Vital Signs Monitoring (VSM) Watch

FEATURES

- Vital signs monitoring platform
- Wearable battery-powered platform
- Real-time live data view
- Data storage to flash memory for offline analysis
- Easy configuration

DEVICES HOSTED IN THE VSM WATCH

- nRF52840
- ADP5360
- ADXL362
- ADPD4100
- AD8233
- AD5940
- AD7156

EVALUATION KIT CONTENTS

- VSM platform (the watch)
- Charging cradle
- USB Type A to micro USB cable
- Firmware debug board

SOFTWARE NEEDED

- VSM WaveTool

GENERAL DESCRIPTION

The vital signs monitoring (VSM) watch, EVAL-HCRWATCH4Z, is a modular development, demonstration, and data collection platform for high performance vital signs monitoring applications based on Analog Devices, Inc., analog front ends (AFEs) and sensors.

The VSM watch is a wearable, battery-powered device that enables the continuous monitoring and on-demand spot check measurement of photoplethysmography (PPG), electrodermal activity (EDA, bioimpedance-based), skin temperature, electrocardiography (ECG, biopotential based), and motion/activity (based on a 3-axis accelerometer).

The VSM watch allows synchronized, multiparameter data storage on internal memory for later data retrieval and offline analysis and/or live monitoring on a PC (Windows® OS) or Android- or iOS-based device.

PREPARING THE VSM WATCH

Before using the VSM watch, proper preparations must be made. Ensure that the battery of the watch is charged and the VSM WaveTool PC program is installed. See the Powering Up the System for the First Time section for installation instructions. Upgrade the watch firmware using the VSM WaveTool.

CONDITIONS REGARDING THE USE OF THIS PRODUCT IN HEALTHCARE APPLICATIONS

This device design is being provided as-is without any express or implied representations or warranties of any kind and the use of this device shall impose no legal obligation on Analog Devices, Inc., and its subsidiaries, employees, directors, officers, servants, and agents. In addition, it is understood and agreed to that the device is not authorized for use in safety critical healthcare applications (such as life support) in which malfunction or failure of a product can be expected to result in personal injury or death. This device must not be used for diagnostic purposes. It must not be used with a defibrillator or other equipment that produces high voltages more than the supply rails on the evaluation board.

This device is provided for evaluation and development purposes only. It is not intended for use as, or as part of, a product. Any use of the device in such applications is at your own risk and you shall fully indemnify Analog Devices, its subsidiaries, employees, directors, officers, servants and agents for all liability and expenses arising from such unauthorized usage. You are solely responsible for compliance with all legal and regulatory requirements connected to such use.

TABLE OF CONTENTS

REVISION HISTORY

12/2021—Revision 0: Initial Version

EVALUATION PLATFORM OVERVIEW

Figure 1. Overview of VSM Watch Platform

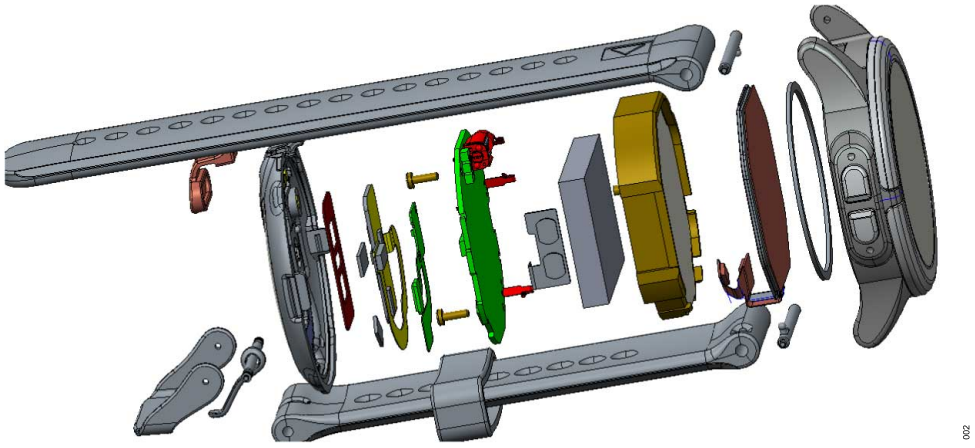

Figure 2. VSM Watch Expanded View

Figure 3. Connections and Buttons–Top of Watch

EVALUATION PLATFORM OVERVIEW

Figure 4. Connections and Buttons–Bottom of Watch

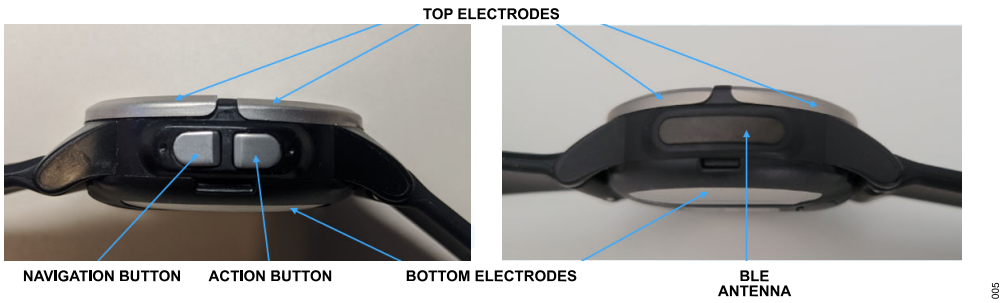

Figure 5. Connections and Buttons–Sides of Watch

Figure 6. Charging Cradle

Figure 7. Firmware Debug Board

EVALUATION PLATFORM OVERVIEW

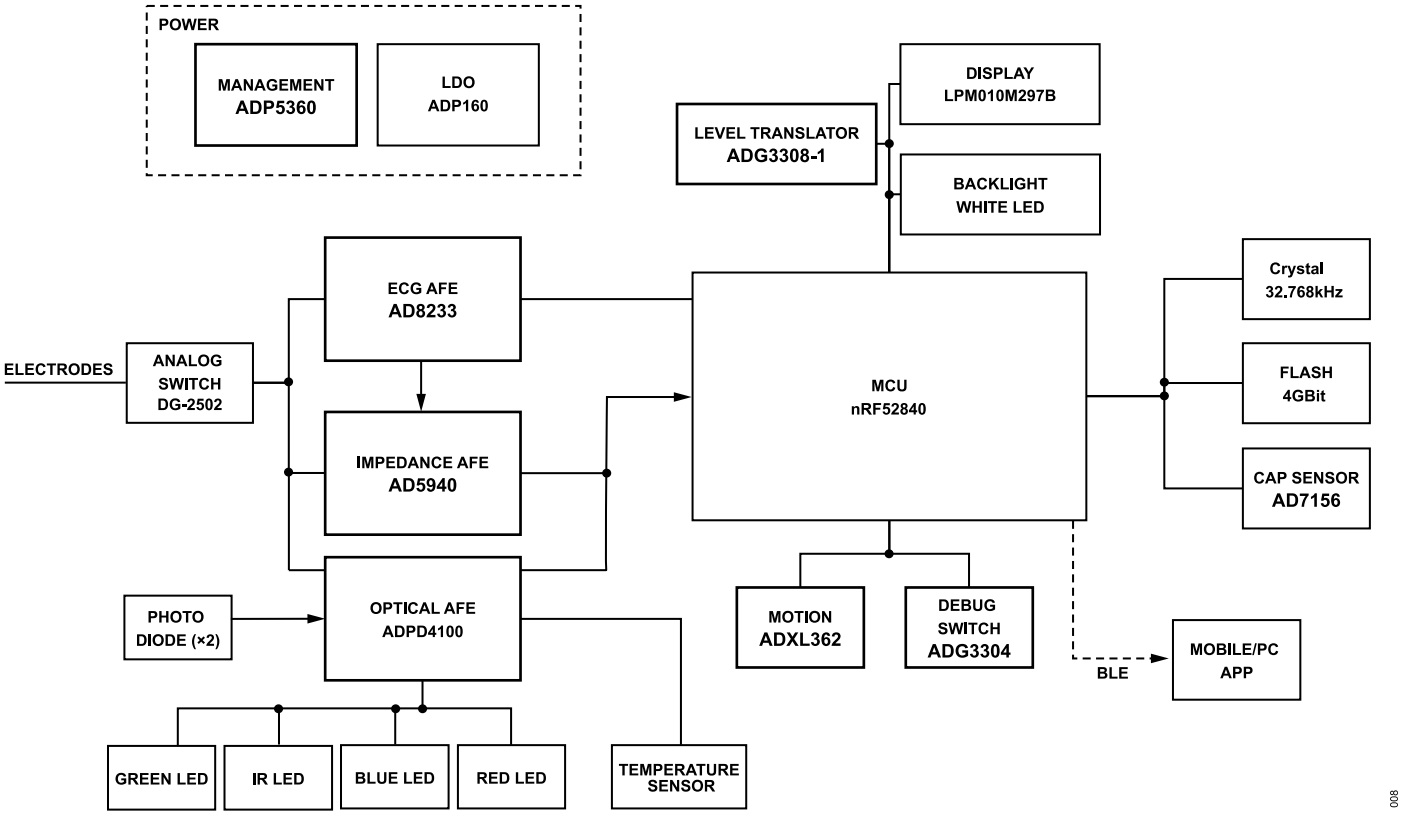

Figure 8. Simplified Electrical Block Diagram

EVALUATION PLATFORM

OVERVIEW

The VSM watch is a modular development, demonstration, and data collection platform for high performance vital signs monitoring applications based on Analog Devices analog front ends and sensors.

The platform optimized electrical and mechanical design hosts all the required circuits to sense, condition, digitize, process, store, and wirelessly transmit real-time, vital sign related data. This platform does the following:

- Minimizes the risks associated with a new electronic design
- Minimizes the time to market for a new final product
- Facilitates the evaluation of a wide range of Analog Devices solutions in a single battery-powered wearable ecosystem
- Highlights and addresses the challenges associated with a wearable device
- Allows the developer to focus on other added value tasks, such as algorithm development, and the overall firmware for engineering and scientific research and validation

This platform is not intended to do the following:

- Act as the final product for a specific application.
- Demonstrate an application-specific optimized design. Trade-offs were made to allow platform flexibility.

The evaluation platform kit contains the following items (see Figure 9:

- VSM platform (the watch)
- Charging cradle
- USB Type A to micro USB cable
- Firmware debug board

Figure 9. Evaluation Kit Contents

The USB cable is used for the following purposes:

- Recharge the battery via the charging cradle (connecting the watch to a PC or wall adapter)
- Upgrade the platform firmware (using VSM Wavetool)
- Download data stored in the internal flash memory for offline data analyses or other purposes

Use the watch only with the USB cable provided.

POWERING UP THE SYSTEM FOR THE FIRST TIME

The VSM watch is shipped from the factory in an ultra low power shipment mode. To exit this power mode, place the watch into the charging cradle and connect the USB cable to provide power.

Before using the watch for the first time, fully charge the battery by connecting the VSM watch to a PC or wall adapter using the USB cable provided.

WATER RESISTANCE

The VSM watch is IP68 rated. Despite this rating, exercise caution if showering, swimming, or doing any other activity with the VSM watch that exposes it directly to moisture.

SOFTWARE

For information on the VSM watch software, refer to the VSM watch software user guide included with the VSM WaveTool (available for download on the Analog Devices website at www.analog.com).

BLUETOOTH USB PC DONGLE (NRF52840)

The VSM watch platform leverages an off-the-shelf Nordic Semiconductor Bluetooth® low energy (BLE) dongle for communicating wirelessly with a PC (see Figure 10). The nRF52840 is available for purchase separately through multiple online vendors.

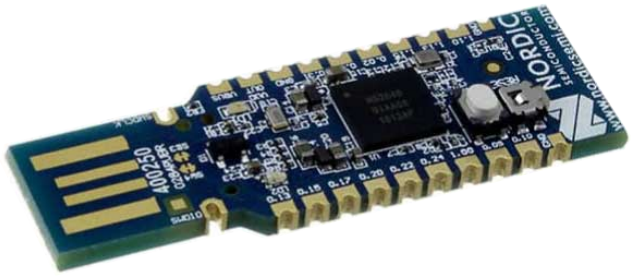

Figure 10. BLE USB PC Dongle (nRF52840)

EVALUATION PLATFORM

BUTTONS

Two buttons are found on the side of the VSM watch. Table 1 to Table 3 explain the uses of these buttons.

Table 1. Button Descriptions

Button	Description
Navigation	Short press to proceed to the next screen
Action	Short press for OK

Table 2. Button Usage in Watch App

Button Combinations	Button Actions	Button Press Timings (sec)
Action Button Short Press	Selects the current page action	0.05
Navigation Button Short Press	Navigates to the next page	0.05
Action Button Long Press	Returns to the previous page action	3
Navigation Button Long Press	Calls a soft reset of the watch app	3
Action and Navigation Button Long Press	Enters the bootloader	3
Navigation Button Long Press When Watch Is Powered Down	Wakes up the watch	1

Table 3. Button Usage in Bootloader

Button Combinations	Button Actions	Button Press Timings (sec)
Action Button Short Press	No action	Not applicable
Navigation Button Short Press	No action	Not applicable
Action Button Long Press	No action	Not applicable
Navigation Button Long Press	Enters watch app	7
Action and Navigation Button Long Press	Enters watch app	7
Action Button Short Press	No action	Not applicable

DISPLAY INDICATORS

Figure 11. Starting Up

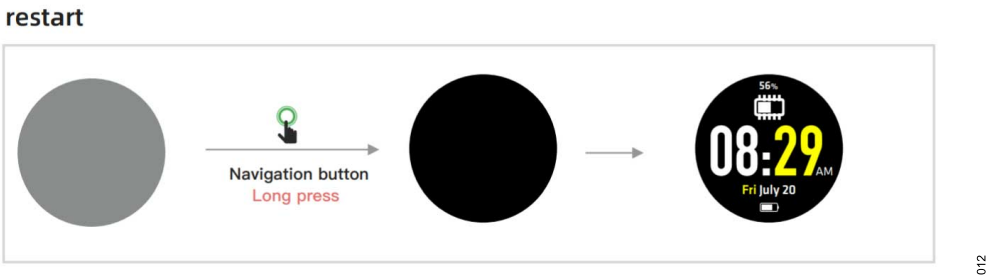

Figure 12. Restart from Any Page

EVALUATION PLATFORM

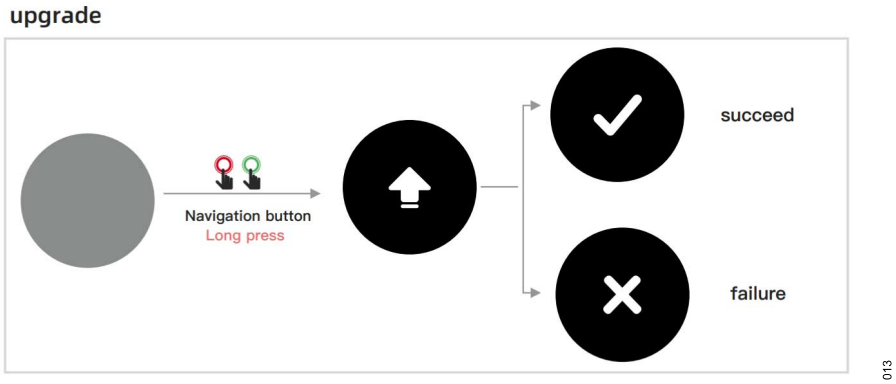

Figure 13. Firmware Upgrade

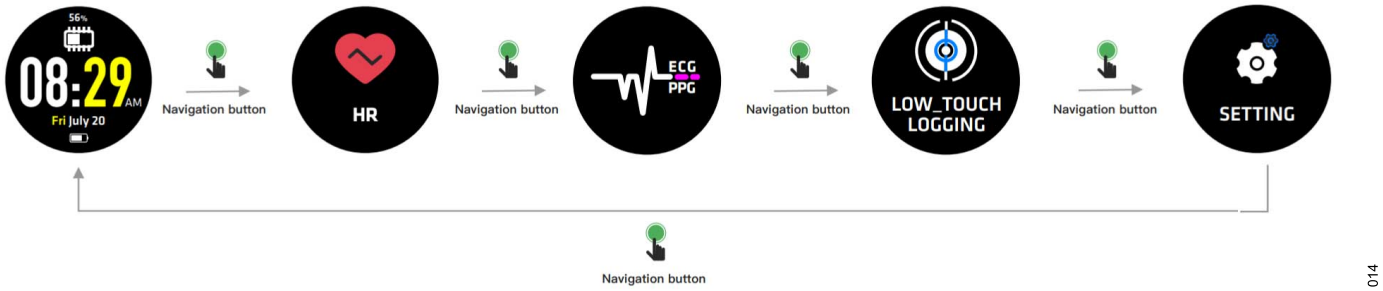

Figure 14. Main Page Interface

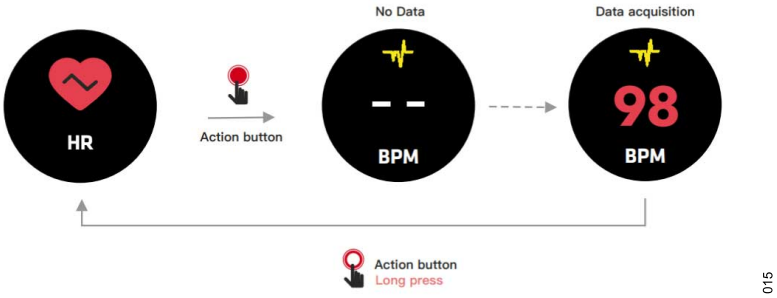

Figure 15. Heart Rate Page

EVALUATION PLATFORM

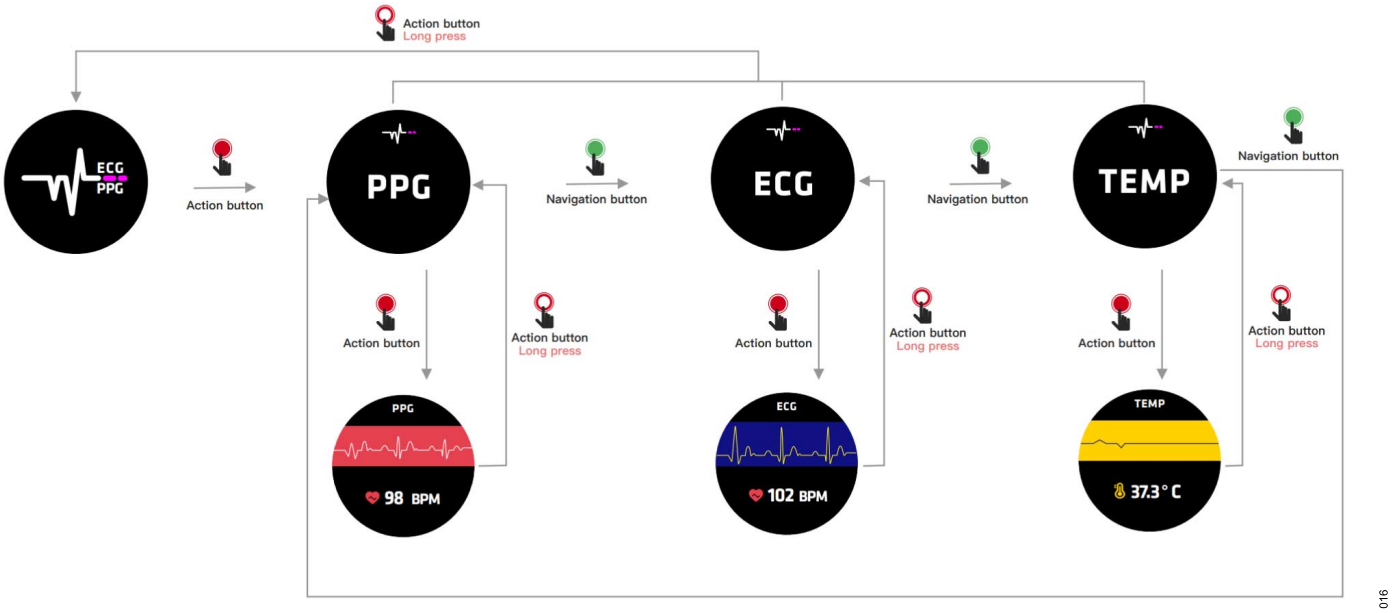

Figure 16. Waveform Page

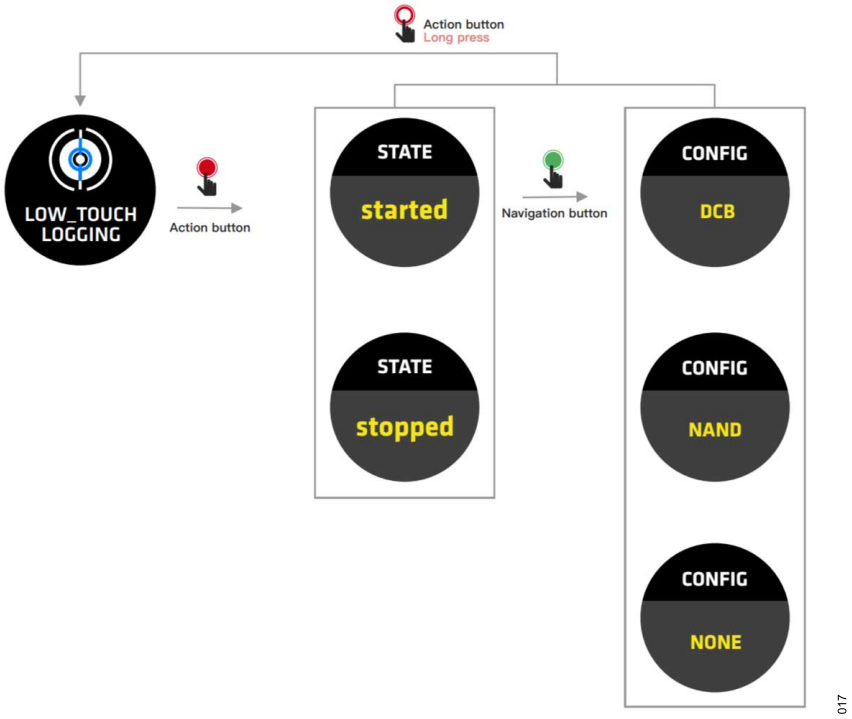

Figure 17. Low Touch Page

EVALUATION PLATFORM

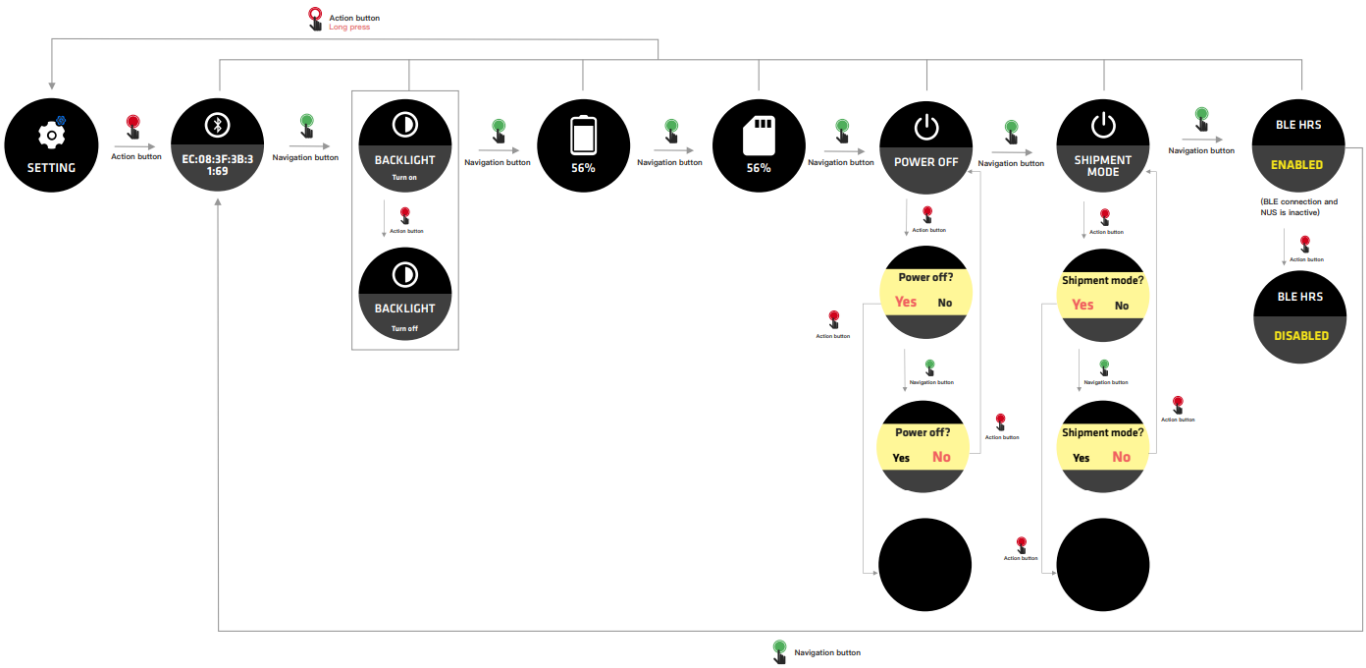

Figure 18. Setting Page

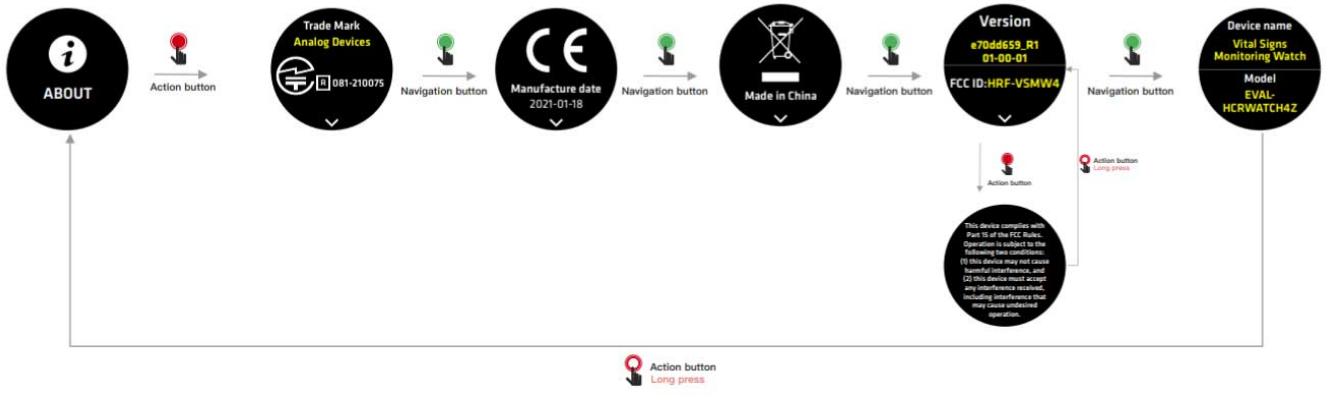

Figure 19. About Page

VITAL SIGNS MONITORED

To minimize the power line interference (50 Hz/60 Hz) and improve the quality of the output signal, use the BLE USB PC dongle as explained in the Bluetooth USB PC Dongle (nRF52840) section.

PHOTOPLETHYSMOGRAPHY—ADPD4100

The ADPD4100 operates as a complete multimodal sensor front end, stimulating up to eight LEDs (four on the VSM watch) and measuring the return signal on up to eight separate current inputs. Twelve time slots are available, enabling 12 separate measurements per sampling period.

The data output and functional configuration use an I^2C interface on the ADPD4101 or a serial port interface (SPI) on the ADPD4100. The control circuitry includes flexible LED signaling and synchronous detection. The devices use a 1.8 V analog core and 1.8 V/3.3 V compatible digital input/output (I/O).

Refer to the ADPD4100 product page and data sheet for further details.

See Table 4 and Table 5 for details on the hardware implementation.

Table 4. Electrical Connections to the ADPD4100 Inputs

Input Pin	Description
IN1	VEMD8080 Photodiode 1
IN2	VEMD8080 Photodiode 2
IN3	Temperature sensor
IN4	Temperature sensor
IN5	Bioimpedance/ECG
IN6	Bioimpedance/ECG
IN7	Bioimpedance/ECG
IN8	Bioimpedance/ECG

Table 5. Electrical Connections to the ADPD4100 LED Current Sinks

Current Sink	Color	Wavelength (nm)	No. of LEDs
LED1A	Green	530	1
LED2A	Infrared	940	1
LED3A	Red	660	1
LED4A	Blue	470	1

For more details on how to configure the various slots of the ADPD4100 and other configuration information, refer to the ADPD4100 data sheet.

MOTION AND ACTIVITY–ADXL362

Motion is sensed by the ADXL362, an ultra low power, 3-axis, ±2 *g*/±4 *g*/±8 *g* digital output high resolution (1 mg/LSB) accelerometer. The power consumption of the ADXL362 is 1.8 µA at 100 samples per second (SPS) and 3.0 µA at 400 SPS, whereas its motion activated wake-up mode only requires 270 nA.

A pedometer algorithm is embedded for evaluation that can be enabled in the VSM WaveTool.

Refer to the ADXL362 data sheet for more details on various configuration options available for this device.

ELECTROCARDIOGRAPHY–AD8233

The AD8233 is a 50 µA, 2.0 mm × 1.7 mm, wafer level chip scale package (WLCSP), low noise, single lead, analog output, biopotential front end.

Integrated ECG Electrodes

The AD8233 is connected to the electrodes hosted in the top and bottom surfaces of the VSM watch. The two electrodes on the top of the watch are connected to the IN− pin and RLD pin, whereas the two electrodes on the bottom of the watch are shorted together (temporarily while this measurement is active) and connected to the IN+ input.

The quality of the contact of the bottom electrodes has a dramatic effect on the output waveform. Dry, hairy skin poses a challenge for this measurement until moisture accumulates between the skin and the electrodes. Moisture accumulation typically happens a few minutes after the user puts on the device. Accumulated moisture decreases the contact impedance and, therefore, the quality of the output waveform improves.

The configuration of this signal chain is similar to an ambulatory ECG device (Holter monitor). See Table 6.

Table 6. Electrical Specifications of the ECG Signal Chain[1]

Specification	Value (Typical)	Unit
Passing Bandwidth	0.4 to 42	Hz
High-Pass Filter	First order	N/A
Low-Pass Filter	Second order (quality factor = 0.671)	N/A
AD8233 Gain	151	V/V
Analog-to-Digital Converter (ADC) Resolution	16	Bits
Noise (Referred to Input)	13	µV p-p
Sampling Rate	50 to 1000	SPS

[1] N/A means not applicable.

Refer to the AD8233 data sheet for more details on the device.

External ECG Cables

The charging cradle provides a secondary micro USB connection to be used with external wired electrodes.

BIOIMPEDANCE–AD5940

Impedance is measured using the AD5940 impedance AFE. Proper electrical contact between the two electrodes and the skin is critical for accurate and reliable long-term measurement. Adequate tightness of the watch strap helps achieve proper contact, and wearing the watch beside, but not on top of, the ulnar styloid process (the

VITAL SIGNS MONITORED

protruding wrist bone) also helps ensure a reliable and high quality measurement. See Table 7.

Note that the two electrodes are also used by the ECG measurement, which temporarily shorts them together. Therefore, the impedance measurement is not valid while the ECG measurement is ongoing.

Table 7. Electrical Specifications of the AD5940

Specification	Value (Typical)	Unit
Conductivity Range	0.2 to 20	µS (3%)
Accuracy at 0.2 µs	3	%
Accuracy at 1 µs	0.8	%
Accuracy at 10 µs	0.1	%
Accuracy at 20 µs	3	%
Resolution at 1 µs	1	nS
Resolution at 10 µs	2	nS
Excitation Frequency	100	Hz
Sampling Rate	30	SPS

SKIN AND AMBIENT TEMPERATURE

The skin temperature measurement is based on a thermistor (NTCG104EF104FTDSX). The thermistor used in the skin temperature measurement is thermally coupled to the bottom of the watch. This thermistor is connected to one of the analog inputs of the ADPD4100, and its performance is heavily dependent on the mechanical connection that is made to the body. This version of the watch has poor heat conduction between the thermistor and watch body that results in a larger inaccuracy in the temperature data than the theoretical value of 0.2°C. To overcome this shortcoming, the user can configure a temperature correction factor using the VSM WaveTool, depending on the temperature deviation seen in their device. The procedure to configure the correction factor is explained in the software user guide included with the VSM WaveTool.

See Table 8 for the electrical specifications of the signal chain that measures skin temperature.

Table 8. Electrical Specifications of the Signal Chain That Measures Skin Temperature

Specification	Value (Typical)
Temperature Range	−30°C to +50°C
Resolution at 25°C	0.1°C

USE CASES

The following basic modes of operation for the VSM watch are selectable by the supplied device configuration files (future use cases will be developed):

- High performance PPG
- Synchronized PGG with EDA
- Synchronized PPG with ECG spot check
- High performance ECG spot check
- Multiwavelength PPG

These modes of operation are intended to demonstrate the different types of configurations that are possible with the VSM watch, but they are not specific to an end application. The high configurability of the VSM watch allows the possibility to program a configuration that cannot be supported by the existing hardware, software, and firmware. Users can load these use cases as a known good starting point to explore measurements of interest before modifying the platform for their specific purpose.

Refer to the software user guide for details on how to evaluate and modify these use cases in the VSM WaveTool.

All use cases are designed to allow automatic logging to the on-board NAND flash when the watch detects that it is being worn, based on its capacitive sensor. The logging in progress indicator on the watch display (as shown in Figure 20) is seen only when this feature is used to indicate active logging and the percentage of memory used.

See Table 9 through Table 13 for more information on the use cases.

Figure 20. NAND Flash Logging Indicator with Percentage of Memory Used

Table 9. Use Cases[1]

Use Case	PPG (SPS)	Motion (SPS)	Impedance (SPS)	ECG (SPS)	Temperature (SPS)
Shipment Mode	Off	Off	Off	Off	Off
Hibernate	Off	Off	Off	Off	Off
PPG–High Performance (1 LED)	500	50	N/A	N/A	1
ECG–High Performance	50	50	N/A	1000	1
PPG and Impedance (1 LED)	100	50	30	N/A	1
PPG and ECG (1 LED)	100	50	N/A	250	1
PPG–All LEDs	100	50	N/A	N/A	1

[1] N/A means not applicable.

Table 10. Default ADPD4100 Configuration for Each Use Case

Use Case	Sampling Rate (SPS)	Transimpedance Amplifier Gain Channel 1/Channel 2	Pulse Width	Slot/Wavelength	Number of Pulses
PPG–High Performance (1 LED)	500	50/50	2	F/530	64
ECG–High Performance	50	50/50	2	F/530	64
PPG and Impedance (1 LED)	100	50/50	2	F/530	64
PPG and ECG (1 LED)	100	50/50	2	F/530	64
PPG–All LEDs	100	50/50	2	F/530, G/660, H/850, I/470	64

Table 11. Default ADXL362 Configuration for Each Use Case

Use Case	Sampling Rate (SPS)	Measurement Range (*g*)
PPG–High Performance (1 LED)	50	8
ECG–High Performance	50	8
PPG and Impedance (1 LED)	50	8
PPG and ECG (1 LED)	50	8
PPG–All LEDs	50	8

USE CASES

Table 12. Default AD5940 Configuration for Each Use Case[1]

Use Case	Sampling Rate (SPS)
PPG–High Performance (1 LED)	N/A
ECG–High Performance	1000
PPG and Impedance (1 LED)	30
PPG and ECG (1 LED)	250
PPG–All LEDs	N/A

[1] N/A means not applicable.

Table 13. Default AD8233 Configuration for Each Use Case[1]

Use Case	AC or DC Coupling	Fast Reset Mode	Gain
PPG–High Performance (1 LED)	N/A	N/A	N/A
ECG–High Performance	DC coupling	On	150
PPG and Impedance (1 LED)	N/A	N/A	N/A
PPG and ECG (1 LED)	DC coupling	On	150
PPG–All LEDs	N/A	N/A	N/A

[1] N/A means not applicable.

EMBEDDED ALGORITHMS FOR EVALUATION

Advanced algorithms with specific device configurations are detailed in the Pedometer section through ECG Heart Rate Monitoring section.

PEDOMETER

A pedometer algorithm takes raw data from the 3-axis accelerometer and outputs the steps taken.

AUTOMATIC GAIN CONTROL

The digitized output of the ADPD4100 is fed to this algorithm to ensure that the LED current and AFE gain is configured appropriately, to maximize the usefulness of the optical signal. The default target is 70% of the allowable range for each LED (independently determined). Automatic gain control is not optimized to achieve an ideal performance vs. power. Further improvements can be made based on the requirements of the end application to improve battery life.

HEART RATE MONITORING

The heart rate monitoring algorithm measures heart rate using a PPG signal while removing the motion based interference. This algorithm operates on a single channel PPG signal, together with the 3-axis accelerometer data to produce the heart rate. The algorithm is provided as a prebuilt Arm® Cortex®-M4 library along with a header file. The algorithm is designed to work with synchronized PPG and accelerometer data at 50 Hz.

SIGNAL QUALITY INDEX

PPG signals collected via wearable devices are prone to noise sources and other artifacts that negatively impact the measurement accuracy of the sensor. The signal quality index (SQI) algorithm gives a score (index) for each time window or segment of the PPG data. This score determines if the PPG data is of a sufficiently high quality to be useful for other vital sign extraction or clinical diagnostic algorithms that estimate the heart rate. The SQI feature is supported for PPG signal frequencies ranging from 25 Hz to 100 Hz. The SQI score is a floating-point value between 0 (poor signal quality) and 1 (excellent quality). The VSM WaveTool has an option to display the SQI in all use case views. The SQI can be calculated on any of the green, red, infrared, or blue LEDs present on the watch.

ECG HEART RATE MONITORING

The ECG heart rate monitoring algorithm measures heart rate from the ECG signal by detecting the QRS peak of the ECG signal. The algorithm is provided as a prebuilt Cortex-M4 library along with a header file. The algorithm is designed to work with an ECG signal with an output date rate up to 200 Hz.

BATTERY LIFE AND MEMORY FOOTPRINT

BATTERY LIFE

The battery life is determined by the type and number of sensors enabled and the sampling rate configured. The battery life is also dependent on other configuration details, such as the LED current in the PPG measurements. See Table 14.

Table 14. System Battery Life for Several Use Cases

Use Case	Memory	Live BLE	Battery Life (Hours)
Shipment Mode	No	No	30000+
Hibernate	No	No	1000+
PPG–High Performance	Yes	Yes	14
ECG–High Performance	Yes	Yes	40
PPG and Impedance	Yes	Yes	50
PPG and ECG	Yes	Yes	40
PPG–All LEDs	Yes	Yes	20

The VSM watch is powered by a rechargeable 200 mAh battery.

All the default use cases are designed to maximize the performance. By modifying various parameters of the AFEs, the user can improve battery duration. For instance, in the ADPD4100, the default gain in the automatic gain control algorithm is set to 25 kΩ, so as to get best PPG performance with various skin tones. Setting the gain to 100 k or 200 k and lowering the current value results in significant improvement in battery duration for continuous usage.

MEMORY FOOTPRINT

The VSM watch hosts a 512 MB memory.

The actual capacity of the memory is determined by the type and number of sensors enabled and the sampling rate configured. See Table 15.

Table 15. Memory Capacity (in Hours) for Different Use Cases

Vital Signs	Memory Capacity (Hours)
PPG–High Performance	18
ECG–High Performance	22
PPG and Impedance	63
PPG and ECG	43
PPG–All LEDs	23

SCHEMATICS AND LAYOUTS

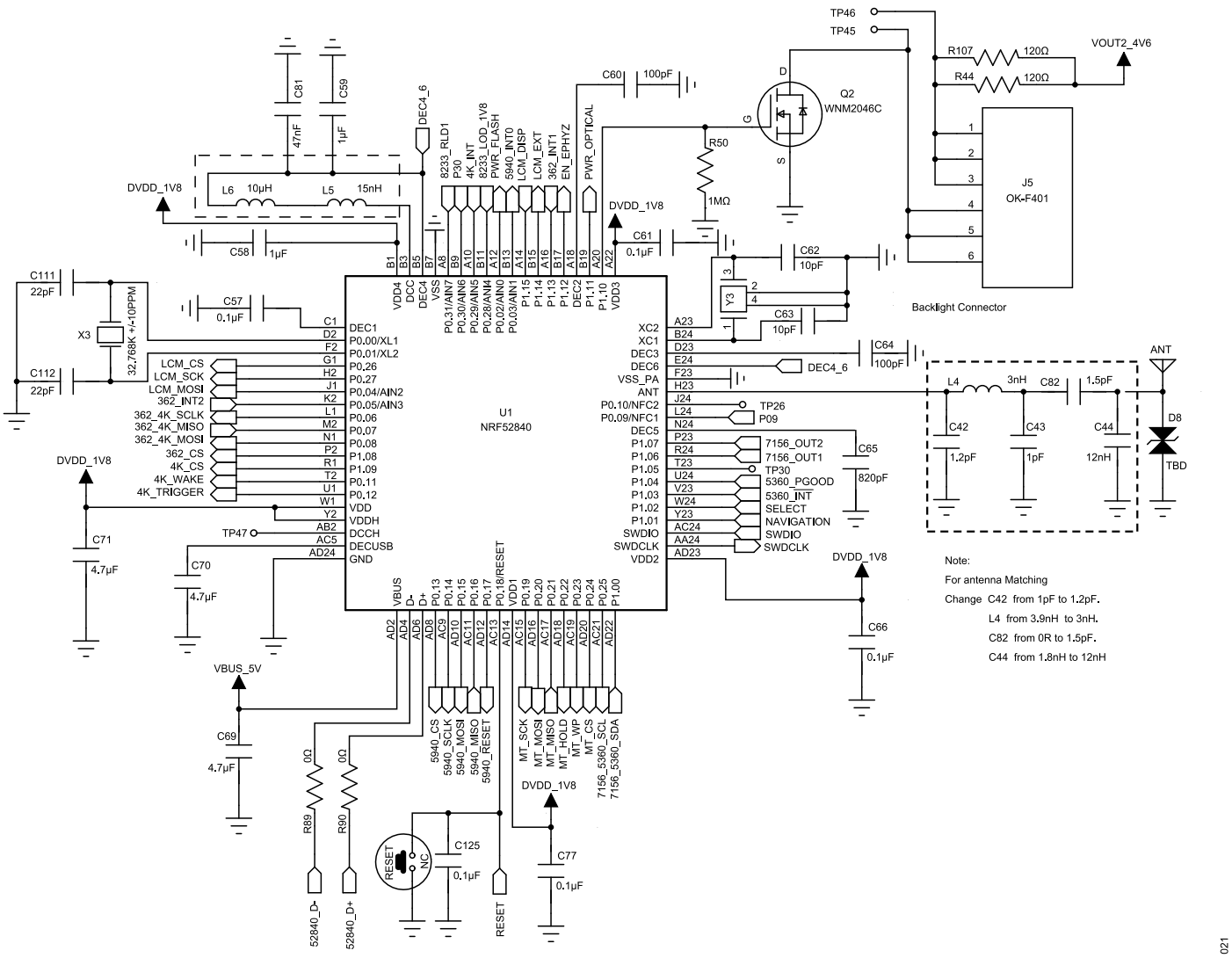

Figure 21. Microcontroller Connections

SCHEMATICS AND LAYOUTS

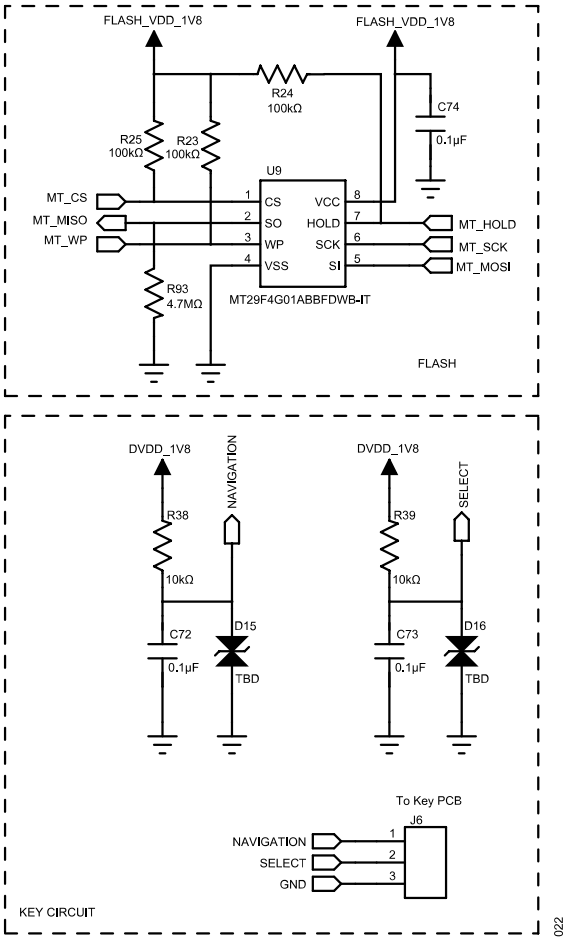

Figure 22. Memory and Buttons

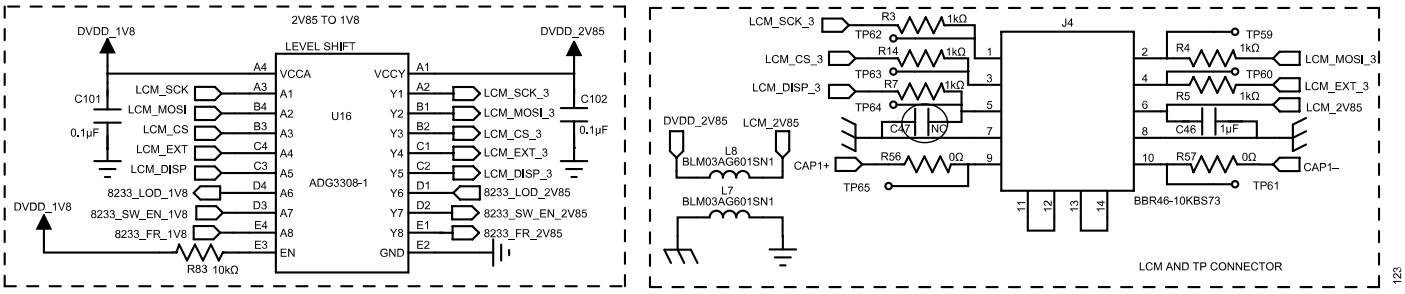

Figure 23. Level Shifter and Display Connections

SCHEMATICS AND LAYOUTS

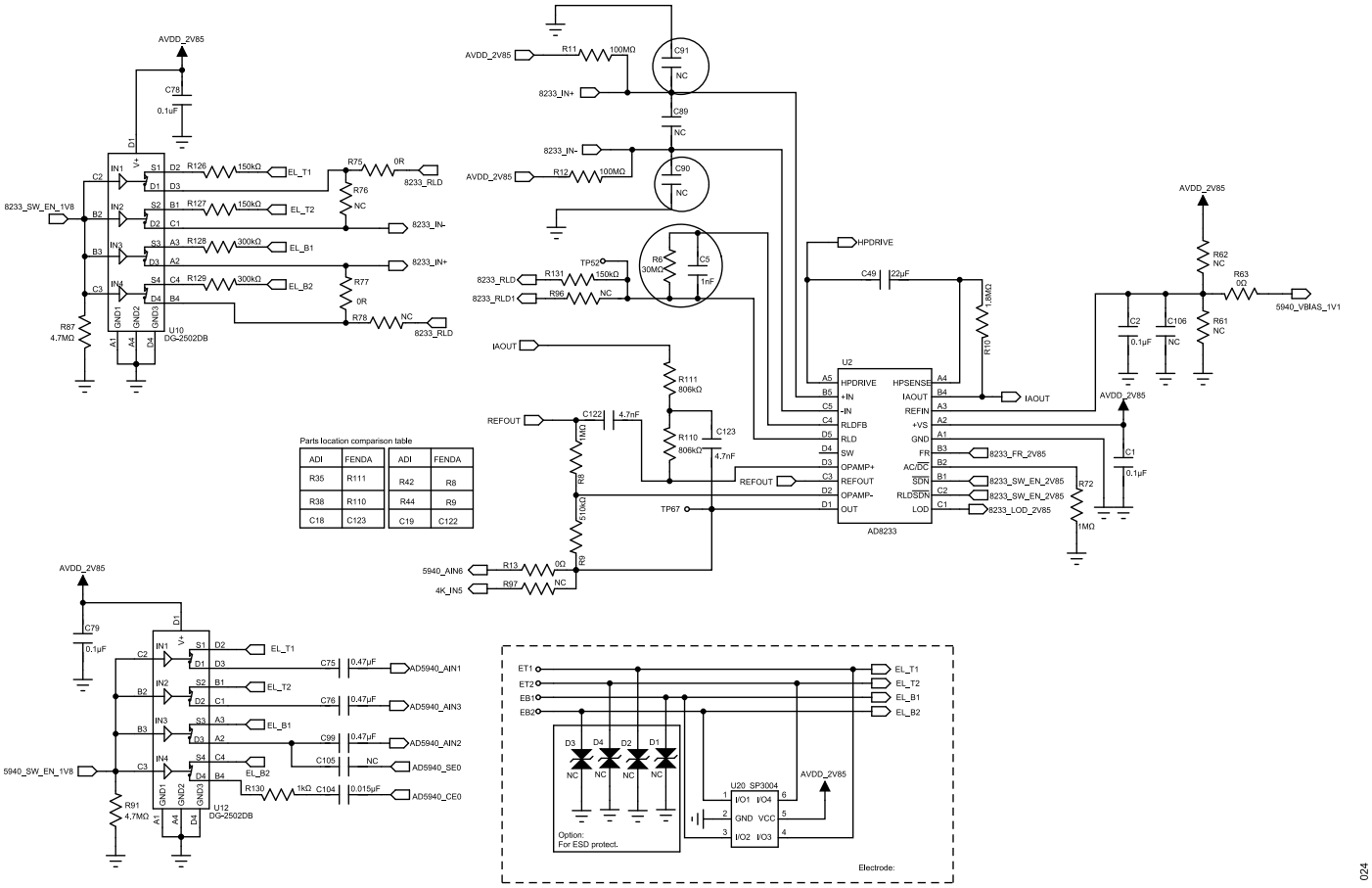

Figure 24. ECG Circuitry

SCHEMATICS AND LAYOUTS

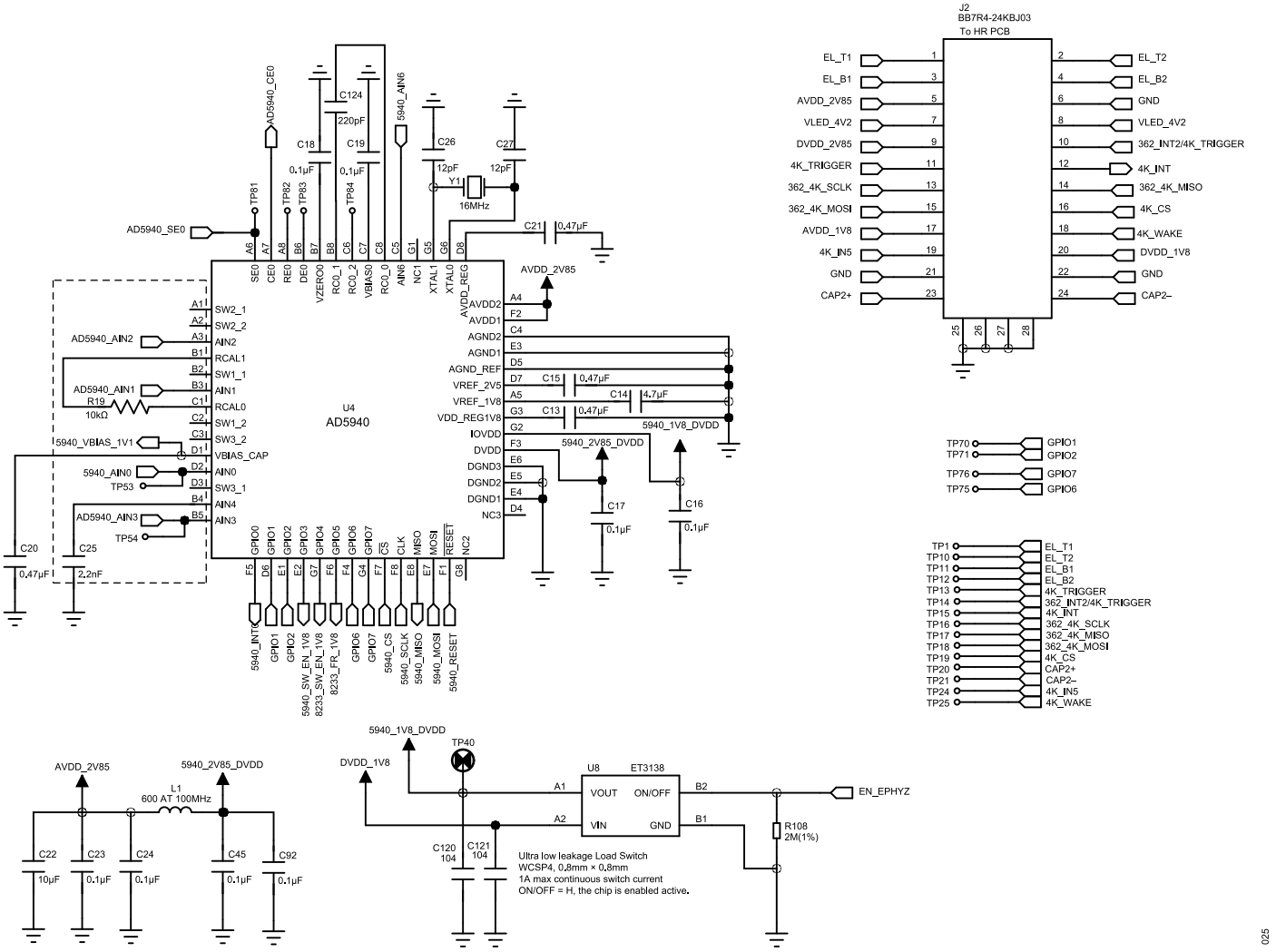

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Figure 25. AD5940 Circuitry and Connection to Optical Board

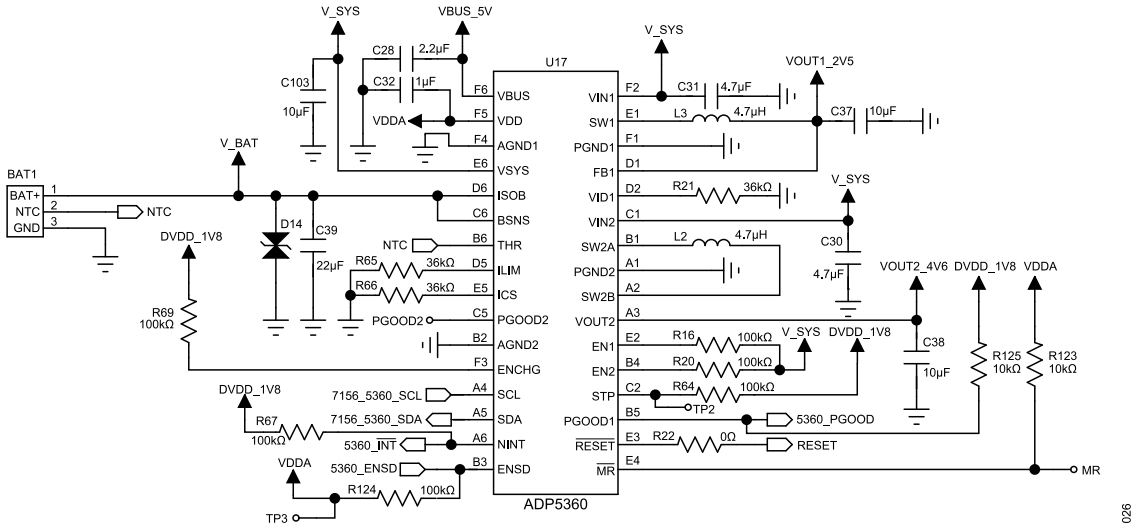

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Figure 26. PMIC Circuitry

SCHEMATICS AND LAYOUTS

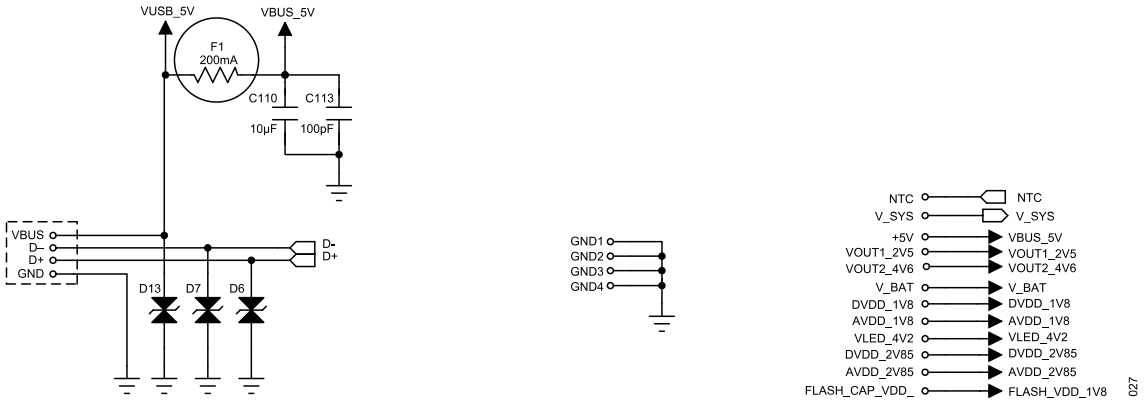

Figure 27. USB Connection and Test Points

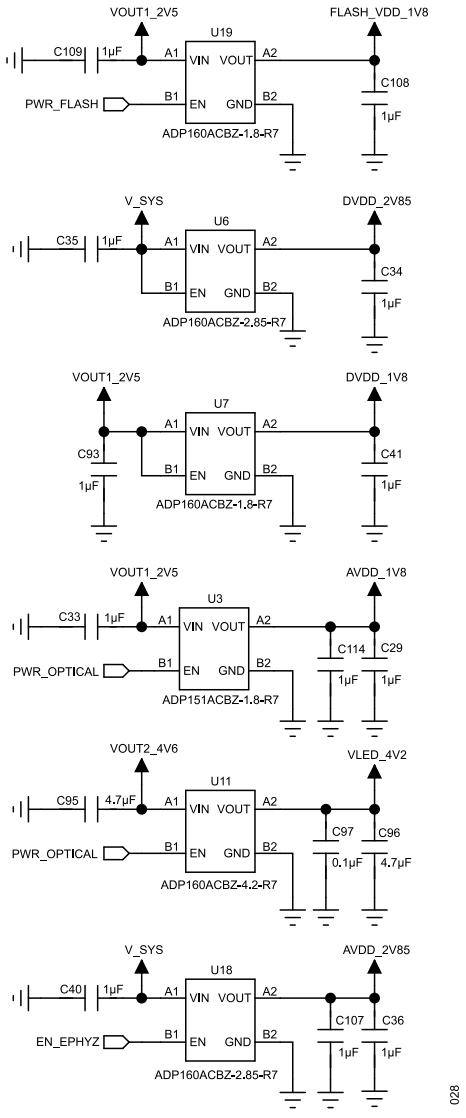

Figure 28. Voltage Regulation

SCHEMATICS AND LAYOUTS

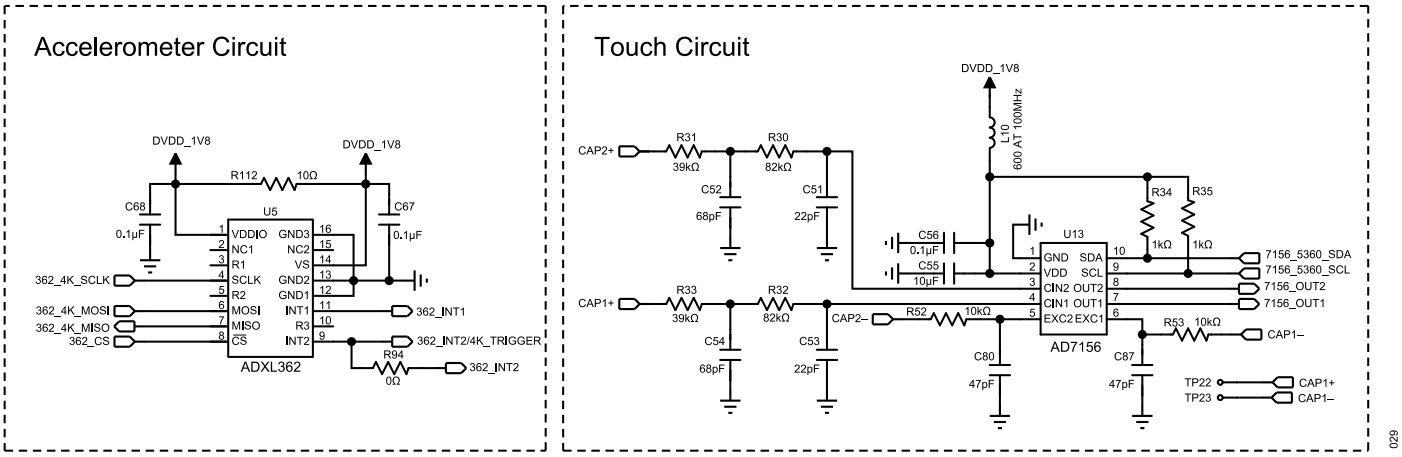

Figure 29. Accelerometer and Capacitive Touch Circuits

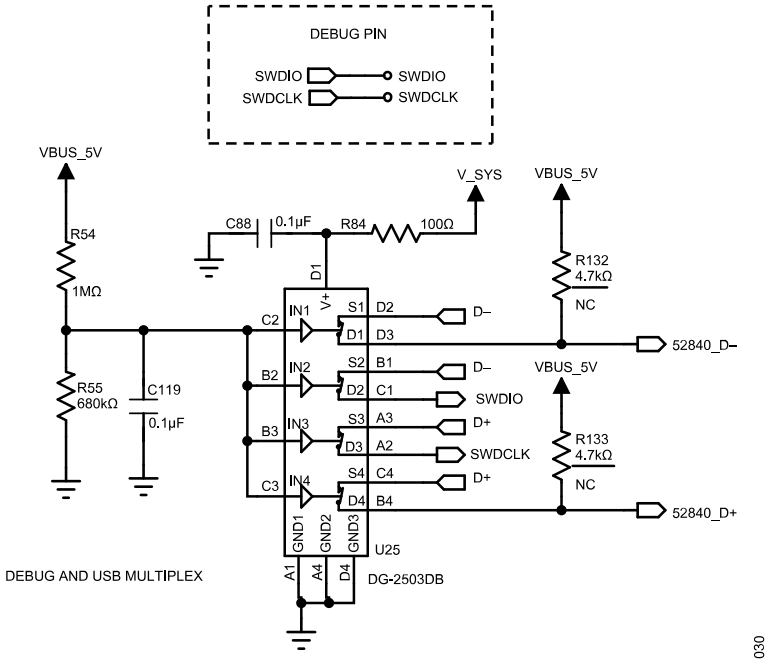

Figure 30. Debug Switch (Communication and FW Programming)

SCHEMATICS AND LAYOUTS

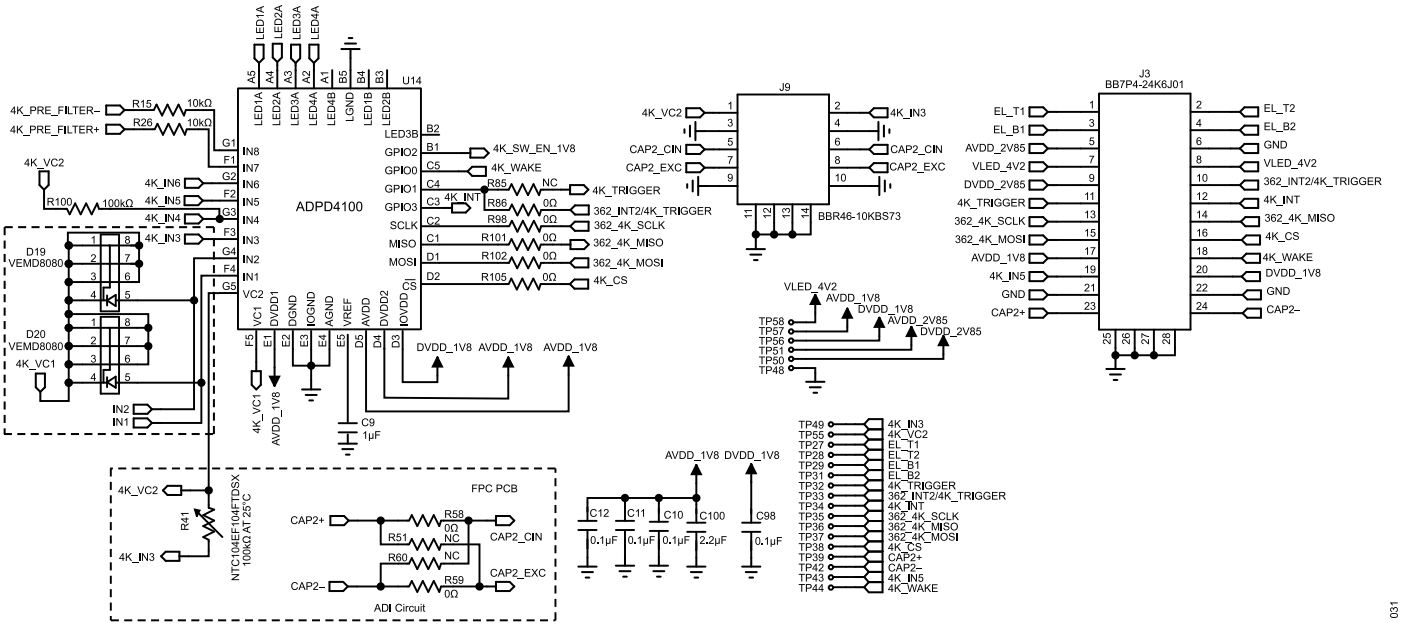

Figure 31. Optical Board Circuitry

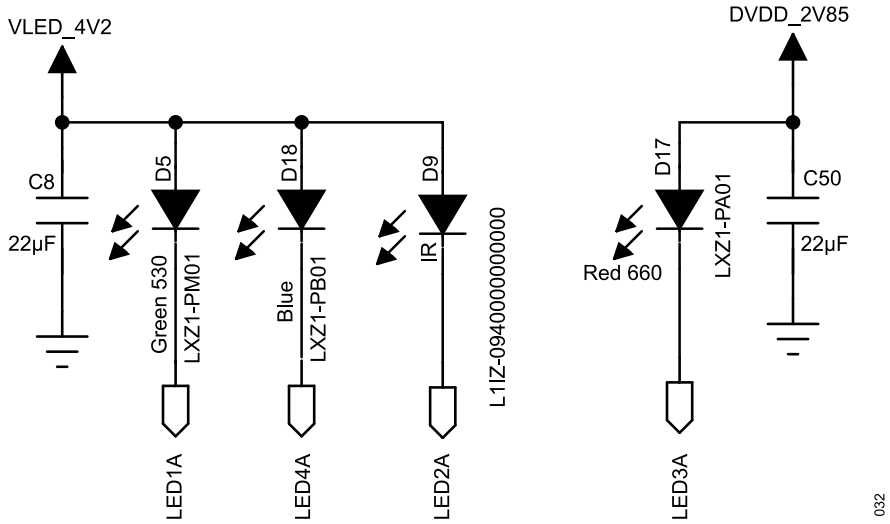

Figure 32. LED Connections

SCHEMATICS AND LAYOUTS

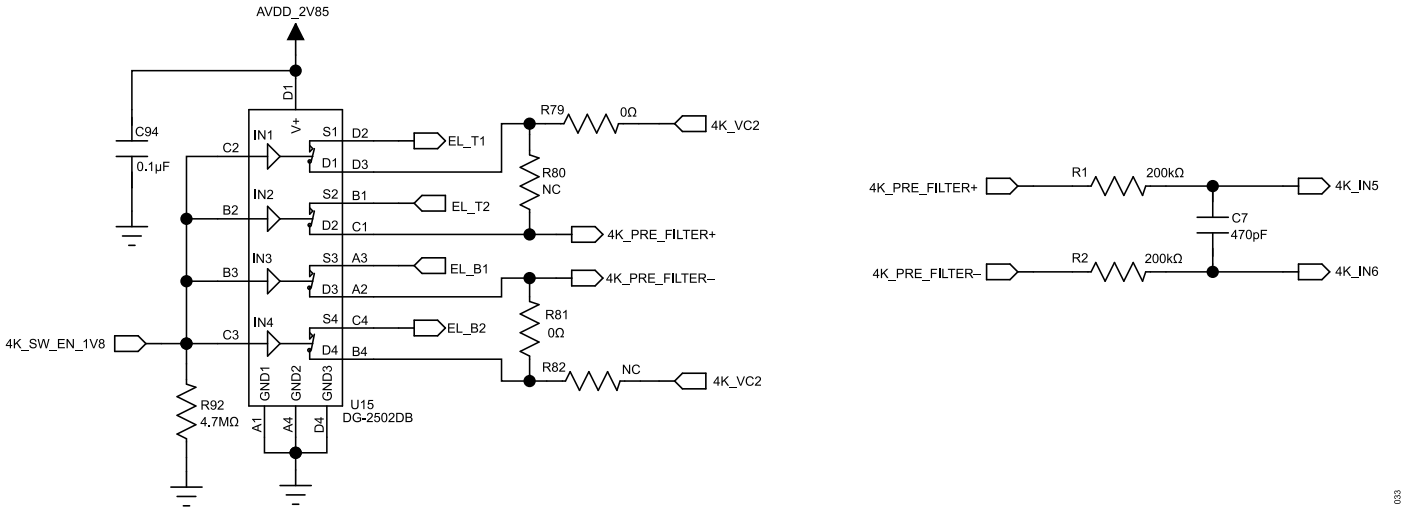

Figure 33. Electrode Connections for ADPD4100

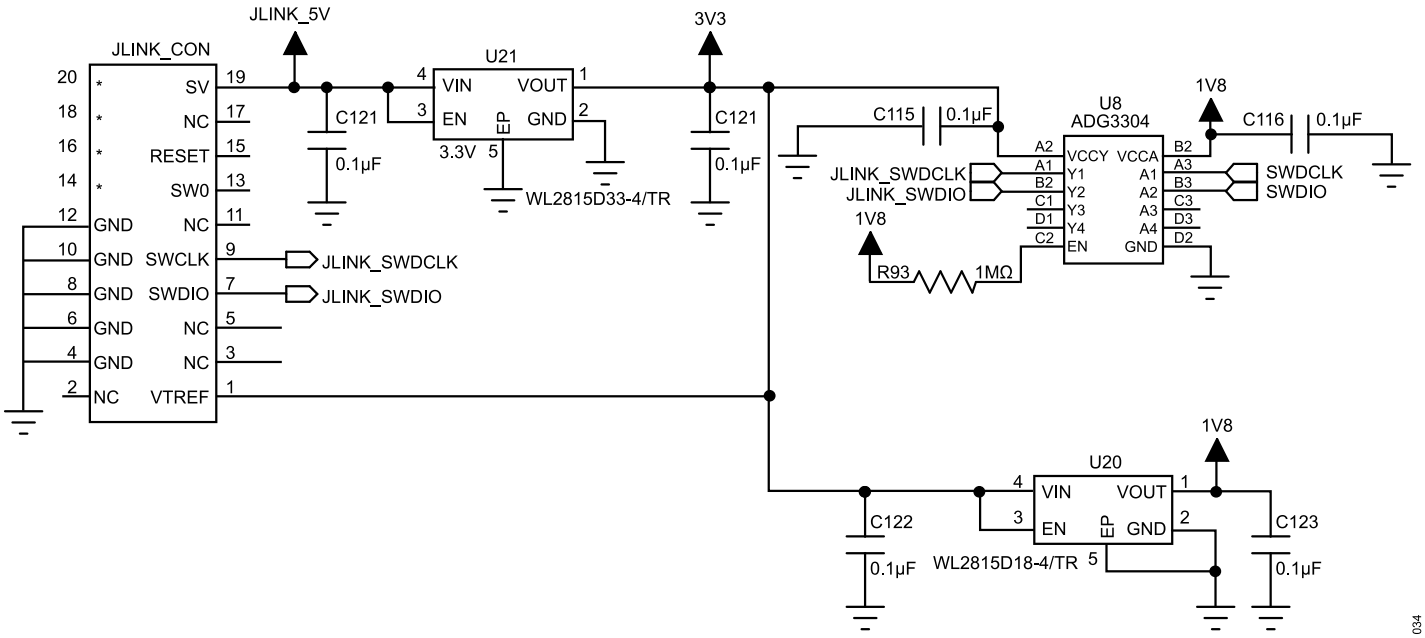

Figure 34. Debug Board Schematic

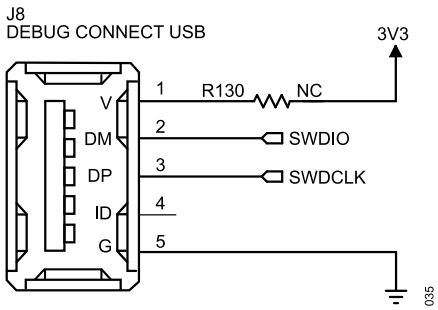

Figure 35. Debug Board Connector Pinout

SCHEMATICS AND LAYOUTS

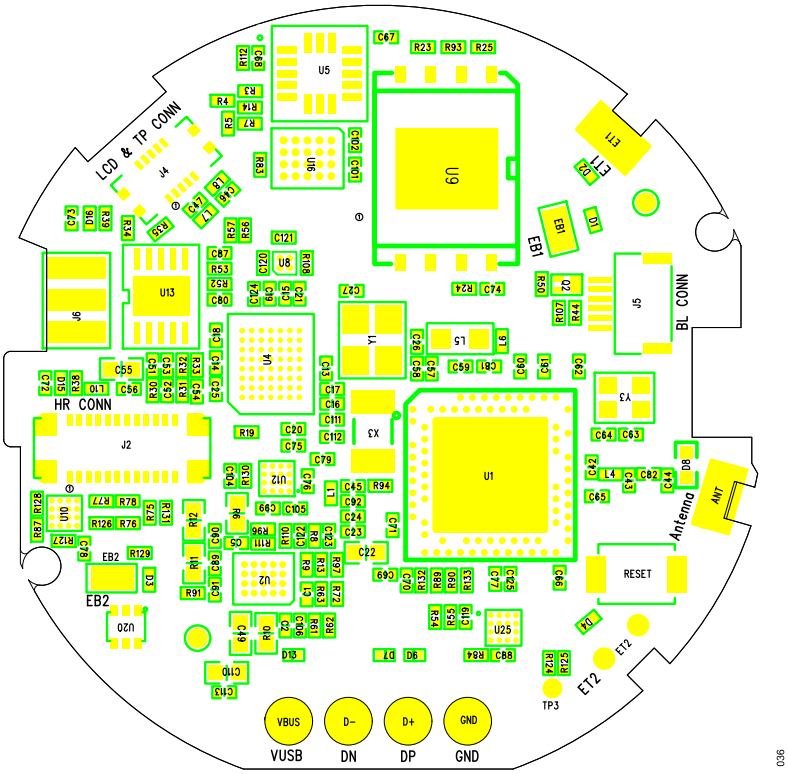

Figure 36. Main Printed Circuit Board (PCB) Layout Top View

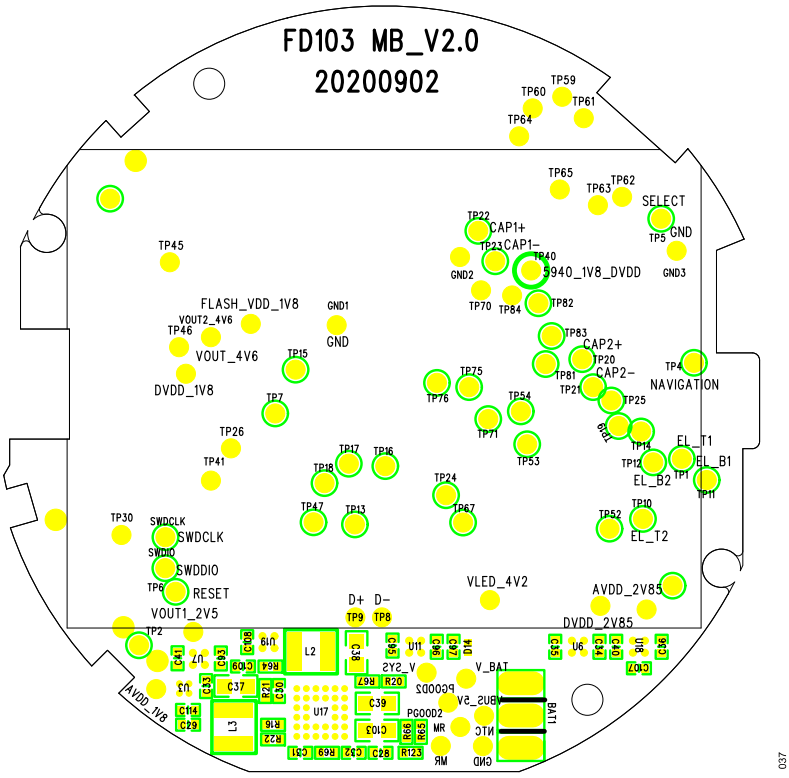

Figure 37. Main PCB Layout Bottom View

SCHEMATICS AND LAYOUTS

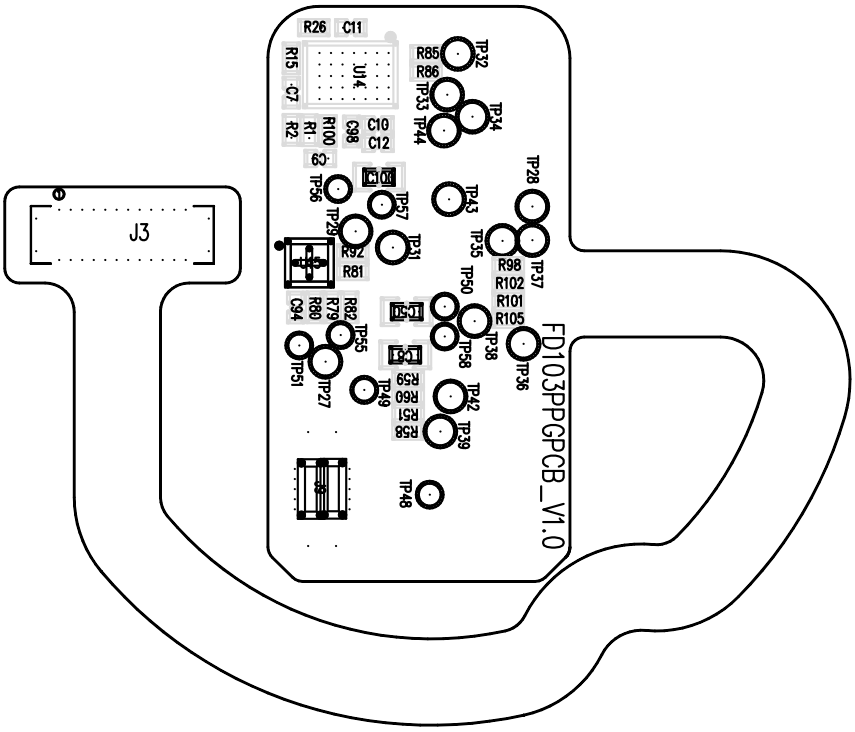

Figure 38. Optical PCB Layout Top View

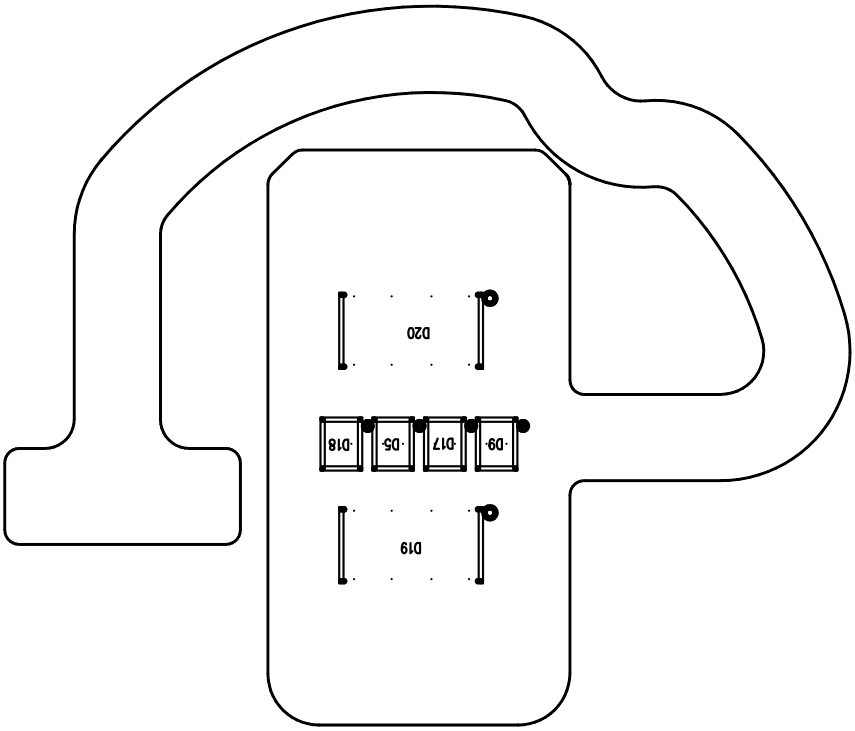

Figure 39. Optical PCB Layout Bottom View

SCHEMATICS AND LAYOUTS

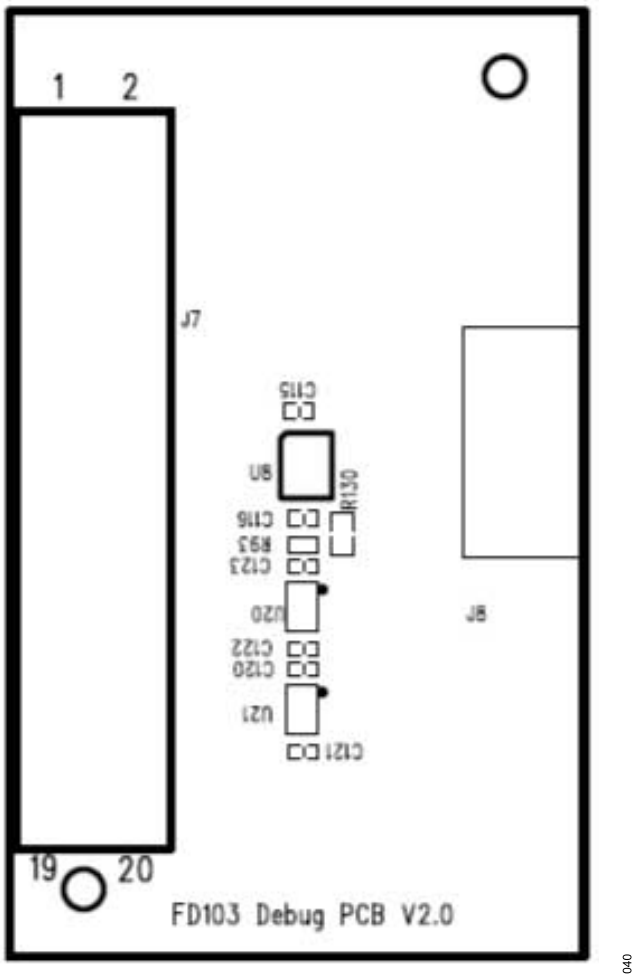

Figure 40. Debug PCB Layout Top View

FCC COMPLIANCE STATEMENT

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

ORDERING INFORMATION

BILL OF MATERIALS

Table 16. Electrical Bill of Materials[1]

No.	Reference Designator	Description	Part Number	Manufacturer	Qty
1	N/A	FD103 Analog Devices assembly	N/A	N/A	N/A
2	BAT1	Li-Ion battery, 3.8 V, 210 mAh, 26.5 mm × 20 mm × 4.0 mm, RoHS 2.0, REACH	N/A	N/A	1
3	For J5	Backlight	B0101105A	Ever Jet	1
4	N/A	FD103 key flexible printed circuit assembly, RoHS 2.0, REACH	N/A	N/A	1
5	N/A	Key FPC with 2-piece dome switch key, FPC, 50 mm × 25 mm × 0.7 mm	N/A	N/A	1
6	Navigation, action	Dome keys	N/A	N/A	2
7	N/A	FD103, liquid crystal module (LCM) with touch panel, RoHS 2.0, REACH	N/A	N/A	
8	For J1	Liquid crystal display (LCD), RGB, 30.591 mm × 29.291 mm × 0.844 mm, RoHS 2.0, REACH	LPM010M297B	JDI	1
9	N/A	Touch panel (29.09 mm × 29.09 mm × 0.2 mm) flexible printed circuit (21.31 mm × 12.1 mm × 0.13 mm)	N/A	N/A	1
10	J1	Flexible printed circuit (FPC) connector, 8-pin, 0.5 pitch, RoHS 2.0, REACH	10062827-0810EDLF	FCI	1
11	J7	Board-to-board connector, 0.35 mm pitch,10-pin, RoHS 2.0, REACH	BBR16-10K6S21	ACON	1
12	N/A	Main printed circuit board assembly, RoHS 2.0, REACH	N/A	N/A	1
13	R44, R107	Surface-mount device (SMD) resistors, 120 Ω, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	N/A	N/A	2
14	R128, R129	SMD resistors, 300 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	multiple	Yageo	2
15	C62, C63	SMD capacitors, medical special, 50 V, 10 pF, ±1%, NP0, 0201, RoHS 2.0, REACH	GRM0335C1H100FA01D	Murata	2
16	N/A	Scan code label, medical special, 7 mm × 7 mm, high temperature resistant, print, RoHS 2.0, REACH	N/A	N/A	1
17	N/A	8-layer PCB, RoHS 2.0, REACH	FR4	N/A	1
18	U4	SMD IC, ECG, 56-ball wafer level chip scale package (WLCSP), high precision, impedance, and electrochemical front end, RoHS 2.0, REACH	AD5940BCBZ	Analog Devices	1
19	U13	SMD IC, 2-channel capacitance converter, 10-lead lead frame chip scale package (LFCSP), RoHS 2.0, REACH	AD7156BCPZ-REEL	Analog Devices	1
20	U2	SMD IC, ECG front-end, 20-ball, backside-coated WLCSP, RoHS 2.0, REACH	AD8233ACBZ-R7	Analog Devices	1
21	U16	SMD IC, 8-channel level translators, 20-ball WLCSP, 2.5 mm × 2 mm, RoHS 2.0, REACH	ADG3308BCBZ-1-REEL	Analog Devices	1
22	U7, U19	SMD ICs, low dropout (LDO), 1.8 V, 150 mA, quiescent current (I_Q), 1 µA, 4-ball WLCSP, RoHS 2.0, REACH	ADP160ACBZ-1.8-R7	Analog Devices	2
23	U11	SMD IC, LDO, 4.2 V, 150 mA, I_Q, 1 µA, 4-ball WLCSP, RoHS 2.0, REACH	ADP160ACBZ-4.2-R7	Analog Devices	1
24	U6, U18	SMD ICs, LDO, 2.85 V, 150 mA, I_Q, 1 µA, 4-ball WLCSP, RoHS 2.0, REACH	ADP160ACBZ-2.85-R7	Analog Devices	2
25	U17	SMD, power management integrated circuit (PMIC) with buck and buck boost, RoHS 2.0, REACH	ADP5360ACBZ-1-R7	Analog Devices	1
26	U5	SMD IC, accelerometer, 16-terminal land grid array (LGA), 3 mm × 3.25 mm, RoHS 2.0, REACH	ADXL362BCCZ-RL7	Analog Devices	1
27	U10, U12	SMD ICs, quad single-pole, single throw (SPST) analog switches, WCSP-16, RoHS 2.0, REACH	DG-2502DB-T2-GE1	Vishay	2
28	U25	SMD IC, quad SPST analog switches, WCSP-16, RoHS 2.0, REACH	DG-2503DB-T2-GE1	Vishay	1
29	U9	SMD IC, flash, 4 GB, U-PDFN, RoHS 2.0, REACH	MT29F4G01ABBFDWB-IT:F	Micron	1

ORDERING INFORMATION

Table 16. Electrical Bill of Materials[1]

No.	Reference Designator	Description	Part Number	Manufacturer	Qty
30	U1	SMD IC, medical special, AQFN73, 7 mm × 7 mm, RoHS 2.0, REACH	NRF52840-QIAA-R D00	Nordic Semiconductor	1
31	U8	SMD IC, load switch, input, 1.2 V to 5.5 V, WLCSP4, RoHS 2.0, REACH	ET3138	Luxeon	1
32	C1, C2, C16, C17, C18, C19, C23, C24, C45, C56, C57, C61, C66, C67, C68, C72, C73, C74, C77, C78, C79, C88, C92, C97, C101, C102, C119, C120, C121, C125	SMD capacitors, 10 V, 0.1 µF, ±10%, X5R, 0201, RoHS 2.0, REACH	CC0201KRX5R6BB104	Yageo	30
33	C13, C15, C20, C21, C75, C76, C99	SMD capacitors, 6.3 V, 0.47 µF, ±10%, X5R, 0201, RoHS 2.0, REACH	CC0201KRX5R5BB474	Yageo	7
34	C44	SMD inductor, 12 nH, ±3%, 500 MHz, 690 MΩ, 250 mA, 0201, RoHS 2.0, REACH	LQP03TQ12NH02D	Murata	1
35	C60, C64, C113	SMD capacitors, medical special, 25 V, 100 pF, ±5%, NP0, 0201, RoHS 2.0, REACH	CC0201JRNPO8BN101	Yageo	3
36	C22, C37, C38, C55, C103	SMD capacitors, 6.3 V, 10 µF, ±20%, X5R, 0402, RoHS 2.0, REACH	CL05A106MQ5NUNC	Samsung	5
37	C110	SMD capacitor, medical special, 10 V, 10 µF, ±20%, X5R, 0402, RoHS 2.0, REACH	CL05A106MP5NUNC	Samsung	1
38	C26, C27	SMD capacitors, 50 V, 12 pF, ±5%, NP0, 0201, RoHS 2.0, REACH	CC0201JRNPO9BN120	Yageo	2
39	C43	SMD capacitor, 25 V, 1 pF, ±0.05 pF, 0201, RoHS 2.0, REACH	GJM0335C1E1R0WB01D	Murata	1
40	C29, C32, C33, C34, C35, C36, C40, C41, C46, C58, C59, C93, C107, C108, C109, C114	SMD capacitors, 10 V, 1 µF, ±20%, X5R, 0201, RoHS 2.0, REACH	CL03A105MP3NSNC	Samsung	16
41	C25	SMD capacitor, 2.2 nF, X5R, crystal, 0201, RoHS 2.0, REACH	C0201X5R222K250NTA		1
42	C28	SMD capacitor, medical special, 10 V, 2.2 µF, ±10%, X5R, 0201, RoHS 2.0, REACH	GRM033R61A225KE47D	Murata	1
43	C51, C53, C111, C112	SMD capacitors, 25 V, 22 pF, ±5%, NP0, 0201, RoHS 2.0, REACH	CC0201JRNPO8BN220	Yageo	4
44	C39, C49	SMD capacitors, 6.3 V, 22 µF, ±20%, X5R, 0402, RoHS 2.0, REACH	CL05A226MQ5QUNC	Samsung	2
45	C14, C30, C31, C69, C70, C71, C95, C96	SMD capacitors, 6.3 V, 4.7 µF, ±20%, X5R, 0201, RoHS 2.0, REACH	GRM035R60J475ME15D	Murata	8
46	C81	SMD capacitor, 47 nF, 6.3 V, X5R, ±10%, 0201, RoHS 2.0, REACH	02016D473KAT2A		1
47	C80, C87	SMD capacitors, 25 V, 47 pF, ±5%, NP0, 0201, RoHS 2.0, REACH	CC0201JRNPO8BN470	Yageo	2
48	C52, C54	SMD capacitors, 50 V, 68 pF, ±5%, C0G, NP0, 0201, RoHS 2.0, REACH	GRM0335C1H680JA01D	Murata	2
49	C65	SMD capacitor, 25 V, 820 pF, ±10%, X7R, 0201, RoHS 2.0, REACH	GRM033R71E821KA01D	Murata	1
50	X3	SMD crystal, 32.768 kHz, ±10 ppm, RoHS 2.0, REACH	N/A	N/A	1
51	Y1	SMD crystal, 16 MHz, ±20 ppm, 8 pF, 2520, RoHS 2.0, REACH	N/A	N/A	1
52	Y3	SMD crystal, medical special, 32 MHz, ±20 ppm, 8 pF, 2016, RoHS 2.0, REACH	XRCGB32M000F2P10R0	Murata	1
53	D6, D7, D13, D14	SMD transient voltage suppression (TVS) diodes, 0201, RoHS 2.0, REACH	LESD11D5.0CT5G	LRC	4
54	D8	SMD TVS diode, 0402, RoHS 2.0, REACH	ESD5311N-2/TR	Willsemi	1
55	D15, D16	SMD TVS diodes, 0201, RoHS 2.0, REACH	BTRD02A035	B-TRON	2
56	L5	SMD inductor, 10 µH, ±20%, 0603, RoHS 2.0, REACH	MGFL1608F100MT-LF	Meije	1
57	L6	SMD power inductor, 15 nH, ±5%, 300 mA, 0201, RoHS 2.0, REACH	LQP03HQ15NJ02	Murata	1
58	L4	SMD inductor, 0201, 3.0 nH, ±0.1 nH, 0.25 Ω, 450 mA, research part, RoHS 2.0, REACH	LQP03TG3N0B02D	Murata	1

ORDERING INFORMATION

Table 16. Electrical Bill of Materials[1]

No.	Reference Designator	Description	Part Number	Manufacturer	Qty
59	L2, L3	SMD inductors, 4.7 µH, ±20%, 1 MHz, 252 MΩ, maximum 1.12 A, 2016, RoHS 2.0, REACH	VLS201612CX-4R7M	TDK	2
60	L1, L7, L8, L10	SMD beads, 600 Ω at 100 MHz, 100 mA, 0201, RoHS 2.0, REACH	BLM03AG601SN1	Murata	4
61	Q2	SMD metal-oxide semiconductor field effect transistor (MOSFET), medical special, n-channel, 0.7 A, 20 V, 0402, RoHS 2.0, REACH	WNM2046	Willsemi	1
62	R13, R22, R56, R57, R63, R75, R77, R89, R90, R94	SMD resistors, medical special, 0 Ω, 1/20 W, ±5%, 0201, RoHS 2.0, REACH	RC0201JR-070RL	Yageo	10
63	R16, R20, R23, R24, R25, R64, R67, R69, R124	SMD resistors, medical special, 100 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-07100KL	Yageo	9
64	R38, R39, R52, R53, R83, R123, R125	SMD resistors, medical special, 10 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-0710KL	Yageo	7
65	R8, R50, R54, R72	SMD resistors, medical special, 1 MΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-071ML	Yageo	4
66	R108	SMD resistor, medical special, 2 MΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-072ML	Yageo	1
67	R84	SMD resistor, medical special, 100 Ω, 1/20 W, ±5%, 0201, RoHS 2.0, REACH	RC0201JR-07100RL	Yageo	1
68	R10	SMD resistor, 1.8 MΩ, 1/16 W, ±1%, 0402, RoHS 2.0, REACH	RC0402FR-071M8L	Yageo	1
69	R11, R12	SMD resistors, 100 MΩ, 1/16 W, ±5%, 0402, RoHS 2.0, REACH	RVC0402JT100M	SEI	2
70	R21, R65, R66	SMD resistors, 36 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201JR-0736KL	Yageo	3
71	R55	SMD resistor, 680 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	N/A		1
72	R31, R33	SMD resistors, 39 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-0739KL	Yageo	2
73	R30, R32	SMD resistors, 82 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	N/A	N/A	2
74	R87, R91, R93	SMD resistors, 4.7 MΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	N/A	N/A	3
75	J2	B-B connector, 0.4 mm pitch, 24-pin, RoHS 2.0, REACH	BB7R4-24KBJ03	ACON	1
76	J5	B-B connector, 0.4 mm pitch, 6-pin, RoHS 2.0, REACH	OK-F401-06125	OCN	1
77	J4	B-B connector, 0.35 mm pitch, 10-pin, RoHS 2.0, REACH	BBR46-10KBS73	ACON	1
78	EB1, EB2	FD103, SMT, pogo ping, 2.2 mm × 1.2 mm × 1.2 mm, SUS301, golden, gold-plated, salt spray, 48 H, SMD, XINGWEI PN:O-shape12B, RoHS 2.0, REACH			2
79	U3	SMD IC, LDO, 1.8 V, 4-ball WLCSP, RoHS 2.0, REACH	ADP151ACBZ-1.8-R7	Analog Devices	1
80	U20	SMD IC, TVS diode array, SOT-563, RoHS 2.0, REACH	SP3004-04XTG	Littelfuse	1
81	R34, R35, R130	SMD resistors, 1 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	R0201RXX102XF20LHZ	EYANG	3
82	R112	SMD resistor, 10 Ω, 1/20 W, ±5%, 0201, RoHS 2.0, REACH	N/A	N/A	1
83	R126, R127, R131	SMD resistors, 150 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	N/A	N/A	3
84	R9	SMD resistor, 510 kΩ, 1/20 W, ±5%, 0201, RoHS 2.0, REACH	N/A	N/A	1
85	R6	SMD resistor, 30 MΩ, 1/16 W, ±1%, 0402, RoHS 2.0+, reach	0402WGF3005TCE	N/A	1
86	R110, R111	SMD resistors, 806 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RTT018063FTH	N/A	2
87	R19	SMD resistor, 10 kΩ, 1/20 W, 0201, ±0.1%, RoHS 2.0, REACH	RTT011002BTH	N/A	1
88	C5	SMD capacitor, 25 V, 1 nF±10%, X7R, 0201, RoHS 2.0, REACH	GRM033R71E102KA01D	Murata	1
89	C122, C123	SMD capacitors, 6.3 V,4.7 nF, ±10%, X5R, 0201, RoHS 2.0, REACH	N/A	N/A	2
90	C124	SMD capacitor, 25 V, 220 pF, ±5%, NP0, 0201, RoHS 2.0, REACH	N/A	N/A	1
91	C104	SMD capacitor, 10 V, 15 nF, 10%, X5R, 0201, RoHS 2.0, REACH	0201X153K100CT	N/A	1
92	R3, R4, R5, R7, R14	SMD resistors, medical special, 1 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-071KL	Yageo	5
93	C42	SMD capacitor, medical special, 50 V, 1.2 pF, ±0.1 pF, NP0, 0201, RoHS 2.0, REACH	GRM0335C1H1R2BA01D	Murata	1
94	C82	SMD capacitor, 25 V, 1.5 pF, ±0.05 pF, 0201, RoHS 2.0, REACH	GJM0335C1E1R5WB01D	Murata	1
95	N/A	FD103, debug adapter PCBA, RoHS 2.0, REACH	N/A	N/A	1
96	U8	SMD IC, level translator, 12-ball WLCSP, RoHS 2.0, REACH	ADG3304BCBZ-REEL7	Analog Devices	1

ORDERING INFORMATION

Table 16. Electrical Bill of Materials[1]

No.	Reference Designator	Description	Part Number	Manufacturer	Qty
97	U20	SMD IC, 1.8 V LDO, DFN1010-4L, RoHS 2.0, REACH	WL2815D18-4/TR	Willsemi	1.0
98	R93	SMD resistor, 1 MΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	N/A	N/A	1.0
99	C115, C116, C120, C121, C122, C123	SMD capacitors, 10 V, 0.1 µF, ±10%, 0201, RoHS 2.0, REACH	C0603X5R1A104K030BC	TDK	6.0
100	U21	SMD IC, 3.3 V LDO, DFN1010-4L, RoHS 2.0, REACH	WL2815D33-4/TR	Willsemi	1.0
101	J8	Micro USB, 5 pF, silver, USB plug, 12.1 mm × 9.23 mm × 2.85 mm, RoHS 2.0, REACH	N/A	N/A	1.0
102	N/A	4-layer PCB, 1.0 mm, FR4, green, white, 33 mm × 20 mm × 1.0 mm, RoHS 2.0, REACH	N/A	N/A	1.0
103	N/A	FD103, HR SMTA assembly, RoHS 2.0, REACH	N/A	N/A	N/A
104	N/A	Scan code label, medical special, 7 mm × 7 mm, high temperature resist, print, RoHS 2.0, REACH	N/A	N/A	1
105	U15	SMD IC, quad single-pole, single throw (SPST) analog switches, WCSP16, RoHS 2.0, REACH	DG-2502DB-T2-GE1	Vishay	1
106	U14	SMD IC, AFE, 35-ball WLCSP, 1.8 V, −40°C to +85°C, RoHS 2.0, REACH	ADPD4100BCBZR7	Analog Devices	1
107	D5	SMD LED, green, 1.7 mm × 1.3 mm × 0.59 mm, RoHS 2.0, REACH	LXZ1-PM01	LUXEON	1
108	D9	Infrared emission tube, SMD, 1.90 mm × 1.37 mm × 0.90 mm, 1 A, 2.9 V, RoHS 2.0, REACH	L1IZ-0940000000000	LUXEON	1
109	D17	SMD LED, red, 1.7 mm × 1.3 mm × 0.59 mm, RoHS 2.0, REACH	LXZ1-PA01	LUXEON	1
110	D18	SMD LED blue, 1.7 mm × 1.3 mm × 0.59 mm, RoHS 2.0, REACH	LXZ1-PB01	LUXEON	1
111	D19, D20	Silicone pin photodiodes, SMT IC, RoHS 2.0, REACH	VEMD8080	N/A	2
112	J9	B-B connector, 0.35 mm pitch, 10-pin, RoHS 2.0, REACH	BBR46-10KBS73	ACON	1
113	J3	B-B connector, 0.4 mm pitch, 24-pin, RoHS 2.0, REACH	BB7P4-24K6J01	ACON	1
114	N/A	SMD resistor, medical special, 0 Ω, 1/20 W, ±5%, 0201, RoHS 2.0, REACH	RC0201JR-070RL	Yageo	9
115	R100	SMD resistor, medical special, 100 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-07100KL	Yageo	1
116	R92	SMD resistor, 4.7 MΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	multiple	N/A	1
117	C10, C11, C12, C94, C98	SMD capacitors, 10 V, 0.1 µF±10%, X5R, 0201, RoHS 2.0, REACH	CC0201KRX5R6BB104	Yageo	5
118	C8, C50	SMD capacitors, 6.3 V, 22 µF, ±20%, X5R, 0402, RoHS 2.0, REACH	CL05A226MQ5QUNC	Samsung	2
119	C7	SMD capacitor, 25 V, 470 pF, ±5%, C0G, 0201, RoHS 2.0, REACH	GRM0335C1E471JA01D	Murata	1
120	C9	SMD capacitor, 10 V1 µF, ±20%, X5R, 0201, RoHS 2.0, REACH	CL03A105MP3NSNC	Samsung	1
121	N/A	6-layer PCB, RoHS 2.0, REACH	FR4	N/A	1
122	R15, R26	SMD resistors, medical special, 10 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-0710KL	Yageo	2
123	R1, R2	SMD resistors, medical special, 200 kΩ, 1/20 W, ±1%, 0201, RoHS 2.0, REACH	RC0201FR-07200KL	Yageo	2
124	C100	SMD capacitor, 6.3 V, 2.2 µF, ±20%, X5R, 0402, RoHS 2.0, REACH	CL05A225MQ5NSNC	Samsung	1
125	J8	B-B connector, thermistor connector	BBR16-10K6S21	ACON	1
126	R41	SMD thermistor	NTC104EF104FTDSX	TDK	1

[1] N/A means not applicable.

ORDERING INFORMATION

Table 17. Mechanical Bill of Materials

No.	Description	Material
1	Top cover case	Panlite 3415 Black
2	Bottom case	CHIMEI 757 ABS
3	Bottom lens	Bayer PC2405
4	Bottom plug	Bayer 9380
5	Electrodes	Stainless steel
6	Antenna	Stainless steel
7	Buttons	Stainless steel
8	Charging case	CHIMEI 757 ABS
9	Watch strap	Silicone
10	Strap keeper	SUS304

DEVICE MODELS

Table 18. Device Models

Model	Description
EVAL-HCRWATCH4Z	Analog Devices study watch for VSM solutions evaluation

I^2C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

ESD Caution
ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.