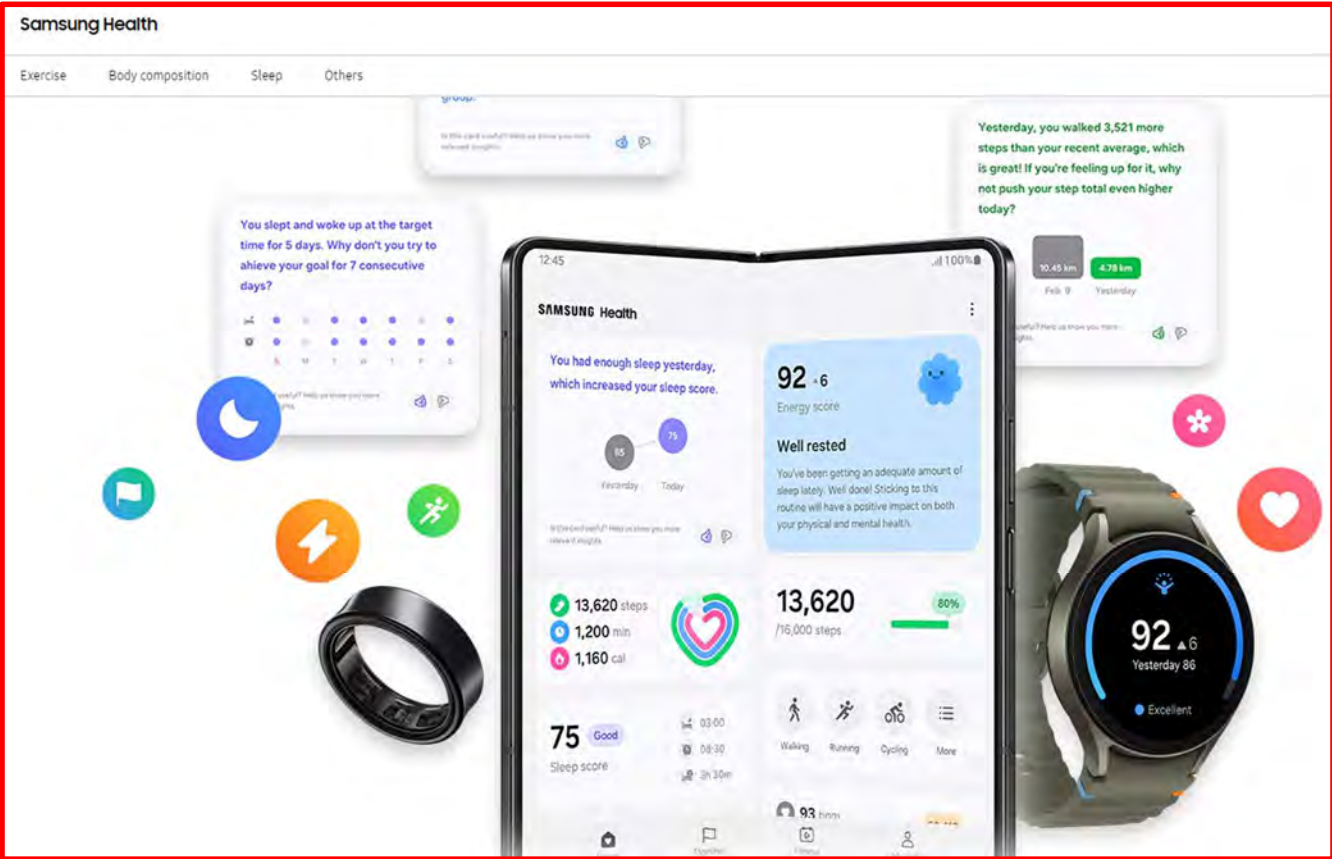


U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

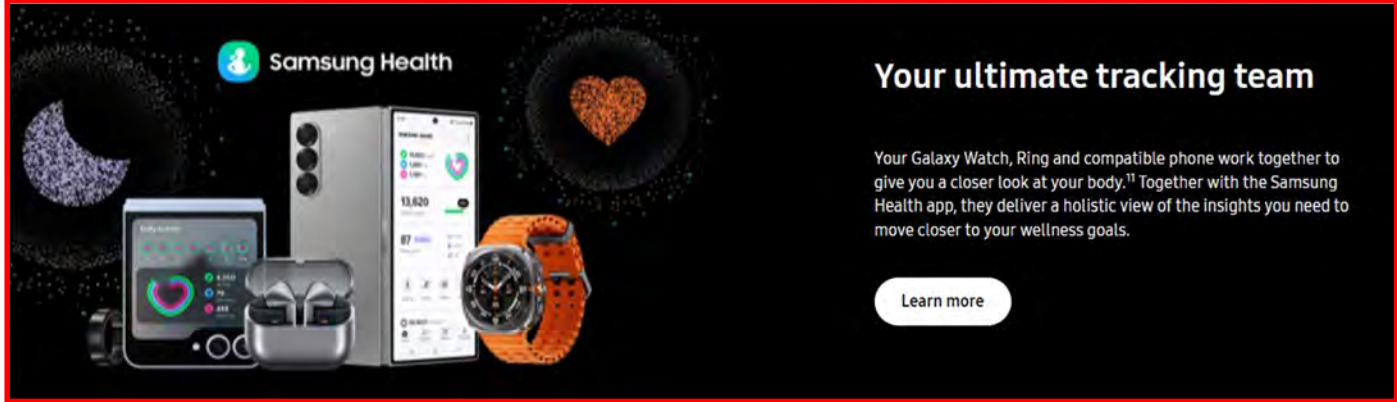
’475 Patent Claim	Samsung Accused Device ¹
<u>1 pre </u> An apparatus adapted to be worn by a user comprising:	Without conceding that the preamble of Claim 1 is limiting, Samsung Electronics, Co. Ltd. and Samsung Electronics America, Inc. (collectively, “Samsung”) have made, used, offered to sell, sold 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, an apparatus adapted to be worn by a user, either literally or under the doctrine of equivalents. For example, Samsung makes, uses, offers to sell, and sells Accused Smartwatches in United States. An Accused Smartwatch is an apparatus adapted to be worn by a user on the user’s wrist.  Source: https://news.samsung.com/global/galaxy-history-%E2%91%A2-evolution-of-the-galaxy-watch-series-reimagining-the-watch

¹ The Accused Device (or “Accused Smartwatch”) 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. Various models of Accused Smartwatches, including the Samsung Galaxy Watch Ultra, are charted here as representative of the Accused Devices and Accused Instrumentalities. 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. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 The screenshot displays the Samsung Health app interface. At the top, there are tabs for 'Exercise', 'Body composition', 'Sleep', and 'Others'. The main screen shows several health metrics: a sleep score of 92 (labeled 'Well rested'), a step count of 13,620 (80% of the goal), a heart rate of 75 (labeled 'Good'), and a sleep score of 75 (labeled 'Good'). There are also motivational messages and a calendar view. A Samsung Watch is shown on the right side of the screen, displaying a heart rate of 92 and a sleep score of 92. The source is cited as: https://www.samsung.com/us/apps/samsung-health/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Samsung Health 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/ 

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/  Source: https://www.youtube.com/watch?v=VQW-ZpdAm5M
1[a] one or more biosensors adapted to be placed on the user, wherein one or more physiological parameters are measured,	The Accused Smartwatch comprises one or more biosensors adapted to be placed on the user, wherein one or more physiological parameters are measured, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch comprises multiple biosensors integrated into the watch that are adapted to be placed on the wrist of a user (e.g., accelerometer, bioelectrical impedance analysis sensor, electrical heart sensor, gyro sensor, infrared temperature sensor, optical heart rate sensor, and SpO2 sensor). The various biosensors in the Accused Smartwatch are used to measure one or more physiological parameters of the user.

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	Galaxy Watch Ultra 47mm Titanium Gray Marine Orange Medium/Large Bluetooth / Wifi + 4G LTE Wifi SM-L709U / SM-L709UGLAXAA ★★★★★ -4.7 (4444) Write a review Compare Specs Key Features  Sensors Accelerometer, Barometer, Bioelectrical Impedance Analysis Sensor, Electrical Heart Sensor, Gyro Sensor, Geomagnetic Sensor, Infrared Temperature Sensor, Light Sensor, Optical Heart Rate Sensor, SpO2 Sensor, AGEs Index Sensor Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device 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/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 BioActive Sensor Precise heart rate readings during workouts and beyond. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ Set your own Heart Rate Zone Exercise at your optimal fitness capacity to reach your workout goals. With the Galaxy Watch Series, you have the flexibility to set your Personalized HR Zone to reach your health and wellness targets.

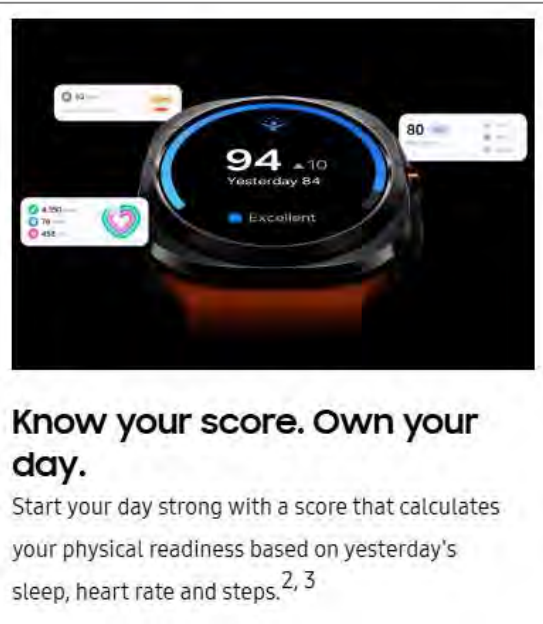
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life
1 b wherein measuring of the one or more physiological parameters comprises a	In the Accused Smartwatch, the measuring of the one or more physiological parameters comprises a differential measurement, either literally or under the doctrine of equivalents. The Accused Smartwatch can measure various physiological parameters using a differential measurement. For example, the Accused Smartwatch uses a differential measurement to measure heart rate metrics, including average heart rate, maximum heart rate, and establish heart rate zones. By way of another

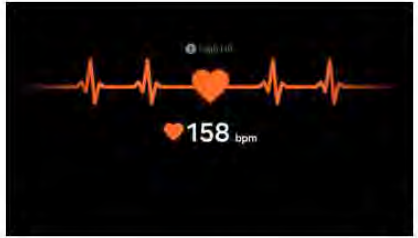
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
differential measurement, and	example, the Accused Smartwatch uses the accelerometer to track differential measurements of a user’s movement and activity, including steps and distance traveled over a period or during a workout. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

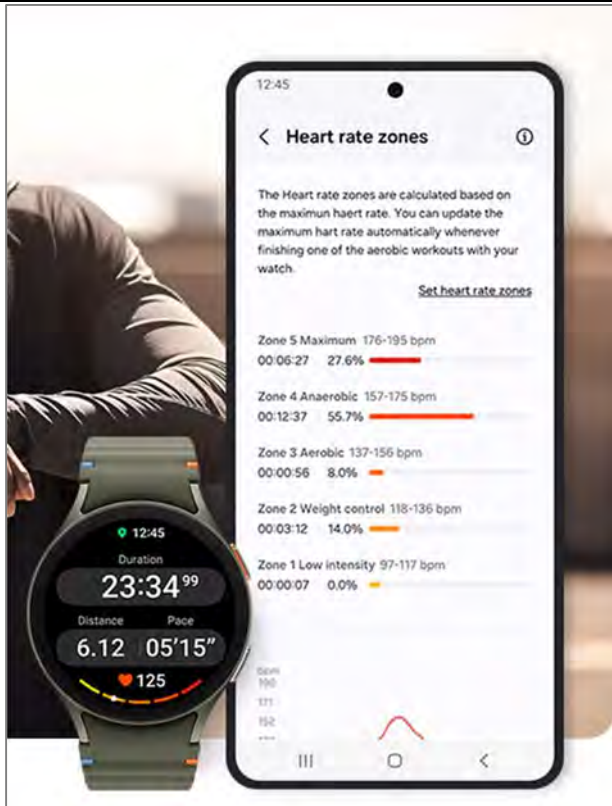
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Know your score. Own your day. 94 ▲10 Yesterday 84 Excellent 93 4,350 steps 76 bpm 458 cal 80  Know your score. Own your day. Start your day strong with a score that calculates your physical readiness based on yesterday's sleep, heart rate and steps.^{2, 3}

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 More precise Heart Rate Tracking 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.  Use yesterday to beat today Perform at your peak on your next run or bike ride using tracking with Galaxy AI² that compares your current performance to your last one.⁶ Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/ Set your own Heart Rate Zone Exercise at your optimal fitness capacity to reach your workout goals. With the Galaxy Watch Series, you have the flexibility to set your Personalized HR Zone to reach your health and wellness targets.

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹																														
	<table><caption>Heart Rate Zones Data from Smartphone Screen</caption><thead><tr><th>Zone</th><th>Category</th><th>Heart Rate Range (bpm)</th><th>Duration</th><th>Percentage</th></tr></thead><tbody><tr><td>Zone 5</td><td>Maximum</td><td>176-195</td><td>00:06:27</td><td>27.6%</td></tr><tr><td>Zone 4</td><td>Anaerobic</td><td>157-175</td><td>00:12:37</td><td>55.7%</td></tr><tr><td>Zone 3</td><td>Aerobic</td><td>137-156</td><td>00:00:56</td><td>8.0%</td></tr><tr><td>Zone 2</td><td>Weight control</td><td>118-136</td><td>00:03:12</td><td>14.0%</td></tr><tr><td>Zone 1</td><td>Low intensity</td><td>97-117</td><td>00:00:07</td><td>0.0%</td></tr></tbody></table> Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life The Galaxy Watch is equipped with Samsung’s unique BioActive Sensor that drives the next era of digital health monitoring. First introduced on the Galaxy Watch4 series, the BioActive Sensor uses a single unique chip that combines three powerful health sensors — Optical Heart Rate, Electrical Heart Signal, and Bioelectrical Impedance Analysis — to deliver extensive readings that include heart rate and blood oxygen level.	Zone	Category	Heart Rate Range (bpm)	Duration	Percentage	Zone 5	Maximum	176-195	00:06:27	27.6%	Zone 4	Anaerobic	157-175	00:12:37	55.7%	Zone 3	Aerobic	137-156	00:00:56	8.0%	Zone 2	Weight control	118-136	00:03:12	14.0%	Zone 1	Low intensity	97-117	00:00:07	0.0%
Zone	Category	Heart Rate Range (bpm)	Duration	Percentage																											
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U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	What is Samsung Health Sensor SDK? The Samsung Health Sensor 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. 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: https://developer.samsung.com/health/sensor/overview.html
<u>1[c]</u> wherein the one or more physiological parameters comprises a pulse rate monitoring and a blood flow measurement;	In the Accused Smartwatch, the one or more physiological parameters comprises a pulse rate monitoring and a blood flow measurement, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch comprises a “BioActive Sensor” featuring optical sensors that detect heart rate by measuring changes in the volume of blood flowing in blood vessels in the skin and underlying connective tissue of a user (<i>e.g.</i>, “a pulse rate monitoring and a blood flow measurement”).

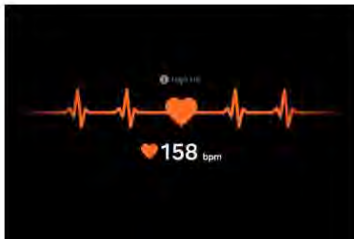
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	The image displays two Samsung smartwatches. The top watch, with an orange band, shows a heart rate monitor interface with 'Average HR' of 142, 'Maximum HR' of 168, and a current heart rate of 126, labeled 'Zone 3'. Below it, text reads 'Heart rate zones' and 'Use improved heart rate monitoring to tailor training for the best results, personalized for you.' The bottom watch, with a black band, shows a heart rate of 94 bpm, a sleep score of 80 (Good), and daily activity stats: 4,350 steps, 76 mins, and 458 cal. The watch face also displays 'Yesterday 84' and 'Excellent'.

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 The screenshot shows the Samsung Health app interface. At the top, it says "HEALTH" and "Understand your body better". Below this are three tabs: "Samsung Health", "Heart Monitor", and "Sleep Coach". The "Heart Monitor" tab is selected. The main display shows a heart rate reading of "158 bpm" with a red heart icon. Above the reading is a small icon and the text "High HR". To the right of the heart rate reading, there is a section titled "More precise Heart Rate Tracking" with a description: "Zero in on more precise readings during workouts using Heart Rate Tracking with Galaxy AI that filters out the physical movements of your body.³ Insights are collected by your Watch and analyzed on your phone." Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	Galaxy Watch Ultra 47mm Titanium Gray Marine Orange Medium/Large Bluetooth / Wifi + 4G LTE Wifi SM-L705V / SM-L705DAAXAA ★★★★★ 4.7 (4444) Write a review Compare Specs Key Features  Sensors Accelerometer, Barometer, Bioelectrical Impedance Analysis Sensor, Electrical Heart Sensor, Gyro Sensor, Geomagnetic Sensor, Infrared Temperature Sensor, Light Sensor, Optical Heart Rate Sensor, SpO2 Sensor, AGEs Index Sensor  Know your score. Own your day. Start your day strong with a score that calculates your physical readiness based on yesterday's sleep, heart rate and steps.^{2, 3}  More precise Heart Rate Tracking 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/

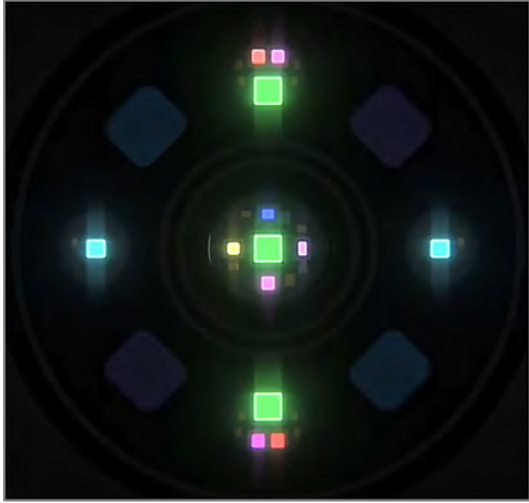
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	Bringing Greater Accuracy and New Possibilities for Preventative Wellness The optimal allocation of Green, Red, and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood oxygen levels, and stress levels.² Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor. Source: https://news.samsung.com/us/samsung-new-galaxy-watch-bioactive-sensor-unlocking-new-possibilities-for-preventative-wellness/ Monitor your heart rate and blood pressure with the Galaxy Watch series The Samsung Health Monitor app allows you to use your Galaxy Watch to help record and monitor your heart health through the ECG feature, Heart rate monitor, and blood pressure monitor. After recording, you can save the data to your Galaxy phone and share the results with your doctors if needed. Review our tips and instructions for how to utilize this helpful tool. 

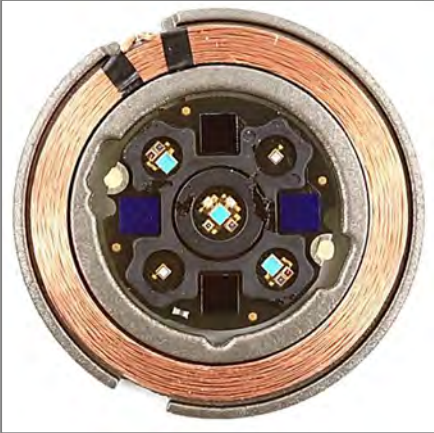
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	Source: https://www.samsung.com/latin_en/support/mobile-devices/measure-your-ecg-with-the-galaxy-watch-series/  Source: https://www.samsung.com/us/support/answer/ANS10003311/
1[d] a light source comprising a plurality of light emitting diodes that are configured to generate an output optical light having one or more optical wavelengths;	The Accused Smartwatch comprises a light source comprising a plurality of light emitting diodes that are configured to generate an output optical light having one or more optical wavelengths, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch includes multiple LEDs, such as a green LED, a red LED, and an infrared LED. Different color LEDs and infrared LEDs each generate an output optical light having 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 Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, available at https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	  Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹						
	 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 The following data types are supported by the Samsung Privileged Health SDK: <table data-bbox="506 867 1526 1289"><tr><td data-bbox="506 867 978 1005">PPG green</td><td data-bbox="978 867 1526 1005">Raw data from PPG green LED. Provided as a batching event.</td></tr><tr><td data-bbox="506 1005 978 1159">PPG IR</td><td data-bbox="978 1005 1526 1159">Raw data from PPG infrared LED. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 1159 978 1289">PPG red</td><td data-bbox="978 1159 1526 1289">Raw data from PPG red LED. Provided as an on-demand event.</td></tr></table>	PPG green	Raw data from PPG green LED. Provided as a batching event.	PPG IR	Raw data from PPG infrared LED. Provided as an on-demand event.	PPG red	Raw data from PPG red LED. Provided as an on-demand event.
PPG green	Raw data from PPG green LED. Provided as a batching event.						
PPG IR	Raw data from PPG infrared LED. Provided as an on-demand event.						
PPG red	Raw data from PPG red LED. Provided as an on-demand event.						

U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹																										
	Source: Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html LEDs outputting light at different colors do so at different optical wavelengths. For example, a green LED, a red LED, and an infrared LED all output light at different optical wavelengths: <table><tr><th colspan="2">Table 1. LEDs – Wavelengths and Applications</th></tr><tr><th>LED Wavelength (Color)</th><th>LED Applications</th></tr><tr><td>410–420 nm (Violet)</td><td>Skin therapy</td></tr><tr><td>430–470 nm (Blue)</td><td>Dental curing instruments</td></tr><tr><td>470 nm (Blue)</td><td>White LEDs using phosphor</td></tr><tr><td>520–530 nm (Green)</td><td>Green traffic signal lights</td></tr><tr><td>580–590 nm (Amber)</td><td>Amber traffic signal lights</td></tr><tr><td>630–640 nm (Red)</td><td>Red signal lights</td></tr><tr><td>660 nm (Deep Red)</td><td>Blood oximetry</td></tr><tr><td>680 nm (Deep Red)</td><td>Blood analysis</td></tr><tr><td>800–850 nm (Near-IR)</td><td>Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr><tr><td>850–940 nm (Near-IR)</td><td>Photoelectric controls</td></tr><tr><td>940 nm (Near-IR)</td><td>Covert illumination CCD-based systems</td></tr></table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706	Table 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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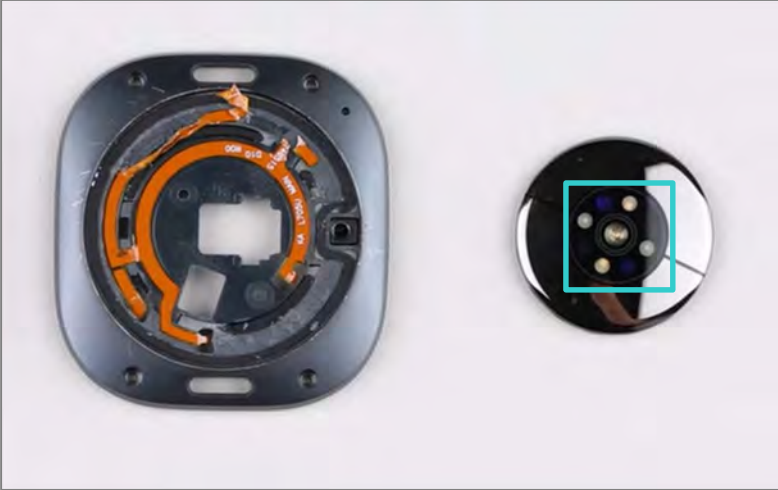
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device ¹
<u>11e</u> one or more lenses configured to receive at least a portion of the output optical light and to deliver a lens output light to tissue comprising skin;	The Accused Smartwatch comprises one or more lenses configured to receive at least a portion of the output optical light and to deliver a lens output light to tissue comprising skin, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch comprises one or more lenses positioned between LEDs and the wrist of a user when worn by the user. The lenses receive output optical light from the LEDs and deliver the light to tissue 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>

U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	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”).  Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0

U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.youtube.com/watch?v=jlW0i7u4FVk 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.

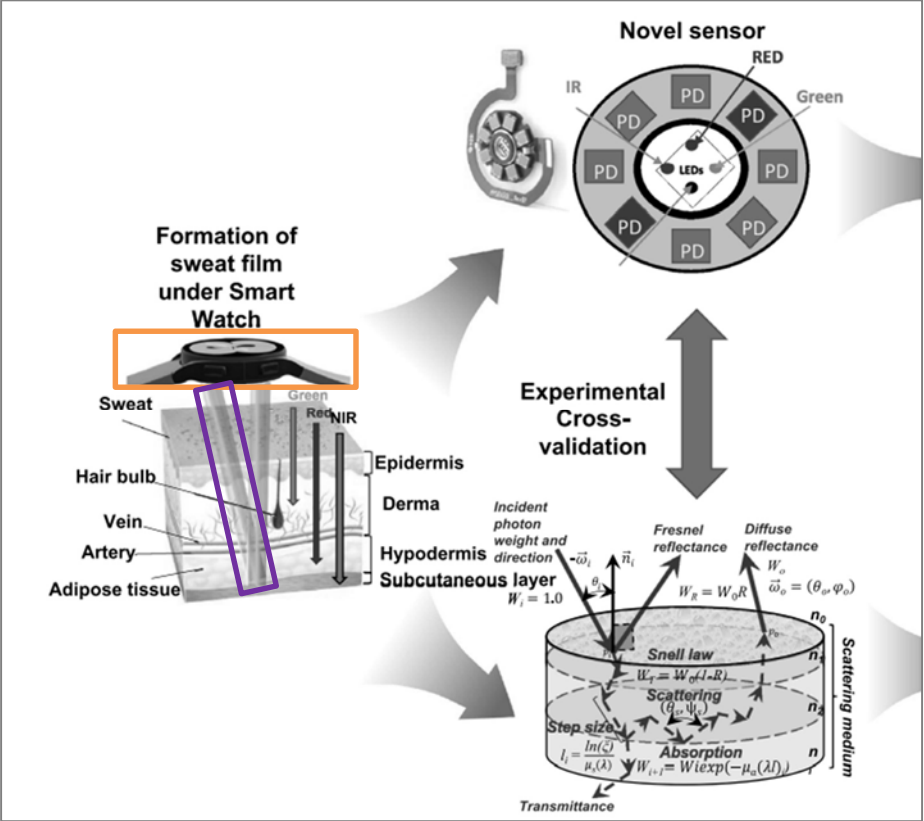
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“Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device ¹
	The Accused Smartwatch 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. 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. 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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'475 Patent Claim	Samsung Accused Device ¹
	Additionally, the following scientific report authored by multiple Samsung engineers further shows lens output light being delivered to tissue of the user:  Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in situ continuous monitoring of human skin hydration and body sweat loss,” Scientific Reports (2023), at 3, available at https://www.nature.com/articles/s41598-023-40339-7.pdf.

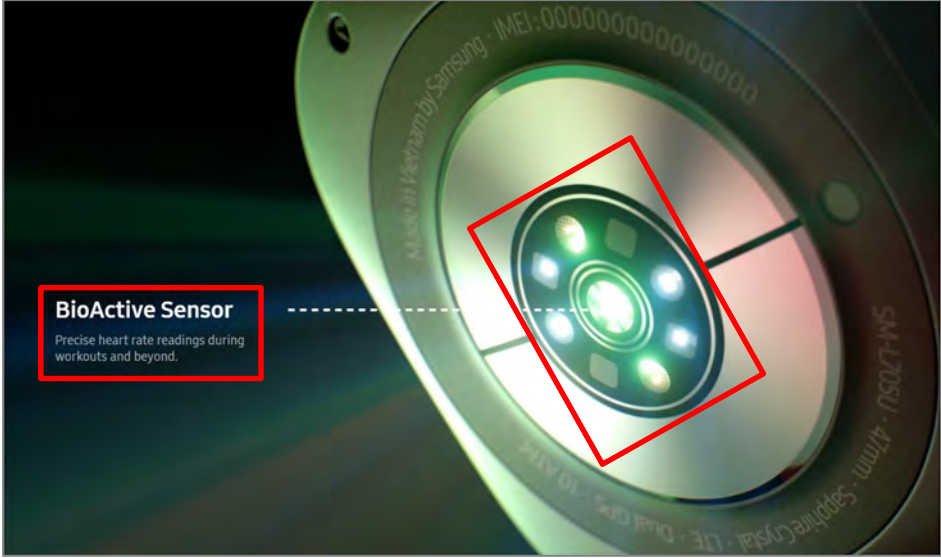
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’475 Patent Claim	Samsung Accused Device ¹
11f a detection system configured to receive at least a portion of the lens output light reflected from the tissue and to generate an output signal having a signal-to-noise ratio,	The Accused Smartwatch comprises a detection system configured to receive at least a portion of the lens output light reflected from the tissue and to generate an output signal having a signal-to-noise ratio, either literally or under the doctrine of equivalents. For example, the BioActive Sensor in the Accused Smartwatch comprises a detection system that: (a) receives light initially output from LEDs that is reflected from tissue of a user (“configured to receive at least a portion of the lens output light reflected from the tissue”), and (b) generates an output PPG signal having a signal-to-noise ratio. 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.

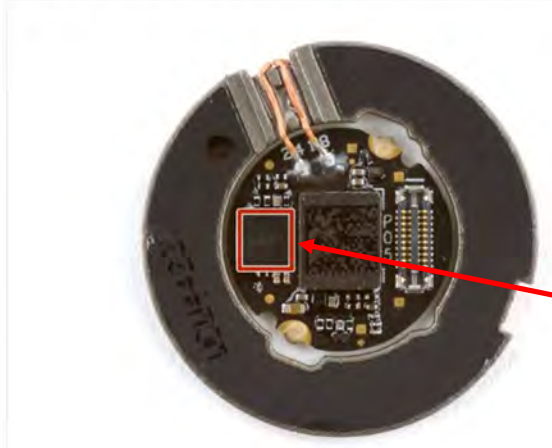
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	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

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	 The image shows the back of a Samsung Galaxy Watch Ultra, focusing on the BioActive Sensor. A red rectangular box highlights the sensor area, which contains several small, glowing green LEDs. A dashed line points from the text 'BioActive Sensor' to the sensor itself. The text 'BioActive Sensor' is enclosed in a red box, and below it, smaller text reads 'Precise heart rate readings during workouts and beyond.' The watch's metal case and the 'Made in Vietnam by Samsung' text are also visible. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

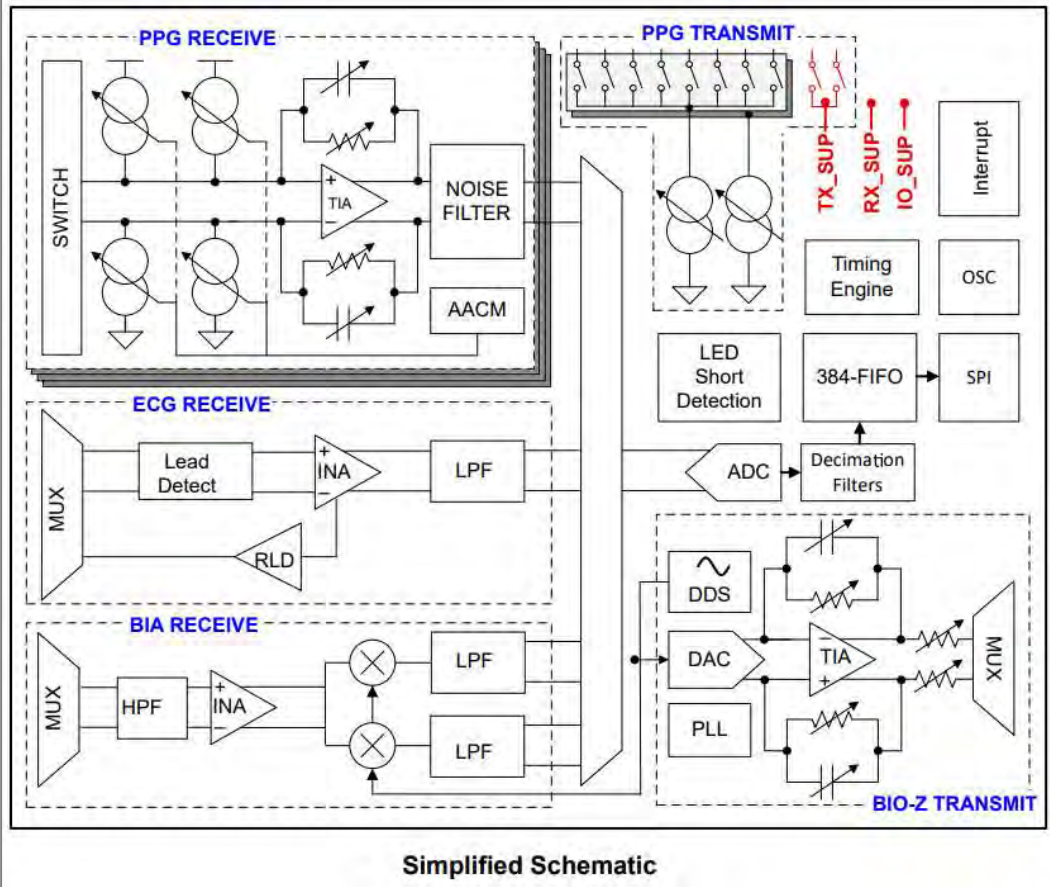
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'475 Patent Claim	Samsung Accused Device ¹
	Step 6 Bio Sensor Assembly   • Texas Instruments AFE4510 biosensing analog front-end Texas Instruments Analog Front End (“AFE”) chip - AFE4510 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 The AFE4510 specification (excerpts shown below) describes a PPG signal receiver, a PPG signal transmitter, and PPG signal acquisition functionality for receiving light output by LEDs that is reflected from skin and body tissue of the user (<i>e.g.</i>, by photodiodes (“PDs”)), and for converting the received light into—<i>i.e.</i>, generating—a PPG output signal having a signal-to-noise ratio (“SNR”).  TEXAS INSTRUMENTS AFE4510 SBASB19 – MARCH 2024 AFE4510 Ultra Small, Integrated AFE for Bio Impedance Analysis, Electrical Bio Sensing & Optical Bio Sensing

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	• 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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	 The diagram is a 'Simplified Schematic' of a wearable device's internal circuitry. It is divided into three main functional blocks on the left: PPG RECEIVE, ECG RECEIVE, and BIA RECEIVE. The PPG RECEIVE block includes a SWITCH, two photodiodes, a TIA (Transimpedance Amplifier), a NOISE FILTER, and an AACM (Ambient Light Sensor). The ECG RECEIVE block includes a MUX (Multiplexer), a Lead Detect block, an INA (Instrumentation Amplifier), an RLD (Right Leg Drive), and an LPF (Low Pass Filter). The BIA RECEIVE block includes a MUX, an HPF (High Pass Filter), an INA, two multipliers (X), and two LPFs. On the right, there are three main functional blocks: PPG TRANSMIT, a central processing block, and BIO-Z TRANSMIT. The PPG TRANSMIT block includes a switch, two photodiodes, and three output lines labeled TX_SUP, RX_SUP, and IO_SUP. The central processing block includes an Interrupt, Timing Engine, OSC (Oscillator), LED Short Detection, 384-FIFO, SPI, ADC (Analog-to-Digital Converter), and Decimation Filters. The BIO-Z TRANSMIT block includes a DDS (Direct Digital Synthesizer), DAC (Digital-to-Analog Converter), PLL (Phase-Locked Loop), a TIA, and a MUX. The entire schematic is labeled 'Simplified Schematic' at the bottom. Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.

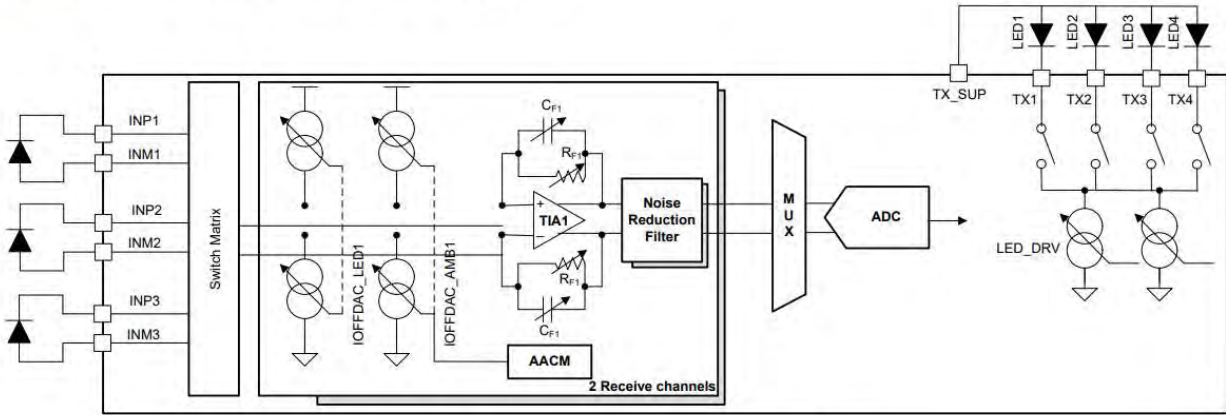
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	The BioActive Sensor (“detection system”) in the Accused Smartwatch is configured to receive lens output light that is reflected from body tissue of the user and to generate and output PPG signal to enable multiple biosensing applications, including optical heart rate monitoring (“OHRM”). For example, TI explains OHRM using its AFE biosensors as follows: <i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or 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).</i> 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.

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	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 (“detection system”) of the Accused Smartwatch is configured to receive a lens output light reflected from tissue of a user and generate a PPG output signal.

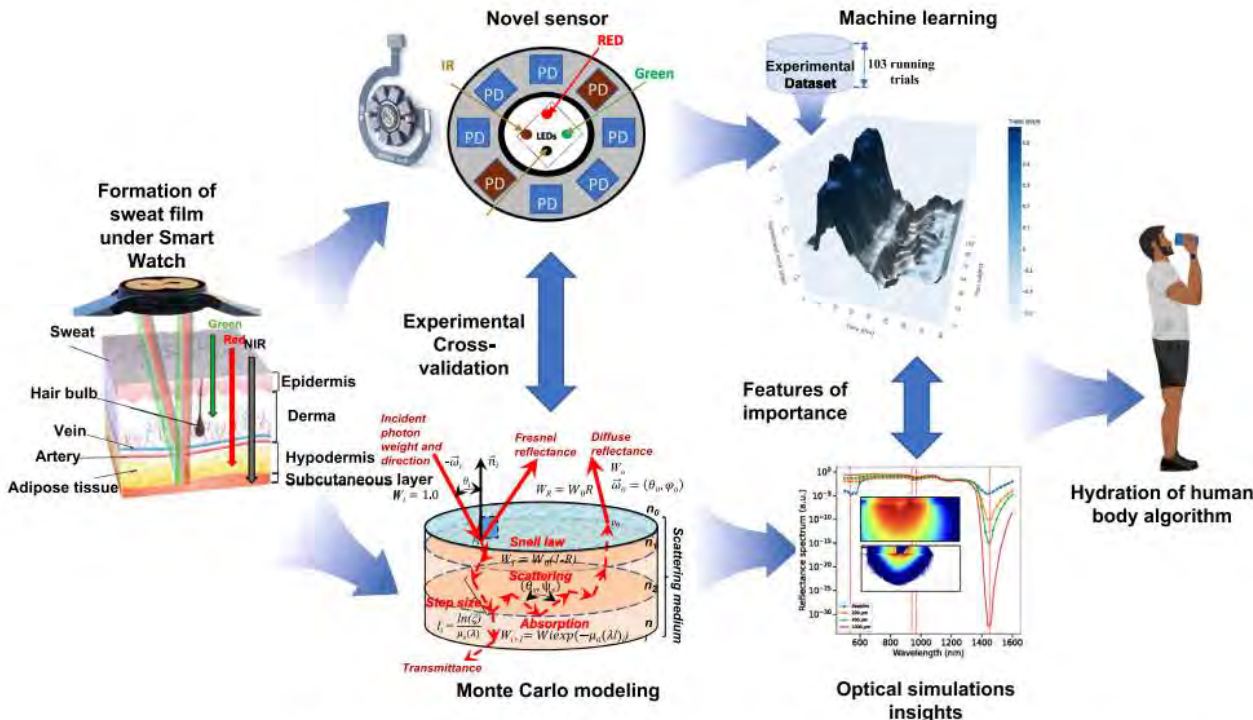
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'475 Patent Claim	Samsung Accused Device ¹
	Figure 3 shows the PPG signal chain in AFE4432.  Figure 3. PPG Signal Chain in AFE4432 The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and noise reduction filters with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). The PPG signal chain for optical heart rate monitoring on wearables is supported on many other AFEs from Texas Instruments such as the AFE4950, AFE4960P, and AFE4500 devices. Source: Texas Instruments, Application Brief, “Optical Heart Rate Monitoring (OHRM) on Wearables,” SBAA564, Nov. 2022, at 2, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf. Samsung engineers further explain in technical papers a detection system configured to receive light reflected from tissue of a user and to generate an output PPG signal. For example: “Recently, the technology is migrated to wearable devices such as wrist-worn smart watch or a wireless ear set. Among them, PPG sensor is a health sensor that measures the change in blood flow to be modulated by the heart rate. When a separate light source (LED) is irradiated to the skin, the light absorption by the blood vessel is changed in synchronization with the heart rate. A sensor measures,

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	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-invasive information of the aforementioned human health indicators with recent additions of temperature, blood oxygen level (SpO₂), etc. monitoring capabilities.”

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

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	The detection system 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 consists of two parts, (a) and (b). Part (a) shows the back of a Samsung Galaxy Gear Fit smartwatch. A red box highlights a sensor module on the back cover. Below it, a disassembled view of the back cover shows the internal circuit board with the sensor module highlighted by a red box. Labels point to the 'Cover glass' and the 'PPG sensor'. Part (b) shows the back of a Samsung Galaxy Watch 3 smartwatch. A red circle highlights the sensor area. Below it, a disassembled view of the back cover shows the internal circuit board with the sensor area highlighted by a red circle. Labels point to the 'optical barrier' and the 'PPG sensor'. 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.

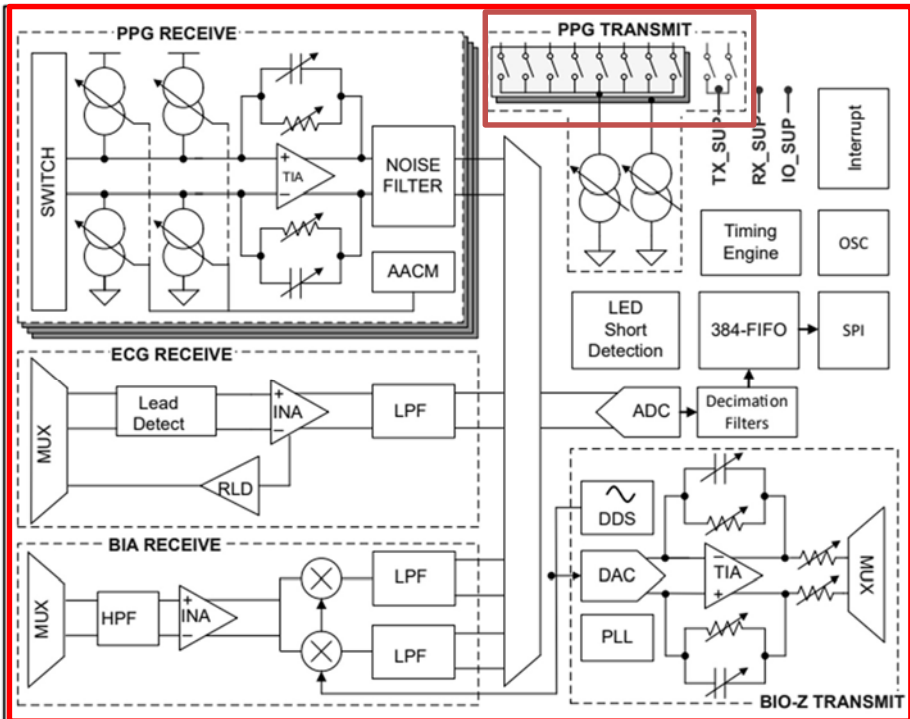
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'475 Patent Claim	Samsung Accused Device ¹
	Figure 5. Examples of PPG sensor configurations that use multiple LEDs and PDs, and their application to commercial smartwatches. (a–d) illustrate different PPG sensor structures, while (e) through (h) present 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.

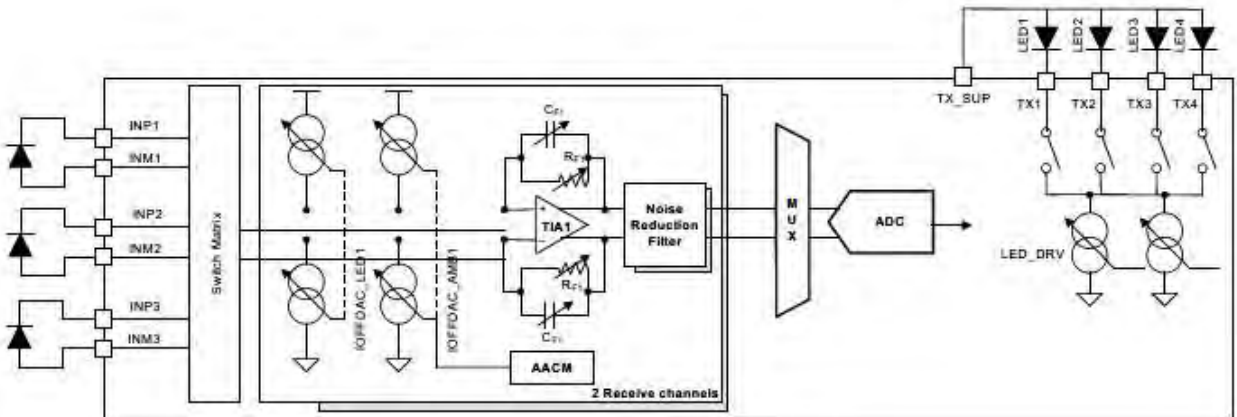
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’475 Patent Claim	Samsung Accused Device ¹
1[g] wherein the detection system is configured to be synchronized to the light source,	The detection system in the Accused Smartwatch is configured to be synchronized to the light source, either literally or under the doctrine of equivalents. For example, the BioActive Sensor (“detection system”) is connected to the light source containing multiple LEDs. It is configured to synchronize with the light source by controlling the LED current (light intensity) and the pulse rate of the LEDs using LED drivers. To measure heart rate, for example, green LEDs are used with a pre-determined intensity and pulse rate. Different LEDs are used to measure other parameters, such as blood oxygen levels. Green LEDs (“light source”) blink when measuring heart rate, and both green and red LEDs (“light source”) blink alternately when measuring blood oxygen levels. This, among other evidence below, shows that the BioActive Sensor (“detection system”) is synchronized with the light source. The BioActive Sensor in the Accused Smartwatch features a biosensing AFE manufactured by TI (e.g., AFE 4510). The AFE component used in the BioActive Sensor includes a detection system that is synchronized to programmable LEDs (“light source”). PPG Transmitter: – 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA – LED Short Detection – <u>Support of 16 LEDs in Common Anode configuration for SpO2, OHRM, Spectroscopy</u>

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'475 Patent Claim	Samsung Accused Device ¹
	 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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'475 Patent Claim	Samsung Accused Device 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, <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 detection system, including how the detection system is configured to synchronize to differing flashing LED colors on the Accused Smartwatch to facilitate calculating different physiological parameters.

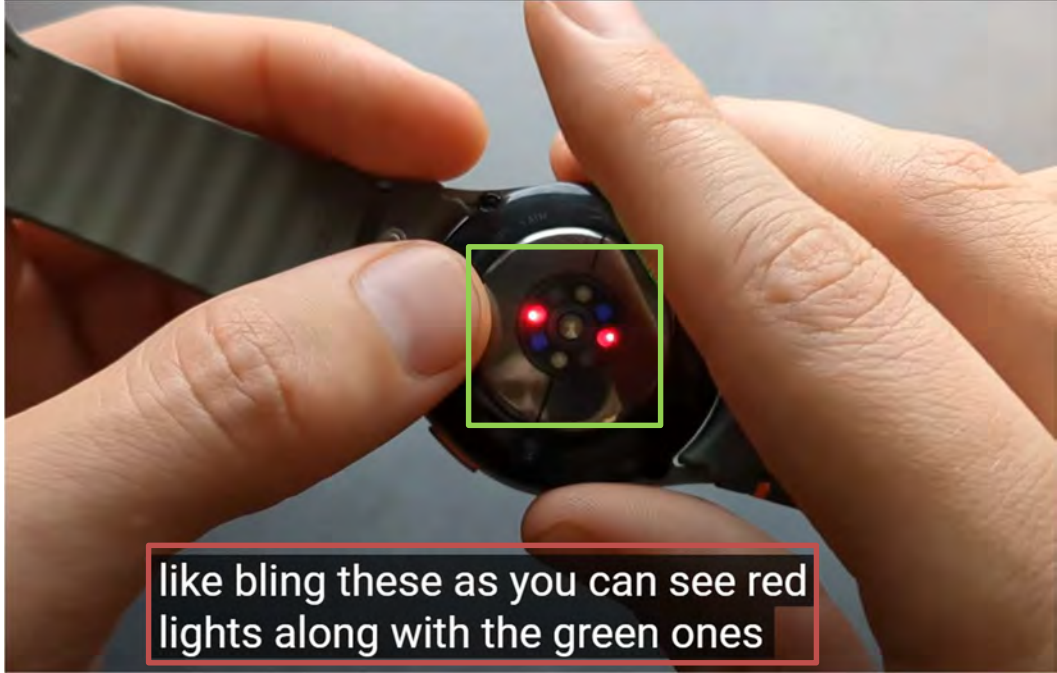
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'475 Patent Claim	Samsung Accused Device ¹
	 heart rate sensors and they basically blink Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:24, https://www.youtube.com/watch?v=JG9pGlqmg&t=23s.

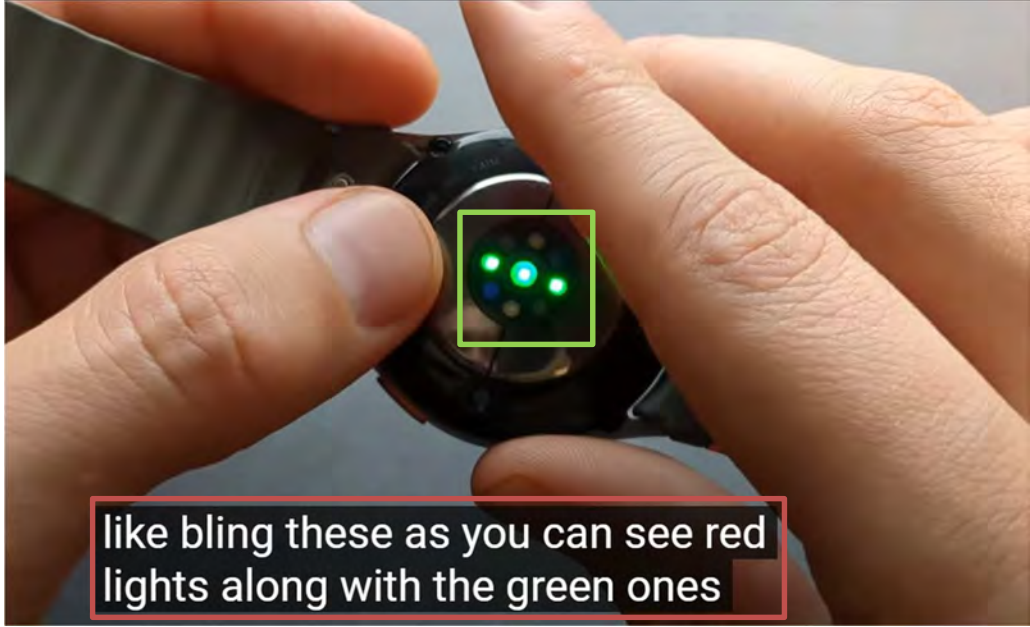
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’475 Patent Claim	Samsung Accused Device ¹
	 Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:37, https://youtu.be/JG9pGlmges?si=IrcplcEOdHE3cB3l&t=37

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'475 Patent Claim	Samsung Accused Device 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/JG9pGlqmgcs?si=xMBhD11dBJQoADTO&t=53

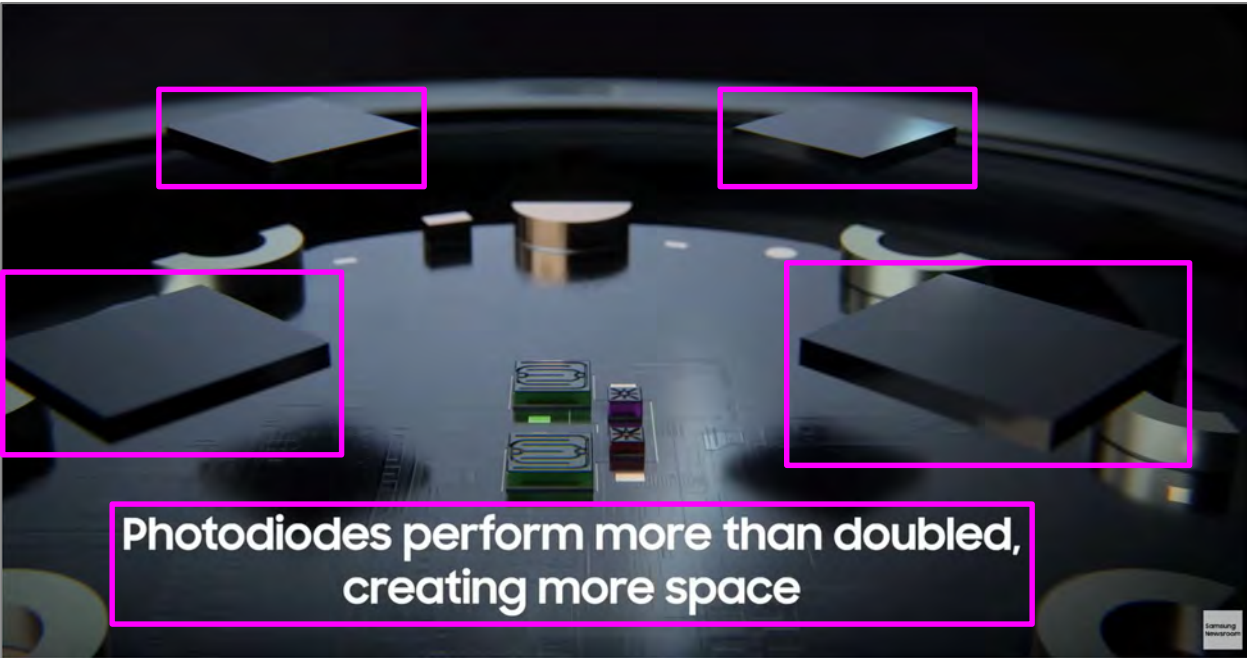
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	 like bling these as you can see red lights along with the green ones Source: Ultra Value Tech, “Green Flashing Lights on Back of Samsung Galaxy Watch 7 – What Are They & How to Turn Them Off,” July 21, 2024, at 0:53, https://youtu.be/JG9pGfqmges?si=YV8CQ6yVqkvL7ITZ&t=53
1[h] wherein the detection system comprises a plurality of detectors that are spatially separated from each other, and	The detection system in the Accused Smartwatch comprises a plurality of detectors that are spatially separated from each other, either literally or under the doctrine of equivalents. For example, the BioActive Sensor (“detection system”) includes multiple spatially separated photodiodes/PDs (“detectors”). “The all-new BioActive Sensor is essential to bringing you better preventative health experiences on the next Galaxy Watch, with design improvements that enable even more precise health insights. Samsung engineers focused on three upgrades to the new sensor: enhancing the performance of light-receiving

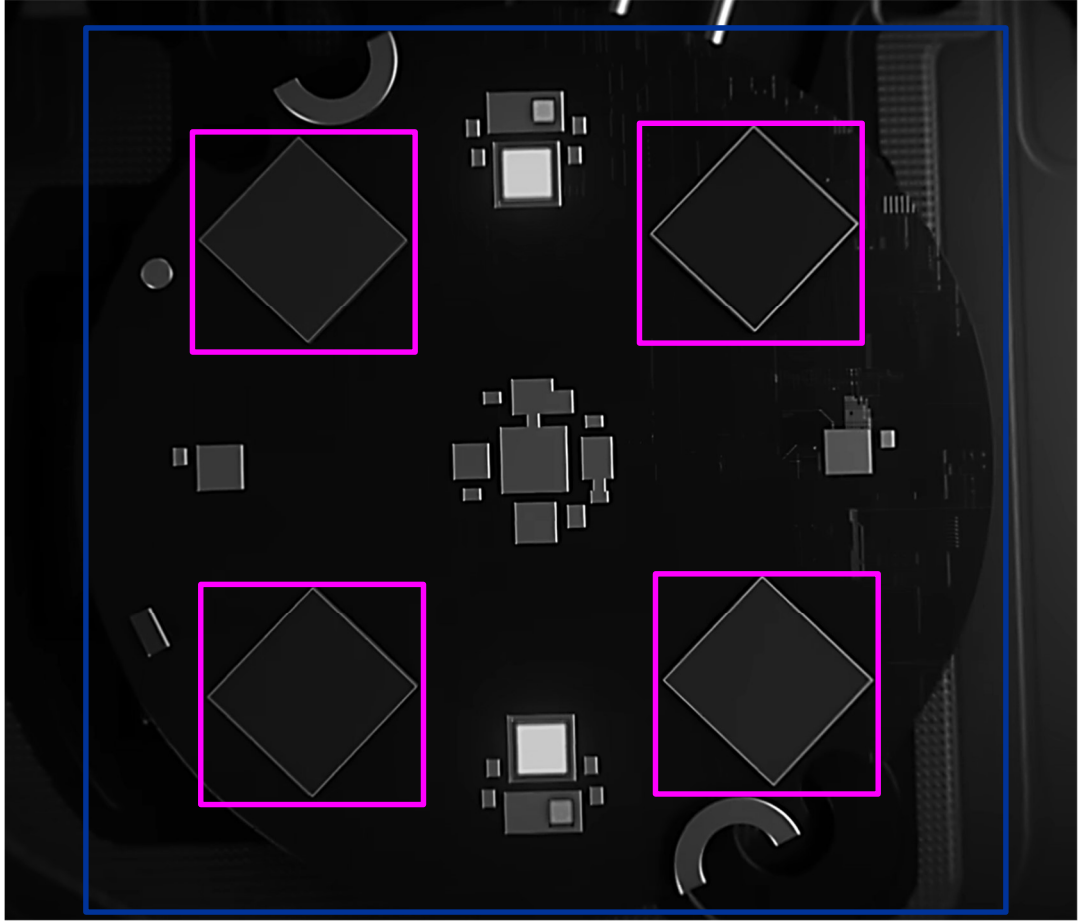
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’475 Patent Claim	Samsung Accused Device ¹
	photodiodes, adding additional colors of light-emitting diodes (LEDs) and arranging them optimally across the sensor.” Samsung more than doubled the performance of each photodiode, successfully decreasing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

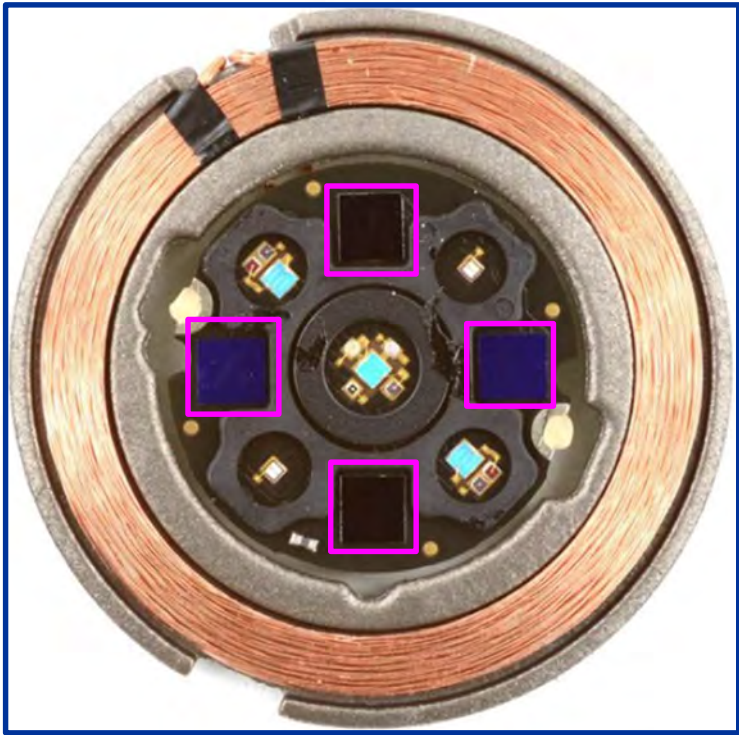
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	 Photodiodes perform more than doubled, creating more space Source: Samsung Newsroom, “Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor,” Jul. 8, 2024, available at https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor; Samsung Newsroom, “Introducing Samsung’s New BioActive Sensor,” July 8, 2024, https://www.youtube.com/watch?v=snMLajaf0tc&t=7s.

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'475 Patent Claim	Samsung Accused Device ¹
	 The image shows the internal components of a Samsung Galaxy Watch BioActive Sensor module. Four diamond-shaped sensors are highlighted with pink boxes, arranged in a 2x2 grid. The sensors are connected to a central circuit board with various electronic components. The entire module is housed in a black plastic casing. Source: Source: Samsung Newsroom, “Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor,” Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor; Samsung Newsroom, “Introducing Samsung’s New BioActive Sensor,” July 8, 2024, https://www.youtube.com/watch?v=snMLajaf0tc&t=7s.

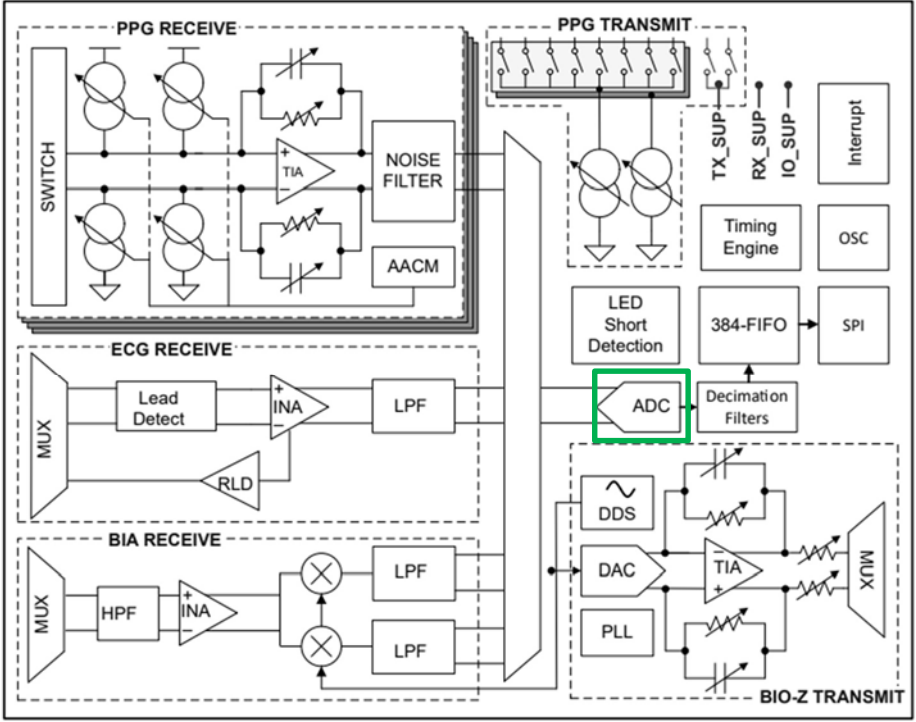
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'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 “The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bioimpedance signals. A PPG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

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

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'475 Patent Claim	Samsung Accused Device ¹
	 Simplified Schematic Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 2, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.
1iii wherein the output signal is indicative of the one or more	The Accused Smartwatch generates an output signal that is indicative of one or more of the physiological parameters, either literally or under the doctrine of equivalents. For example, the PPG signal (“output signal”) from the BioActive Sensor indicates, among other things, heart rate and blood oxygen levels (“one or more of the physiological parameters”).

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physiological parameters;	 Heart rate zones Use improved heart rate monitoring to tailor training for the best results, personalized for you.^{3, 6} Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

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

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’475 Patent Claim	Samsung Accused Device ¹
	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

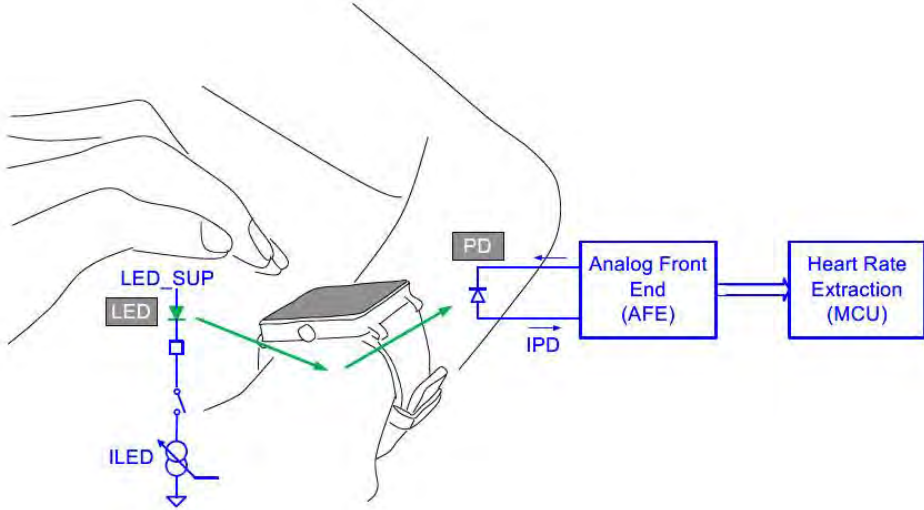
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	<u>PPG signal acquisition:</u> – Acquisition of 24 PPG signal sets (LED, AMB) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ measurement – Low Current for Continuous Operation with a Typical Value: 19μA for the Receiver <u>PPG Transmitter:</u> – 8-Bit Programmable LED Current with a range adjustable from 50mA to 300mA – LED Short Detection – Support of 16 LEDs in Common Anode configuration for SpO₂, <u>OHRM</u>, Spectroscopy <u>OHRM: Optical Heart-rate monitoring</u> Source: Texas Instruments, AFE4510, SBASB19 – March 2024, at 1-4, <i>available at</i> https://www.ti.com/lit/ds/symlink/afe4510.pdf.

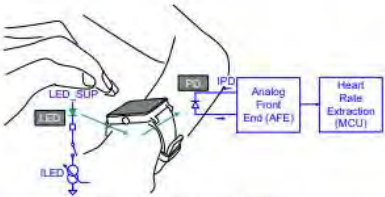
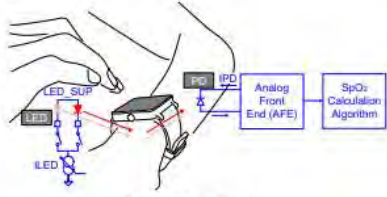
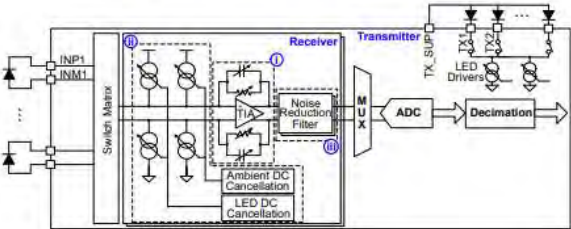
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹
	Application <i>Optical Heart Rate Monitoring (OHRM)</i> uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or reflected to a photodiode (PD), the pulsating waveform can be converted to a signal current. As shown in Figure 1, an analog front-end (AFE) converts the signal current waveform from the PD to a digitized waveform which can then be processed by a signal processing algorithm in the MCU to extract the heart rate (HR).

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'475 Patent Claim	Samsung Accused Device 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, available at https://www.ti.com/lit/ab/sbaa564/sbaa564.pdf.

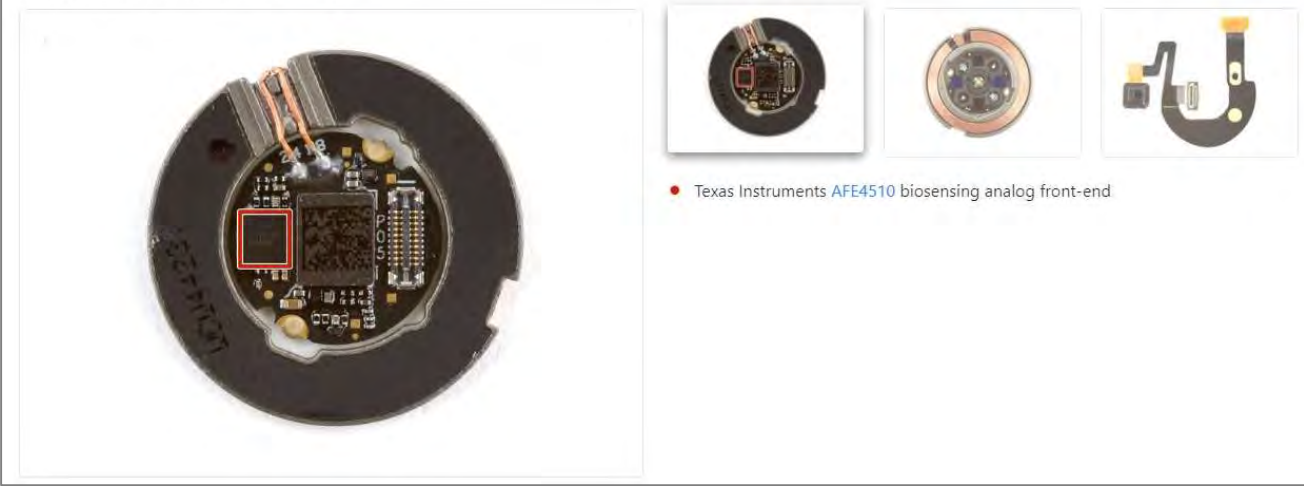
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	<i>Product Overview</i> Photoplethysmography (PPG) With Integrated AFE for Optical Biosensing  TEXAS INSTRUMENTS Applications like optical heart rate and SpO₂ 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.  Heart Rate Monitoring  SpO₂ Monitoring  Block Diagram Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i>

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’475 Patent Claim	Samsung Accused Device ¹
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1[k] the apparatus being configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the plurality of light emitting diodes from an initial light intensity; and	The Accused Smartwatch is configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the plurality of light emitting diodes from an initial light intensity, either literally or under the doctrine of equivalents. For example, the Galaxy Watch Ultra increases the signal-to-noise ratio (“SNR”) of the PPG signal received from the BioActive Sensor. The BioActive Sensor has a peak system SNR of 115 dB, which indicates that the general output SNR is lower than this peak value. To achieve peak SNR, the sensor is configured to increase the LED current (“increasing light intensity”) of the LEDs.

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'475 Patent Claim	Samsung Accused Device ¹
	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.

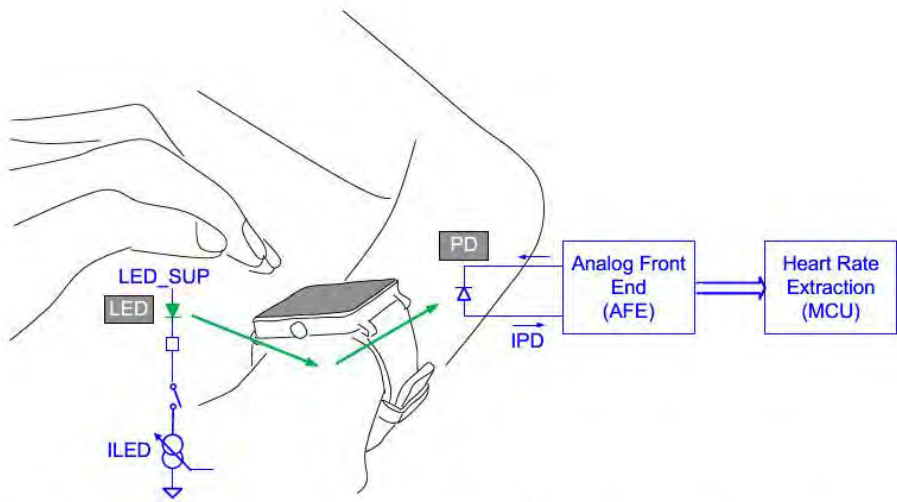
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’475 Patent Claim	Samsung Accused Device ¹
	3 Description The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bio-impedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that 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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'475 Patent Claim	Samsung Accused Device ¹
	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 <i>Optical Heart Rate Monitoring (OHRM)</i> uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or reflected to a photodiode (PD), the pulsating waveform can be converted to a signal current. As shown in Figure 1, an analog front-end (AFE) converts the signal current waveform from the PD to a digitized waveform which can then be processed by a signal processing algorithm in the MCU to extract the heart rate (HR).

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'475 Patent Claim	Samsung Accused Device ¹
	 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.

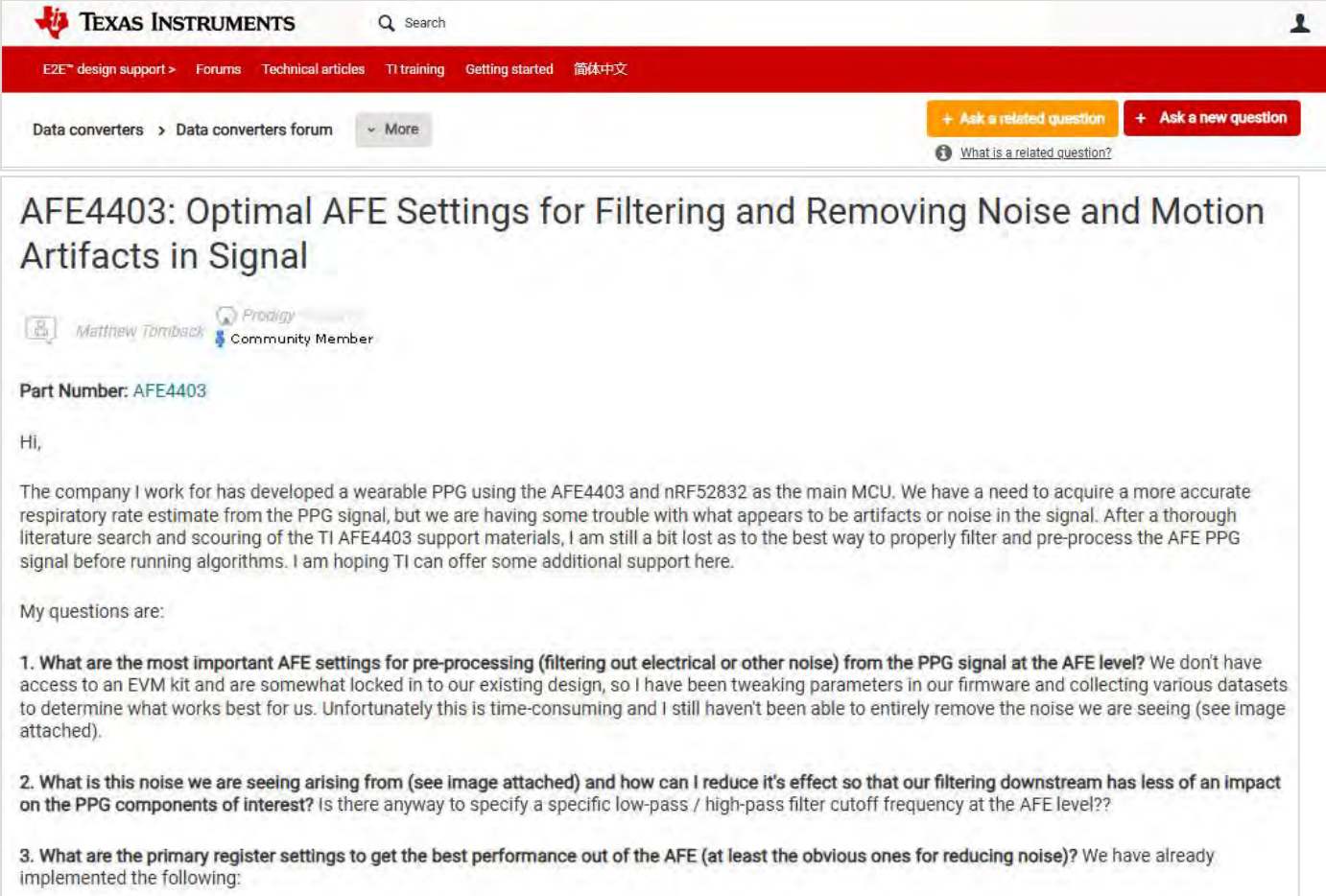
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	Block Diagram Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i> https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F. 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.

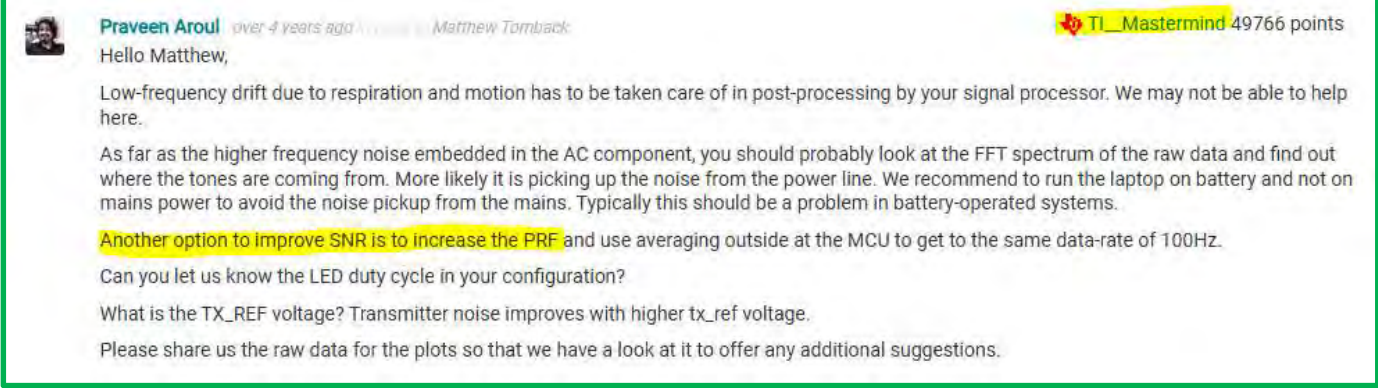
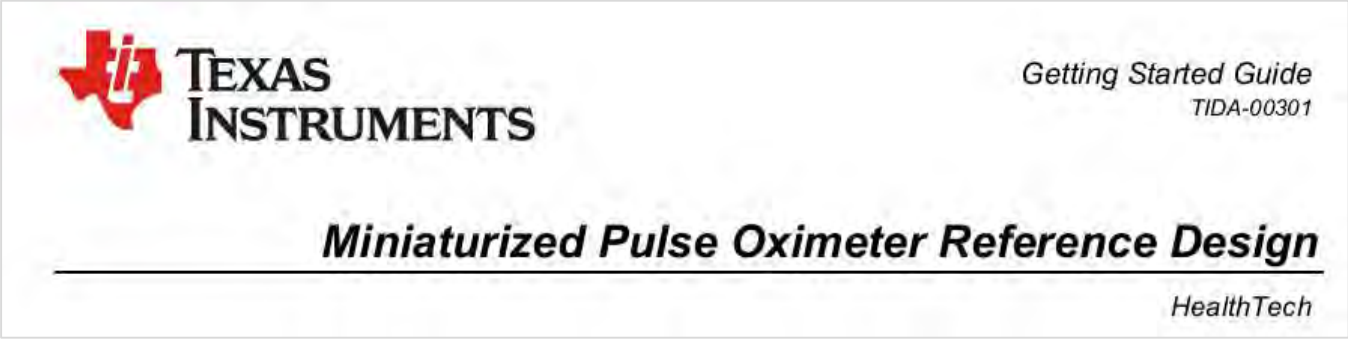
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	“However, increasing the LED current gives better signal quality from the SNR perspective. The optimal AFE configuration settings are completely dependent on the application. This includes the separation of LED and PD, location of the sensor, and 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><thead><tr><th>PARAMETER</th><th>TEST CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr></thead><tbody><tr><td colspan="6">PERFORMANCE (Full-Signal Chain)</td></tr><tr><td rowspan="7">I_{IN_FS} Full-scale input current</td><td>R_F = 10 kΩ</td><td></td><td>50</td><td></td><td>μA</td></tr><tr><td>R_F = 25 kΩ</td><td></td><td>20</td><td></td><td>μA</td></tr><tr><td>R_F = 50 kΩ</td><td></td><td>10</td><td></td><td>μA</td></tr><tr><td>R_F = 100 kΩ</td><td></td><td>5</td><td></td><td>μA</td></tr><tr><td>R_F = 250 kΩ</td><td></td><td>2</td><td></td><td>μA</td></tr><tr><td>R_F = 500 kΩ</td><td></td><td>1</td><td></td><td>μA</td></tr><tr><td>R_F = 1 MΩ</td><td></td><td>0.5</td><td></td><td>μA</td></tr><tr><td>PRF Pulse repetition frequency</td><td></td><td>62.5</td><td></td><td>2000</td><td>SPS</td></tr><tr><td>DC_{PRF} PRF duty cycle</td><td></td><td></td><td></td><td>25%</td><td></td></tr></tbody></table> 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:	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	PERFORMANCE (Full-Signal Chain)						I _{IN_FS} Full-scale input current	R _F = 10 kΩ		50		μA	R _F = 25 kΩ		20		μA	R _F = 50 kΩ		10		μA	R _F = 100 kΩ		5		μA	R _F = 250 kΩ		2		μA	R _F = 500 kΩ		1		μA	R _F = 1 MΩ		0.5		μA	PRF Pulse repetition frequency		62.5		2000	SPS	DC _{PRF} PRF duty cycle				25%	
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	 TEXAS INSTRUMENTS Search E2E™ design support > Forums Technical articles TI training Getting started 简体中文 Data converters > Data converters forum More + Ask a related question + Ask a new question What is a related question? AFE4403: Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal  Matthew Tomback  Prodigy Community Member Part Number: AFE4403 Hi, The company I work for has developed a wearable PPG using the AFE4403 and nRF52832 as the main MCU. We have a need to acquire a more accurate respiratory rate estimate from the PPG signal, but we are having some trouble with what appears to be artifacts or noise in the signal. After a thorough literature search and scouring of the TI AFE4403 support materials, I am still a bit lost as to the best way to properly filter and pre-process the AFE PPG signal before running algorithms. I am hoping TI can offer some additional support here. My questions are: 1. What are the most important AFE settings for pre-processing (filtering out electrical or other noise) from the PPG signal at the AFE level? We don't have access to an EVM kit and are somewhat locked in to our existing design, so I have been tweaking parameters in our firmware and collecting various datasets to determine what works best for us. Unfortunately this is time-consuming and I still haven't been able to entirely remove the noise we are seeing (see image attached). 2. What is this noise we are seeing arising from (see image attached) and how can I reduce it's effect so that our filtering downstream has less of an impact on the PPG components of interest? Is there anyway to specify a specific low-pass / high-pass filter cutoff frequency at the AFE level?? 3. What are the primary register settings to get the best performance out of the AFE (at least the obvious ones for reducing noise)? We have already implemented the following:

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	 Praveen Aroul over 4 years ago · 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 Miniaturized Pulse Oximeter Reference Design HealthTech

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	ABSTRACT The scope of this document is to provide a miniaturized pulse oximeter reference design for high end clinical application. This reference design features AFE4403, TI's high performance Analog Front End for pulse oximeters, an ultra-low power microcontroller and a highly optimized integrated dual light emitting diodes (LED) and photodiode optical sensor. This reference design simplifies and accelerates the pulse oximeter system design while still ensuring the highest quality clinical measurements. The sampling duration is termed the receiver (<i>Rx</i>) <i>sample time</i> 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 “<i>ratio of ratios</i>” or <i>Pulse Modulation ratio</i> R which is defined as the ratio of AC/DC of red and IR LEDs as mentioned in Section 2. The PPG signal is normally contaminated with noise which could come from various sources like the power supply noise, motion artifact etc. An essential component as part of the data preprocessing is filtering out the unwanted signal of interest. Since the DC component resides in frequencies below 0.5Hz, a low pass filter with a cutoff frequency of 5Hz can be used for the SpO₂ estimation. This filtering stage is left for the user to implement. Source: Texas Instruments, “Miniaturized Pulse Oximeter Reference Design,” Getting Started Guide, TIDA-00301, at 1, 11-14, 20, available at

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	https://www.ti.com/lit/ug/tidu475/tidu475.pdf?ts=1724347486358&ref_url=https%253A%252F%252Fwww.google.com%252F%20. Samsung patent documents describe wearable devices that are configured to increase the signal-to-noise ratio by increasing light intensity of at least one of the semiconductor sources from an initial light intensity and by increasing a pulse rate of at least one of the semiconductor sources from an initial pulse rate. For example: (12) United States Patent Lee et al. (10) Patent No.: US 11,974,838 B2 (45) Date of Patent: May 7, 2024 (54) ELECTRONIC DEVICE FOR ACQUIRING BIOMETRICS USING PPG SENSOR, AND METHOD THEREFOR (71) Applicant: Samsung Electronics Co., Ltd., Gyeonggi-do (KR) (57) ABSTRACT An electronic device may include a PPG sensor including a light emitter that applies a current in a specified range and emits a light signal corresponding to the current and a light detector that amplifies a received light signal by applying one of a plurality of gain values, a memory that stores a plurality of sets of PPG models corresponding to the plu- (Continued)

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	To obtain bio information from the PPG signal, the PPG signal needs to have an appropriate level. For example, when the PPG signal is saturated or a signal to noise ratio (SNR) is low, it may be difficult to extract bio information from the PPG signal. 45 The level of the PPG signal may be proportional to the intensity of light emitted by the light emitter and the intensity of light collected by the light detector. The intensity 50 of light emitted by the light emitter may be proportional to the intensity of a current applied to the light emitter. The light detector may amplify the collected light according to a predetermined gain value. 5 device 100 may be referred to as a user terminal. The electronic device 100 may analyze a PPG signal acquired and acquire bio information. Therefore, the PPG signal may need to have an appropriate level to extract bio information. For example, the higher the level of the PPG 10 signal, the greater the signal to noise ratio (SNR) of the PPG signal. However, when power consumed by the PPG sensor increases and the PPG signal is out of a reception range of a photo detector, the PPG signal may be saturated. When the In various embodiments, to improve the accuracy of the heart rate estimated from the measured PPG, it is possible to 10 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 15 in maximizing the SNR of a heart rate signal included in the PPG signal.

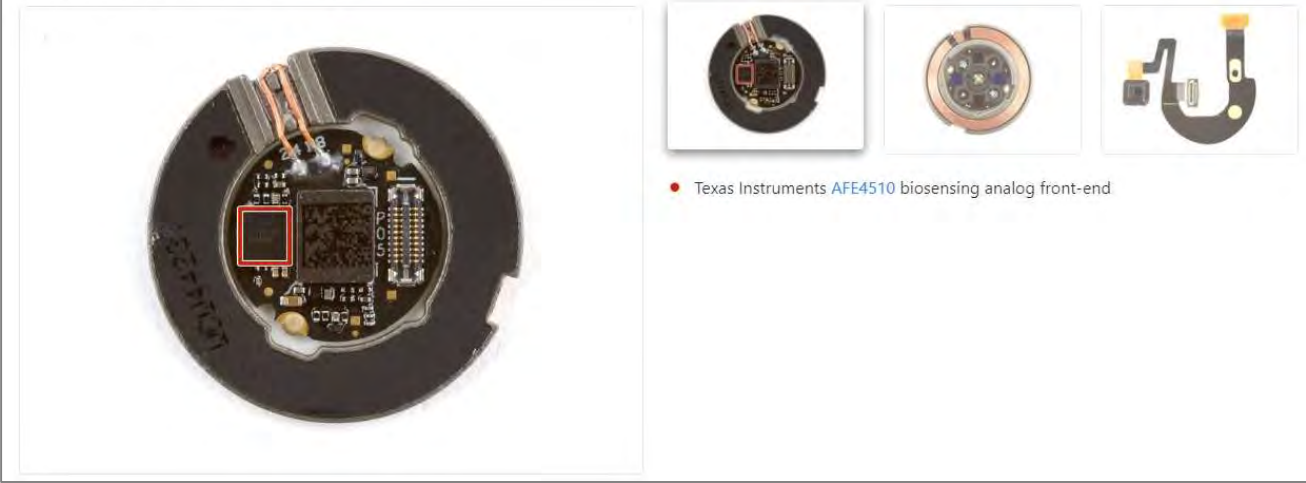
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	FIG. 5 Source: US 11,974,838 at Abstract, 1:43-54, 6:6-38, 12:8-16, FIG. 5. Increasing SNR generally yields more accurate health measurements. Samsung advertises that the Accused Smartwatch provides health measurements with enhanced accuracy, indicating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

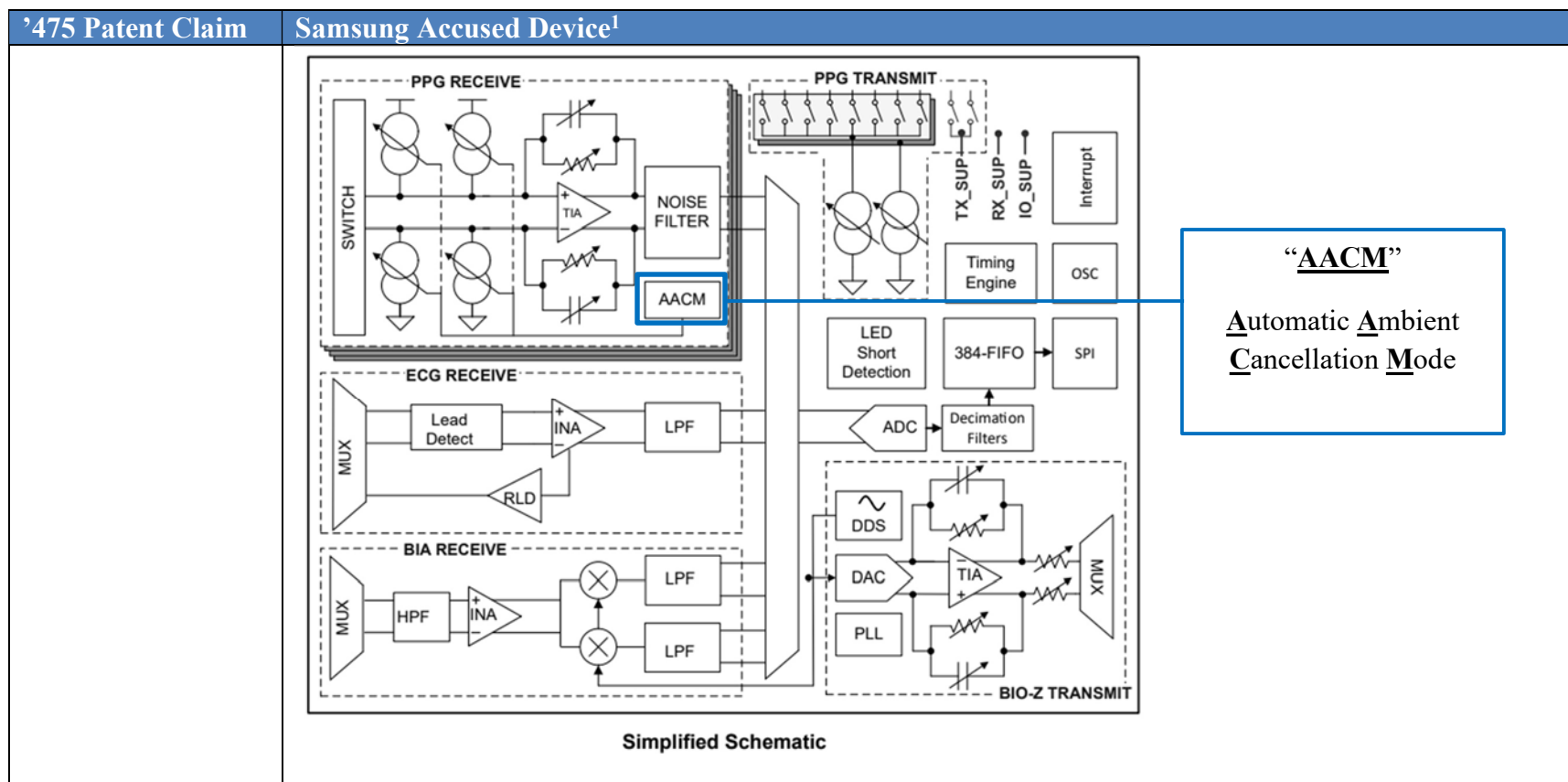
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	 The diagram illustrates the data flow from a Samsung BioActive Sensor watch to a Wear OS Application. On the left, a smartwatch displays 'Heart Rate 71' and 'SpO2 96%'. A flowchart to the right shows 'Sensor Data' being processed by the 'Samsung Privileged Health SDK' (labeled 'Tracking Raw / Processed Health Sensor Data') and then sent to a 'Wear OS Application'. “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
111 the detection system further configured to: generate a first signal responsive to light received while	The detection system in the Accused Smartwatch is further configured generate a first signal responsive to light received while the light emitting diodes are off, generate a second signal responsive to light received while at least one of the light emitting diodes is on, and increase the signal-to-noise ratio by comparing the first signal and the second signal, 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

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the light emitting diodes are off, generate a second signal responsive to light received while at least one of the light emitting diodes is on, and increase the signal-to-noise ratio by comparing the first signal and the second signal; and	“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. 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  • 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 – <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 <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 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
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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.																			

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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. TEXAS INSTRUMENTS 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. Heart Rate Monitoring SpO₂ Monitoring Block Diagram

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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*.xslm 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*.xslm 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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	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.
1[m] wherein the apparatus is at least in part configured to determine, based at least in part on the	The Accused Smartwatch is at least in part configured to determine, based at least in part on the output signal, that the apparatus is being worn by the user, either literally or under the doctrine of equivalents. For example, the Accused Device comprises biosensors for sensing one or more physiological parameters of the user. In response to one of the biosensors having measured a physiological parameter of the user, the

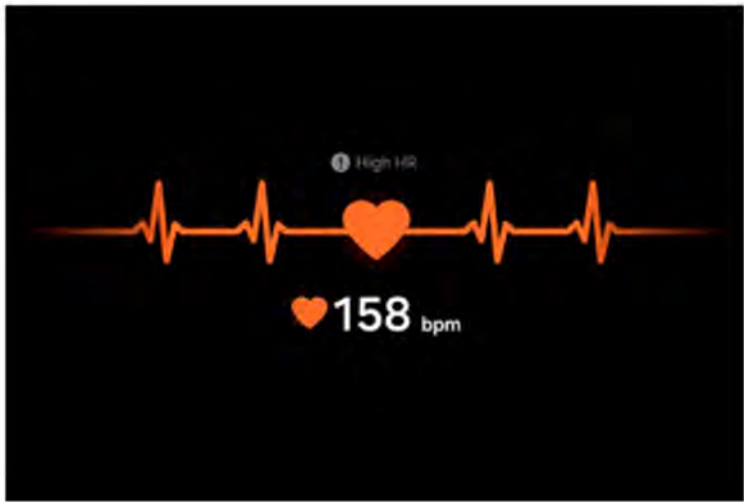
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output signal, that the apparatus is being worn by the user.	optical PPG Sensor generates an output photoplethysmography (“PPG”) signal, which the Accused Device uses at least in part to determine that the apparatus is being worn by the user. For example, the Galaxy Watch Ultra is at least in part configured to recognize or establish when it is being worn by a human user by identifying one or more physiological parameters of the human user (<i>e.g.</i>, human health metrics and data such as heart rate, SpO2, and sleep metrics). In doing so, the Accused Smartwatch is also at least in part configured to recognize or establish details about the user’s blood (<i>e.g.</i>, constituents in the blood and/or oxygen saturation of the user’s blood), which enables a determination that the device is worn by a human user. “Some features on Galaxy Watch running Wear OS powered by Samsung function only when the watch is being worn on the user’s wrist. Notifications are an important example of one such feature. When the watch is not being worn, phone notifications are not synchronized to the watch and local notifications generated on the watch are muted. Off-Body detection enables you to determine if the user is wearing the watch. To enable this, the watch contains a Low Latency Off-Body sensor. The data from this sensor allows you to enhance your application by implementing it to, for example, send or avoid notifications or to show or hide sensitive information, as appropriate.” S. Nasrin, “Detect When a Galaxy Watch Is Being Worn,” Samsung Developer, June 14, 2023, https://developer.samsung.com/sdp/blog/en/2023/06/14/detect-when-a-galaxy-watch-is-being-worn. <u>Wrist detection</u> When enabled the watch <u>automatically detects when the watch is being worn</u>. It is advisable to only turn this feature off if your watch has trouble detecting when it is on your wrist. ○ From  Settings, tap  Security and privacy > Wrist detection.

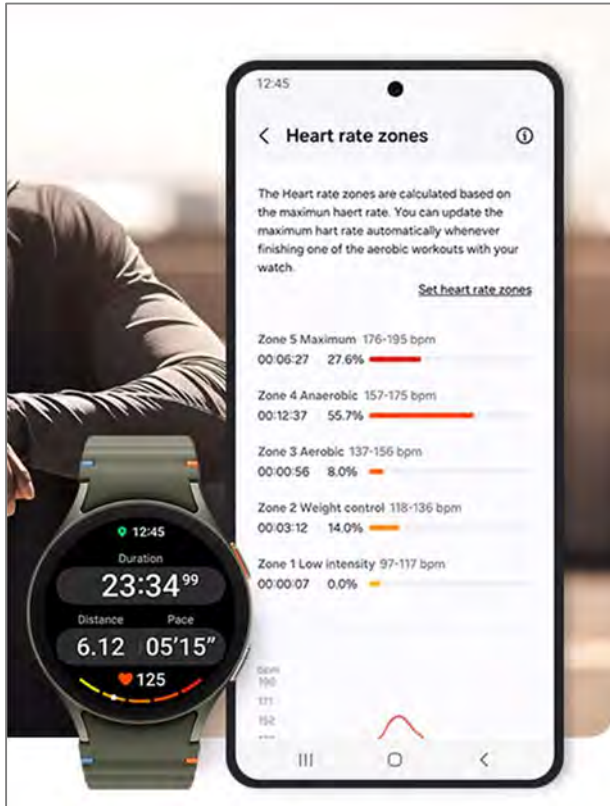
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	Source: Samsung Galaxy Watch7 Watch Ultra User Guide at 65, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf .

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 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 More precise Heart Rate Tracking 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/

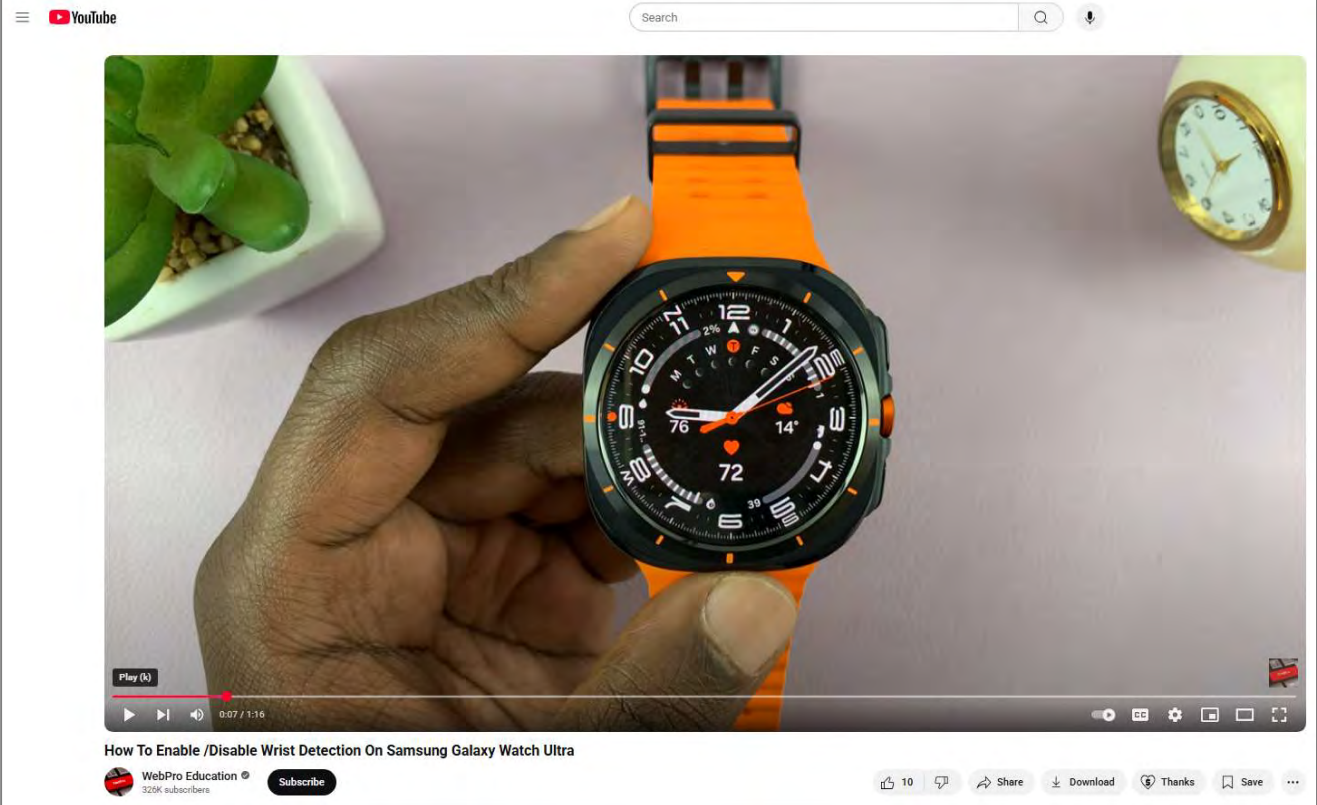
U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹																		
	Set your own Heart Rate Zone Exercise at your optimal fitness capacity to reach your workout goals. With the Galaxy Watch Series, you have the flexibility to set your Personalized HR Zone to reach your health and wellness targets. Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life <table><tr><th>Zone</th><th>Heart Rate Range (bpm)</th><th>Percentage of Max HR</th></tr><tr><td>Zone 5 Maximum</td><td>176-195 bpm</td><td>27.6%</td></tr><tr><td>Zone 4 Anaerobic</td><td>157-175 bpm</td><td>55.7%</td></tr><tr><td>Zone 3 Aerobic</td><td>137-156 bpm</td><td>8.0%</td></tr><tr><td>Zone 2 Weight control</td><td>118-136 bpm</td><td>14.0%</td></tr><tr><td>Zone 1 Low intensity</td><td>97-117 bpm</td><td>0.0%</td></tr></table> Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life	Zone	Heart Rate Range (bpm)	Percentage of Max HR	Zone 5 Maximum	176-195 bpm	27.6%	Zone 4 Anaerobic	157-175 bpm	55.7%	Zone 3 Aerobic	137-156 bpm	8.0%	Zone 2 Weight control	118-136 bpm	14.0%	Zone 1 Low intensity	97-117 bpm	0.0%
Zone	Heart Rate Range (bpm)	Percentage of Max HR																	
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U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device ¹
	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 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

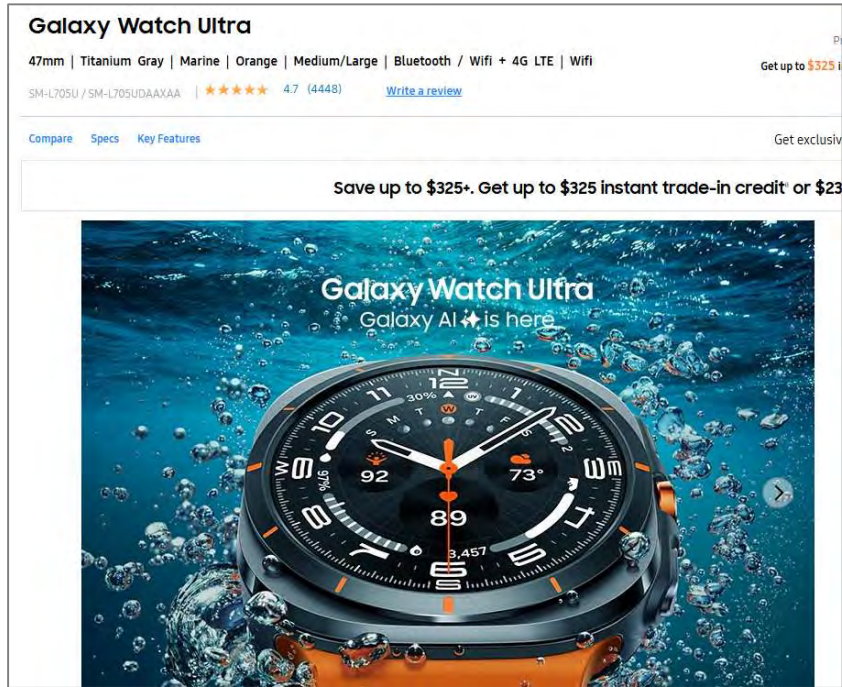
U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	

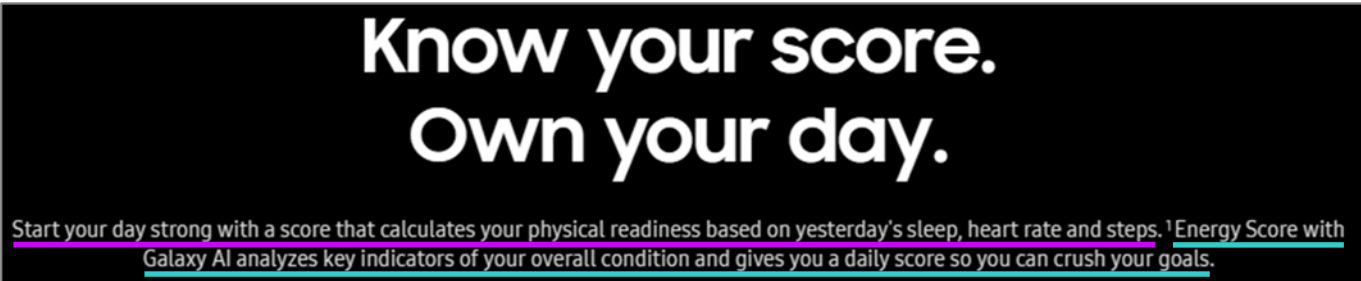
U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 How To Enable /Disable Wrist Detection On Samsung Galaxy Watch Ultra WebPro Education 329K subscribers Subscribe 10 Share Download Thanks Save WebPro Education, “How to Enable/Disable Wrist Detection on Samsung Galaxy Watch Ultra,” YouTube, Aug. 1, 2024, https://www.youtube.com/watch?v=c7YCtsavwHA. See also https://us.community.samsung.com/t5/Galaxy-Watch/Turn-off-wrist-detection/td-p/2617387.

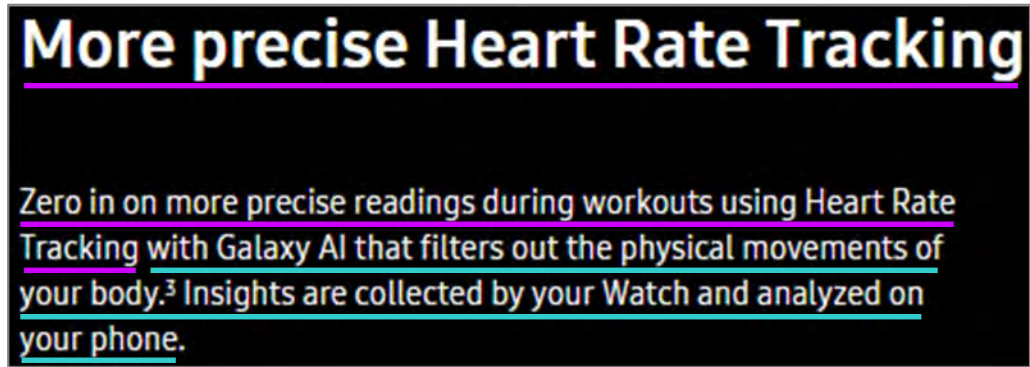
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
5. The apparatus of claim 1, wherein the apparatus further comprises a processor configured to be coupled to a non-transitory computer readable medium, and wherein the apparatus including the processor is configured to use artificial intelligence in making decisions associated with at least a portion of the output signal.	The Accused Smartwatch comprises a processor configured to be coupled to a non-transitory computer readable medium, and wherein the apparatus including the processor is configured to use artificial intelligence in making decisions associated with at least a portion of the output signal, either literally or under the doctrine of equivalents. For example, the Galaxy Watch Ultra comprises a processor and memory (“a non-transitory computer readable medium”) and is configured to use Galaxy AI (“artificial intelligence”) to process the output signal.  Processor Processor Speed, Type 1.6GHz,1.5GHz Memory Available Storage (GB) 21.1 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/  Source: https://www.samsung.com/us/apps/samsung-health/  Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/#galaxy-ai

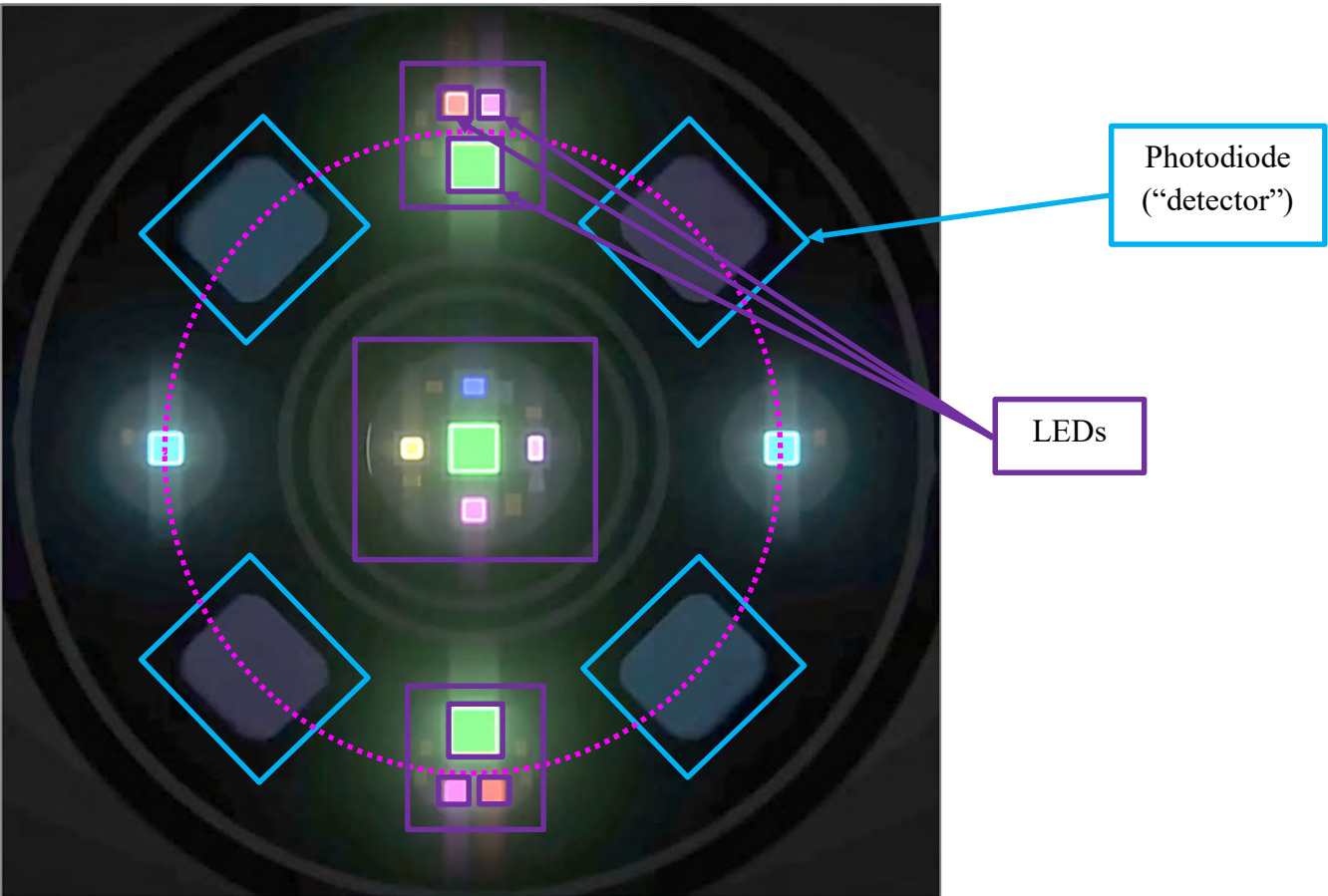
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/#galaxy-ai  Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/#galaxy-ai

U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device ¹
	Earlier this year, Samsung established the era of mobile AI with the launch of the Galaxy S24 series, and committed to introducing Galaxy AI¹ on a wider range of devices. True to this promise, Samsung is now bringing Galaxy AI to Galaxy Watch, enhancing its popular health features. By combining powerful on-device AI with the extensive Samsung Health app, Samsung is on the path to building some of the most personalized and secure health experiences yet. Samsung has been on a mission to deliver an advanced health and wellness experience, starting by utilizing meaningful and actionable insights to help you gain a better understanding of your health patterns. Now, by combining Galaxy AI with Samsung Health, new health features will provide you with more comprehensive health insights, along with motivational encouragement to help you improve your daily wellness. With Energy Score,² you can receive a better understanding of your daily condition through a combined analysis of personal health metrics including sleep time average, sleep time consistency, bed/wake time consistency, sleep timing, previous day activity, sleeping heart rate and heart rate variability³ to help you take on your day. Plus, Wellness Tips⁴ helps you reach your personal health goals by offering insights, motivational tips and guidance based on the specific goal you’re looking to achieve. Accurate and comprehensive health metrics are foundational to the best intelligent health experiences. Enhanced health algorithms and advanced tracking tools will provide more holistic, personalized and actionable insights when combined with AI. Since good health starts with a good night’s rest, Samsung is enhancing our sleep AI algorithm to provide additional in-depth sleep insights. Newly added sleep indicators for Sleep Insights offer you a more detailed and accurate analysis of your sleep quality so you can better understand your sleep patterns and build better habits. These added metrics include movement during sleep, sleep latency, heart rate and respiratory rate during sleep in addition to previously supported metrics like snoring hours, blood oxygen level and sleep cycle. Source: https://news.samsung.com/global/galaxy-ai-is-coming-to-new-galaxy-watch-for-more-motivational-health

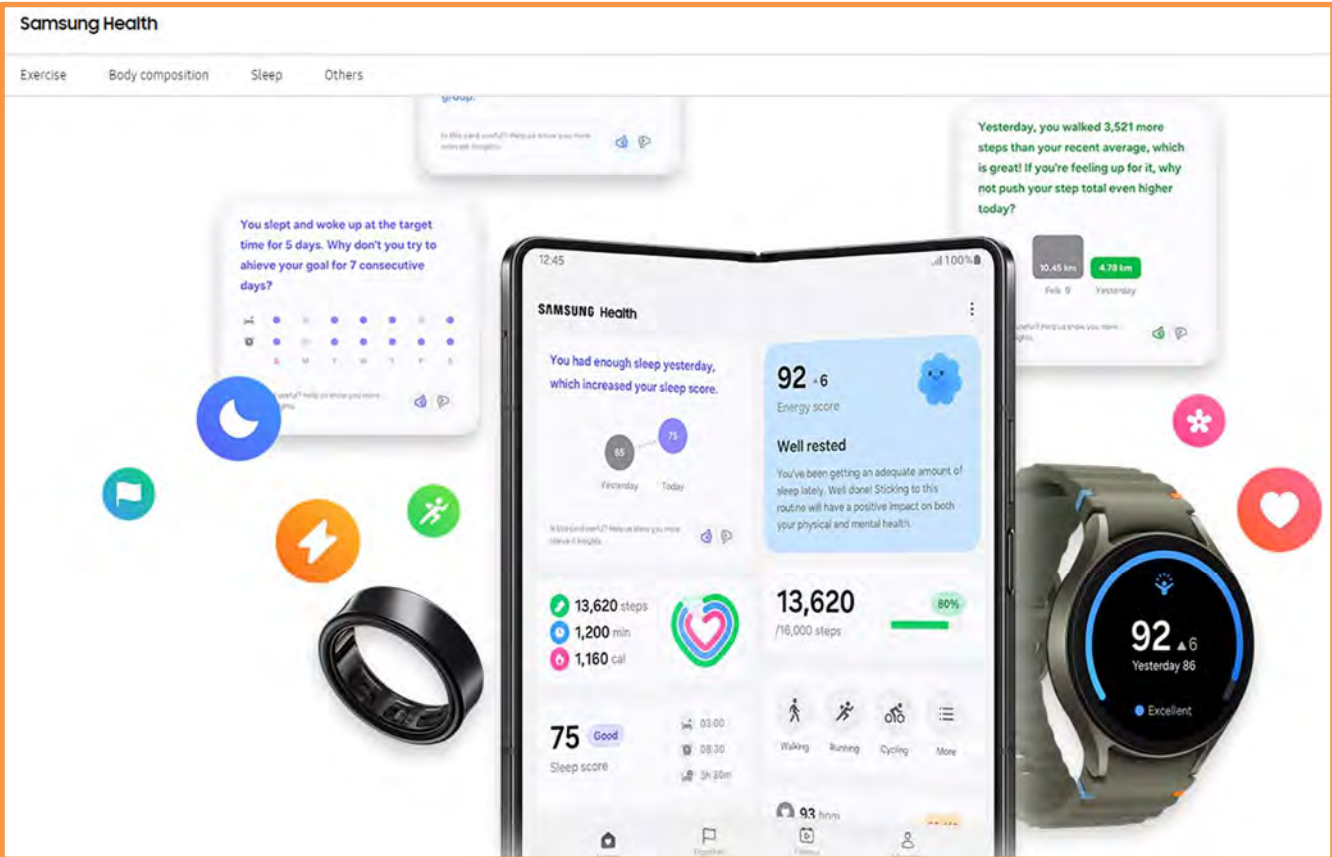
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
6. The apparatus of claim 1, wherein the plurality of light emitting diodes comprises six light emitting diodes, and wherein the detection system comprises the plurality of detectors arranged along an arc.	The plurality of light emitting diodes in the Accused Smartwatch comprise six light emitting diodes, and the detection system comprises the plurality of detectors arranged along an arc, either literally or under the doctrine of equivalents.  Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

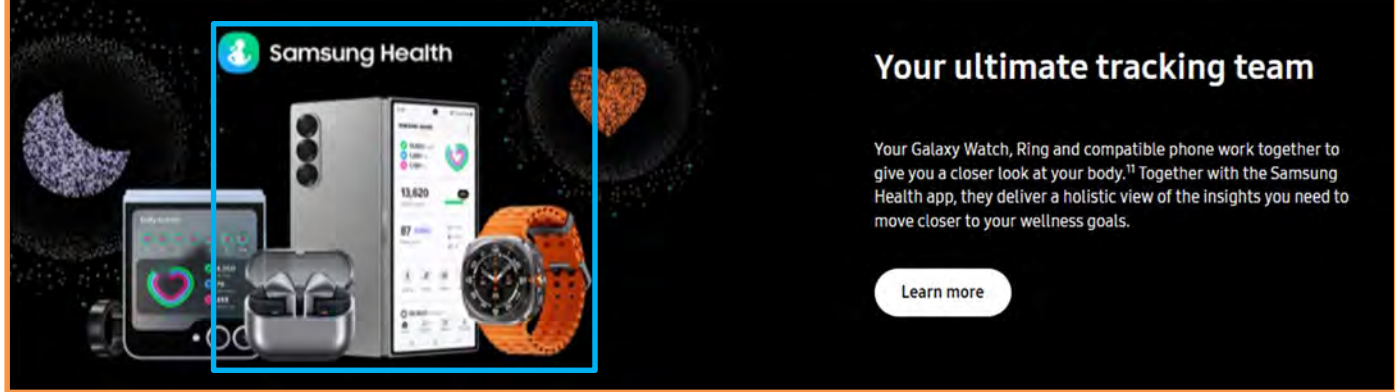
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹
7. The apparatus of claim 6, wherein the apparatus is further configured to communicate with a smart phone or a tablet, the smart phone or the tablet comprising a wireless receiver, a wireless transmitter, a display, a speaker, a voice input module, one or more buttons or knobs, a microprocessor, and a touch screen.	The Accused Smartwatch is configured to communicate with a smart phone or a tablet that comprises a wireless receiver, a wireless transmitter, a display, a speaker, a voice input module, one or more buttons or knobs, a microprocessor, and a touch screen. For example, Samsung provides a system including an Accused Smartwatch such as the Galaxy Watch Ultra and a Samsung smartphone or tablet for measuring physiological parameters of a user. When the user wears a Galaxy Watch Ultra on their wrist, the watch measures physiological parameters using various hardware components, such as Samsung’s “BioActive sensor,” and is configured to transfer the information related to these parameters to a smart phone.

U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	 The image shows a smartphone screen displaying the Samsung Health app. The app interface includes several widgets: a sleep score widget showing a score of 75 (Good), an energy score widget showing 92 (Well rested), and a steps widget showing 13,620 steps. There are also motivational messages and icons for different activities like walking, running, and cycling. A Samsung Watch is shown next to the phone, displaying a large heart rate monitor (HRM) widget with a reading of 92 bpm. Source: https://www.samsung.com/us/apps/samsung-health/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 The image is a promotional banner for Samsung Health. It features a dark background with a glowing heart and a crescent moon. In the center, there is a smartphone displaying the Samsung Health app interface, a Samsung Galaxy Watch Ultra with an orange strap, and a Samsung Galaxy Ring. The text 'Your ultimate tracking team' is prominently displayed on the right, followed by a description of how the devices work together to provide health insights. A 'Learn more' button is located at the bottom right of the text area. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

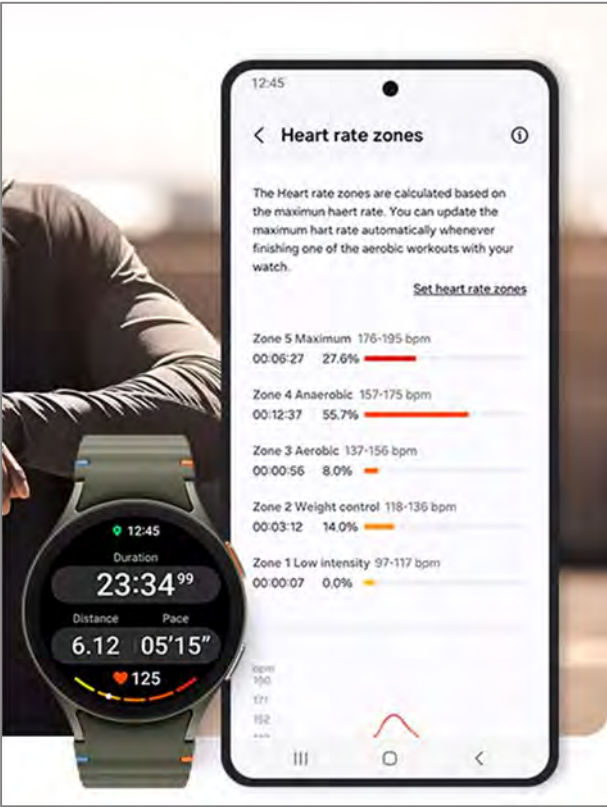
U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device 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. <u>Insights are collected by your Watch and analyzed on your phone.</u> Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	Set your own Heart Rate Zone Exercise at your optimal fitness capacity to reach your workout goals. With the Galaxy Watch Series, you have the flexibility to set your Personalized HR Zone to reach your health and wellness targets. Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life 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. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device 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

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	Source: https://www.youtube.com/watch?v=VQW-ZpdAm5M  BioActive Sensor Precise heart rate readings during workouts and beyond. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ The Accused Smartwatch is configured to communicate with a smart phone comprising a wireless receiver, a wireless transmitter, a display, a speaker, a voice input module, one or more buttons or knobs, a microprocessor and a touch screen, either literally or under the doctrine of equivalents. 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.

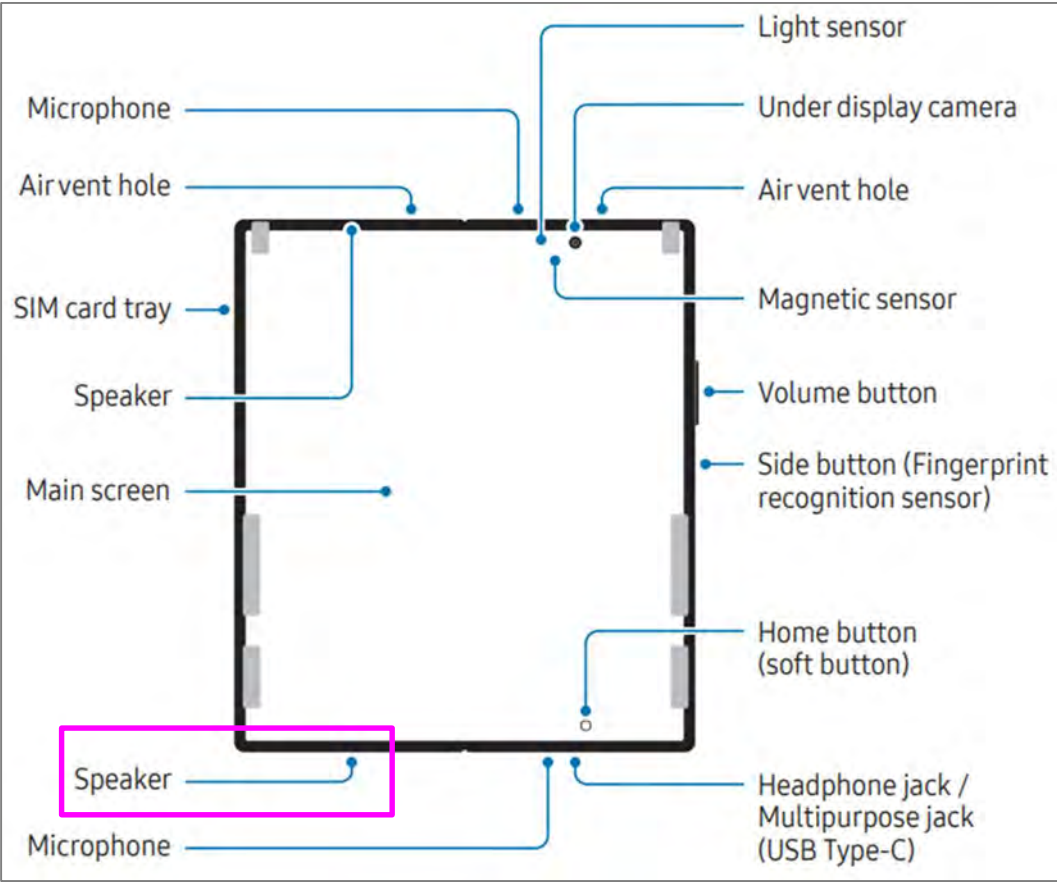
U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

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

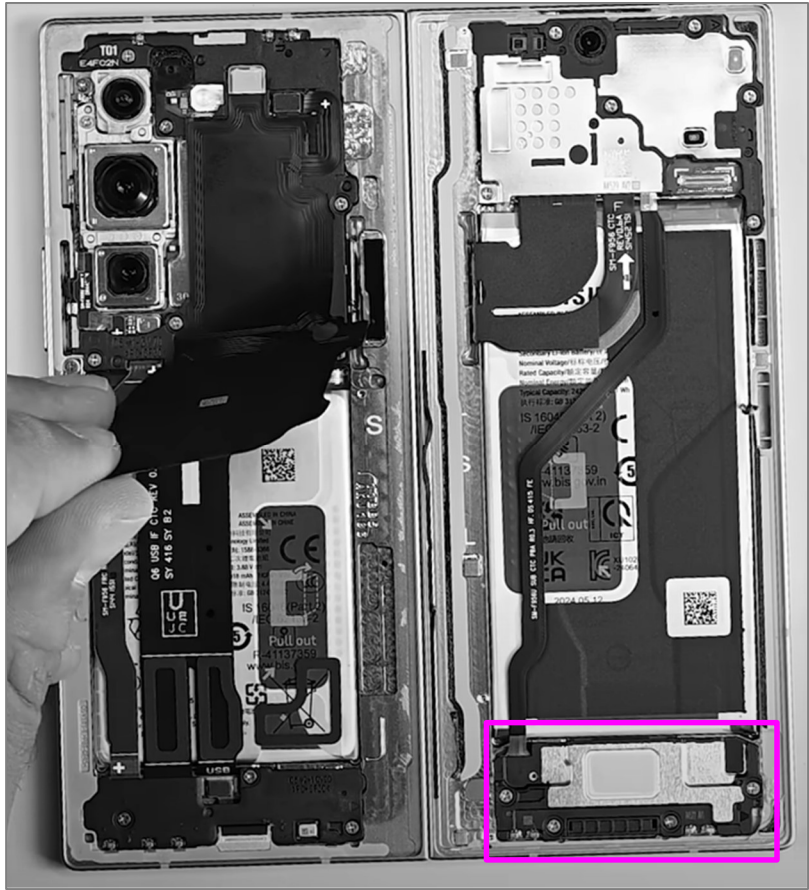
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹						
	Connectivity Wi-Fi Connectivity 802.11a/b/g/n/ac/ax 2.4GHz+5GHz+6GHz, HE160, MIMO, 1024-QAM Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/ The Galaxy Z Fold6 (“smart phone”) further includes a display, a speaker, and a microphone (“a voice input module”). Display <table><tr><th>Resolution (Main Display)</th><th>Main Display Size</th><th>Technology (Main Display)</th></tr><tr><td>2160 x 1856 (QXGA+)</td><td>193.2mm (7.6" full rectangle) / 192.5mm (7.6" rounded corners)</td><td>Dynamic AMOLED 2X</td></tr></table> Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/	Resolution (Main Display)	Main Display Size	Technology (Main Display)	2160 x 1856 (QXGA+)	193.2mm (7.6" full rectangle) / 192.5mm (7.6" rounded corners)	Dynamic AMOLED 2X
Resolution (Main Display)	Main Display Size	Technology (Main Display)					
2160 x 1856 (QXGA+)	193.2mm (7.6" full rectangle) / 192.5mm (7.6" rounded corners)	Dynamic AMOLED 2X					

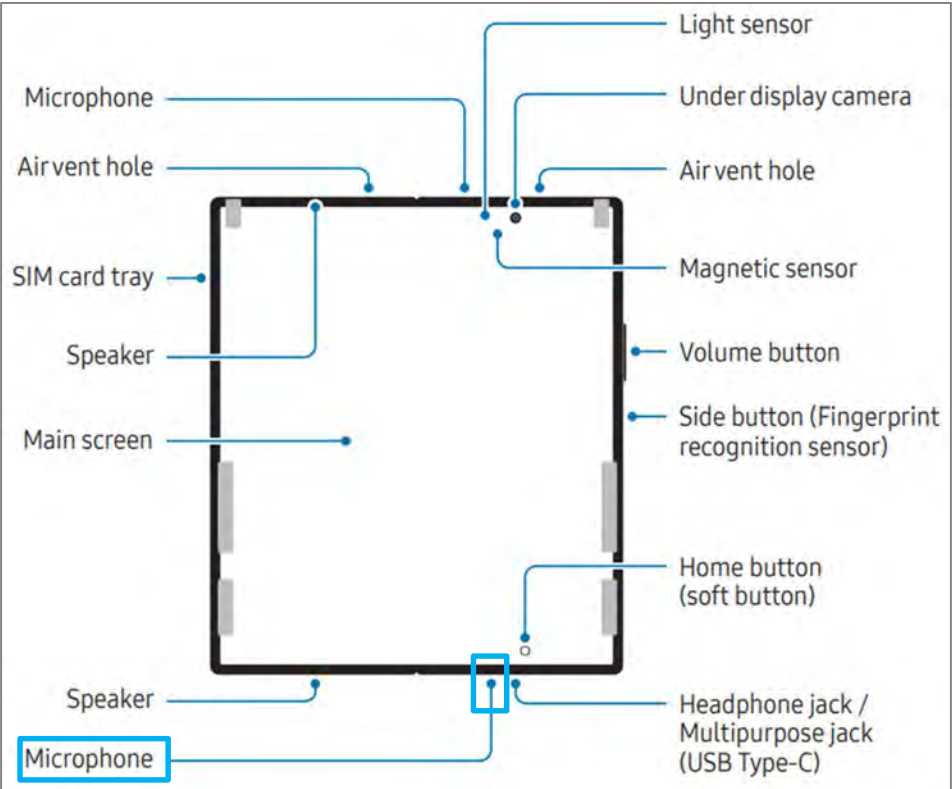
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	 The diagram shows a top-down view of a rectangular smartphone. Various components are labeled with blue lines pointing to their locations on the device: Top edge: Light sensor, Under display camera, Air vent hole (two locations). Left edge: Microphone, Air vent hole, SIM card tray, Speaker, Main screen. Right edge: Magnetic sensor, Volume button, Side button (Fingerprint recognition sensor), Home button (soft button). Bottom edge: Speaker (highlighted with a pink box), Microphone (highlighted with a pink box), Headphone jack / Multipurpose jack (USB Type-C). Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 5]

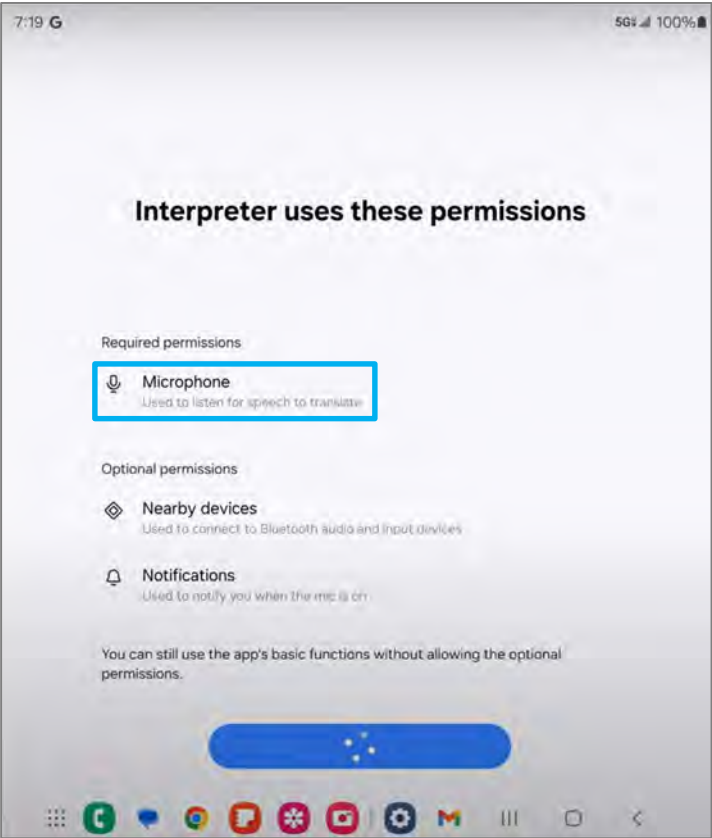
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.youtube.com/watch?v=xYIe5uDVDWI

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 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Microphone Air vent hole SIM card tray Speaker Main screen Speaker Microphone Light sensor Under display camera Air vent hole Magnetic sensor Volume button Side button (Fingerprint recognition sensor) Home button (soft button) Headphone jack / Multipurpose jack (USB Type-C) 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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 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device 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.

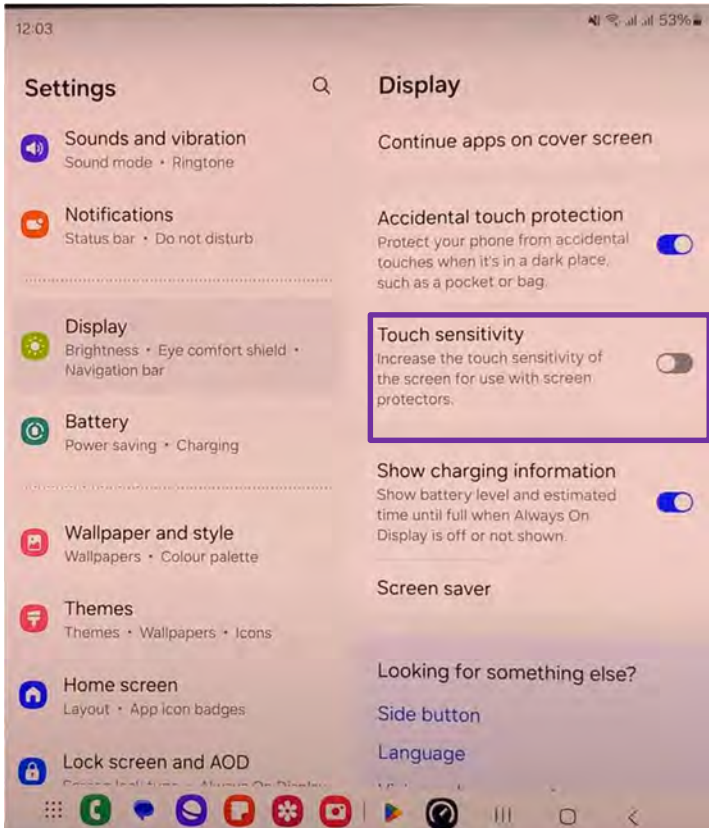
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹
	The image shows the back of a white Samsung Galaxy Z Fold6 smartphone. It features three large, vertically aligned camera lenses on the left side. An orange rectangular box is drawn on the left edge of the phone, highlighting a small, circular sensor located between the camera module and the bottom edge. This sensor is the subject of the patent claim. Source: https://www.samsung.com/us/smartphones/galaxy-z-fold6/buy/galaxy-z-fold6-512gb-unlocked-sm-f956uakexaa/

U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device 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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'475 Patent Claim	Samsung Accused Device ¹
	CPU Name: Qualcomm® Kryo™ Architecture: 64-bit Clock 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  The screenshot shows the 'Settings' app on a Samsung smartphone. 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 purple box. It includes the text 'Increase the touch sensitivity of the screen for use with screen protectors.' and a toggle switch that is currently turned off.

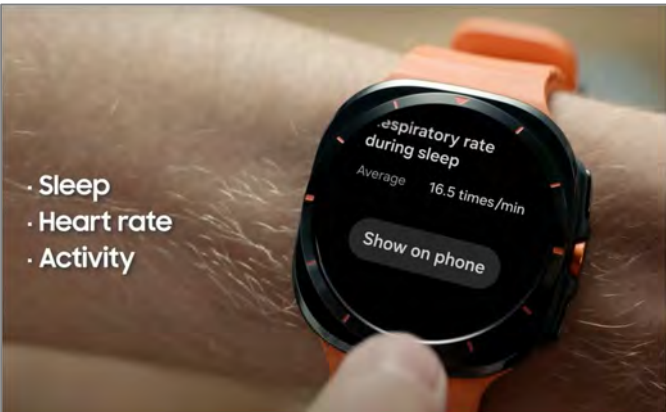
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹												
	Source: https://www.youtube.com/watch?v=cn2UQ6Fr4hM Controlling the screen <table><tr><td>Tapping Tap the screen.</td><td></td><td>Touching and holding Touch and hold the screen for approximately 2 seconds.</td><td></td></tr><tr><td>Dragging Touch and hold an item and drag it to the target position.</td><td></td><td>Double tapping Double tap the screen.</td><td></td></tr><tr><td>Swiping Swipe upwards, downwards, to the left, or to the right.</td><td></td><td>Spreading and pinching Spread two fingers apart or pinch on the screen.</td><td></td></tr></table> Source: https://downloadcenter.samsung.com/content/UM/202407/20240729134626727/SM-F956B_UG_EU_UU_Eng_Rev.1.0_240717.pdf [Page: 26]	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.	
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.											

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’475 Patent Claim	Samsung Accused Device ¹
8[pre] A wearable device configured to be worn by a user, the wearable device comprising:	Without conceding that the preamble of Claim 8 is limiting, Samsung has made, used, offered to sell, sold in the United States, and/or has 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, wearable device configured to be worn by a user, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch is a wearable device configured to be worn on the wrist of a user.  Source: https://news.samsung.com/global/galaxy-history-%E2%91%A2-evolution-of-the-galaxy-watch-series-reimagining-the-watch

U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/  Source: https://www.youtube.com/watch?v=VQW-ZpdAm5M

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’475 Patent Claim	Samsung Accused Device ¹
8[a] a light source configured to be on or off, responsive to the light source being on, the light source generates an output light;	The Accused Smartwatch comprises a light source configured to be on or off, and responsive to the light source being on, the light source generates an output light, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch includes multiple LEDs, such as a green LED, a red LED, and an infrared LED. The LEDs are each configured to be on or off, and responsive to being on, each generates an output light. 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 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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'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor  Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327

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“Wearable device for differential measurement on pulse rate and blood flow”

'475 Patent Claim	Samsung Accused Device ¹						
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/ The following data types are supported by the Samsung Privileged Health SDK: <table data-bbox="506 911 1526 1333"><tr><td data-bbox="506 911 978 1052">PPG green</td><td data-bbox="978 911 1526 1052">Raw data from PPG <u>green</u> LED. Provided as a batching event.</td></tr><tr><td data-bbox="506 1052 978 1203">PPG IR</td><td data-bbox="978 1052 1526 1203">Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 1203 978 1333">PPG red</td><td data-bbox="978 1203 1526 1333">Raw data from PPG <u>red</u> LED. Provided as an on-demand event.</td></tr></table>	PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.	PPG IR	Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.	PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.
PPG green	Raw data from PPG <u>green</u> LED. Provided as a batching event.						
PPG IR	Raw data from PPG <u>infrared</u> LED. Provided as an on-demand event.						
PPG red	Raw data from PPG <u>red</u> LED. Provided as an on-demand event.						

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'475 Patent Claim	Samsung Accused Device ¹
8[b] a lens positioned to direct at least a portion of the output light towards a bodily tissue of the user;	Source: Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html The Accused Smartwatch comprises a lens positioned to direct at least a portion of the output light towards a bodily tissue of the user, either literally or under the doctrine of equivalents. 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 direct at least a portion of the output light towards a bodily tissue of the user (e.g., 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

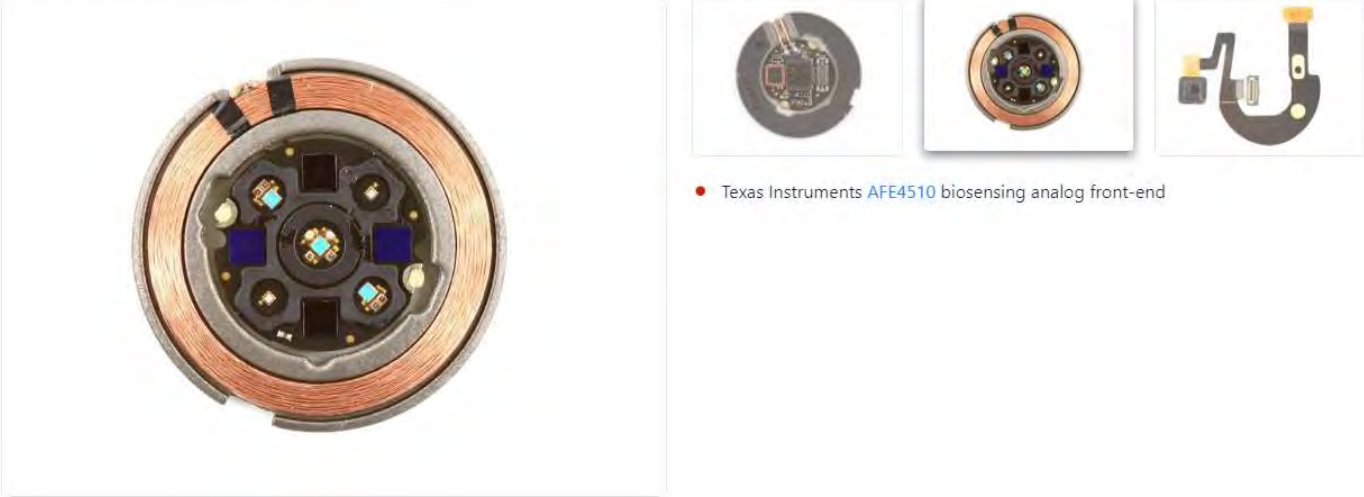
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	light, such as skin discoloration or a rash.” Samsung Newsroom, Unlocking New Possibilities for Preventative Wellness with New Galaxy Watch and BioActive Sensor, Jul. 8, 2024, <i>available at</i> https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-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”). Source: https://www.youtube.com/watch?v=lZ6Q7JqtiA0

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'475 Patent Claim	Samsung Accused Device ¹
	Source: https://www.youtube.com/watch?v=jlW0i7u4FVk 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.

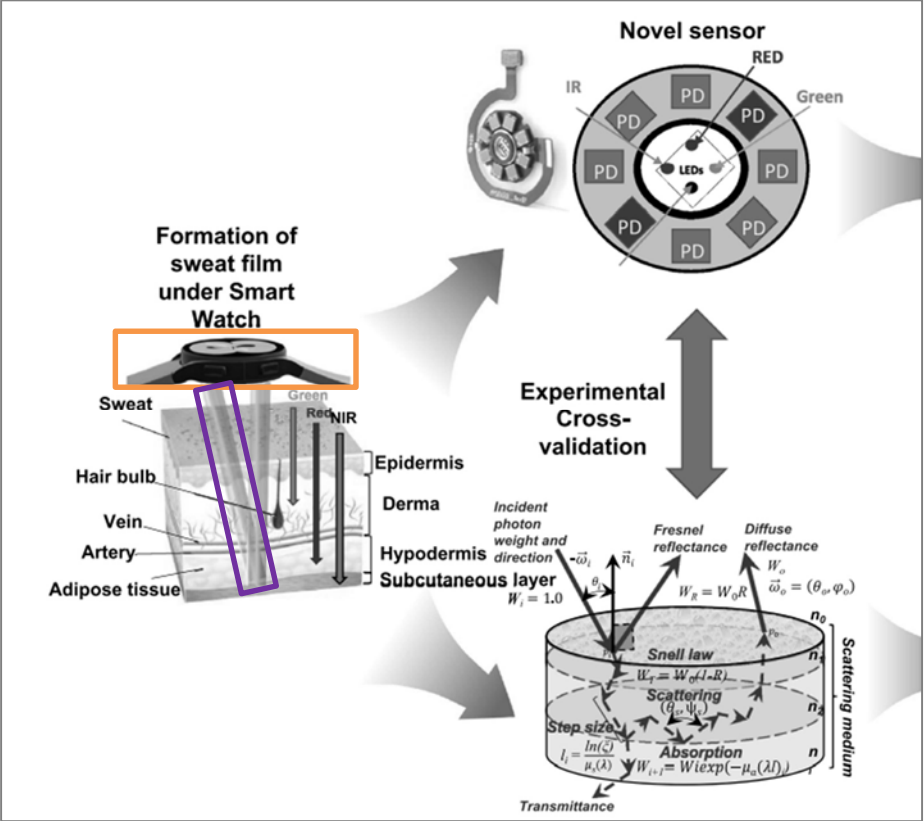
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'475 Patent Claim	Samsung Accused Device ¹
	The Accused Smartwatch (“wearable measurement device”) utilizes a biosensor manufactured by Texas Instruments (“TI”)—<i>e.g.</i>, an analog front end (“AFE”) integrated circuit component for PPG, electrocardiography (“ECG”) and other biosensing applications. 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. Such AFEs from TI include AFE44S30, AFE4432, AFE44I30, AFE4460, AFE49I30, AFE4950, AFE4500. See Texas Instruments, Biosensing AFEs, https://www.ti.com/data-converters/integrated-special-function/medical-afes/biosensing-afes/overview.html. TI’s AFEs enable wearable devices to perform multiple optical biosensing applications. For example, TI explains in a technical paper:

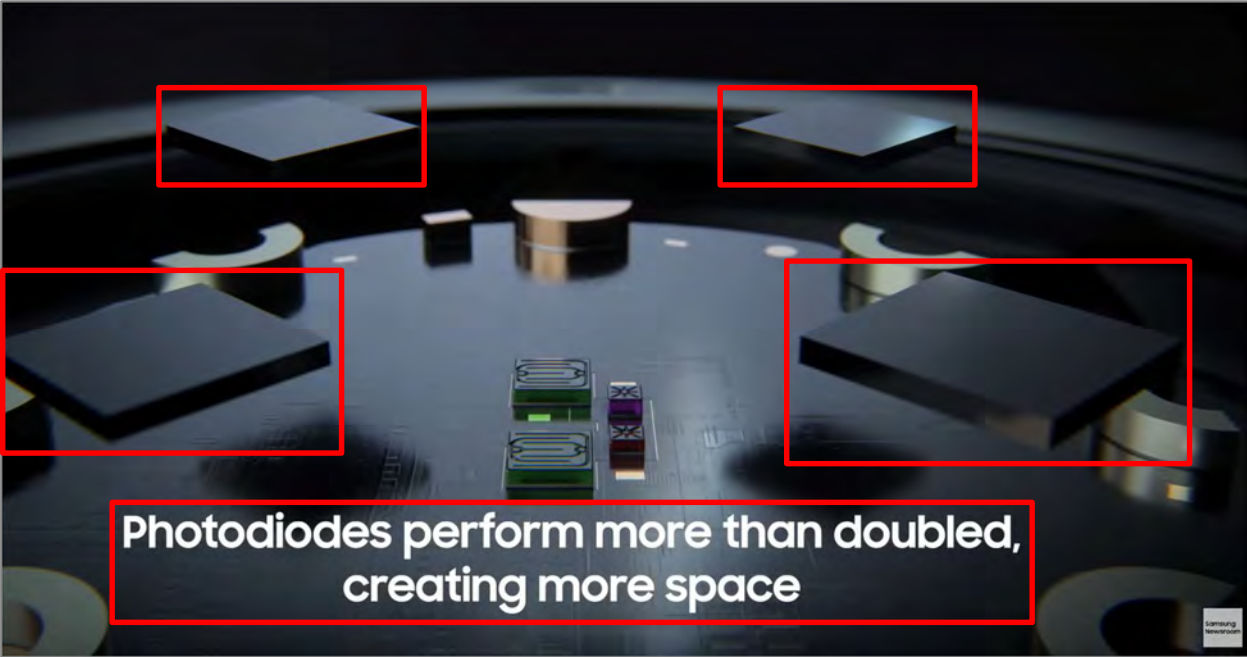
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹
	Application <i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate.</i> For a healthy individual, 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.

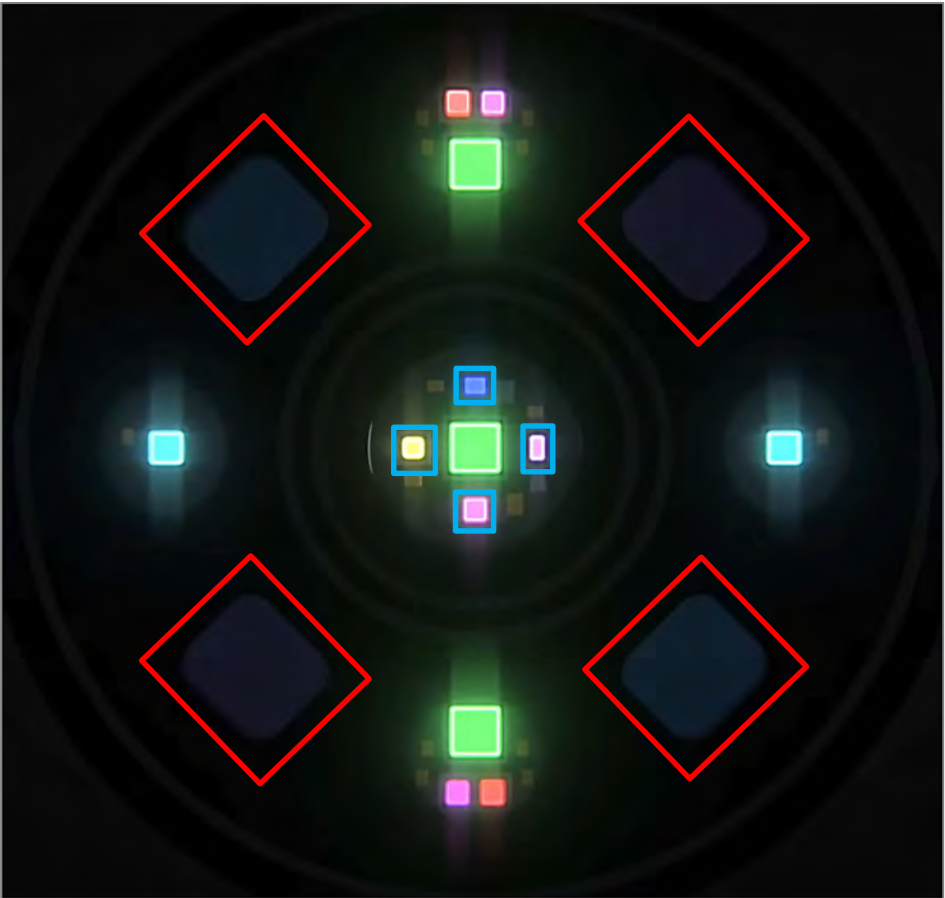
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	Additionally, the following scientific report authored by multiple Samsung engineers further shows an analysis output beam being delivered to a tissue sample of the user:  Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in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

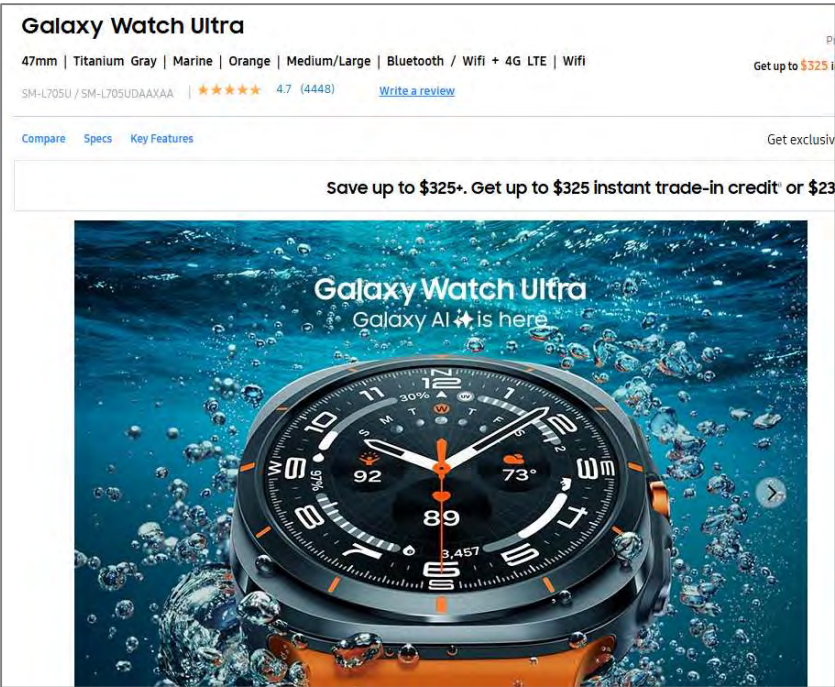
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'475 Patent Claim	Samsung Accused Device ¹
8[c] a detector; and	The Accused Smartwatch comprises a detector, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch contains multiple photodiodes (<i>e.g.</i>, “detectors”).  Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

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'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor
8[d] a processor configured to:	The Accused Smartwatch comprises a processor, either literally or under the doctrine of equivalents.

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	For example, the Galaxy Watch Ultra comprises a computer processor configured to process data obtained by the watch’s various sensors, including data associated with a user’s physiological information obtained by the BioActive Sensor.  Processor Processor Speed, Type 1.6GHz,1.5GHz Memory Available Storage (GB) 21.1 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/buy/galaxy-watch-ultra-47mm-titanium-gray-sm-l705udaaxaa/
8 e (i) responsive to the light source being on and the detector receiving at least a portion of the	The processor in the Accused Smartwatch is configured to, responsive to the light source being on and the detector receiving at least a portion of the output light that is reflected from the bodily tissue of the user, generate a first output signal having a first signal-to-noise ratio, either literally or under the doctrine of equivalents.

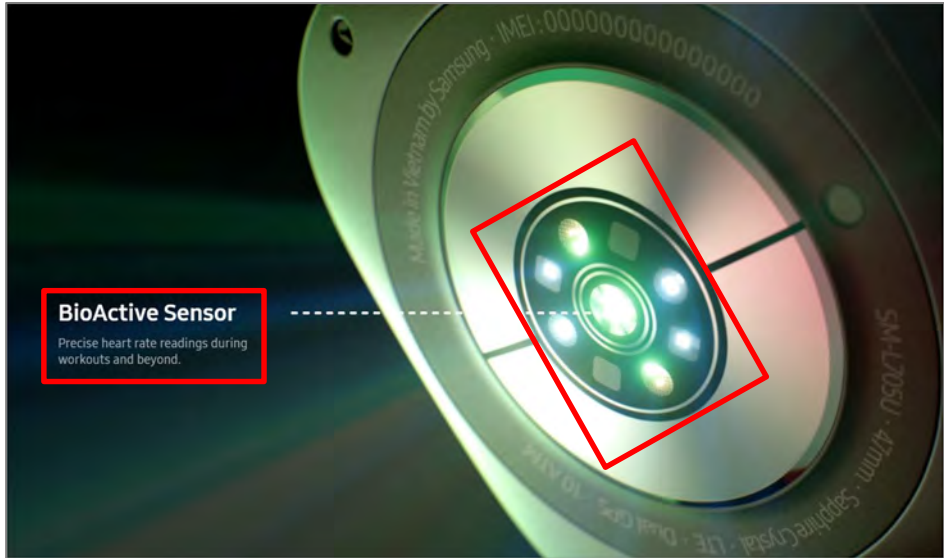
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
output light that is reflected from the bodily tissue of the user, generate a first output signal having a first signal-to-noise ratio; and	For example, the BioActive Sensor in the Accused Smartwatch includes or is coupled to a processor, which receives and processes at least a portion of the output light that is reflected from the bodily tissue of the user and generates an output PPG signal that has a signal-to-noise ratio (“SNR”). The diagram shows a side view of a smartwatch with a circular face and a strap. Several components are labeled with lines pointing to them: 'Optical bio-signal sensor' (on the back of the watch face, highlighted with a red box), 'Microphone' (on the side of the watch face), 'Speaker' (on the side of the watch face), 'Electrical bio-signal sensors' (on the back of the watch face), 'Band release button' (on the side of the watch face), 'Band' (the strap), 'Pressure vent' (on the back of the watch face), and 'Infrared temperature sensor' (on the back of the watch face). Source: Samsung Galaxy Watch7 / Galaxy Watch Ultra User Guide (06/2024, Rev.1.0), at 8, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240711132033461/SM-L30X_L31X_L705F_UG_EU_Android_Eng_Rev.1.0_240626.pdf; <i>see also</i> Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html.

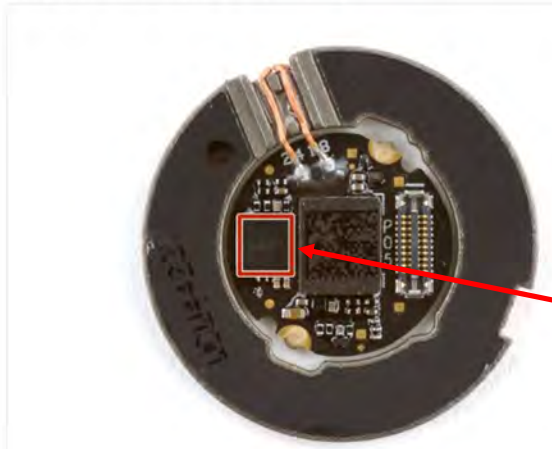
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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'475 Patent Claim	Samsung Accused Device ¹
	 Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

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

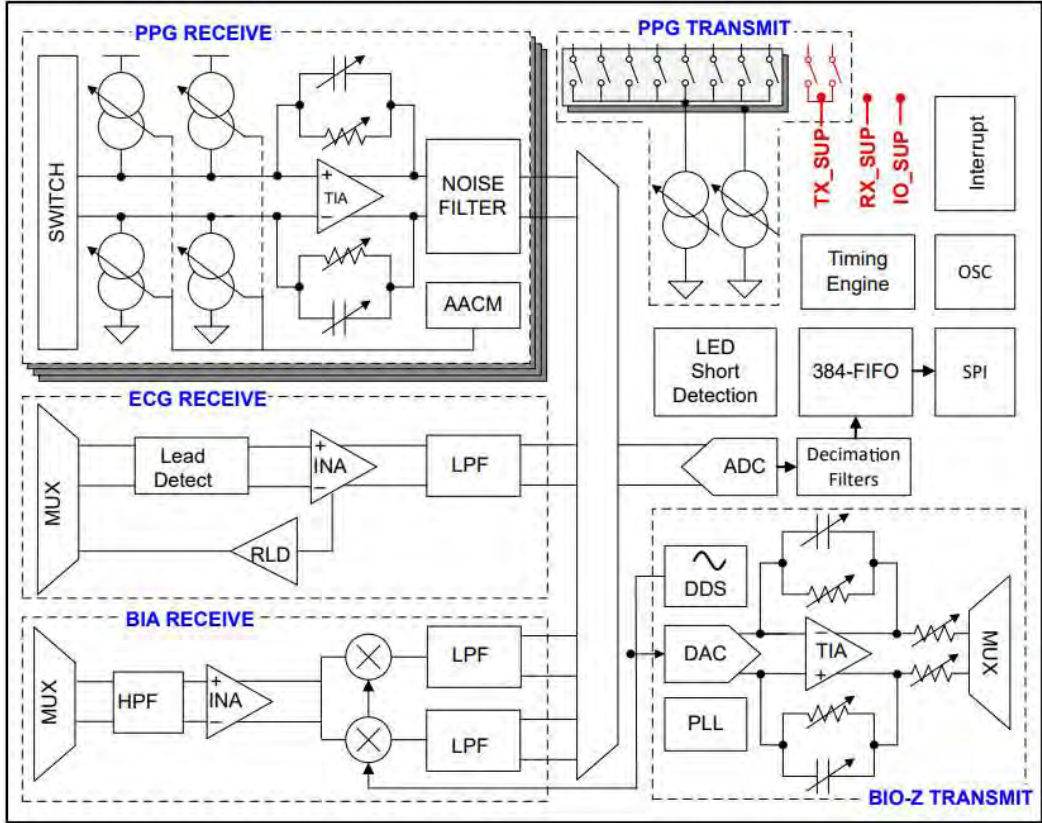
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'475 Patent Claim	Samsung Accused Device ¹
	Step 6 Bio Sensor Assembly   • Texas Instruments AFE4510 biosensing analog front-end Texas Instruments AFE (Analog Front End) chip - AFE4510 Source: IFIXIT, Samsung Galaxy Watch Ultra Chip ID, https://www.ifixit.com/Guide/Samsung+Galaxy+Watch+Ultra+Chip+ID/175327 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.  TEXAS INSTRUMENTS AFE4510 SBASB19 – MARCH 2024 AFE4510 Ultra Small, Integrated AFE for Bio Impedance Analysis, Electrical Bio Sensing & Optical Bio Sensing

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	• 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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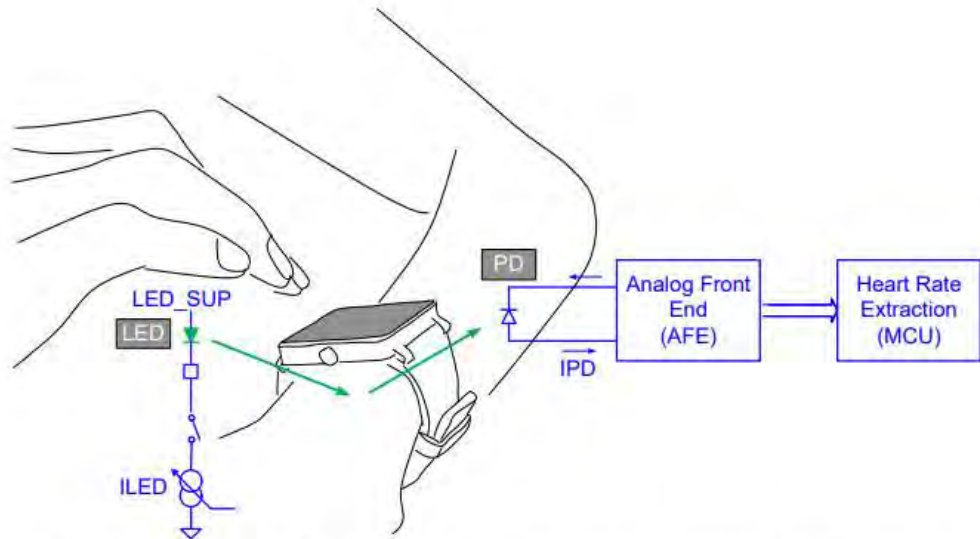
'475 Patent Claim	Samsung Accused Device ¹
	 Simplified Schematic The schematic illustrates the internal components of the Samsung Accused Device, organized into three main functional blocks: PPG RECEIVE, ECG RECEIVE, and BIA RECEIVE, along with their respective transmit paths and shared processing blocks. PPG RECEIVE: This block includes a SWITCH, a TIA (Transimpedance Amplifier), a NOISE FILTER, and an AACM (Analog-to-Digital Converter). ECG RECEIVE: This block includes a MUX (Multiplexer), a Lead Detect block, an INA (Instrumentation Amplifier), an RLD (Right Leg Drive), and an LPF (Low Pass Filter). BIA RECEIVE: This block includes a MUX, an HPF (High Pass Filter), an INA, two LPF blocks, and two multipliers (X). PPG TRANSMIT: This block includes a TX_SUP (Transmit Supply), an RX_SUP (Receive Supply), an IO_SUP (IO Supply), an Interrupt block, a Timing Engine, and an OSC (Oscillator). BIO-Z TRANSMIT: This block includes a DDS (Direct Digital Synthesizer), a DAC (Digital-to-Analog Converter), a PLL (Phase-Locked Loop), a TIA, and a MUX. Shared Processing Blocks: These include an LED Short Detection block, a 384-FIFO block, an SPI block, an ADC (Analog-to-Digital Converter), and Decimation Filters. The diagram shows the flow of data from the receive paths through the shared processing blocks to the transmit paths.

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

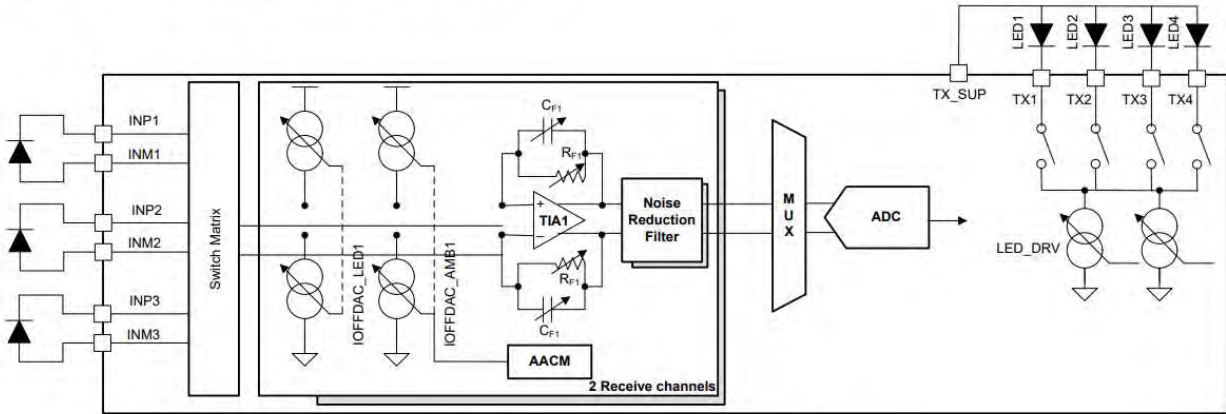
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’475 Patent Claim	Samsung Accused Device ¹
	The BioActive Sensor in the Accused Smartwatch is configured to receive and process at least a portion of the output light that is reflected from the bodily tissue of the user and to generate an output PPG signal to enable multiple biosensing applications, including optical heart rate monitoring (“OHRM”). For example, TI explains OHRM using its AFE biosensors as follows: <i>Optical Heart Rate Monitoring (OHRM) uses the principle of photoplethysmography (PPG) to determine the heart rate. For a healthy individual, the heart pumps blood to all parts of the body in each cardiac cycle. This causes the volume of the blood in the arteries to have a pulsating component that has the periodicity of the heart rate. By illuminating the skin using a light-emitting diode (LED) and measuring the amount of light either transmitted or <u>reflected to a photodiode (PD)</u>, the pulsating waveform can be 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).</i> 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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	 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 and a processor of the Accused Smartwatch are configured to receive and process at least a portion of light reflected from a body tissue sample of the user and to generate an output PPG signal.

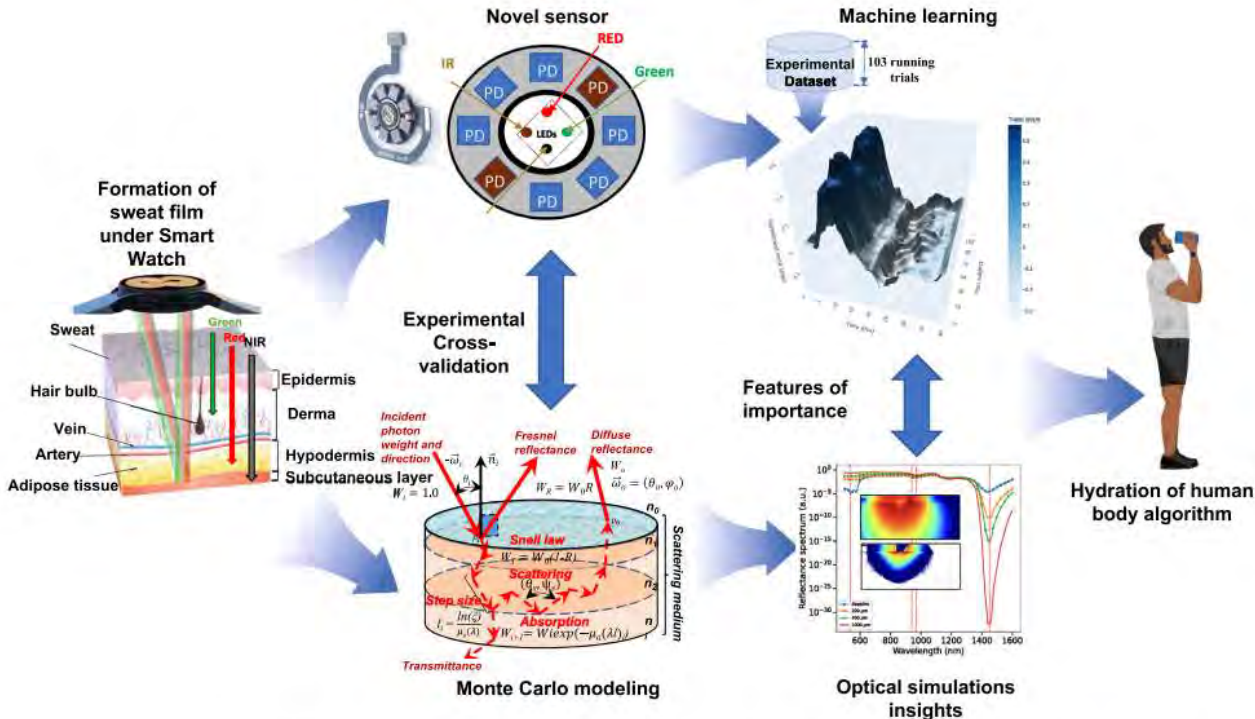
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	Figure 3 shows the PPG signal chain in AFE4432.  Figure 3. PPG Signal Chain in AFE4432 The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (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 light 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 absorption by the blood vessel is changed in synchronization with the heart rate. A sensor measures,

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	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-invasive information of the aforementioned human health indicators with recent additions of temperature, blood oxygen level (SpO₂), etc. monitoring capabilities.”

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

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	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.

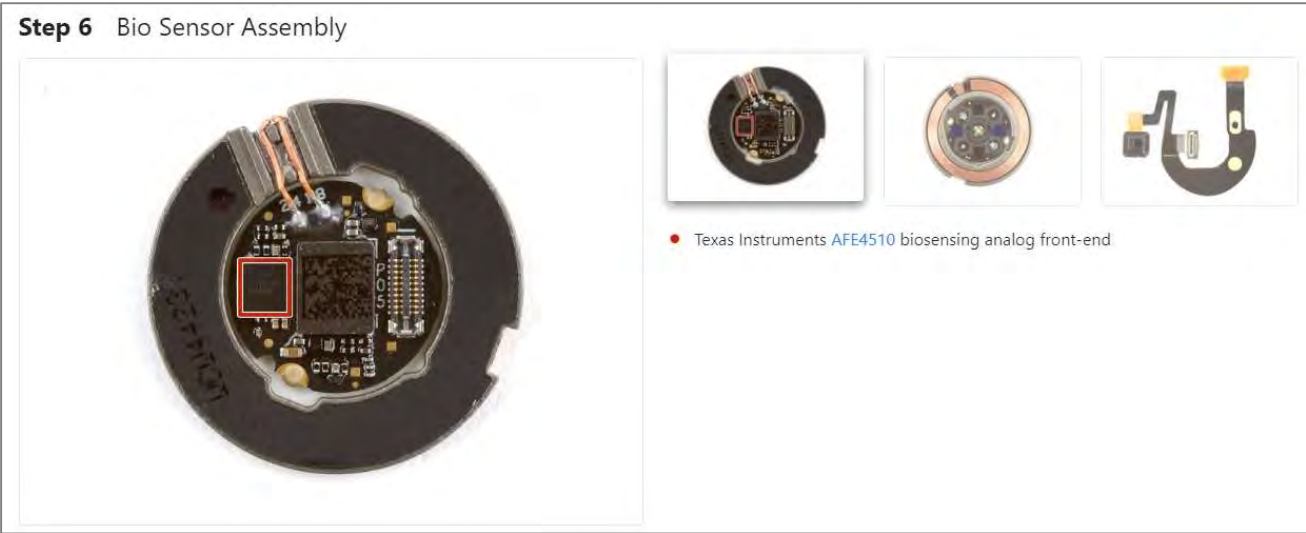
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	Figure 4 consists of two parts, (a) and (b). Part (a) shows the back of a Samsung Galaxy Gear Fit with a red box highlighting a sensor module. Below it is a disassembled view of the device showing the internal circuitry with the same red box. Part (b) shows the back of a Samsung Galaxy Watch 3 with a red circle highlighting the sensor area. Below it is a disassembled view of the watch back showing the internal sensor components, including a circular array of LEDs and PDs, with a red circle highlighting the same area. Labels 'Cover glass', 'PPG sensor', and 'optical barrier' are present in both parts. 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.

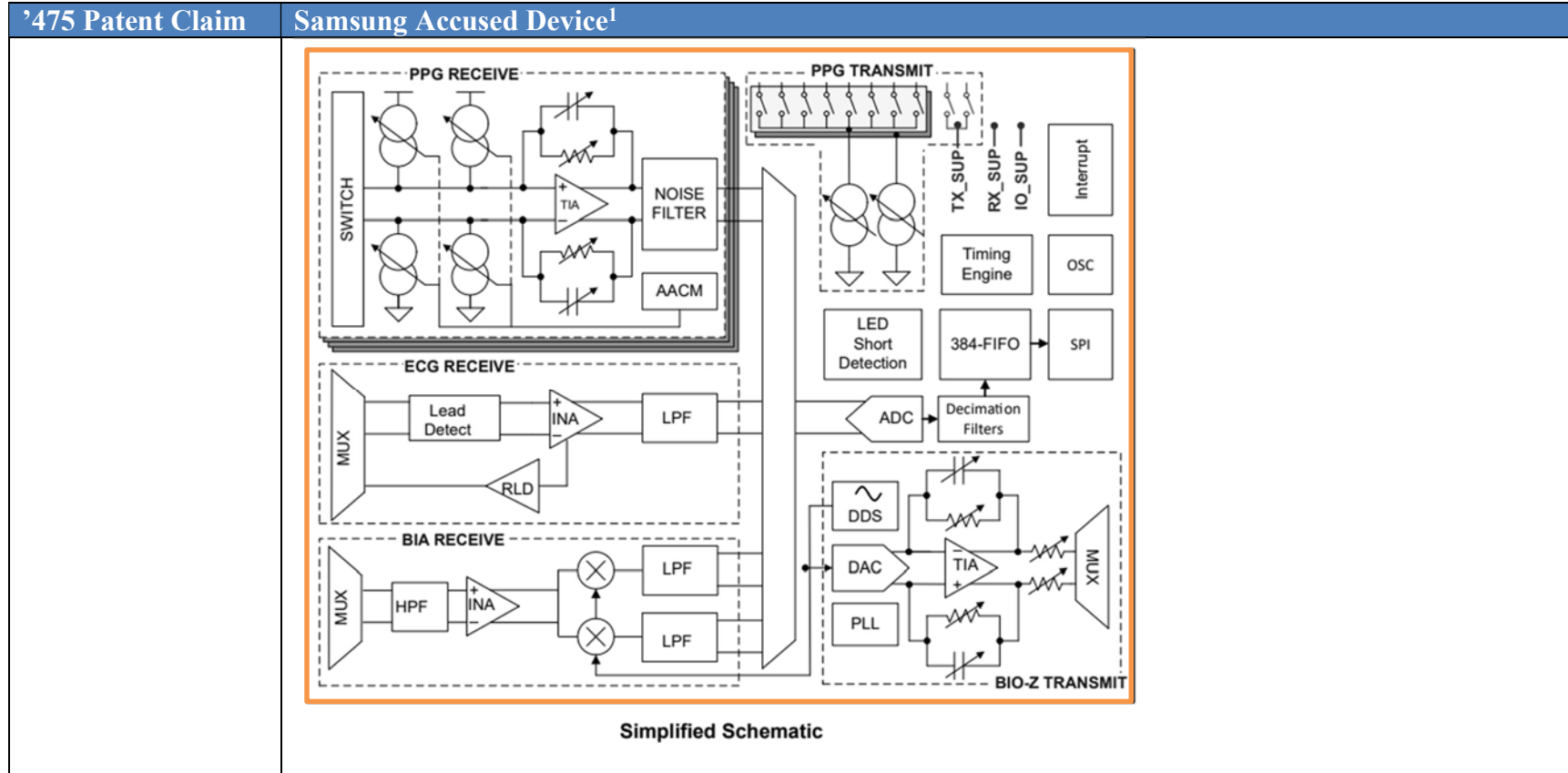
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	Figure 5. Examples of PPG sensor configurations that use multiple LEDs and PDs, and their application to commercial smartwatches. (a–d) illustrate different PPG sensor structures, while (e) through (h) present examples of these structures in use: (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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'475 Patent Claim	Samsung Accused Device ¹
81f1 (ii) responsive to the light source being off and the detector receiving ambient light, generate a second output signal having a second signal-to-noise ratio;	The processor in the Accused Smartwatch is configured to, responsive to the light source being off and the detector receiving ambient light, generate a second output signal having a second signal-to-noise ratio, either literally or under the doctrine of equivalents. For example, the BioActive Sensor that includes or is coupled to a processor 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 having a second SNR. 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_SwZ7O5CP4JlQFSWUnKHWqSe9g6SXYqF3F-NzUYIGpw.

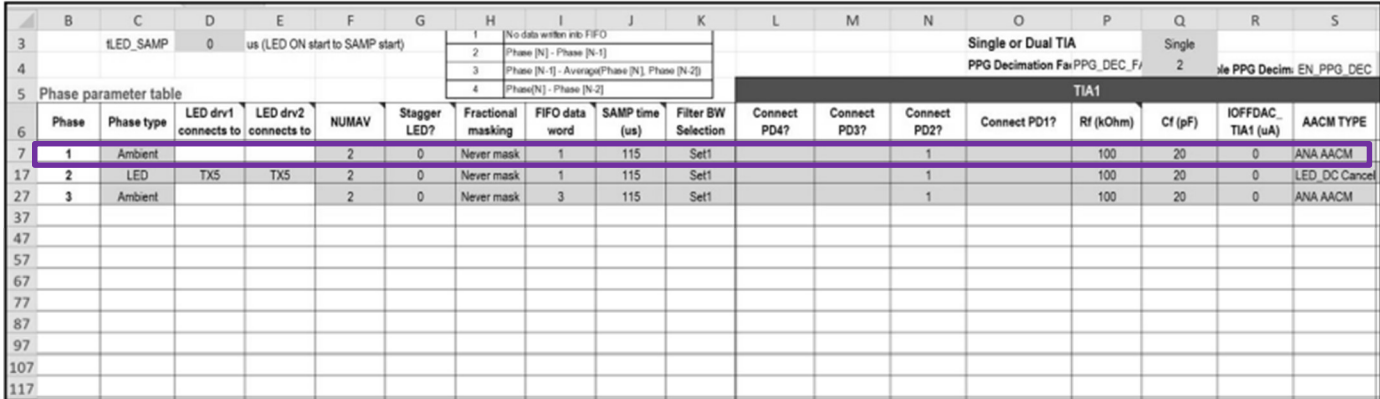
U.S. Patent No. 12,268,475 (the “’475 Patent”)
 “Wearable device for differential measurement on pulse rate and blood flow”



U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device 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/symmlink/afe4510.pdf.

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’475 Patent Claim		Samsung Accused Device ¹	
		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.	
		 Figure 5-1. PPG per-phase configuration	

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'475 Patent Claim

Samsung Accused Device¹

	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																					
67																					
77																					
87																					
97																					
107																					
117																					

Figure 5-1. PPG per-phase configuration

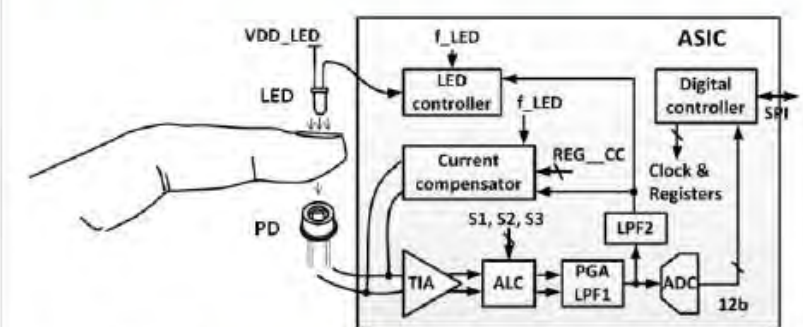
Source: Texas Instruments, AFE4500 EVM User Guide, SBAU370 – April 2021, at 23, *available at* <https://www.manualslib.com/download/2652772/Texas-Instruments-Afe4500evm.html>.

“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 diagrams of a hand wearing a device. The left diagram, labeled 'Heart Rate Monitoring', shows green light (LED) and red light (LED) being emitted from the device, with a photodiode (PD) and photointerrupter (IPD) receiving the reflected light. The right diagram, labeled 'SpO2 Monitoring', shows the same setup but with a different light path. Below these is a 'Block Diagram' of the PPG system. It includes a 'Switch Matrix' with inputs INP1, INM1, and others. The signal path goes through a 'Receiver' block containing a 'TIA' (Transimpedance Amplifier) and a 'Noise Reduction Filter'. There are also 'Ambient DC Cancellation' and 'LED DC Cancellation' blocks. The signal then passes through a 'MUX' (Multiplexer), an 'ADC' (Analog-to-Digital Converter), and finally 'Decimation'. 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. 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:

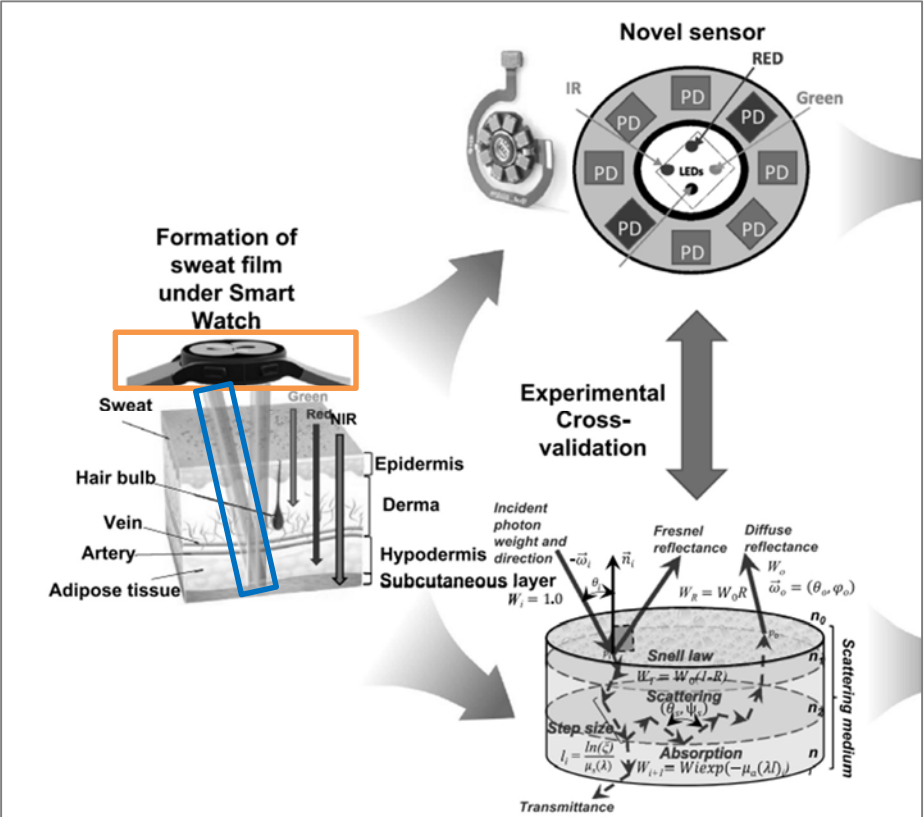
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'475 Patent Claim	Samsung Accused Device ¹
	<i>B. Ambient Light Cancellation (ALC)</i> The ambient light component in the detected PPG signal can be removed in the ALC block, which is shown in Fig. 2. When the LED light turns on, the measured signal 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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'475 Patent Claim	Samsung Accused Device 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. 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

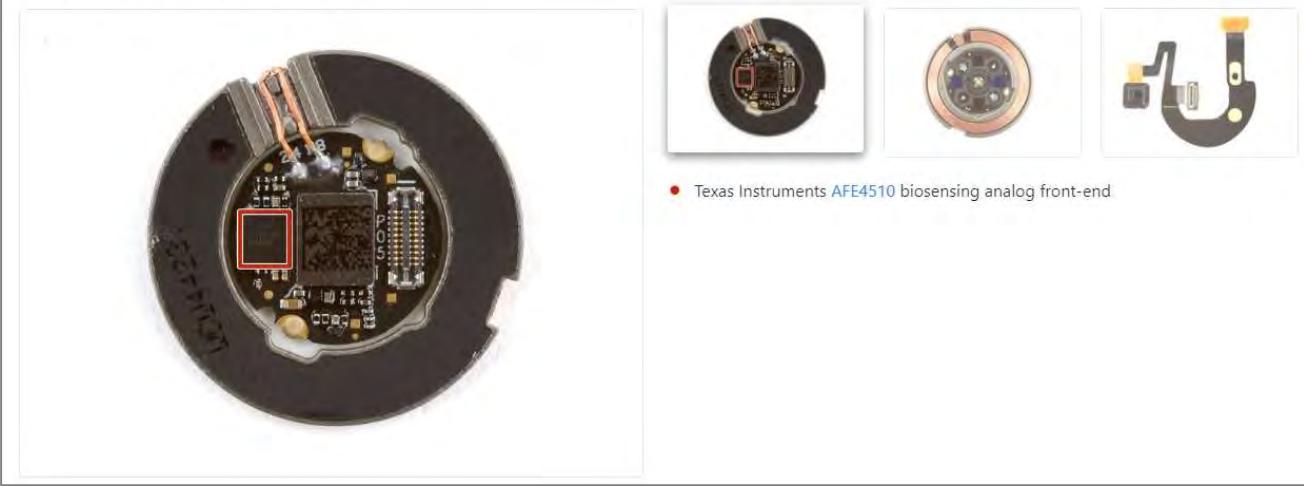
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'475 Patent Claim	Samsung Accused Device ¹
	the sensor on the body, and other end-user interactions.” Samsung Galaxy Watch7 Watch Ultra User Guide, at p. 42, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf. 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: 

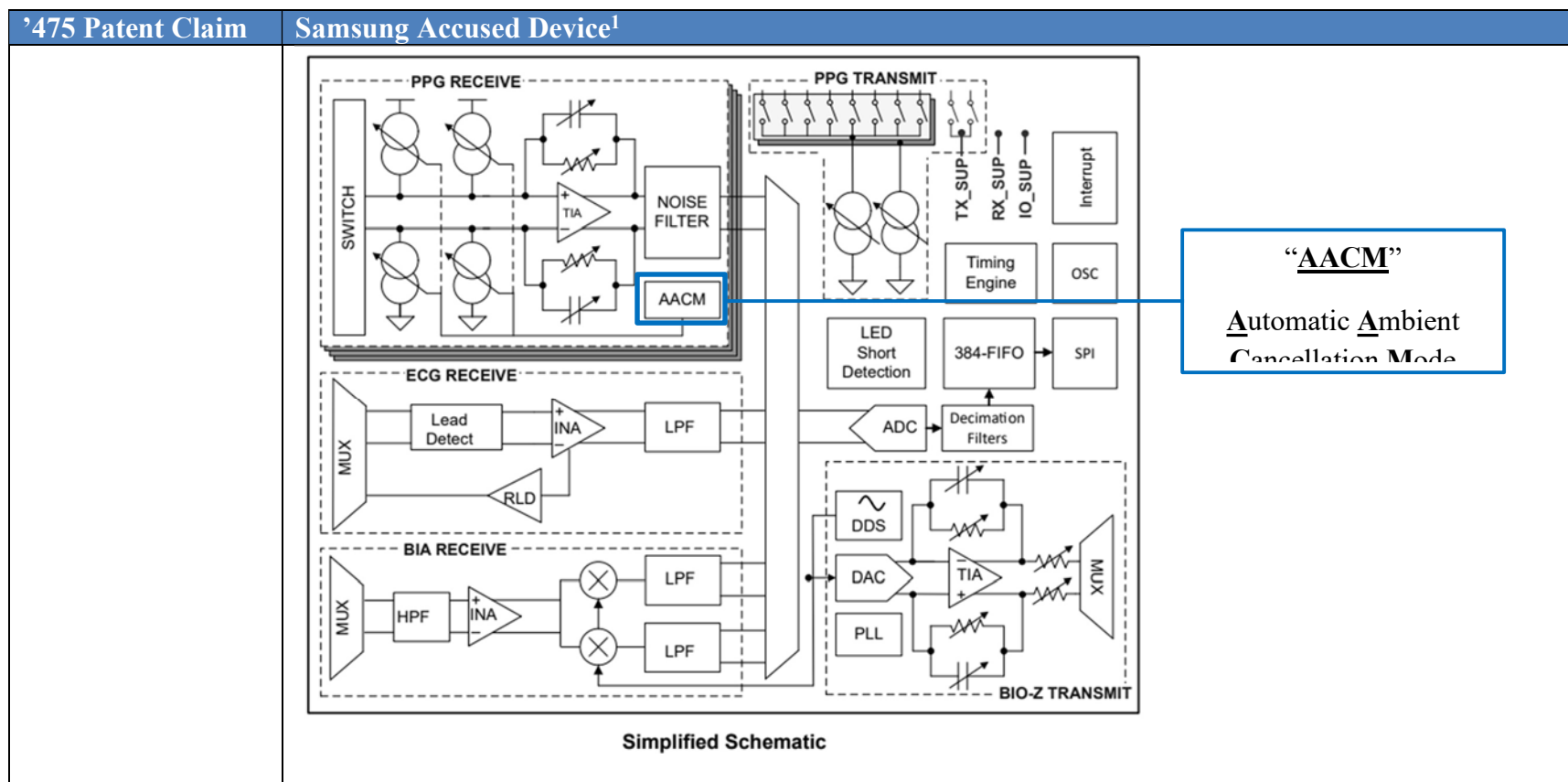
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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’475 Patent Claim	Samsung Accused Device ¹
	Source: E. Volkova et al., “Multispectral sensor fusion in SmartWatch for in situ continuous monitoring of human skin hydration and body sweat loss,” Scientific Reports (2023), at 3, <i>available at</i> https://www.nature.com/articles/s41598-023-40339-7.pdf .
8[g] (iii) generate a third output signal using at least a portion of the first output signal and at least a portion of the second output signal, the third output signal having a third signal-to-noise ratio that is greater than the first signal-to-noise ratio and greater than the second signal-to-noise ratio, the third output signal being associated with a physiological parameter of the user; and	The processor in the Accused Smartwatch is configured to generate a third output signal using at least a portion of the first output signal and at least a portion of the second output signal, the third output signal having a third signal-to-noise ratio that is greater than the first signal-to-noise ratio and greater than the second signal-to-noise ratio, the third output signal being associated with a physiological parameter of the user For example, ambient light contributes noise to PPG signals. Therefore, the presence of ambient light decreases the SNR of PPG sensors. Ambient light cancellation is performed to cancel out the ambient light noise, which includes generating a third output signal using at least a portion of the first output signal and at least a portion of the second output signal that has an SNR that is greater than the SNR associated with the first and second output signals. For instance, the BioActive Sensor of the Galaxy Watch Ultra (including a processor) performs ambient light cancellation (also referred to as “Digital Ambient Subtraction”), to generate a signal having increased SNR, by comparing the measured signal when the LED sources are on (“first output signal”) and the measured signal when the LED sources are off (“second output signal”).

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'475 Patent Claim	Samsung Accused Device ¹
	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.

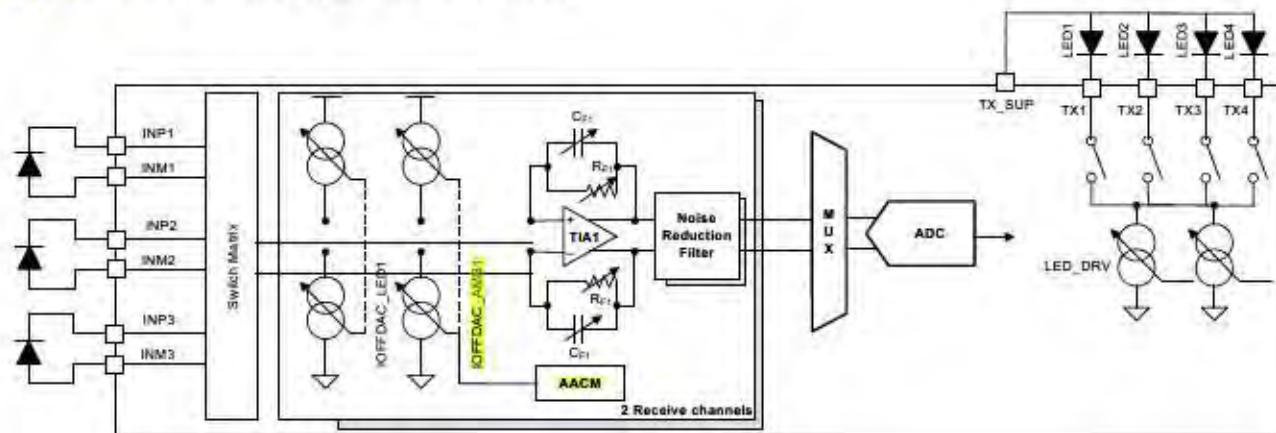
U.S. Patent No. 12,268,475 (the “’475 Patent”)
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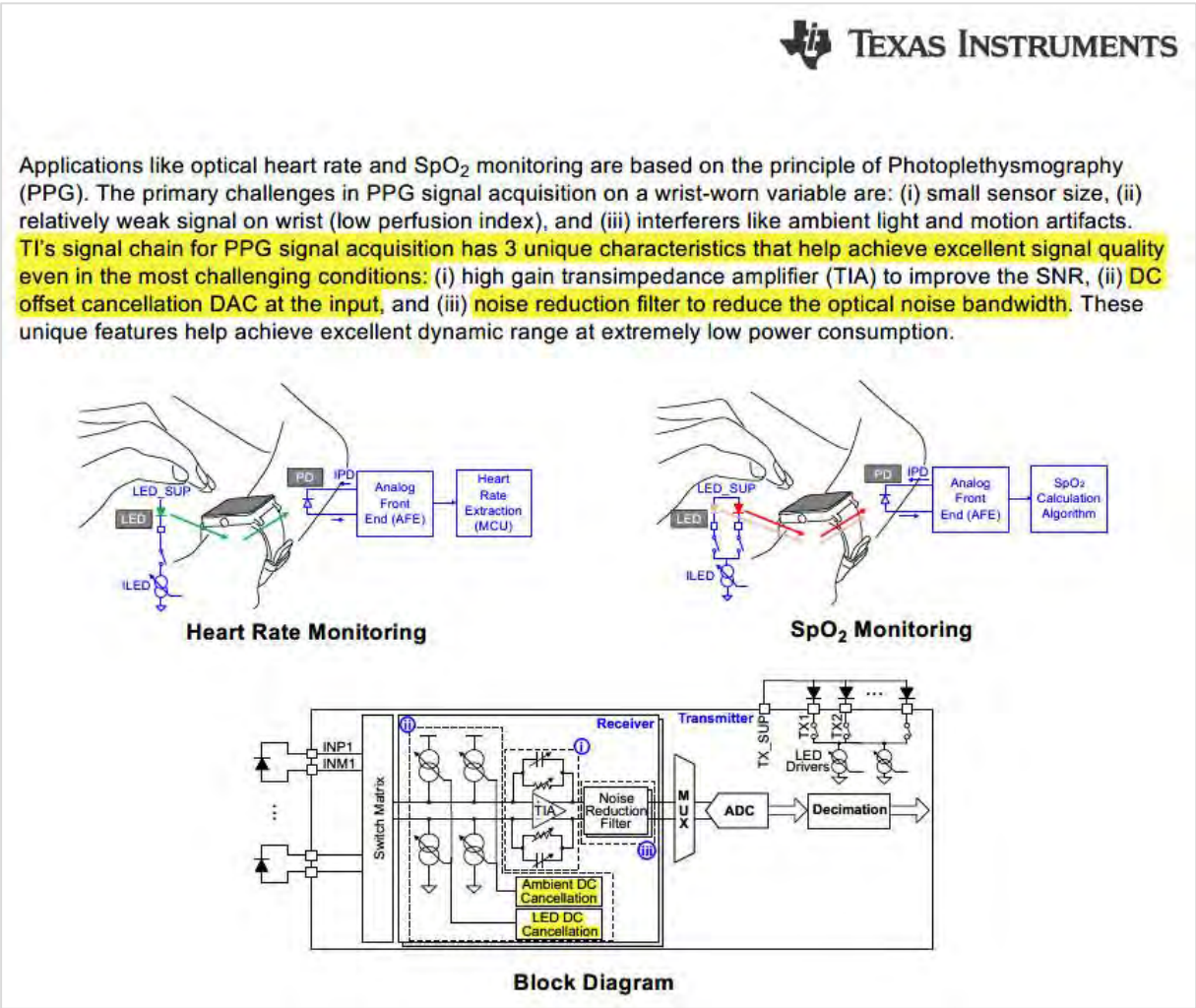
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’475 Patent Claim	Samsung Accused Device ¹
	PPG signal acquisition: – Acquisition of 24 PPG signal sets (<u>LED</u>, <u>AMB</u>) – Supports PPG sensors at different data rates – Peak system SNR of 115 dB in 0.5-10Hz band enables high-accuracy SpO₂ 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.

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'475 Patent Claim	Samsung Accused Device 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 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
System Specifications	AFE4432	Comments																	
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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.																			

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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.  Heart Rate Monitoring SpO₂ Monitoring Block Diagram 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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’475 Patent Claim	Samsung Accused Device ¹
	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*.xism 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*.xism 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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'475 Patent Claim	Samsung Accused Device ¹
	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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'475 Patent Claim	Samsung Accused Device 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.
8[h] (iv) determine, based at least in part on the third output signal, that the wearable device is	The processor in the Accused Smartwatch is configured to determine, based at least in part on the third output signal, that the wearable device is being worn by the user, either literally or under the doctrine of equivalents. For example, the Accused Device comprises biosensors for sensing one or more physiological parameters of the user. In response to one of the biosensors having measured a physiological parameter of the user, the

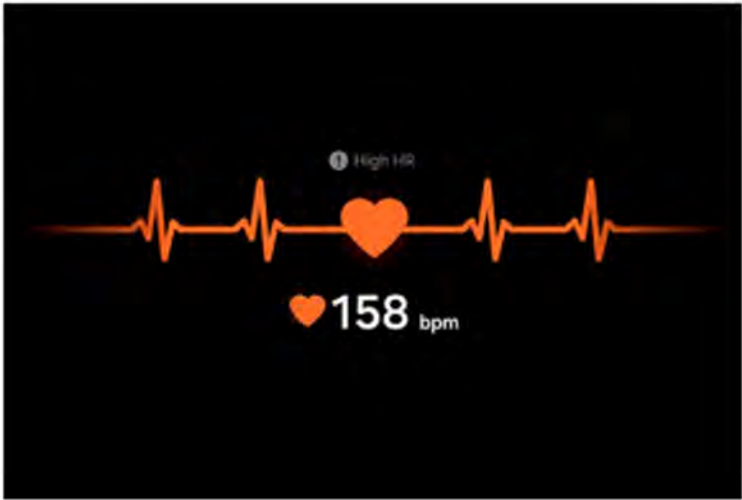
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’475 Patent Claim	Samsung Accused Device ¹
being worn by the user.	optical PPG Sensor generates an output photoplethysmography (“PPG”) signal, which the Accused Device uses at least in part to determine that the apparatus is being worn by the user. For example, the Galaxy Watch Ultra is at least in part configured to recognize or establish when it is being worn by a human user by identifying one or more physiological parameters of the human user (<i>e.g.</i>, human health metrics and data such as heart rate, SpO2, and sleep metrics). In doing so, the Accused Smartwatch is also at least in part configured to recognize or establish details about the user’s blood (<i>e.g.</i>, constituents in the blood and/or oxygen saturation of the user’s blood), which enables a determination that the device is worn by a human user. “Some features on Galaxy Watch running Wear OS powered by Samsung function only when the watch is being worn on the user’s wrist. Notifications are an important example of one such feature. When the watch is not being worn, phone notifications are not synchronized to the watch and local notifications generated on the watch are muted. Off-Body detection enables you to determine if the user is wearing the watch. To enable this, the watch contains a Low Latency Off-Body sensor. The data from this sensor allows you to enhance your application by implementing it to, for example, send or avoid notifications or to show or hide sensitive information, as appropriate.” S. Nasrin, “Detect When a Galaxy Watch Is Being Worn,” Samsung Developer, June 14, 2023, https://developer.samsung.com/sdp/blog/en/2023/06/14/detect-when-a-galaxy-watch-is-being-worn. <u>Wrist detection</u> When enabled the watch <u>automatically detects when the watch is being worn</u>. It is advisable to only turn this feature off if your watch has trouble detecting when it is on your wrist. ○ From  Settings, tap  Security and privacy > Wrist detection.

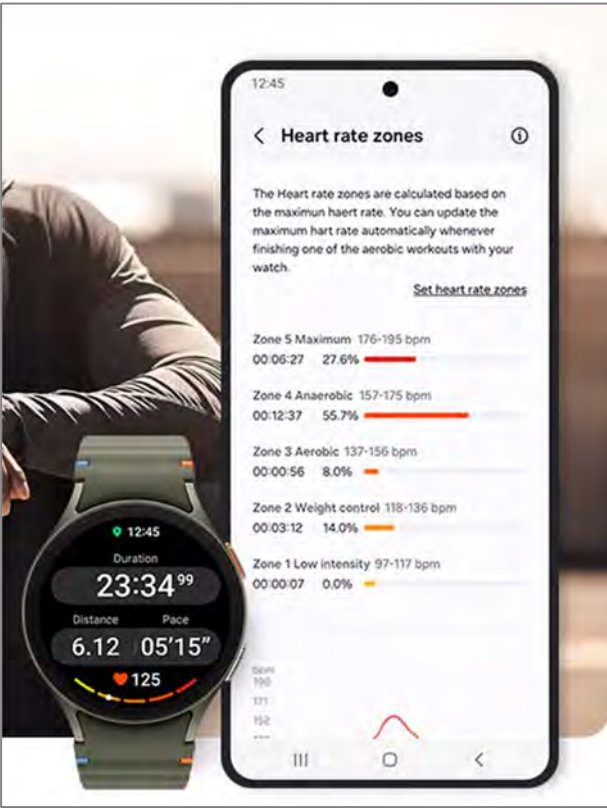
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’475 Patent Claim	Samsung Accused Device ¹
	Source: Samsung Galaxy Watch7 Watch Ultra User Guide at 65, <i>available at</i> https://downloadcenter.samsung.com/content/UM/202407/20240717003704208/WEA_L30X_L31X_L70X_EN_UG_XF3_070324_FINAL.pdf .

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'475 Patent Claim	Samsung Accused Device ¹
	 More precise Heart Rate Tracking 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/

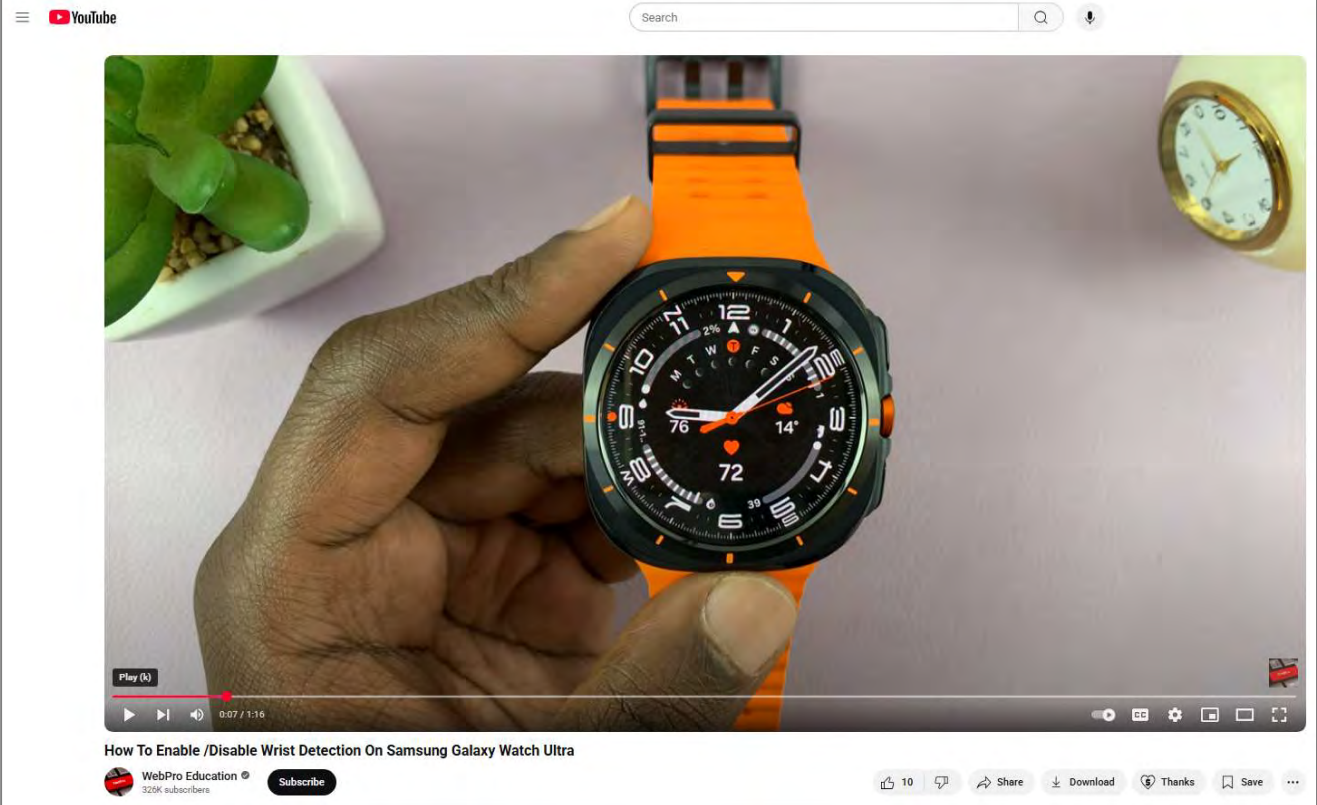
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'475 Patent Claim	Samsung Accused Device ¹
	Set your own Heart Rate Zone Exercise at your optimal fitness capacity to reach your workout goals. With the Galaxy Watch Series, you have the flexibility to set your Personalized HR Zone to reach your health and wellness targets. Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life  The screenshot shows the 'Heart rate zones' screen in the Samsung Health app. It lists five zones with their respective heart rate ranges and progress bars: - Zone 5 Maximum: 176-195 bpm, 00:06:27, 27.6% - Zone 4 Anaerobic: 157-175 bpm, 00:12:37, 55.7% - Zone 3 Aerobic: 137-156 bpm, 00:00:56, 8.0% - Zone 2 Weight control: 118-136 bpm, 00:03:12, 14.0% - Zone 1 Low intensity: 97-117 bpm, 00:00:07, 0.0% Below the zones, a Galaxy Watch is shown displaying workout metrics: Duration 23:34⁹⁹, Distance 6.12, Pace 05'15", and Heart Rate 125 bpm. Source: https://www.samsung.com/us/apps/samsung-health/#Improve_your_life

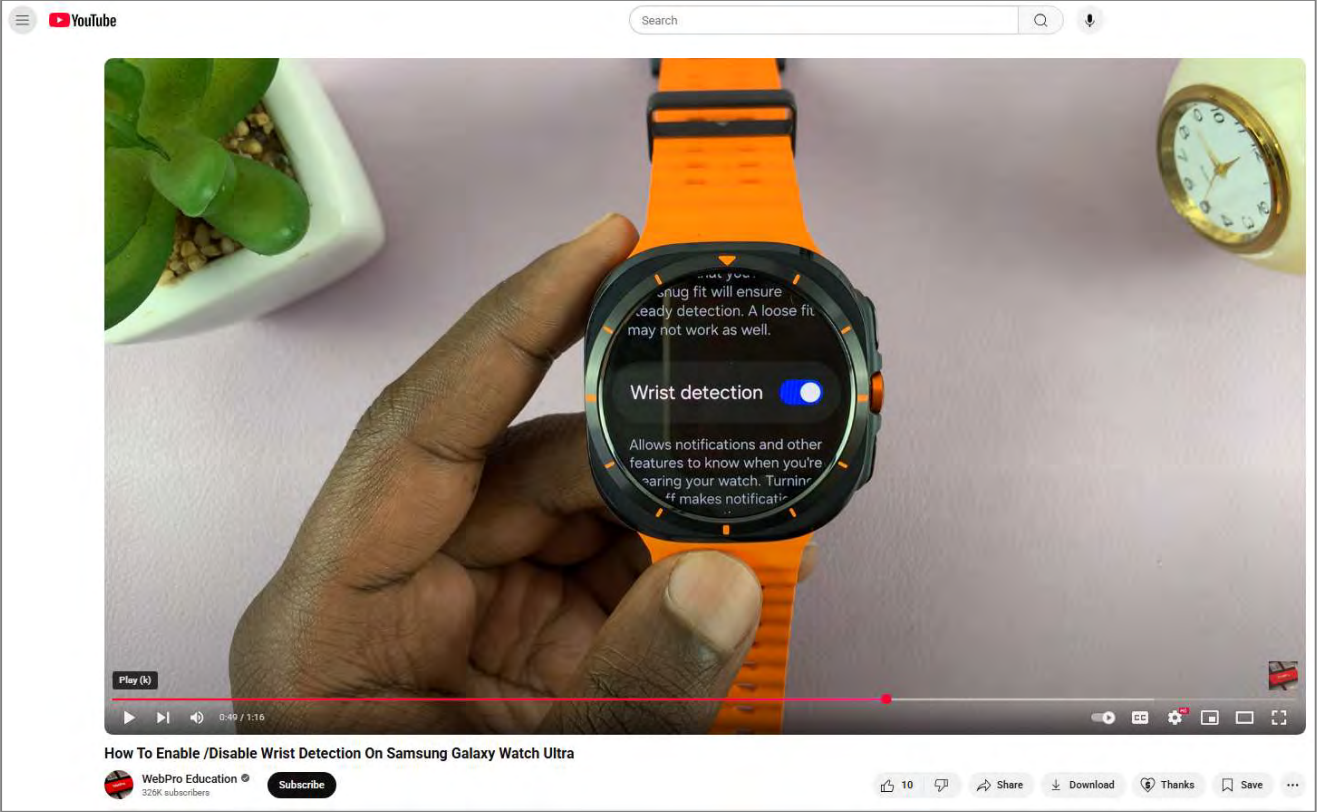
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	Samsung states that “[t]he optimal allocation of Green, Red and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive 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 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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'475 Patent Claim	Samsung Accused Device ¹
	 WebPro Education, “How to Enable/Disable Wrist Detection on Samsung Galaxy Watch Ultra,” YouTube, Aug. 1, 2024, https://www.youtube.com/watch?v=c7YCtsavwHA. See also https://us.community.samsung.com/t5/Galaxy-Watch/Turn-off-wrist-detection/td-p/2617387.

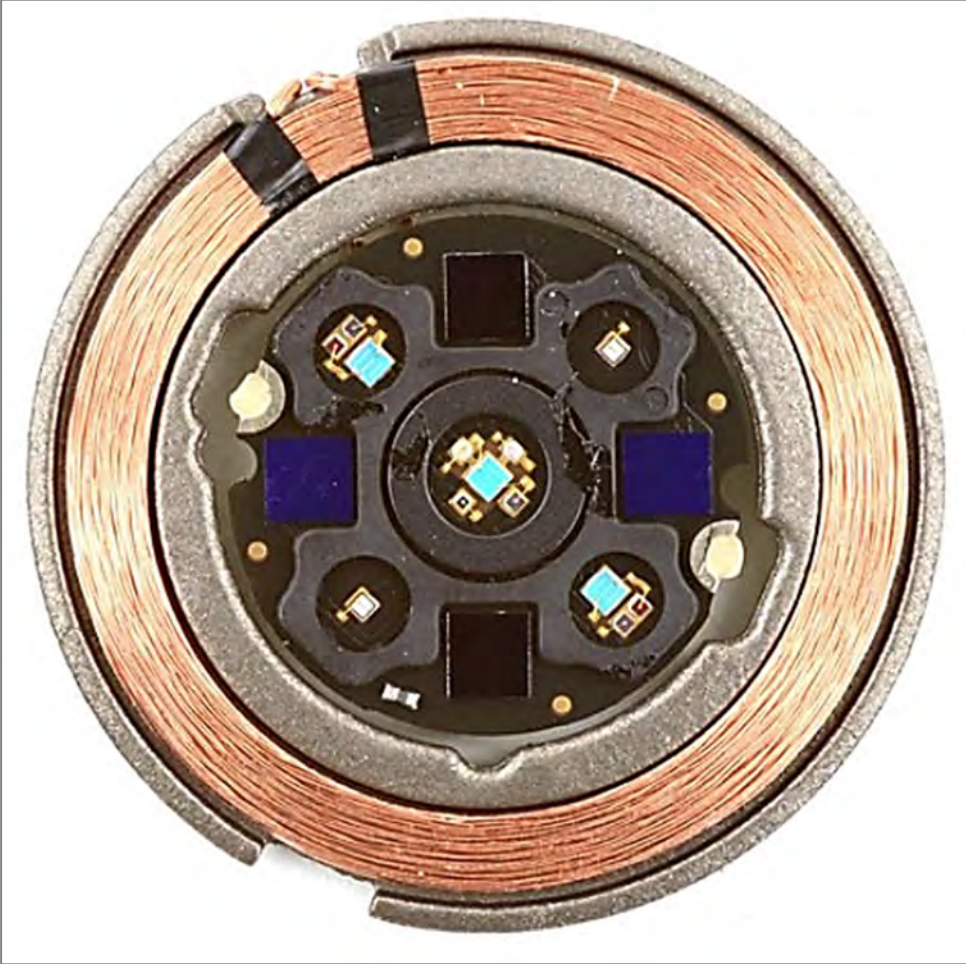
U.S. Patent No. 12,268,475 (the “’475 Patent”)
“Wearable device for differential measurement on pulse rate and blood flow”

’475 Patent Claim	Samsung Accused Device ¹						
11. The wearable device of claim 8, wherein at least a portion of the output light has an optical wavelength between about 700 nanometers and about 2500 nanometers.	The output light from the Accused Smartwatch has an optical wavelength between about 700 nanometers and about 2500 nanometers, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch includes multiple LEDs, 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 in the optical wavelength range between about 700 nanometers and about 2500 nanometers. 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 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="506 943 1528 1362"><tr><td data-bbox="506 943 978 1081">PPG green</td><td data-bbox="978 943 1528 1081">Raw data from PPG green LED. Provided as a batching event.</td></tr><tr><td data-bbox="506 1081 978 1232">PPG IR</td><td data-bbox="978 1081 1528 1232">Raw data from PPG infrared LED. Provided as an on-demand event.</td></tr><tr><td data-bbox="506 1232 978 1362">PPG red</td><td data-bbox="978 1232 1528 1362">Raw data from PPG red LED. Provided as an on-demand event.</td></tr></table>	PPG green	Raw data from PPG green LED. Provided as a batching event.	PPG IR	Raw data from PPG infrared LED. Provided as an on-demand event.	PPG red	Raw data from PPG red LED. Provided as an on-demand event.
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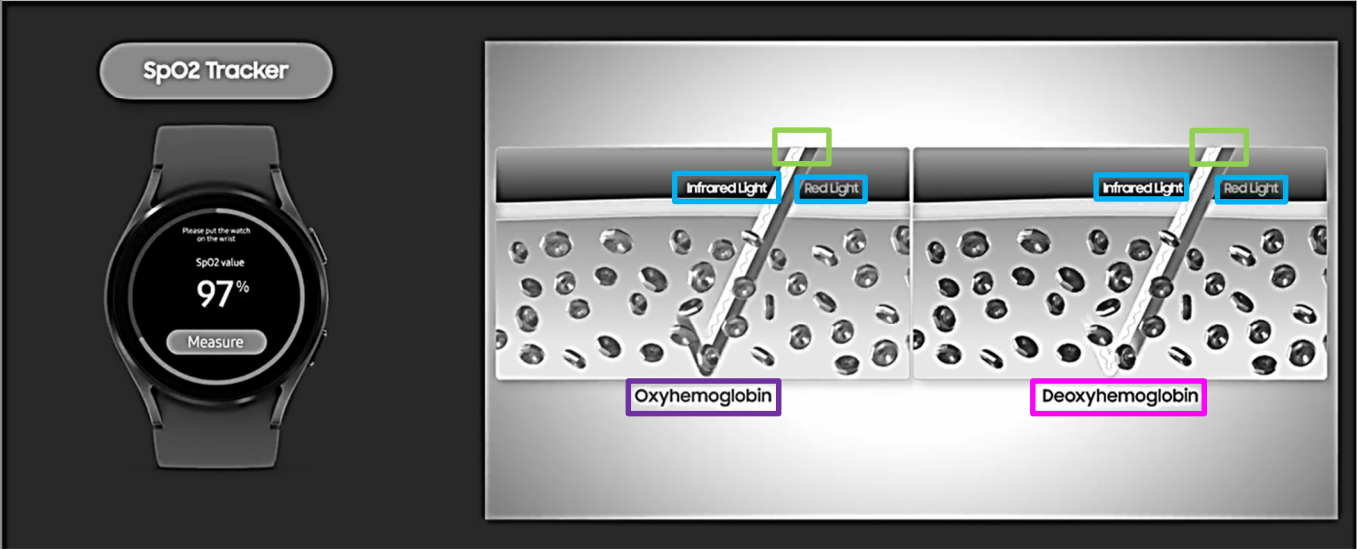
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'475 Patent Claim	Samsung Accused Device ¹
	Source: Samsung Developer, Samsung Privileged Health SDK, <i>available at</i> https://developer.samsung.com/health/privileged/overview.html  Source: https://news.samsung.com/global/unlocking-new-possibilities-for-preventative-wellness-with-new-galaxy-watch-and-bioactive-sensor

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'475 Patent Claim	Samsung Accused Device 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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'475 Patent Claim	Samsung Accused Device ¹
	For example, the output optical light (from the LEDs), for measuring oxy-hemoglobin and deoxy-hemoglobin levels (during SpO₂ measurement/measuring blood oxygen level) includes red and infrared light, which have wavelengths between 600 nm and 1000 nm. SpO₂ On-demand measurement for blood oxygen level  Source: https://developer.samsung.com/conference/sdc22/sessions/expand-health-experiences-with-galaxy-watch

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	<table border="1"> <thead> <tr> <th colspan="2" data-bbox="512 246 1495 297">Table 1. LEDs – Wavelengths and Applications</th></tr> <tr> <th data-bbox="512 297 905 347">LED Wavelength (Color)</th><th data-bbox="905 297 1495 347">LED Applications</th></tr> </thead> <tbody> <tr> <td data-bbox="512 347 905 397">410–420 nm (Violet)</td><td data-bbox="905 347 1495 397">Skin therapy</td></tr> <tr> <td data-bbox="512 397 905 448">430–470 nm (Blue)</td><td data-bbox="905 397 1495 448">Dental curing instruments</td></tr> <tr> <td data-bbox="512 448 905 498">470 nm (Blue)</td><td data-bbox="905 448 1495 498">White LEDs using phosphor</td></tr> <tr> <td data-bbox="512 498 905 548">520–530 nm (Green)</td><td data-bbox="905 498 1495 548">Green traffic signal lights</td></tr> <tr> <td data-bbox="512 548 905 599">580–590 nm (Amber)</td><td data-bbox="905 548 1495 599">Amber traffic signal lights</td></tr> <tr> <td data-bbox="512 599 905 649">630–640 nm (Red)</td><td data-bbox="905 599 1495 649">Red signal lights</td></tr> <tr> <td data-bbox="512 649 905 699">660 nm (Deep Red)</td><td data-bbox="905 649 1495 699">Blood oximetry</td></tr> <tr> <td data-bbox="512 699 905 750">680 nm (Deep Red)</td><td data-bbox="905 699 1495 750">Blood analysis</td></tr> <tr> <td data-bbox="512 750 905 800">800–850 nm (Near-IR)</td><td data-bbox="905 750 1495 800">Night-vision illuminators and beacons for use with night-vision goggles or CCDs</td></tr> <tr> <td data-bbox="512 800 905 850">850–940 nm (Near-IR)</td><td data-bbox="905 800 1495 850">Photoelectric controls</td></tr> <tr> <td data-bbox="512 850 905 901">940 nm (Near-IR)</td><td data-bbox="905 850 1495 901">Covert illumination CCD-based systems</td></tr> </tbody> </table> Source: https://www.photonics.com/Articles/Light-Emitting_Diodes_A_Primer/a36706 “Infrared radiation (IR), also known as thermal radiation, is that band in the electromagnetic radiation spectrum with wavelengths above red visible light between 780 nm and 1 mm.” Source: https://www.icnirp.org/en/frequencies/infrared/index.html	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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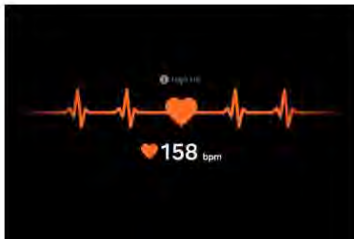
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'475 Patent Claim	Samsung Accused Device ¹
12. The wearable device of claim 8, wherein the physiological parameter of the user is associated with a blood constituent or a blood flow of the user.	In the Accused Smartwatch, the physiological parameter of the user is associated with a blood constituent or a blood flow of the user, either literally or under the doctrine of equivalents. For example, the Accused Smartwatch comprises a “BioActive Sensor” featuring optical sensors that detect heart rate by measuring changes in the volume of blood flowing in blood vessels in the skin and underlying connective tissue of a user (<i>e.g.</i>, “a pulse rate monitoring and a blood flow measurement”). For example, the Galaxy Watch Ultra is at least in part configured to recognize or establish when it is being worn by a human user by identifying one or more physiological parameters of the human user (<i>e.g.</i>, human health metrics and data such as heart rate, SpO2, and sleep metrics). In doing so, the Accused Smartwatch is also at least in part configured to recognize or establish details about the user’s blood (<i>e.g.</i>, constituents in the blood or oxygen saturation of the user’s blood). The Galaxy Watch Ultra is also configured such that it enables a user to establish Heart Rate Alerts and Heart Rate Zones, to which heart rate measurements taken of the user by the BioActive Sensor can be compared. 

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	 The screenshot shows the Samsung Health app interface on a Samsung Watch Ultra. The top section displays a heart rate of 94 bpm with a blue circular progress indicator and a label 'Excellent'. Below this, it shows 'Yesterday 84'. To the left, a summary card displays 4,350 steps, 76 mins, and 458 cal. To the right, a sleep score of 80 is shown with a 'Good' status. The bottom section is titled 'HEALTH Understand your body better' and features three tabs: 'Samsung Health', 'Heart Monitor', and 'Sleep Coach'. The 'Heart Monitor' tab is active, showing a heart rate of 158 bpm with a 'High HR' warning. A text box on the right explains 'More precise Heart Rate Tracking' using Galaxy AI. Source: https://www.samsung.com/us/watches/galaxy-watch-ultra/

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'475 Patent Claim	Samsung Accused Device ¹
	Galaxy Watch Ultra 47mm Titanium Gray Marine Orange Medium/Large Bluetooth / Wifi + 4G LTE Wifi SM-L705V / SM-L705DAAXAA ★★★★★ 4.7 (4444) Write a review Compare Specs Key Features  Sensors Accelerometer, Barometer, Bioelectrical Impedance Analysis Sensor, Electrical Heart Sensor, Gyro Sensor, Geomagnetic Sensor, Infrared Temperature Sensor, Light Sensor, Optical Heart Rate Sensor, SpO2 Sensor, AGEs Index Sensor  Know your score. Own your day. Start your day strong with a score that calculates your physical readiness based on yesterday's sleep, heart rate and steps.^{2, 3}  More precise Heart Rate Tracking 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/

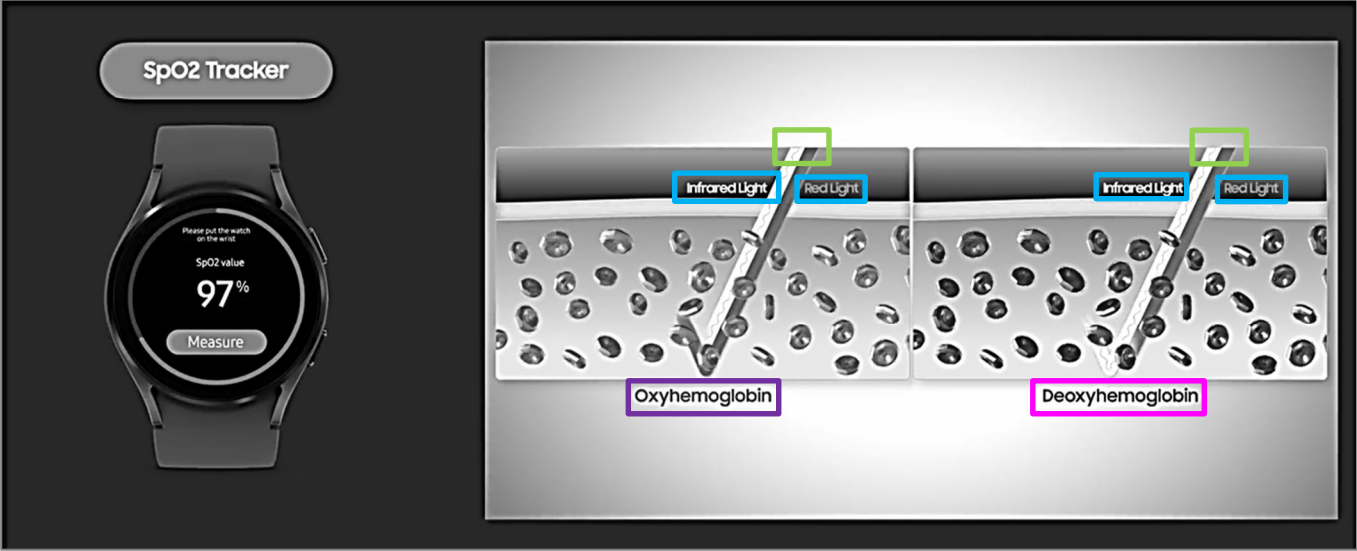
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’475 Patent Claim	Samsung Accused Device ¹
	Bringing Greater Accuracy and New Possibilities for Preventative Wellness The optimal allocation of Green, Red, and Infrared LEDs sets new standards in wearable technology by improving accuracy and enabling exceptional performance across a broad array of health metrics. This allows the new BioActive Sensor to more accurately measure health metrics such as heart rate, sleep quality, blood oxygen levels, and stress levels.² Even the measurement of heart rate during intensive workouts is 30% more accurate compared to its predecessor. Source: https://news.samsung.com/us/samsung-new-galaxy-watch-bioactive-sensor-unlocking-new-possibilities-for-preventative-wellness/ Monitor your heart rate and blood pressure with the Galaxy Watch series The Samsung Health Monitor app allows you to use your Galaxy Watch to help record and monitor your heart health through the ECG feature, Heart rate monitor, and blood pressure monitor. After recording, you can save the data to your Galaxy phone and share the results with your doctors if needed. Review our tips and instructions for how to utilize this helpful tool. 

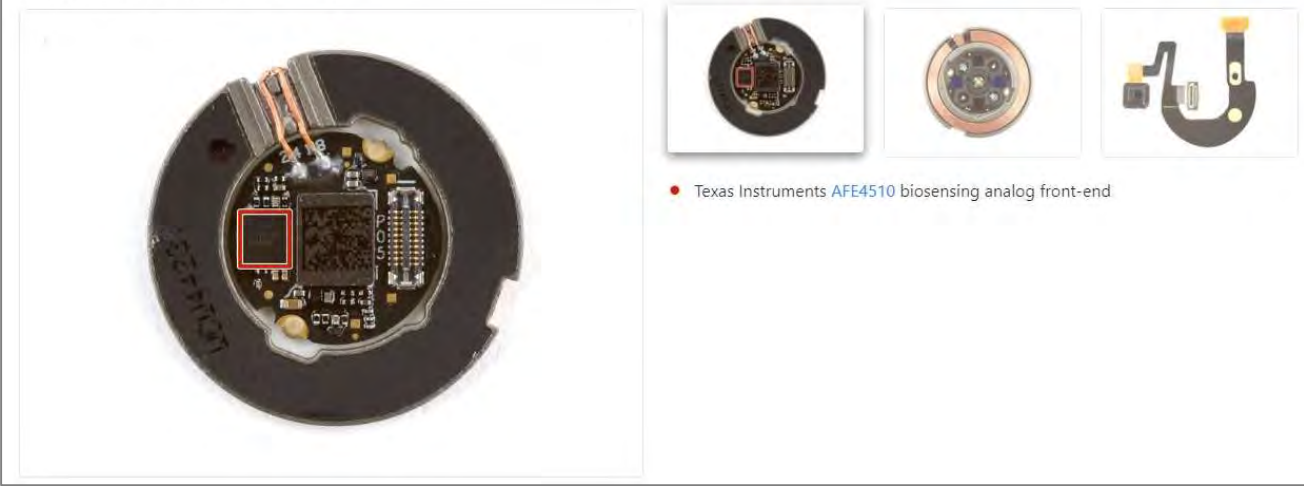
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'475 Patent Claim	Samsung Accused Device ¹
	Source: https://www.samsung.com/latin_en/support/mobile-devices/measure-your-ecg-with-the-galaxy-watch-series/ Monitor your heart rate on your Samsung smart watch The lower your heart rate is during exercise, the more in shape you are and vice versa. Use your smart watch to keep track of your heart rate whenever you work out or go for a jog, so you can see how far you've come.  Source: https://www.samsung.com/us/support/answer/ANS10003311/

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'475 Patent Claim	Samsung Accused Device ¹
	SpO2 On-demand measurement for blood oxygen level  The image shows a screenshot of the 'SpO2 Tracker' app on a smartwatch. The watch face displays 'Please put the watch on the wrist', 'SpO2 value 97%', and a 'Measure' button. To the right is a diagram illustrating the measurement principle. It shows two cross-sections of skin. The left section is labeled 'Oxyhemoglobin' and shows red light (red box) and infrared light (green box) penetrating the skin. The right section is labeled 'Deoxyhemoglobin' and shows infrared light (green box) and red light (red box) penetrating the skin. The light sources are labeled 'Infrared Light' and 'Red Light' in blue boxes. Source: https://developer.samsung.com/conference/sdc22/sessions/expand-health-experiences-with-galaxy-watch
13. The wearable device of claim 8, wherein the processor is further configured to modulate the light source with a modulation frequency.	The processor in the Accused Smartwatch is further configured to modulate the light source with a modulation frequency, either literally or under the doctrine of equivalents. For example, the BioActive Sensor (including a processor) in the Galaxy Watch Ultra is configured to drive output light from the LEDs according in pulsed manner in accordance with a pulse frequency, also referred to as a pulse repetition frequency (“PRF”) (e.g., “modulate the light source with a modulation frequency”).

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	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.

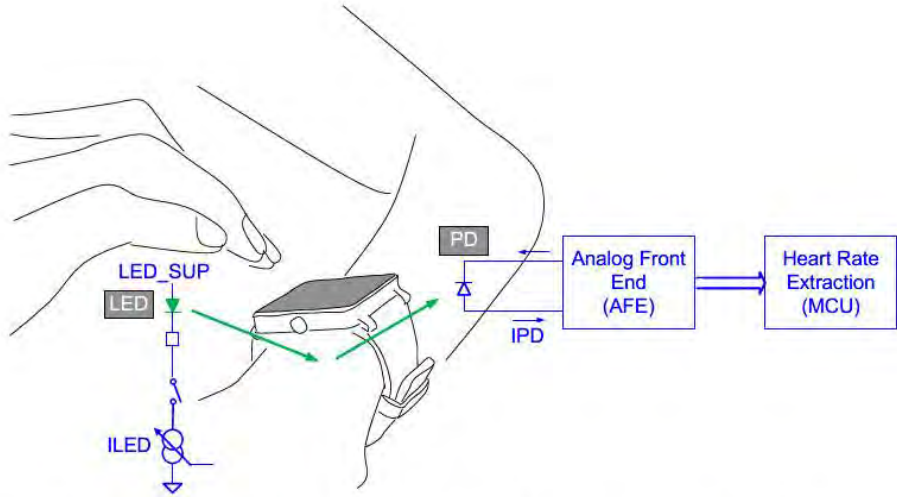
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’475 Patent Claim	Samsung Accused Device ¹
	3 Description The AFE4510 is a versatile signal acquisition system that supports acquiring PPG, EDA, ECG, and Bio-impedance signals. A PPG signal chain comprises a current driver for LEDs and a receiver that 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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'475 Patent Claim	Samsung Accused Device ¹
	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> Optical Heart Rate Monitoring (OHRM) on Wearables  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).

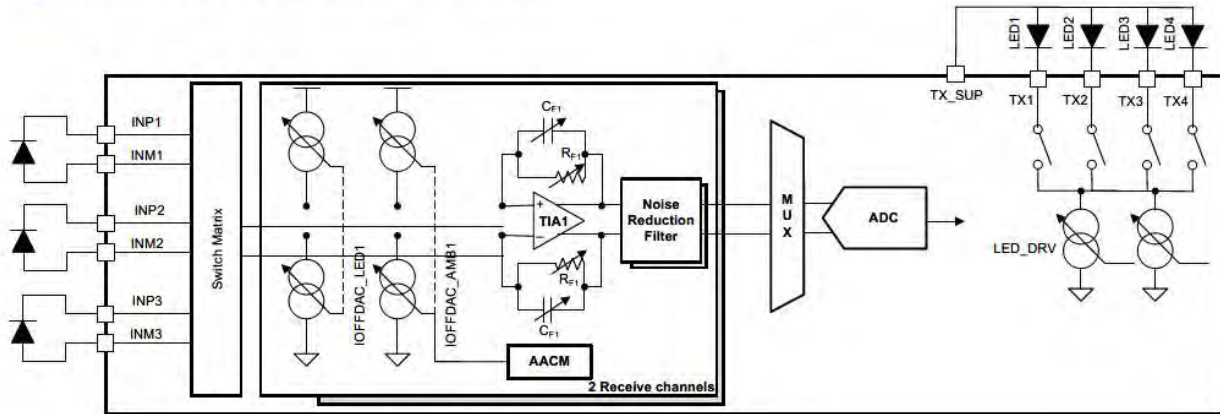
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	 Figure 1. Heart Rate Monitoring on a Wearable Device In a device like a smartwatch, the LED and PD both face the wrist. The light from the LED is incident on the skin, and the reflection of the light from the artery results in a pulsating component. 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><caption>Table 1. Specifications for OHRM on Wearables</caption><thead><tr><th>System Specifications</th><th>AFE4432</th><th>Comments</th></tr></thead><tbody><tr><td>Multi-sensor support</td><td>4 LEDs, 3 PDs</td><td>Combining signals from multiple PDs and LEDs helps mitigate motion artifacts</td></tr><tr><td>Sampling rate</td><td>1 Hz–1 kHz</td><td>A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM</td></tr><tr><td>Current consumption</td><td>12 μA</td><td>For the receiver at 25 Hz PRF</td></tr><tr><td>Peak SNR</td><td>115 dB over 10-Hz bandwidth</td><td>Important consideration to achieve good accuracy in low perfusion cases.</td></tr><tr><td>Ambient rejection</td><td>> 70 dB up to 160 Hz</td><td>Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting</td></tr></tbody></table>	System Specifications	AFE4432	Comments	Multi-sensor support	4 LEDs, 3 PDs	Combining signals from multiple PDs and LEDs helps mitigate motion artifacts	Sampling rate	1 Hz–1 kHz	A sampling rate of 25 Hz to 100 Hz is typically used for continuous HRM	Current consumption	12 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
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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.

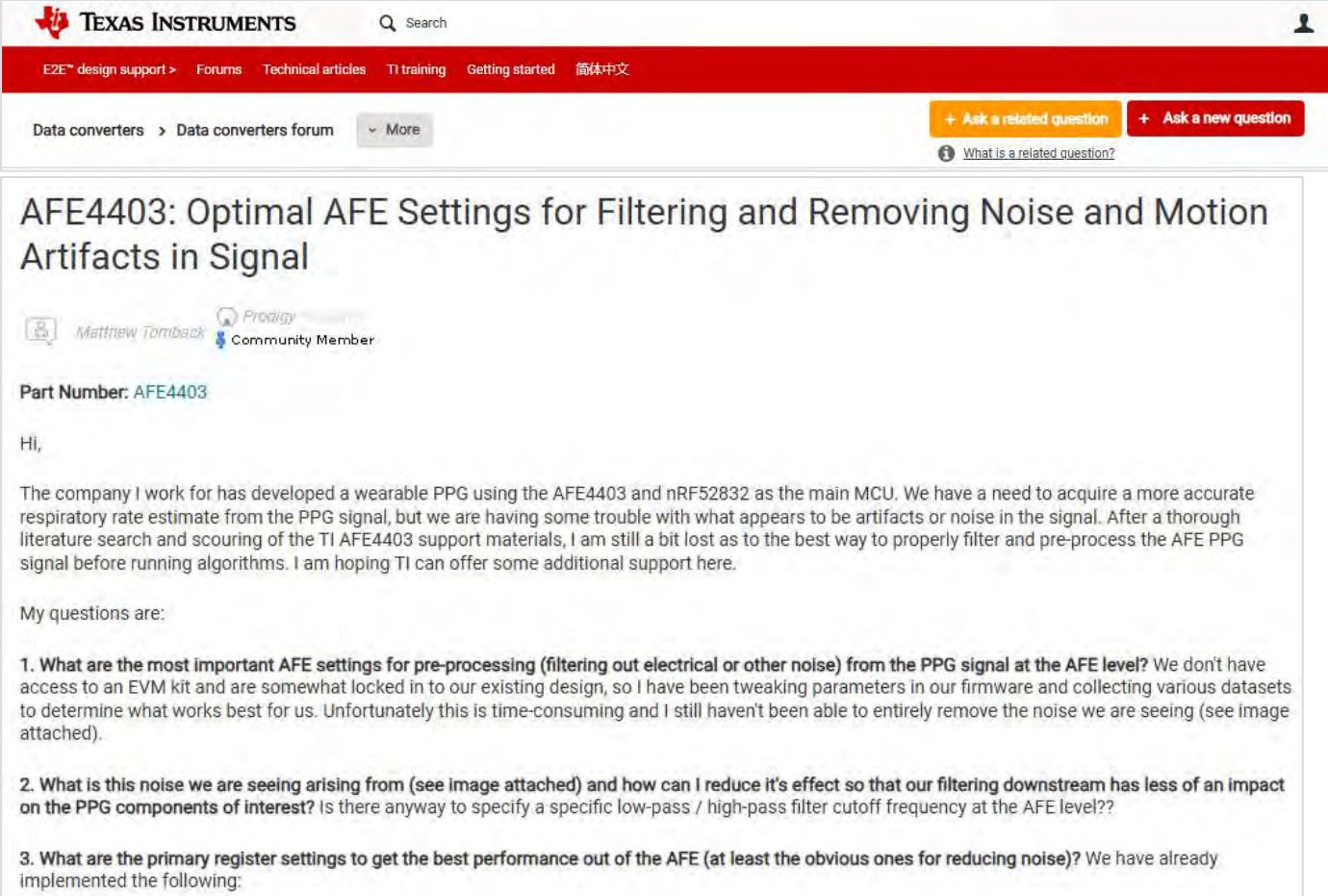
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	Block Diagram Source: Texas Instruments, Product Overview, “Photoplethysmography (PPG) with Integrated AFE for Optical Biosensing,” Oct. 2023, at 1, <i>available at</i> https://www.ti.com/lit/po/sbat014/sbat014.pdf?ts=1724246538793&ref_url=https%253A%252F%252Fwww.google.com%252F. 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.

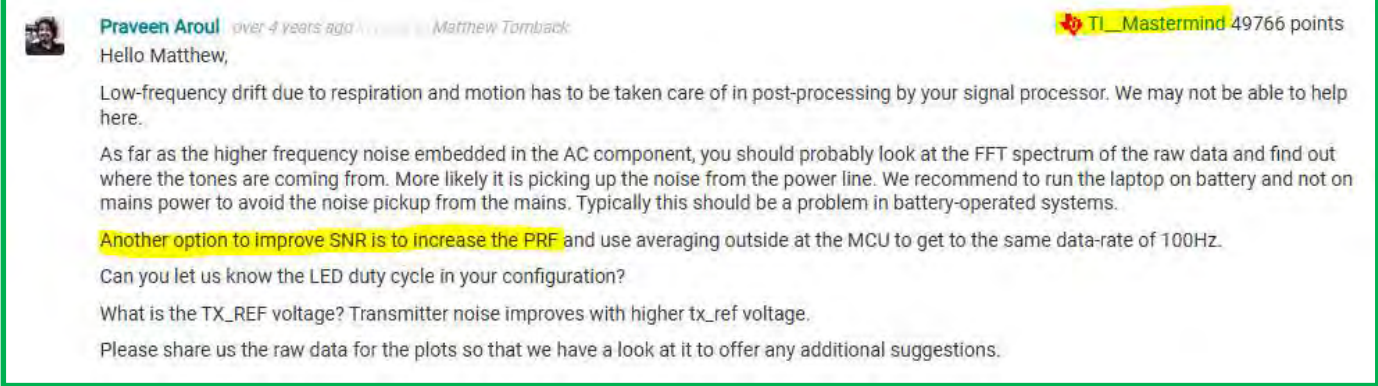
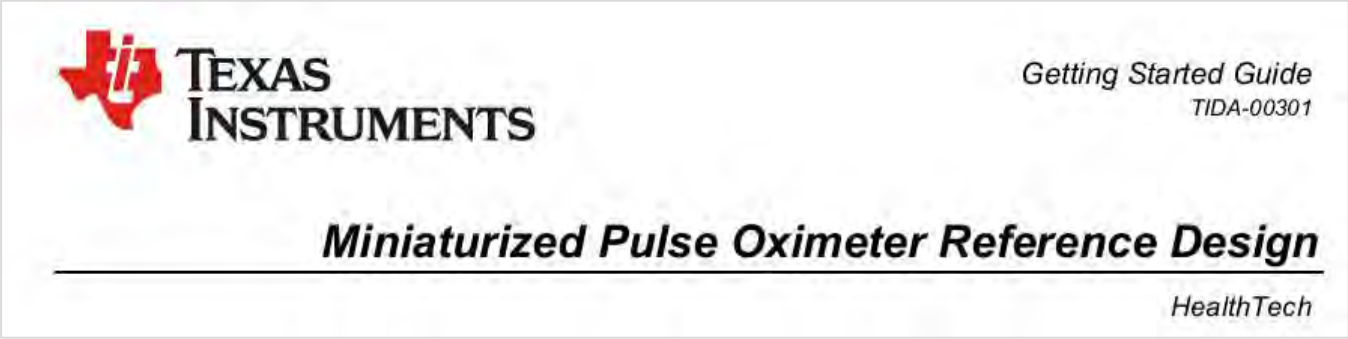
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	“However, increasing the LED current gives better signal quality from the SNR perspective. The optimal AFE configuration settings are completely dependent on the application. This includes the separation of LED and PD, location of the sensor, and 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%	
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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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	 TEXAS INSTRUMENTS Search E2E™ design support > Forums Technical articles TI training Getting started 简体中文 Data converters > Data converters forum More + Ask a related question + Ask a new question What is a related question? AFE4403: Optimal AFE Settings for Filtering and Removing Noise and Motion Artifacts in Signal Matthew Tomback Prodigy Community Member Part Number: AFE4403 Hi, The company I work for has developed a wearable PPG using the AFE4403 and nRF52832 as the main MCU. We have a need to acquire a more accurate respiratory rate estimate from the PPG signal, but we are having some trouble with what appears to be artifacts or noise in the signal. After a thorough literature search and scouring of the TI AFE4403 support materials, I am still a bit lost as to the best way to properly filter and pre-process the AFE PPG signal before running algorithms. I am hoping TI can offer some additional support here. My questions are: 1. What are the most important AFE settings for pre-processing (filtering out electrical or other noise) from the PPG signal at the AFE level? We don't have access to an EVM kit and are somewhat locked in to our existing design, so I have been tweaking parameters in our firmware and collecting various datasets to determine what works best for us. Unfortunately this is time-consuming and I still haven't been able to entirely remove the noise we are seeing (see image attached). 2. What is this noise we are seeing arising from (see image attached) and how can I reduce it's effect so that our filtering downstream has less of an impact on the PPG components of interest? Is there anyway to specify a specific low-pass / high-pass filter cutoff frequency at the AFE level?? 3. What are the primary register settings to get the best performance out of the AFE (at least the obvious ones for reducing noise)? We have already implemented the following:

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	 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. 

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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 (<i>Rx</i>) <i>sample time</i> 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 “<i>ratio of ratios</i>” 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

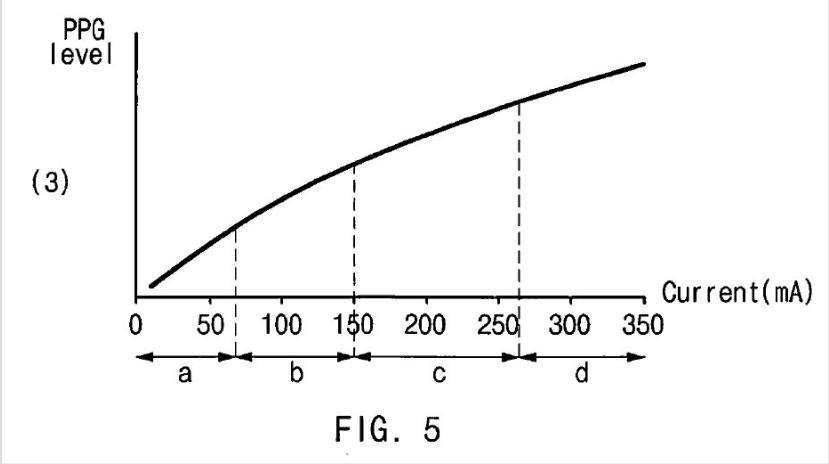
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	https://www.ti.com/lit/ug/tidu475/tidu475.pdf?ts=1724347486358&ref_url=https%253A%252F%252Fwww.google.com%252F%20. Samsung patent documents describe wearable devices that are configured to modulate the light source with a modulation frequency. For example: (12) United States Patent Lee et al. (10) Patent No.: US 11,974,838 B2 (45) Date of Patent: May 7, 2024 (54) ELECTRONIC DEVICE FOR ACQUIRING BIOMETRICS USING PPG SENSOR, AND METHOD THEREFOR (71) Applicant: Samsung Electronics Co., Ltd. Gyeonggi-do (KR) (57) ABSTRACT An electronic device may include a PPG sensor including a light emitter that applies a current in a specified range and emits a light signal corresponding to the current and a light detector that amplifies a received light signal by applying one of a plurality of gain values, a memory that stores a plurality of sets of PPG models corresponding to the plu- (Continued)

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	To obtain bio information from the PPG signal, the PPG signal needs to have an appropriate level. For example, when the PPG signal is saturated or a signal to noise ratio (SNR) is low, it may be difficult to extract bio information from the PPG signal. 45 The level of the PPG signal may be proportional to the intensity of light emitted by the light emitter and the intensity of light collected by the light detector. The intensity 50 of light emitted by the light emitter may be proportional to the intensity of a current applied to the light emitter. The light detector may amplify the collected light according to a predetermined gain value. 5 device 100 may be referred to as a user terminal. The electronic device 100 may analyze a PPG signal acquired and acquire bio information. Therefore, the PPG signal may need to have an appropriate level to extract bio information. For example, the higher the level of the PPG 10 signal, the greater the signal to noise ratio (SNR) of the PPG signal. However, when power consumed by the PPG sensor increases and the PPG signal is out of a reception range of a photo detector, the PPG signal may be saturated. When the In various embodiments, to improve the accuracy of the heart rate estimated from the measured PPG, it is possible to 10 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 15 in maximizing the SNR of a heart rate signal included in the PPG signal.

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

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	“The SDK supports an improved health tracking capability to allow your applications to track the user’s health data accurately with the accelerometer, raw ECG (Electrocardiogram), PPG (Photoplethysmogram), and heart rate including inter-beat interval. In addition, it provides more advanced health features such as the body composition measurement, to enable compelling use cases for health and fitness applications. The blood oxygen level and sweat loss after a running workout are also useful data to check a user's health status.” Source: Samsung Developer, “Samsung Privileged Health SDK,” https://developer.samsung.com/health/privileged/overview.html

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