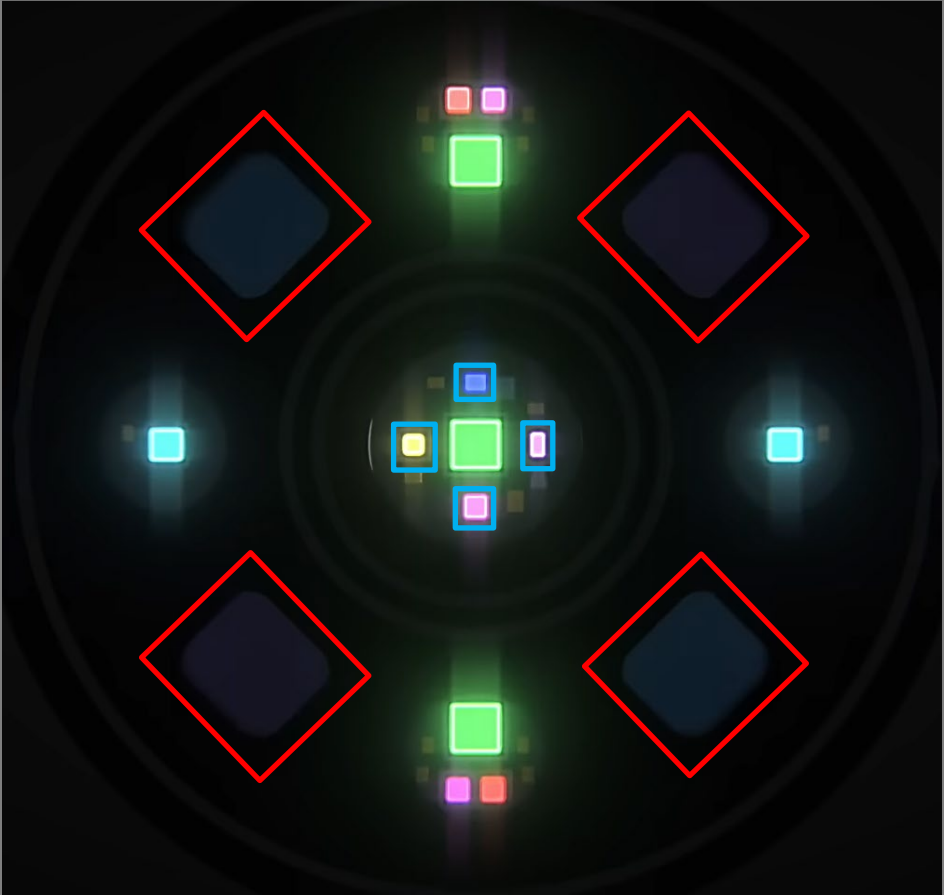
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sources are arranged along a second arc that is offset from the first arc.	 Photodiodes perform more than doubled, creating more space Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

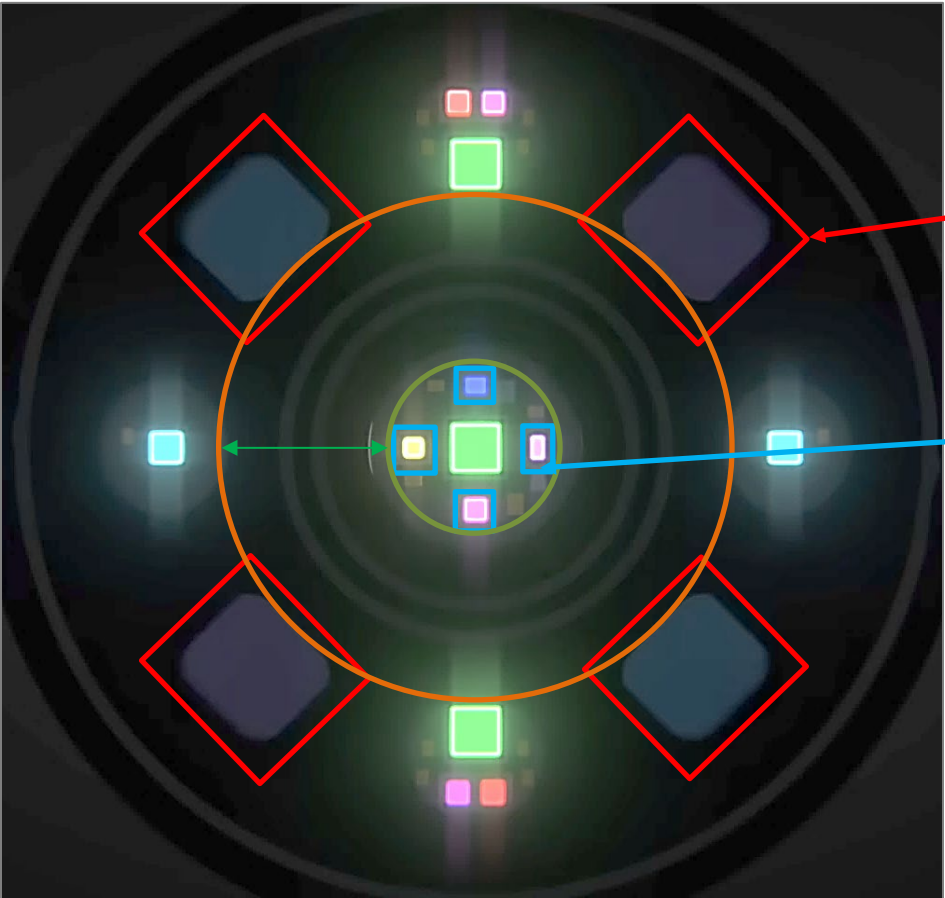
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'304 Patent Claim	Samsung Accused System ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

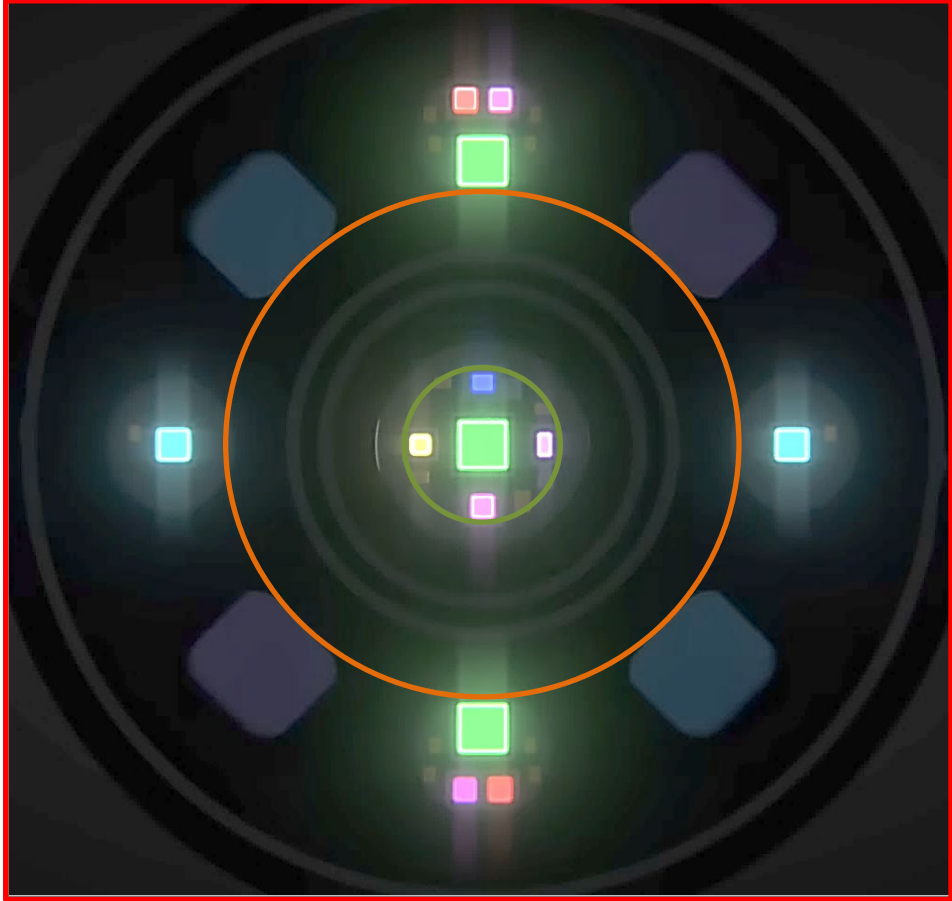
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'304 Patent Claim	Samsung Accused System ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor
22. The wearable device of claim 21, wherein the first arc	The Accused Smartwatch contains multiple LEDs and multiple photodiodes. The photodiodes are arranged along a first concentric arc, while the LEDs are arranged along a second concentric arc.

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'304 Patent Claim	Samsung Accused System ¹
and the second arc are concentric.	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

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098715-000005