User Manual

DA14681 Wearable Development Kit Hardware Manual

UM-B-077

Abstract

This document describes the hardware design of the DA14681 Wearable Development Kit, which is based on the Dialog Semiconductor DA14681 Bluetooth® low energy SoC. This wearable module includes a geomagnetic sensor, an accelerometer, a combined environmental sensor that can sense temperature, pressure and humidity levels, a heart rate monitor, and NFC functionality. It can display environmental readings as well as health data such as step count, distance traveled, calories burned and heart rate. All these functions are combined in a wearable-like watch, enabling the user to physically wear it and keep a track of his day-to-day activities.

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1 Terms and Definitions

APDU	Application Protocol Data Unit
BLE	Bluetooth low energy
CIB	Communication Interface Board
DCR	Direct Current Resistance
DCXO	Digitally Controlled Crystal Oscillator
HRM	Heart Rate Monitor
HW	hardware
IF	Infrared
IFA	Inverted-F Antenna
IoT	Internet of Things
JTAG	Join Test Action Group (test interface)
LED	Light Emitting Diode
LDO	Low Drop-Out (regulator)
NFC	Near Field Communication
PCBA	Printed Circuit Board Assembled
RF	Radio Frequency
RTC	Real Time Clock
SE	Secure Element
SMD	Surface Mounted Device
SOC	System on Chip
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus

2 System Overview

2.1 Features

- Highly integrated Dialog Semiconductor DA14681 Bluetooth® Smart SoC
- Stand-alone module
- High capacity slim size 190 mAh rechargeable LiPo battery
- Low power 80 µA (sleep current)
- Low cost PCB touch pads
- Incorporated heart rate monitor
- Environmental sensor for temperature, humidity and air pressure readings
- Combined Gyro/Accelerometer sensor unit
- NFC module for payment applications
- Access to processor via JTAG and UART from the enclosure
- Compact design
- 35 mm x 39 mm x 9 mm PCBA

2.2 Electrical Characteristics

Table 1: DA14681 Wearable Reference Design

Parameter	Description	Conditions	Min	Typ	Max	Unit
V_{BAT}	battery supply voltage		3.6	3.8	4.2	V
I_{SLEEP_TOTAL}	average sleep current	conducted; T_A = 25 °C		18		µA
$I_{CONNECTED}$	average current when connected to a host	conducted; T_A = 25 °C		550		µA
f_{OPER}	operating frequency		2400		2483.5	MHz
P_O	RF output power	conducted; $\mathbf{V}_{BAT}$ = 3 V; T_A = 25 °C		0		dBm

3 Introduction

Wearable devices are miniature electronic devices worn on the body, often integrated with or designed to replace an existed accessory, such as a watch. This market segment is currently booming and is enabled by Internet of Things (IoT) technology. Thus the need for smaller, low power devices is rapidly increasing. Some of the current trends are smart watches, smart glasses, and sports and fitness activity tracker equipment. In addition to the consumer market, the medical industry is creating a demand for such devices that monitor physical conditions and functions.

The DA14681 wearable reference design described in this manual, is a low power and compact prototype that can easily fit in a suitable enclosure to form a wearable smart watch. The PCB layout of the wearable reference design is shown in Figure 2 (top view) and Figure 3 (bottom view).

Each subblock of the system is described in sufficient detail to quickly start using it and test the functionality. Section 7 presents the actual power measurements taken and describes the wrist watch type enclosure.

The top level block diagram of the reference design is illustrated in Figure 1.

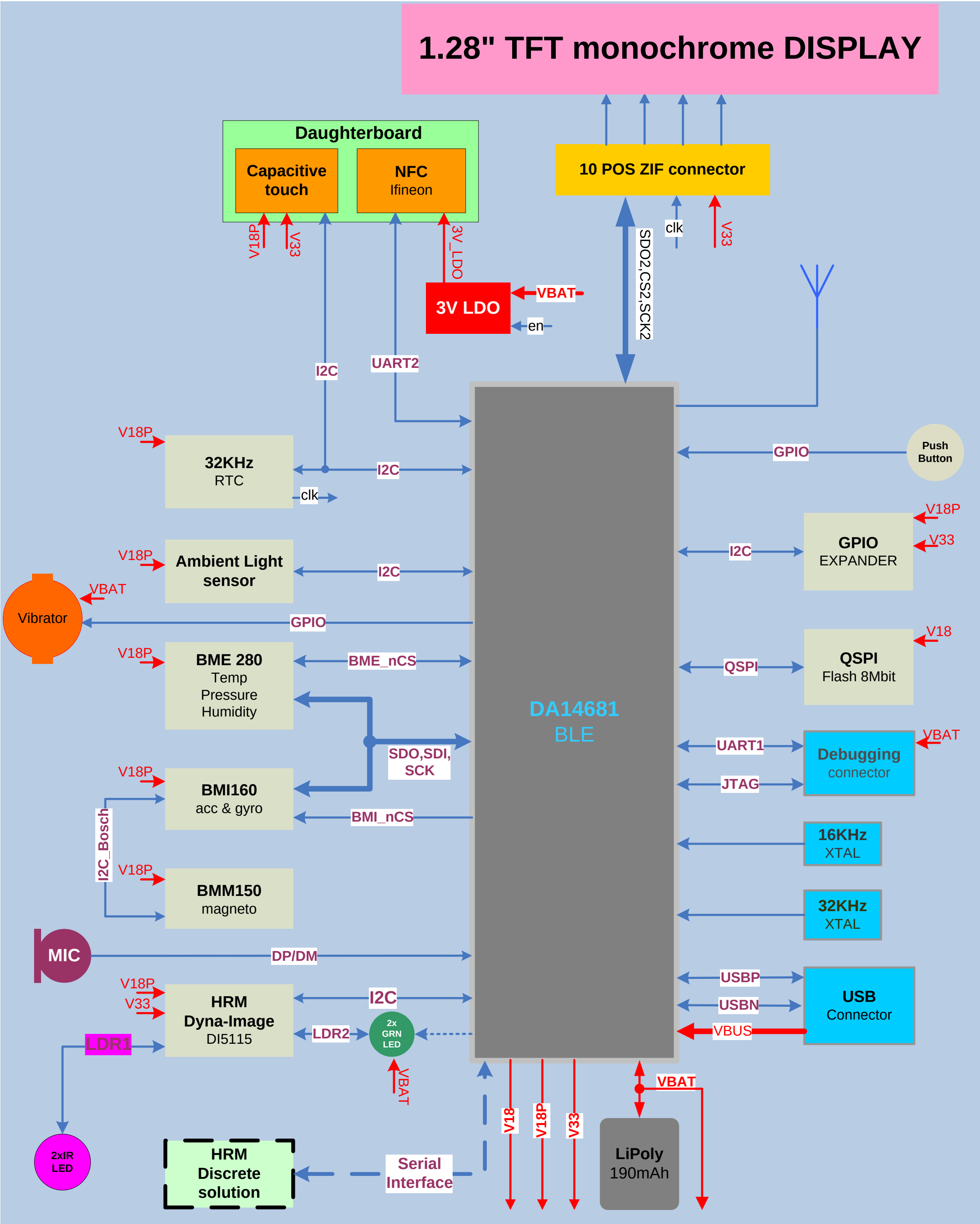

Figure 1: Top Level Block Diagram of the DA14681 Wearable Reference Design

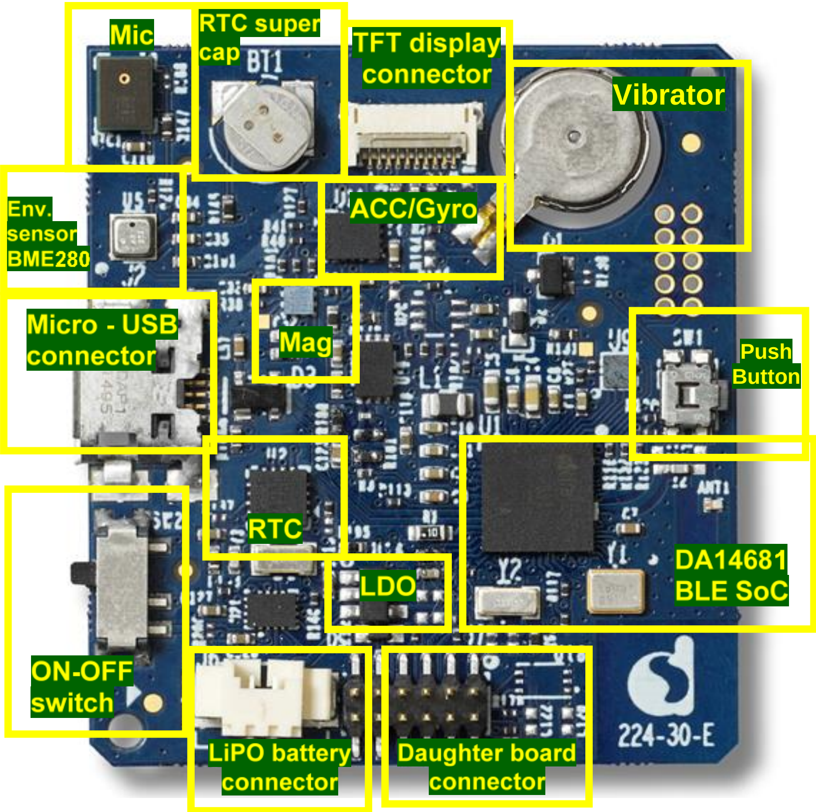

Figure 2: 680-RD-wearable-mb_vE- Top view

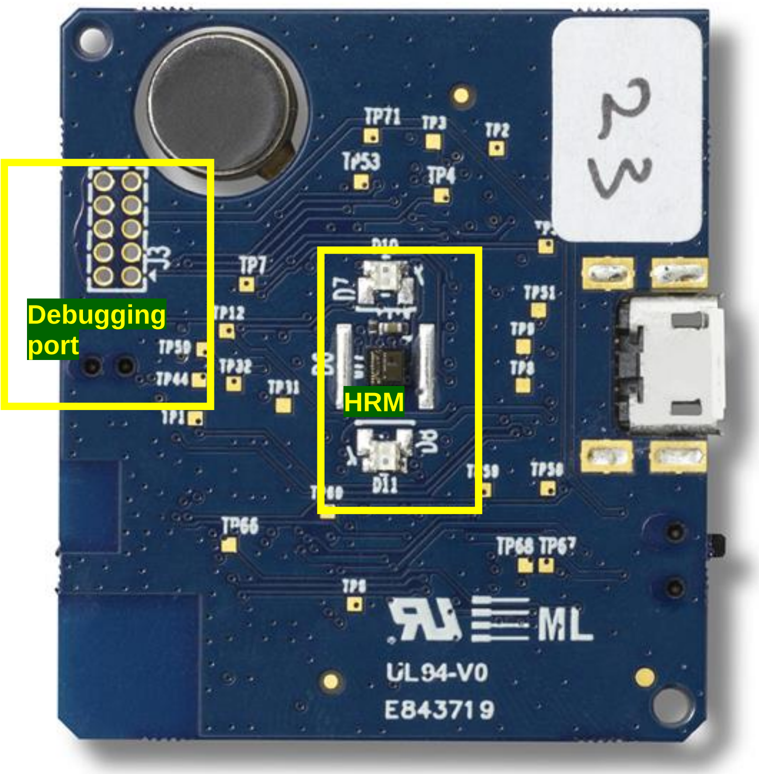

Figure 3: 680-RD-wearable-mb_vE- Bottom view

4 DA14681 Reference Design - Motherboard

4.1 DA14681 System

The DA14681 is a flexible Bluetooth® low energy System-on-Chip combining an application processor, memories, cryptography engine, power management unit, digital and analog peripherals and a radio transceiver.

The DA14681 is based on an ARM® Cortex®-M0 CPU delivering up to 84 DMIPS and provides a flexible memory architecture, enabling code execution from embedded memory (RAM, ROM) or non-volatile memory (OTP or external Quad-SPI Flash memory for DA14681). The advanced power management unit of the DA14681 enables it to run from primary and secondary batteries, as well as provide power to external devices.

An on-chip PLL enables on-the-fly tuning of the system clock between 32 kHz and 96 MHz to meet the high processing requirements.

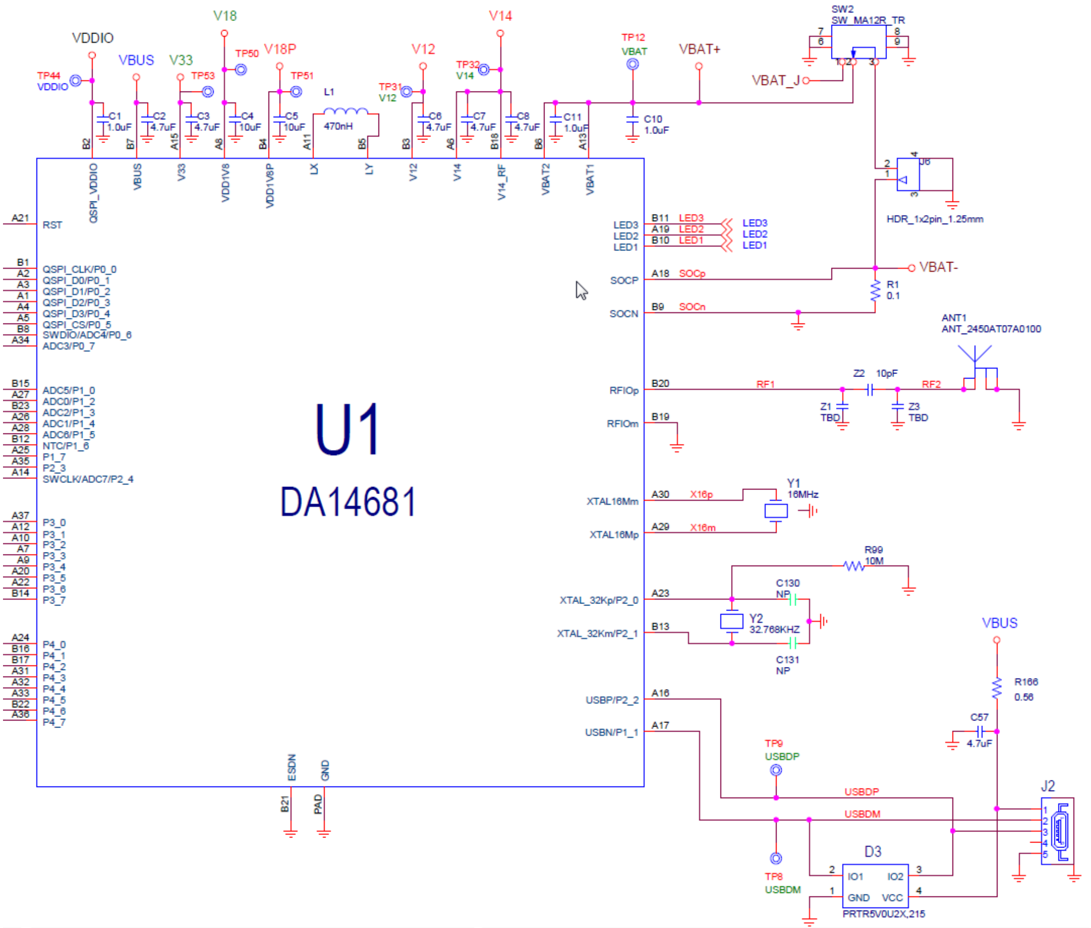

Figure 4: DA14681 System Schematic

The DA14681 SoC power management subsystem consists of:

VBUS: Battery charger input as well as USB bus voltage. A decoupling capacitor equal or less than 4.7 µF is placed close to VBUS pin.

VBAT1: Battery connection. A 1 µF decoupling capacitor (C10), is required close to the pin (0402 package, 6.3 V). Voltage range for VBAT1 is 1.7 V to 4.75 V.

VBAT2: Input of the SIMO DC-DC converter. It is shorted externally with VBAT1. A 1 µF decoupling capacitor (C11) is required next to the pin (0402 package, 6.3 V).

V33: Output voltage rail (3.3 V). A ceramic decoupling capacitor of 4.7 µF (C3), (0402 package, 6.3 V) is placed. V33 cannot be turned off.

SIMO DC-DC converter outputs: V18, V18P, V12, V14. The inductor needed for DC-DC operation is placed externally. A low DCR inductor (L1) of 470 nH, 0805 is connected on LX/ LY pins.

V18, V18P: Power rails (1.8 V) for supplying external devices, even when the system is in sleep mode. Decoupling ceramic capacitors (C4, C5) of 10 µF (0603 package, 16 V), are placed as close as possible to the V18, V18P pins. V18 is assigned to the external Flash memory. The current delivery capability of the V18, V18P power rails in active mode is 75 mA, whereas in sleep mode it is 2 mA. When in sleep mode the 1.8 V is supplied directly from the LDO, while in active mode from a DC-DC converter.

V12: Power rail that supplies the digital core of the DA14681 and delivers up to 50 mA at 1.2 V when in active mode. A 4.7 µF decoupling capacitor (C6) is used (0402 package, 6.3 V).

V14: Power rail that delivers up to 20 mA at 1.4 V and should **not** be used for supplying external devices. A 4.7 µF decoupling capacitor (C7) is placed close to the V14 pin (0402 package, 6.3 V).

V14_RF: Supply voltage input. It is shorted to V14 on the PCB layout. V14_RF powers the RF circuits via a number of dedicated internal LDOs. A 4.7 µF decoupling capacitor (C8) is placed as close to the V14_RF pin as possible.

VDDIO: QSPI Flash interface supply voltage. It is connected to the same power rail as the Flash memory. A 1 µF decoupling capacitor (C1) is added. (0402 package, 6.3 V).

4.1.1 Debugging Section

The DA14681 wearable reference design has a dedicated debugging port as shown in Figure 3. Two debugging ports, JTAG and UART are used on the DA14681 SoC.

The USB-to-JTAG and USB-to-UART functions are implemented by an external Communication Interface Board (CIB) as shown in Figure 5. This interface board has a SEGGER chip running the JLink-OB firmware.

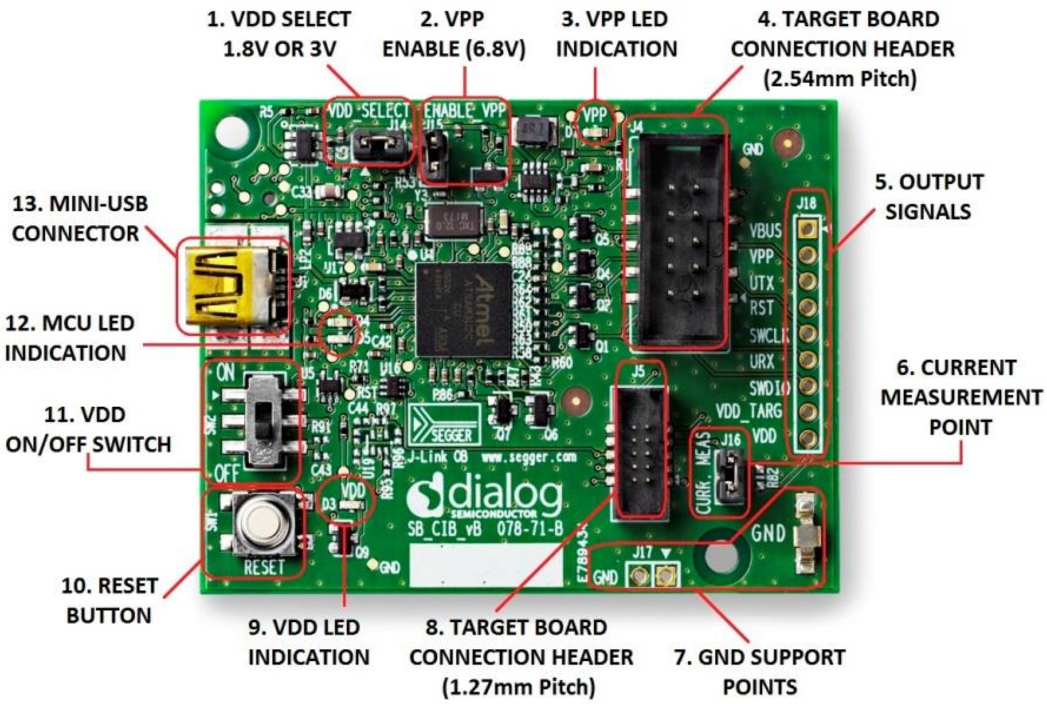

Figure 5: Communication Interface Board (CIB)

The following functions are performed by the interface board:

- Connectivity of PC to the DA14681 JTAG port.
- Connectivity of PC to the DA14681 UART port (full UART is possible but it must be enabled on the PC driver).
- Hardware RESET capability through the T_RESET signal. Note that the signal T_RESET is active low and therefore is inverted by U7 before reaching the RST pin on the DA14681.

The following on-board settings have to be enforced in order to be able to program /debug the wearable reference design board:

Interface board settings (see Figure 5):

- ON-OFF switch set to ON
- USB cable connected at the mini USB connector
- IDC-10 cable from the 1.27 mm pitch header to the target board

Wearable reference design board settings (see Figure 2 and Figure 3):

- IDC-10 cable from interface board is connected at the **bottom** of the wearable reference design board (target board).
- ON-OFF switch has to be positioned towards the USB connector in order to be powered by the communication interface board.

The connection between the interface board and the wearable reference design board (or enclosure) is shown in Figure 6 and Figure 7.

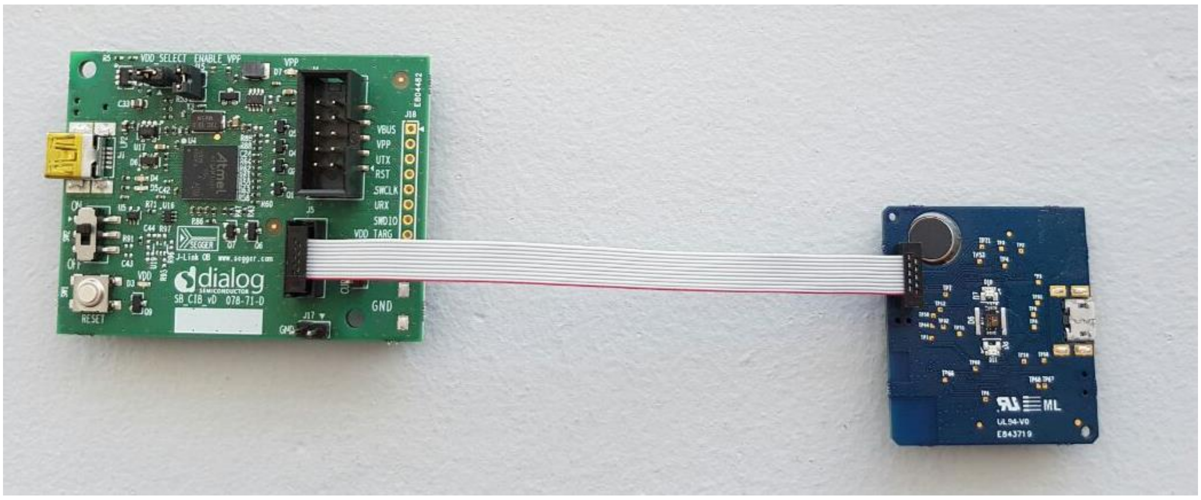

Figure 6: IDC-10 Cable between Interface Board and Wearable Reference Design Board

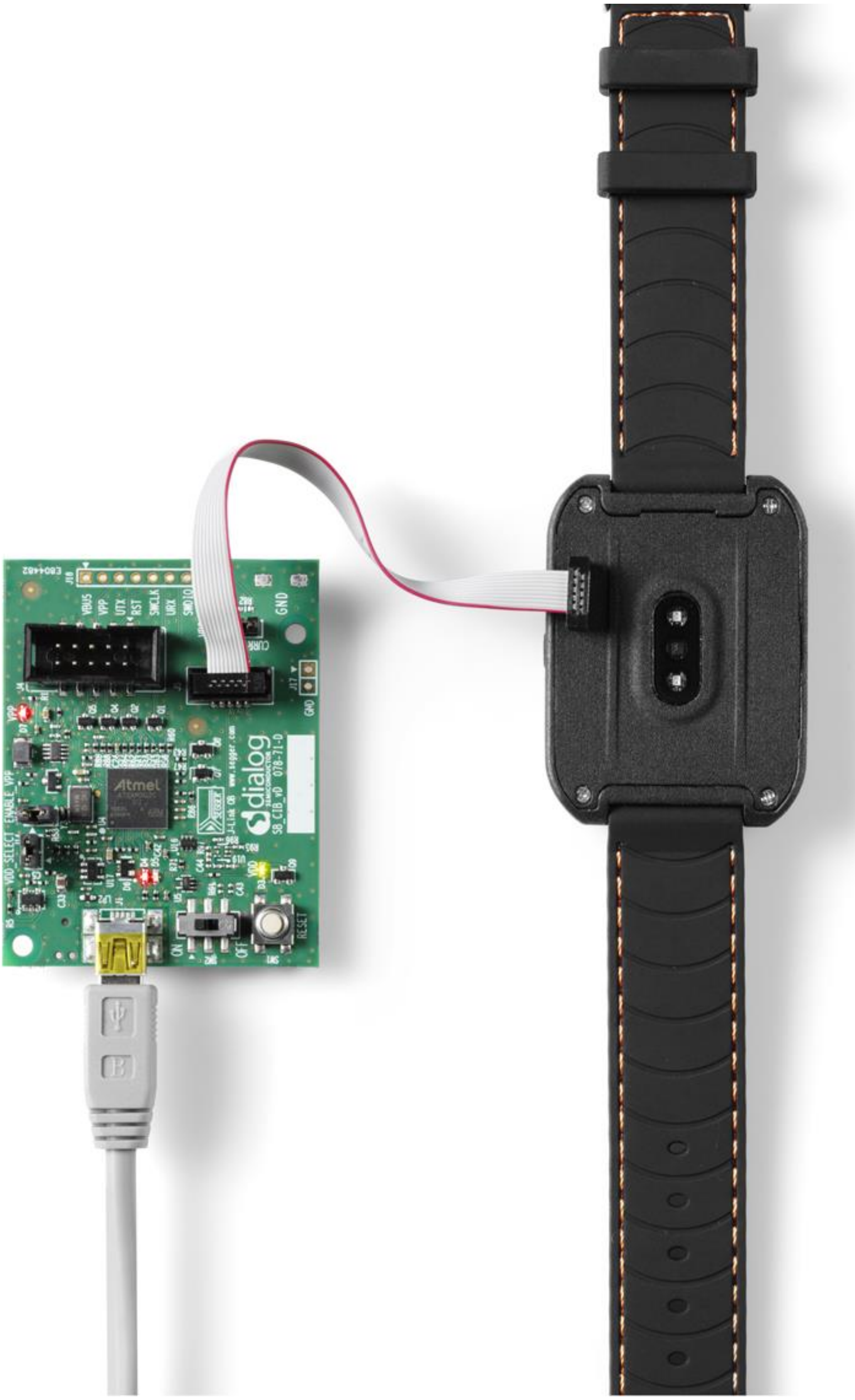

Figure 7: IDC-10 Cable between Interface Board and Wearable Reference Design Enclosure

4.1.2 QSPI Data Flash Memory

The DA14681 wearable reference design includes an external QSPI Data Flash memory from Winbond. The W25Q80EW is a 1.8 V, 8 Mbit Flash memory that supports the standard Serial Peripheral Interface (SPI), Dual/Quad I/O SPI as well as 2-clock instruction cycle Quad Peripheral Interface (QPI), Serial Clock, Chip Select, Serial Data I/O0 (DI), I/O1(D0), I/O2 (/WP) and I/O3(/HOLD).

QSPI is supplied from the V18 voltage rail. The same supply voltage is connected to the DA14681 VDDIO pin.

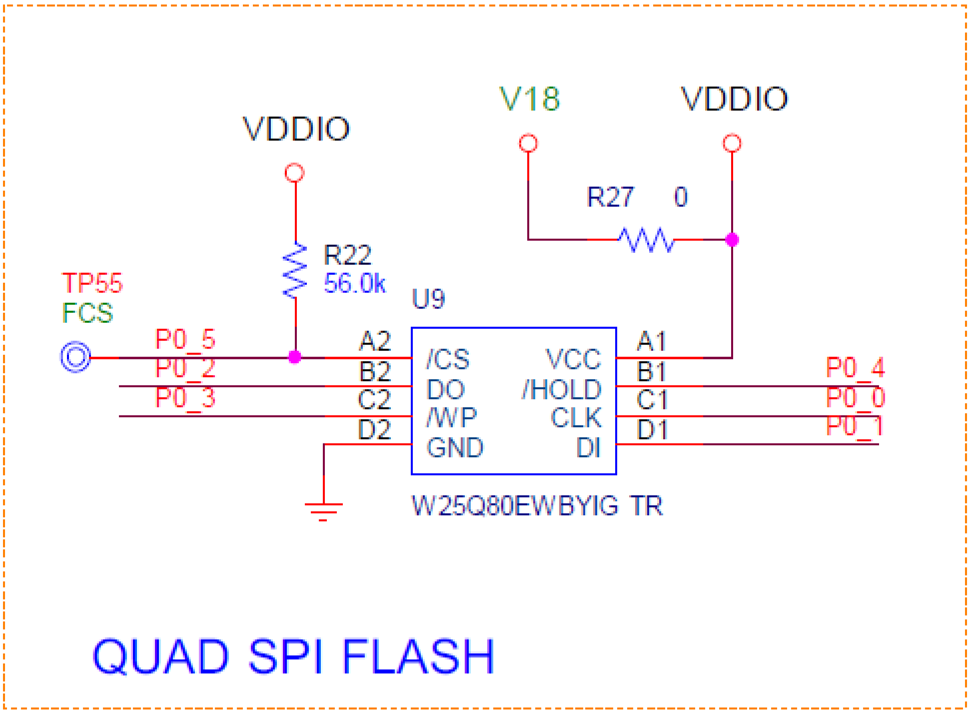

Figure 8: QSPI Data Flash Schematic

The DA14681 uses the external Flash memory for directly executing code with some help from the internal cache, or simply for mirroring the contents in RAM during booting (option selectable via the binary image header).

4.1.3 Crystal Oscillators

The DA14681 SoC has two Digitally Controlled Crystal Oscillators (DCXO), one at 16 MHz (XTAL16M) and a second at 32.768 kHz (XTAL32K). The 32.768 kHz oscillator has no trimming capabilities and is used as the clock for the Extended/Deep Sleep modes. The 16 MHz oscillator can be trimmed.

The crystals used on the wearable reference design are specified in Table 2 and Table 3.

Table 2: Y1 (16 MHz Crystal) Characteristics

Reference Designator	Value
Part Number	7M-16.000MEEQ-T
Frequency	16 MHz
Accuracy	±10 ppm
Load Capacitance (CL)	10 pF

Reference Designator	Value
Shunt Capacitance (C0)	3 pF
Equivalent Series Resistance (ESR)	100 Ω
Drive Level (PD)	50 µW

Table 3: Y2 (32 kHz Crystal) Characteristics

Reference Designator	Value
Part Number	ABS07-32.768KHZ-7-T
Frequency	32.768 kHz
Accuracy	±20 ppm
Load Capacitance (CL)	7 pF
Shunt Capacitance (C0)	0.9 pF to 1.2 pF
Equivalent Series Resistance (ESR)	70 kΩ
Drive Level (PD)	0.5 µW

4.1.4 DA14681 Pin Assignment

Table 4 shows the pin assignment and related pin names on the aQFN60 package of the DA14681.

Table 4: 680-RD-wearable-mb_vE Pin Assignment

DA14681 AQFN60 Pin Name	Reference Design Signal	Section
P0_0	QSPI_CLK	QSPI data flash
P0_1	QSPI_D0	QSPI data flash
P0_2	QSPI_D1	QSPI data flash
P0_3	QSPI_D2	QSPI data flash
P0_4	QSPI_D3	QSPI data flash
P0_5	QSPI_CS	QSPI data flash
P0_6	SWDIO	Debugging – JTAG
P0_7	PDM_DATA	Microphone
P1_0	HRM_AIN	Heart Rate Monitor
P1_1	USBP	DA14681
P1_2	CAPS_INT	Touch
P1_3	UTX	Debugging –UART
P1_4	SPI2_MOSI	LCD
P1_5	Test point	
P1_6	SPI2_CS	LCD
P1_7	SPI2_SCK	LCD
P2_0	XTAL32kp	DA14681
P2_1	XTAL32kn	DA14681
P2_2	USBM	DA14681
P2_3	URX/BUTTON	

DA14681 AQFN60 Pin Name	Reference Design Signal	Section
P2_4	SWCLK	DA14681
P3_0	SPI_MOSI	Sensors
P3_1	SPI_MISO	Sensors
P3_2	SPI_SCK	Sensors
P3_3	BMI_nCS	Sensors
P3_4	BME_nCS	Sensors
P3_5	7816CLK	NFC
P3_6	BMI_INT	Sensors
P3_7	VDDSE	NFC
P4_0	7816IO (URX side)	NFC
P4_1	VIB_EN	Vibrator
P4_2	RTC_IRQ	RTC
P4_3	7816IO (UTX side)	NFC
P4_4	HRM_INT	Heart Rate Monitor
P4_5	PDM_CLK	Microphone
P4_6	SDA	Sensors/HRM/RTC/Touch
P4_7	SCL	Sensors/HRM/RTC/Touch
LED1	LED1	Optional enable to vibrator motor
LED2	LED2	Heart Rate Monitor
LED3	LED3	Heart Rate Monitor

4.2 GPIO Expander

Due to the high GPIO demand in this reference design a GPIO expander was necessary. The component used is the low power I2C controlled FXL6408UMX from Fairchild. It uses both power rails of 1.8 V and 3.3 V while its power consumption remains very low at only 1.5 µA (Sleep current).

Table 5: GPIO Expander Pin Assignment

GPIO Expander	Pin Name	Section
P0	Test point	
P1	Test point	
P2	MIC_EN	Microphone
P3	TFT_EN	LCD
P4	HRM_EN	Heart Rate Monitor
P5	NFC_EN(3V Ldo)	NFC
P6	ENVDDSE	NFC
P7	7816RST	NFC

Driving signals (I2C) are supplied from the 1.8 V rail whereas the output signals are driven from the 3.3 V voltage rail.

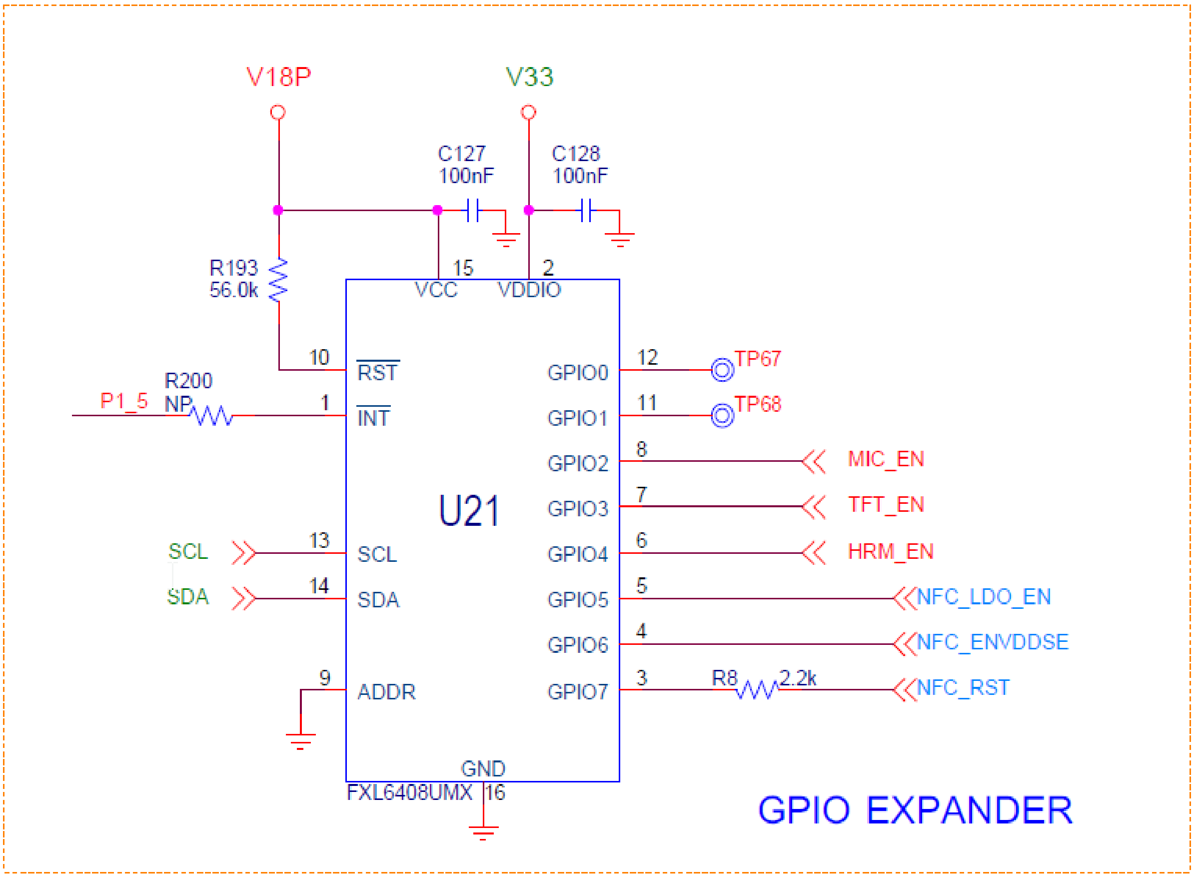

Figure 9: GPIO Expander Schematic

4.3 Microphone

The SPK0838HT4H-B from Knowles is a miniature, high performance, low power, top port silicon digital microphone with a single-bit PDM output. In this reference design the microphone's data signal is driven by the GPIO P0_7 from the DA14681 SoC. Its power consumption during sleep is only 4.6 μA.

The microphone is supplied from an output pin (GPIO2) of the GPIO expander. In this way, the user can turn off the microphone completely when it is not used. Default state for the microphone is OFF.

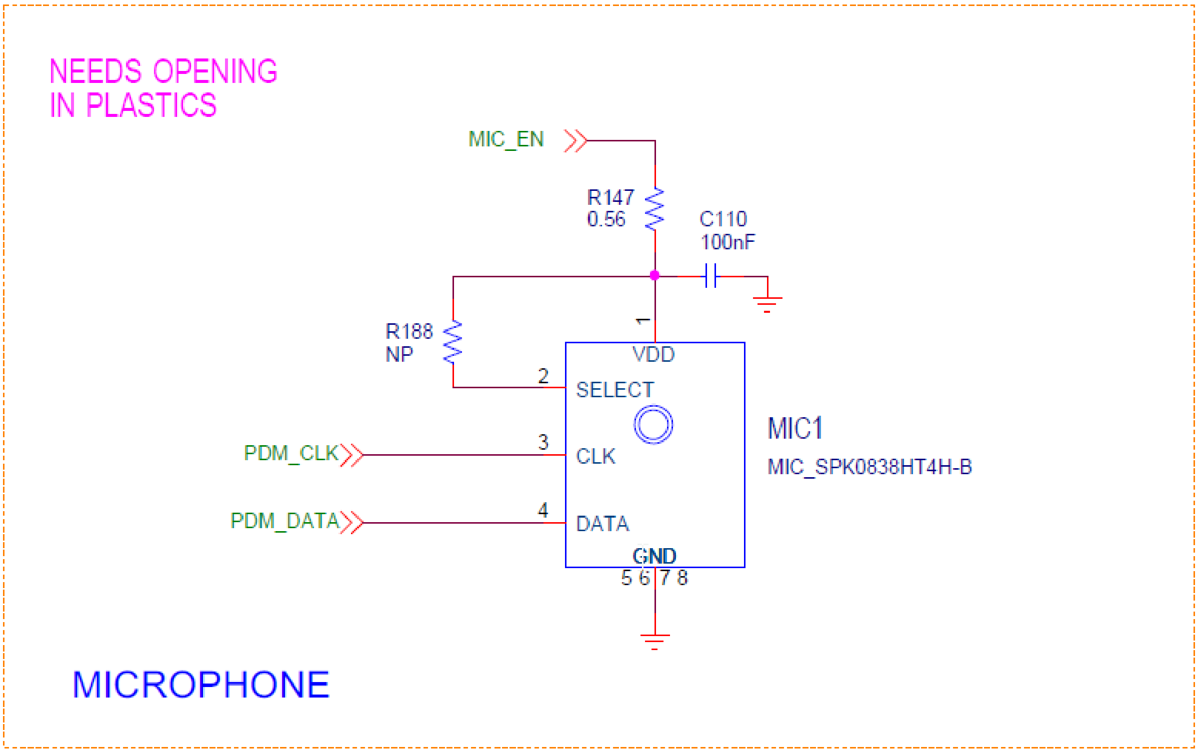

Figure 10: SPK0838HT4H Microphone Schematic

4.4 Li-Po Battery

The battery used is a rechargeable Li-Po from HHS, which is available with capacities of 190 mAh and 250 mAh. Table 6 shows the battery dimensions.

Table 6: Battery Dimensions

Capacity (mAh)	Dimensions (mm)	Thickness (mm)
190	30 x 30	3.2
250	30 x 30	3.7

The actual Li-Po battery rechargeable battery can be seen in Figure 11:

Figure 11: 3.7 V 190 mAh Li-Po Battery

The charging and discharging curves of the 190 mAh battery are illustrated in Figure 12.

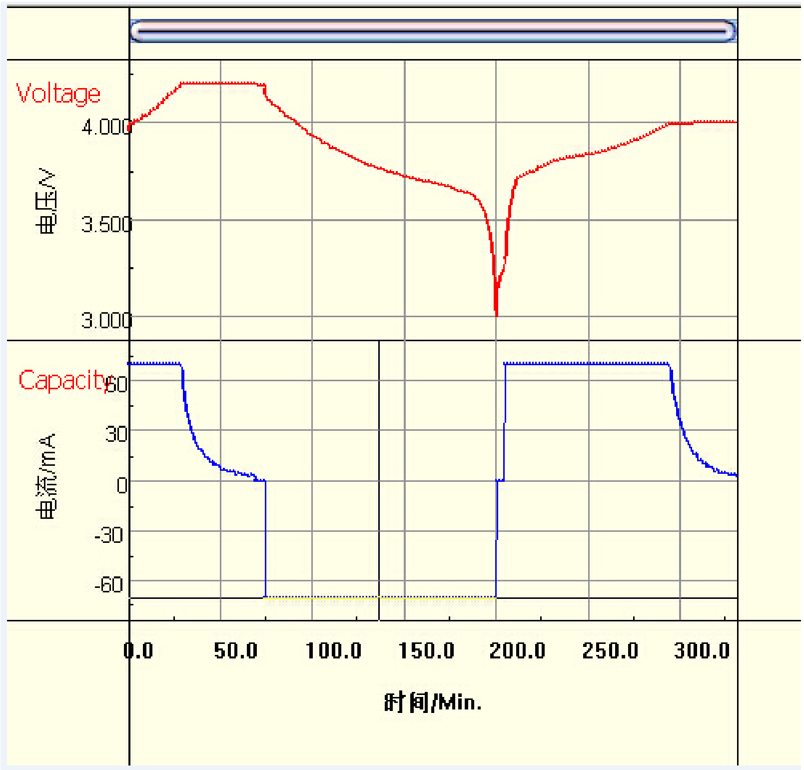

Figure 12: Li-Po Battery Charging/Discharging Curves

Charging Time		2-3H
Charge Method		CC-CV (constant current and constant voltage)
Recharge Cycle Life		300 times
Working Temperature	Charge	0~45°C,45~85%RH
	Dis-charge	-20~60°C,45~85%RH
Storage Temperature and Humidity	One month	-20~60°C,45~85%RH
	Three months	-20~45°C,45~85%RH
	One year	-20~25°C,45~85%RH
Protection Functions		Over charge, Over discharge, Over load, Short Circuit
Warranty		12 months

Figure 13: Technical Characteristics of the 190 mAh Li-Po Battery

The LiPo battery discussed is equipped with a protection circuit module (PCM). The PCM will generally provide the battery with overcharge/discharge protection, short circuit protection, current limitation, and voltage and current balancing in each cell. All of these factors are important in obtaining the maximum output and longest operating life from a rechargeable lithium battery.

4.5 LCD Display

The LCD display selected is a 1.28 inch, 128 x 128 resolution monochrome HR-TFT transflective panel (LS013B7DH03 from Sharp). The most significant advantage of this display is that it does not require an external controller. This is due to the fact that each pixel forms a 1-bit write-only memory. This feature minimizes the processor resources used as there are no continuous data transfers to refresh the image; the image needs to be written just once.

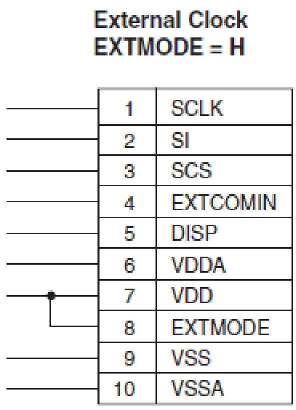

Figure 14: TFT Display External Clock Selection

The alternating signal needed to prevent any DC bias from building up inside the display is supplied by an external clock signal generated by a Real Time Clock module (see section 4.7).

Figure 15 illustrates the TFT display connectivity necessary to implement the external clock functionality. The clock frequency in this case is set to 64 Hz and it is fed into the display via the RTC_SQW pin of the RTC module. By default this clock is provided by the RTC, alternatively it can also be supplied by the DA14681 SoC.

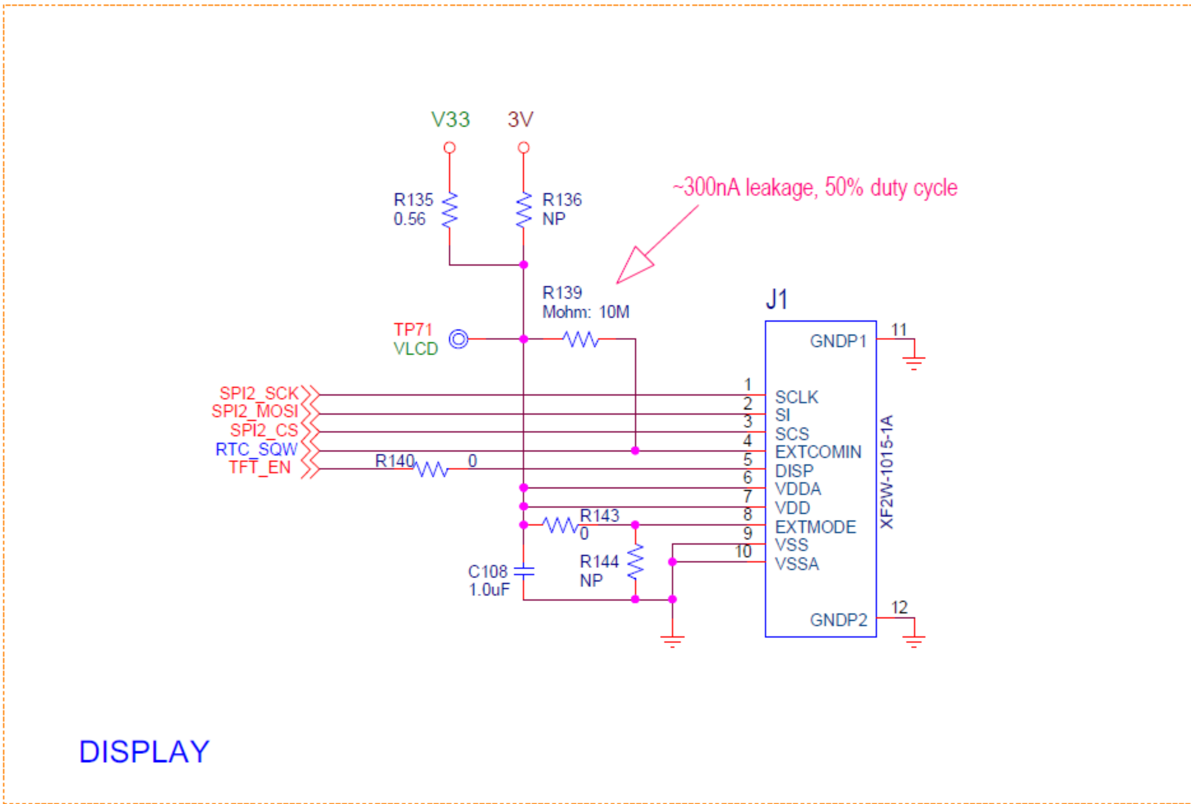

Figure 15: TFT Display Connector Schematic

The TFT display is powered by the V33 output voltage rail of the DA14681 BLE SoC.

Main features include:

- Display control with serial data signal communication
- Internal 1-bit memory within the panel for data memory
- Super low power consumption TFT panel
- Module outline dimensions (mm): 26.6 (W) x 30.3 (H) x 0.741 (T)

Table 7: Recommended Operating Conditions

Parameter	Description	Min	Typ	Max	Unit
VDDA	Analog supply voltage	2.7	3.0	3.3	V
VDD	Logic supply voltage	2.7	3.0	3.3	V
VIH	High level input voltage	VDD - 0.1	-	VDD	V
VIL	Low level input voltage	VSS	-	VSS + 1	V

Table 8: Power Consumption

Mode	Min	Typ	Max	Unit
Sleep	-	12	50	µW

Mode	Min	Typ	Max	Unit
Active	-	50	130	µW

Figure 16: TFT Display

Measured power consumption figures are presented in section 7 of this document.

4.6 DA14681 Wearable Reference Design Sensors

The wearable reference design consists of the following sensor components from Bosch SensorTec:

- BMI160: Combined Inertial Measurement Unit and Accelerometer
- BMM150: Magnetometer
- BME280: Environmental Sensor
- BH1750FVI: Ambient Light Sensor

4.6.1 BMI160 - Combined Inertial Measurement Unit and Accelerometer

The BMI160 is a low-power, low-noise inertial measurement unit, designed for use in mobile and indoor applications which require highly accurate, real-time sensor data. In full operation mode, with the accelerometer and gyroscope enabled, the current consumption is typically 950 µA, while this is dropped down to 3 µA is suspend mode.

The BMI160 module is connected to the DA14681 via an SPI interface. In this reference design the secondary I2C interface of the BMI160 is used to connect the BMM150 (magnetometer) to the BMI160 in slave mode, in order to acquire the data in synchronized form. This configuration is called *cascade mode* and minimizes the number of the GPIOs needed as well as the processor resources.

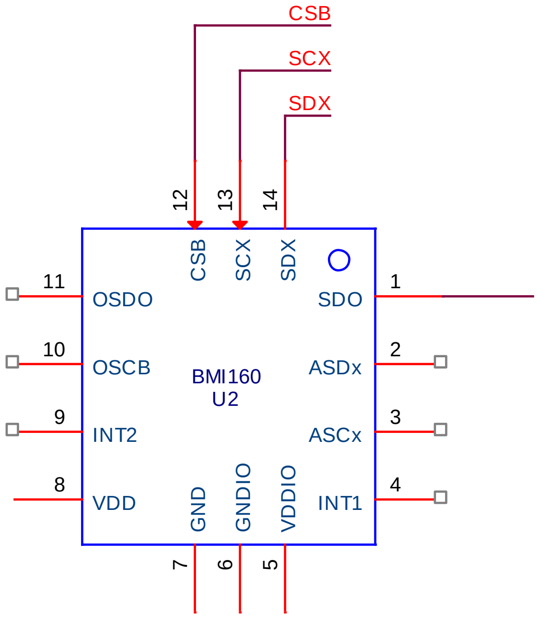

Figure 17: BMI160- Inertial Sensor Schematic

Table 9: BMI160 Inertial Sensor - Electrical Characteristics

Parameter	Min	Typ	Max	Unit
Supply Voltage (VDD)	1.71	3.0	3.6	V
Supply Voltage (VDD I/O)	1.2	2.4	3.6	V
Voltage Input Low Level			0.3*VDD I/O	V
Voltage Input High Level	0.7*VDD I/O			V
Voltage Output Low Level			0.2*VDD I/O	V
Voltage Output High Level			0.23*VDD I/O	V
Operating Temperature	-40		85	°C

4.6.2 BMM150 - Magnetometer

The BMM150 is a standalone geomagnetic sensor for consumer market applications. It allows measurements of the magnetic field in three perpendicular axes. The BMM150 is carefully tuned and perfectly matches the demanding requirements of all 3-axis mobile applications such as electronic compass, navigation or augmented reality applications. The magnetometer is not connected directly to the DA14681 but only via the BMI160 and through the I2C interface. The current consumption is 500 μA in normal mode, while in sleep mode it is 3 μA.

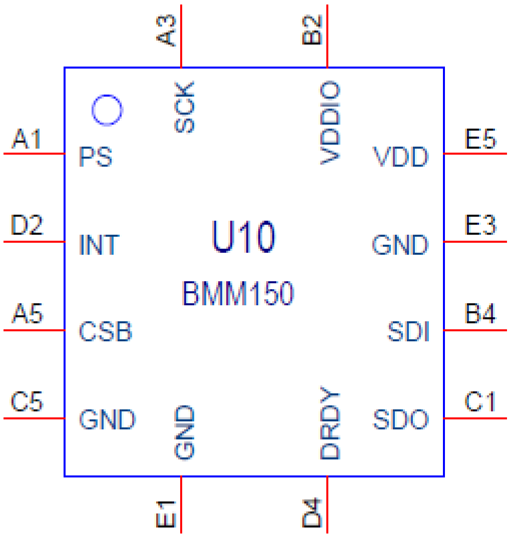

Figure 18: BMM150- Geomagnetic Sensor Schematic

Table 10: BMM150 Geomagnetic Sensor - Electrical Characteristics

Parameter	Min	Typ	Max	Unit
Supply Voltage (VDD)	1.62	2.4	3.6	V
Supply Voltage (VDD I/O)	1.2	1.8	3.6	V
Operating Temperature	-40	25	85	°C

4.6.3 BME280 - Environmental Sensor

The BME280 is an integrated environmental sensor developed specifically for mobile applications. The built-in humidity sensor features an extremely fast response time, which supports performance requirements for emerging applications such as context awareness, and high accuracy over a wide temperature range. The humidity sensor features an extremely fast response time. The pressure sensor is an absolute barometric pressure sensor with features exceptionally high accuracy and resolution at very low noise. The integrated temperature sensor is primarily used for temperature compensation of the pressure and humidity sensors, and can also be used for estimating ambient temperature. The BME280 is connected to the DA14681 BLE using an SPI interface. The current consumption in normal mode is 3.6 µA, while in sleep mode it is 0.1 µA.

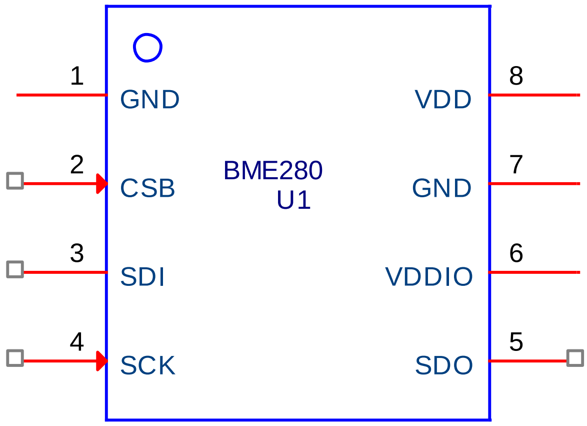

Figure 19: BME280- Environmental Sensor Schematic

Table 11: BME280 Environmental Sensor – Electrical Characteristics

Parameter	Min	Typ	Max	Unit
Supply Voltage (VDD)	1.71	1.8	3.6	V
Supply Voltage (VDD I/O)	1.2	1.8	3.6	V
Operating Temperature	-40	25	85	°C

4.6.4 BH1750FVI – Ambient Light Sensor

The BH1750FVI is a digital ambient light sensor IC for the I2C bus interface. Its purpose is to obtain ambient light data for adjusting the LCD or keypad backlighting power of a mobile phone. It connects to the DA14681 BLE via the I2C interface.

Note: This component is not mounted in Revision E of the wearable reference design.

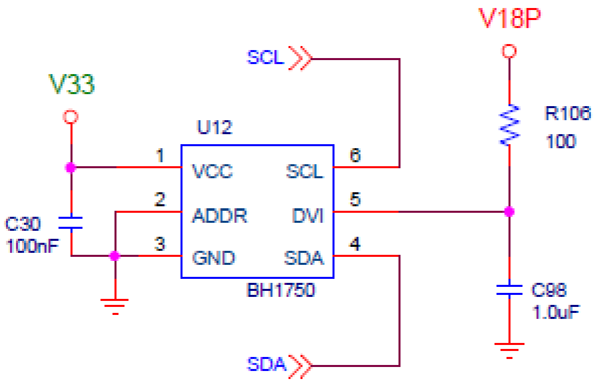

Figure 20: BH1750FVI Ambient Light Sensor Schematic

4.7 RTC – Real Time Clock

This module has two purposes:

- It provides real time clock functionality in the absence of battery power.
- It provides the alternating signal needed to stop any DC bias from building up in the TFT display.

Its main unit is the AB08X5 from Abracon, which includes on-chip oscillators to provide minimum power consumption, full RTC functions including battery backup and programmable counters and alarms for timer and watchdog functions, and an I2C interface for communication with the DA14681. The RTC schematic is shown in Figure 21. The power consumption during sleep mode is 0.34 µA.

When initialized, it charges a 80 mF super capacitor XH414HG-IV01E from Seiko, connected at the VBAT pin. This serves as a backup power supply in the absence of the Li-Po battery in order to maintain clock synchronization.

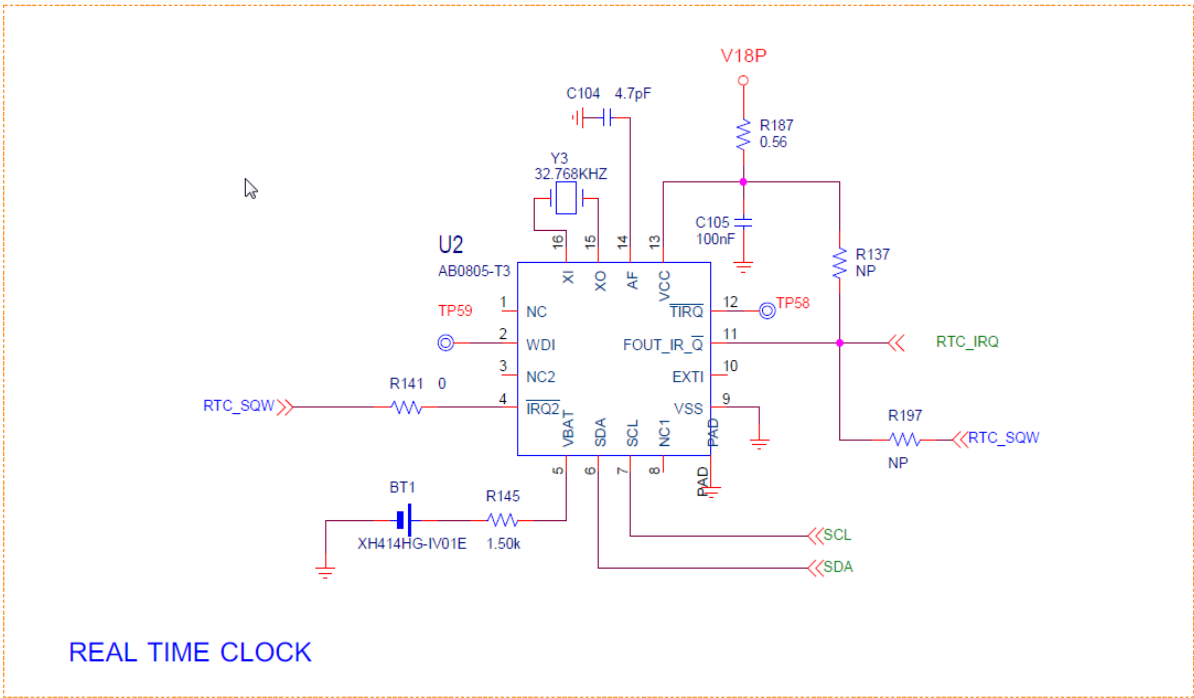

Figure 21: RTC Schematic

4.8 Antenna

A ceramic type of chip antenna (2450AT18A100 from Johanson) is currently used in the wearable reference design. This selection has been made for the following advantages:

- SMD miniature type of manufacturability
- Remains reliable and versatile
- Easy tuning

Mechanical Dimensions

	In	mm
L	0.039 ± 0.004	1.00 ± 0.10
W	0.020 ± 0.004	0.50 ± 0.10
T	0.014	0.37
a	0.006 +.004/-.006	0.15 +0.1/-0.05
b	0.010 +.004/-.006	0.25 +0.1/-0.05
c	0.003 +.004/-.006	0.08 +0.1/-0.05

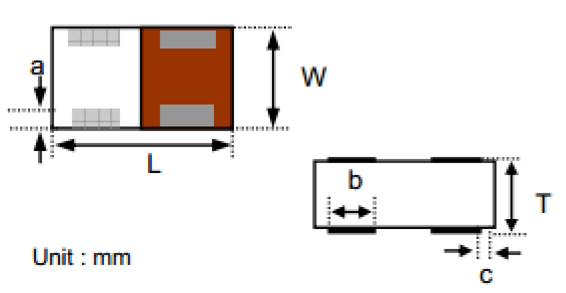

Figure 22: Ceramic Antenna PCB Footprint and Mechanical Specifications

Table 12: Key Antenna Characteristics

Part Number	Frequency (MHz)	Peak Gain (dBi)	Average Gain (dBi)	Return Loss (dB)
2450AT18A100	2400 to 2500	0.5 (XZ-V)	0.5 (XZ-V)	9.5 (Min)

4.9 Heart Rate Monitor (HRM)

Traditional heart rate measurement equipment has been restricted to the use of chest straps linked to an external device, such as a smartphone via the BLE protocol. These HRM solutions exhibit some disadvantages: chest straps are often inconvenient and uncomfortable to wear, while smartphones can be difficult to be monitored when exercising.

Wrist-based HRM technology introduces a new way of biometric monitoring by providing a more convenient and comfortable way to measure heart rate, rivalling the accuracy of chest-strap-based designs.

The DA14681 wearable reference design incorporates such a wrist-based heart rate monitor based on the DI5115 HRM module from Dyna Image. The DI5115 sends bright light via Green LEDs (D10B, D11B) through the skin and then measure the amount of light that comes back. Blood absorbs light, so variations in light that the heart rate sensors detect can be used to determine your pulse rate.

The DI5115 module uses a set of combined IR-Green LEDs (IRG1615D01, 940 nm 530 nm Green Infrared LED from Dyna Image) that comes in single package. The key characteristics of the LEDs can be found in Table 13, Table 14 and Table 15.

Other green LEDs (such as QBLP676-IG from QT Brightek) can be used to replace the IRG1615D01 LED module. The only requirement is that they must have the same wavelength and the cross point must be checked against the new package.

In this implementation the IR LED is not used. For maximum power transfer it is advised that the value of the resistors R180, R181 and R190 should be 0 Ω.

For optimum performance the pitch between the LEDs and HRM module (DI5115) should be 3.5 mm.

Table 13: Green - IR LED Maximum Ratings

Parameter	Symbol	Rating	Green	Unit
Power Dissipation at or below 25°C	P_D	100	72	mW
Continuous Forward Current	I_F	20	20	mA
Peak Forward Current	I_{FP}	100	100	mA
Reverse Voltage	V_R	5		V
Operating Temperature	T_{OPR}	-40 to +85		°C
Storage Temperature	T_{STG}	-40 to +85		°C
Soldering Temperature	T_{SOL}	≤ 260		°C

Table 14: Electrical Characteristics – IR LED

Parameter	Symbol	Min	Typ	Max	Unit
Radiant Intensity	I_E	0.92	1.83	-	mW/sr
Forward Voltage	V_F	--	1.25	1.7	V
Reverse Current	I_R	--	--	100	µA
Peak Wavelength	λ_P	--	940	--	nm
Spectral Line Half-width	Δλ	--	50	--	nm
Rise/Fall Time	T_R	--	50	--	ns
	T_F	--	20	--	
Viewing Angle	$2\theta_{1/2}$	--	120	--	deg

Table 15: Electrical Characteristics – Green LED

Parameter	Symbol	Color	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	Green	--	3.2	3.4	V
Luminous Intensity	I_V	Green	715	1070	-	mcd
Reverse Current	I_R	Green	--	--	1	μA
Peak Wavelength	λ_P	Green	--	530	--	nm
Dominant Wavelength	λ_D	Green	530	--	540	nm
Spectral Line Half-width	$\Delta\lambda$	Green	--	35	--	nm
Viewing Angle	2θ1/2	Green	--	120	--	deg

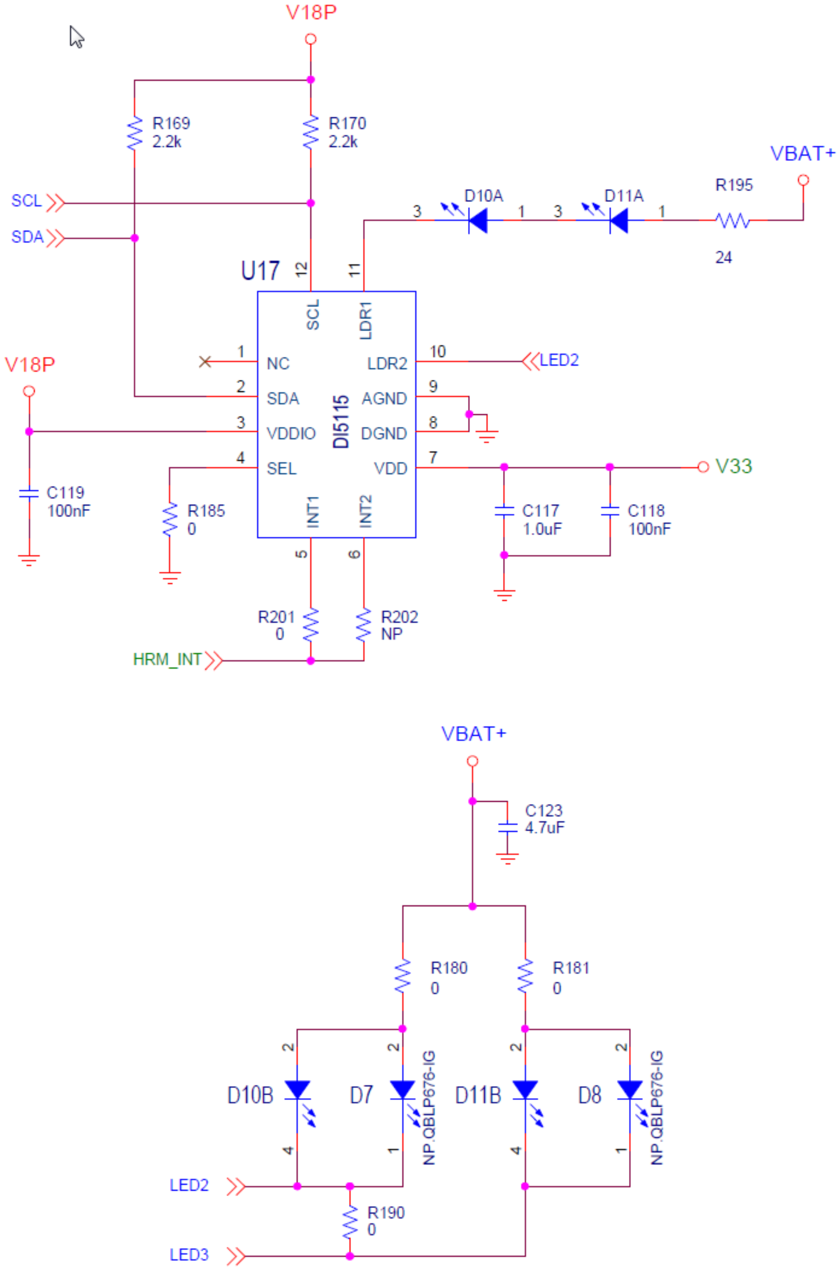

Figure 23: HRM Schematic

4.10 DA14681 Wearable Reference Design- Motherboard Schematics

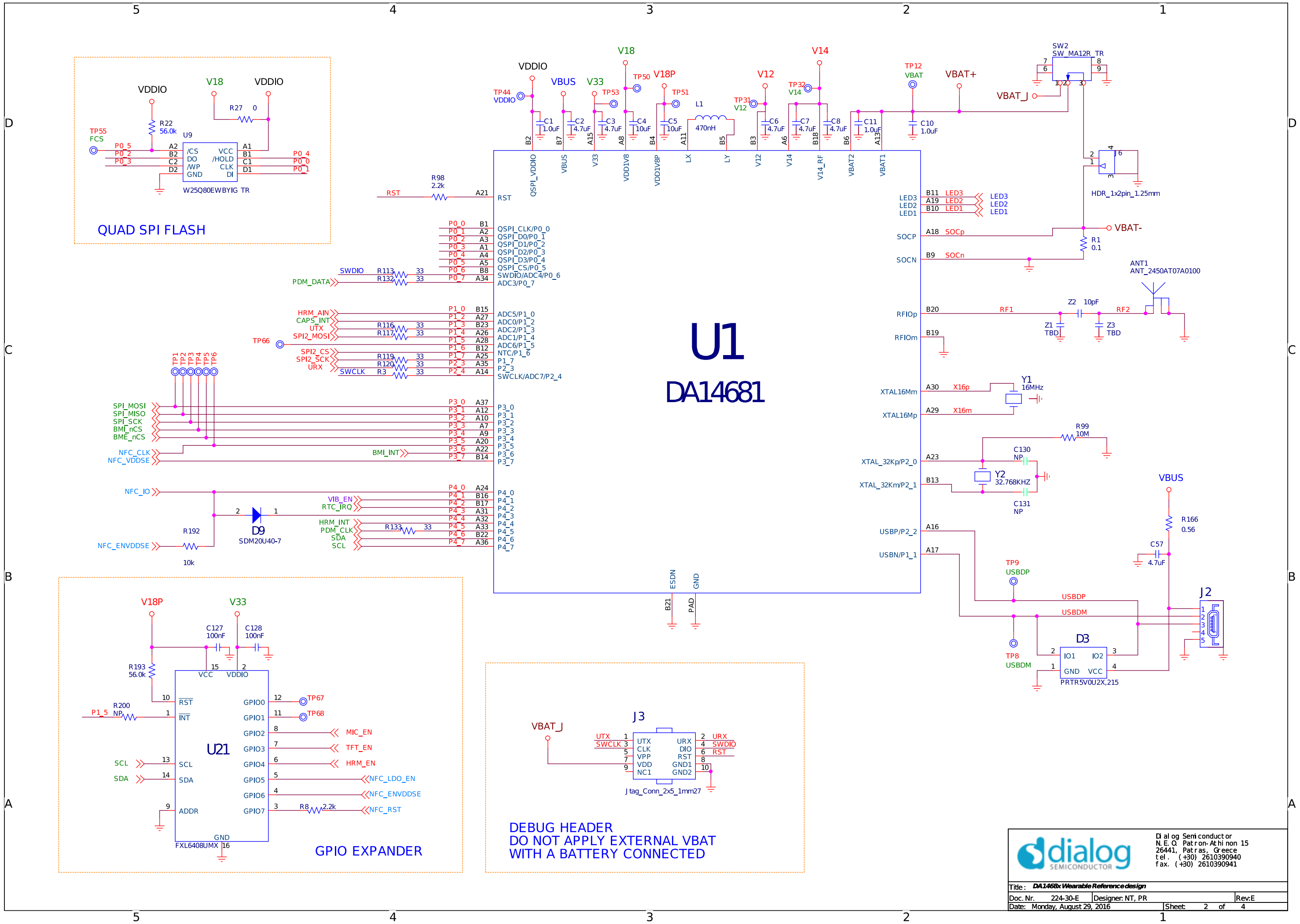

Figure 24: 680-RD-wearable-mb_vE - BLE SoC, QSPI, GPIO Expander Schematic

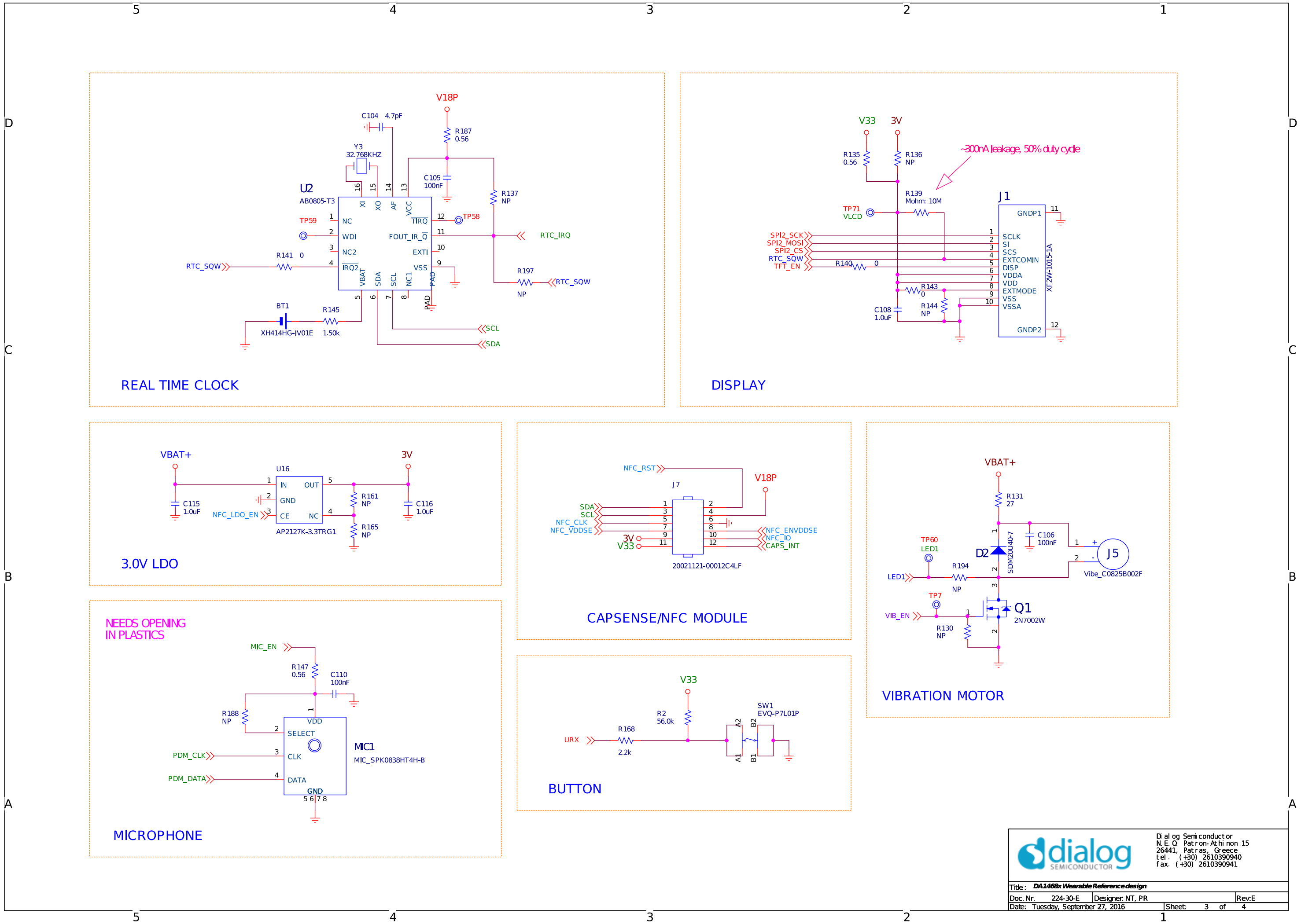

Figure 25: 680-RD-wearable-mb_vE - Peripherals Schematic

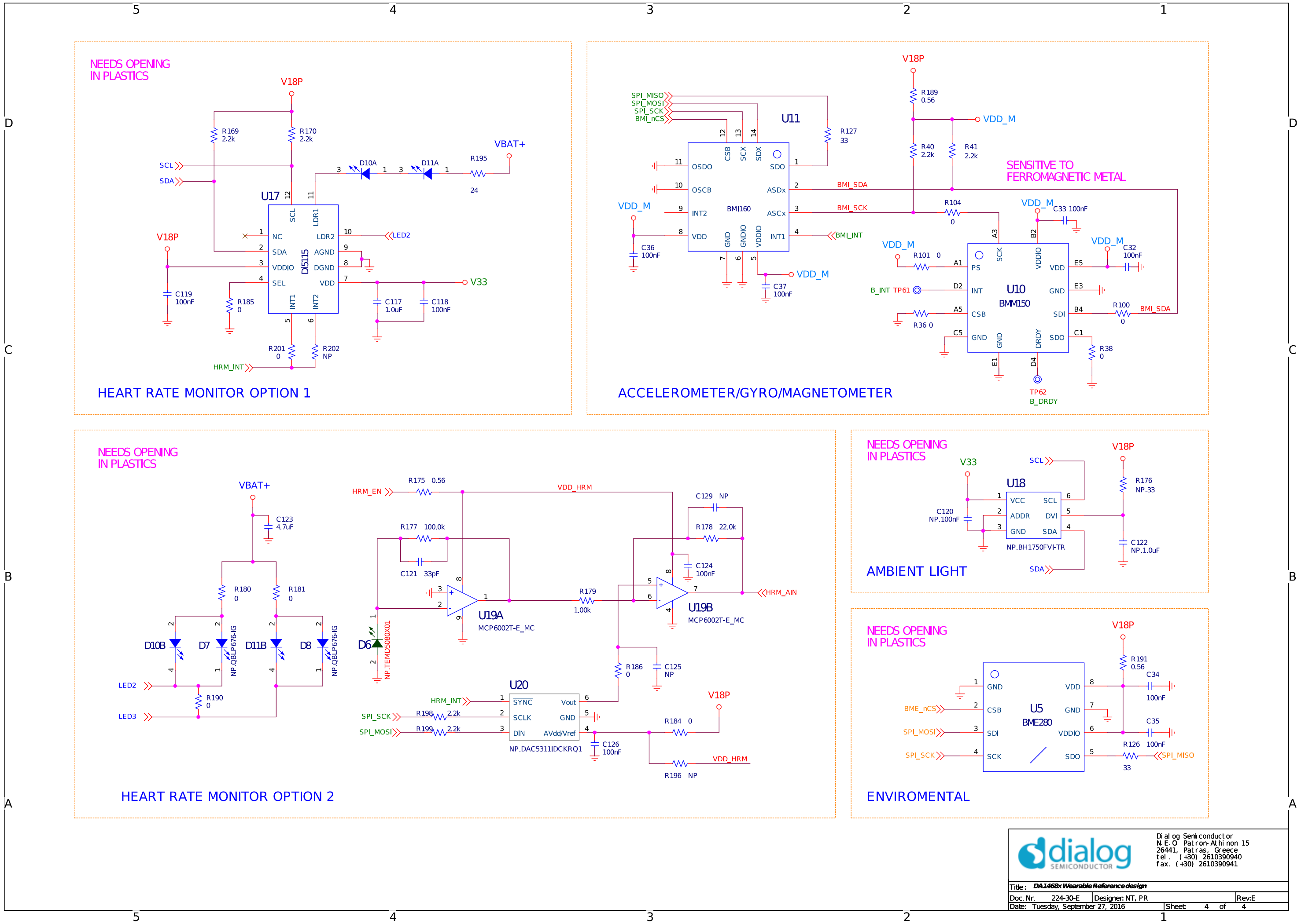

Figure 26: 680-RD-wearable-mb_vE - Sensors Schematic

5 DA14681 Reference Design - Daughterboard

The DA14681 reference design daughterboard consists of the following components:

- Near Field Communication (NFC) module
- Capacitive touch controller

5.1 Near Field Communication (NFC)

Near field communication is a short range wireless connectivity technology designed to establish communication between two devices. The NFC technology in this reference design is used for contactless (proximity) smartcards and the related standard is ISO 14443. The main characteristics of NFC are the operating frequency of 13.56 MHz and the 10 cm range. Typical applications include: ticketing, payment access etc. The NFC module used in this reference design is the LA66002 from Infineon and is suitable to implement the following modes:

- **Read/Write Mode:** The NFC module reads data from an NFC smart object and acts accordingly. NFC smart poster applications can be supported via the ISO 14443 scheme
- **Card Emulation Mode:** The NFC module emulates a contactless card to enable operations such as contact less payments, ticketing etc.

In the NFC module LA66002 the Read/Write mode is implemented via the Host Communication mode of the secure element (SE). The communication between the NFC module and the host (DA14681) is established via the ISO 7816 standard. The Card Emulation (contactless) mode is implemented via the RF Communication Mode and is executed by the analog front-end of the NFC module. A simplified top level block diagram of the NFC module is shown in Figure 27.

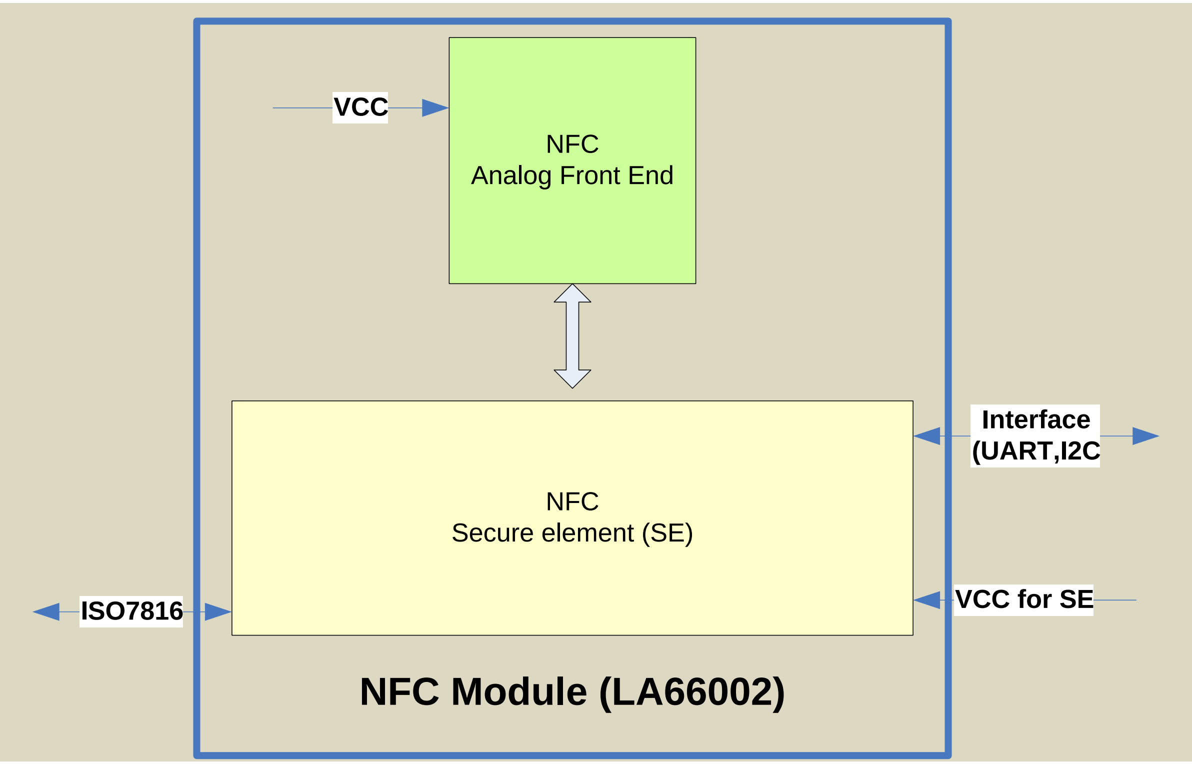

Figure 27: Simplified Block Diagram of the NFC Module

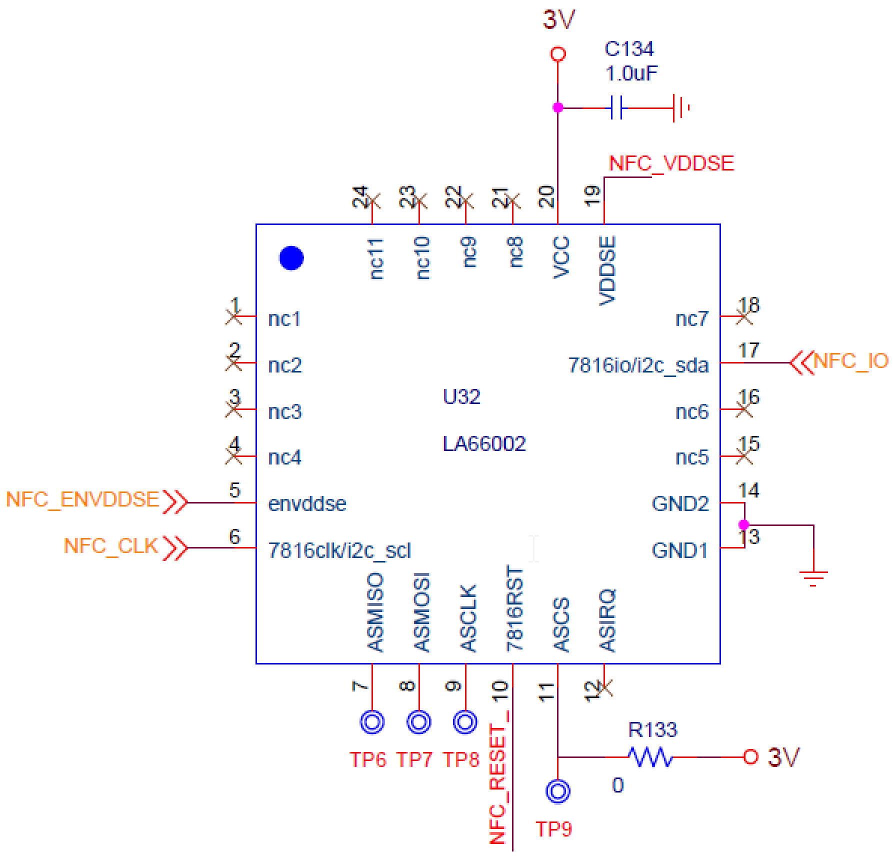

Figure 28: NFC Module Schematic

The LA66002 is a boosted NFC module providing hassle free and immediate connectivity, unlike traditional NFC devices that sometimes are unable to establish immediate connection. So it works much better in payment or in transport infrastructure applications where the transactions are faster.

From a hardware perspective, the benefits of using a boosted NFC device are the use of a smaller antenna, which is mostly incorporated in the NFC module, and that there is no need for an external antenna and front-end.

Due to its high power consumption during operation the LA66002 NFC module is powered separately by a 3.3 V LDO (AP2127K-3.3TRG1 from Diodes Inc).

Table 16: NFC Module Pin Description (Partial)

Pin Number	Pin Name	Description
5	ENVDDSE	Digital input that controls VDD of the secure element.
6	7816CLK	Clock when in ISO 7816 usage.
10	7816RST	ISO 7816 enable/disable pin, when high host communication mode is activated.
17	7816IO	Half duplex IO port when in ISO 7816 mode.
19	VDDSE	Power supply for the secure element (SE) in the NFC module.

Table 16 gives a description of the most important pins of the NFC module, the voltage level of which determines the operating mode: Communication mode or RF mode. Figure 29 outlines the schematic implementation of the Communication mode. The logic values for each signal per mode are illustrated in Figure 30 and Figure 31.

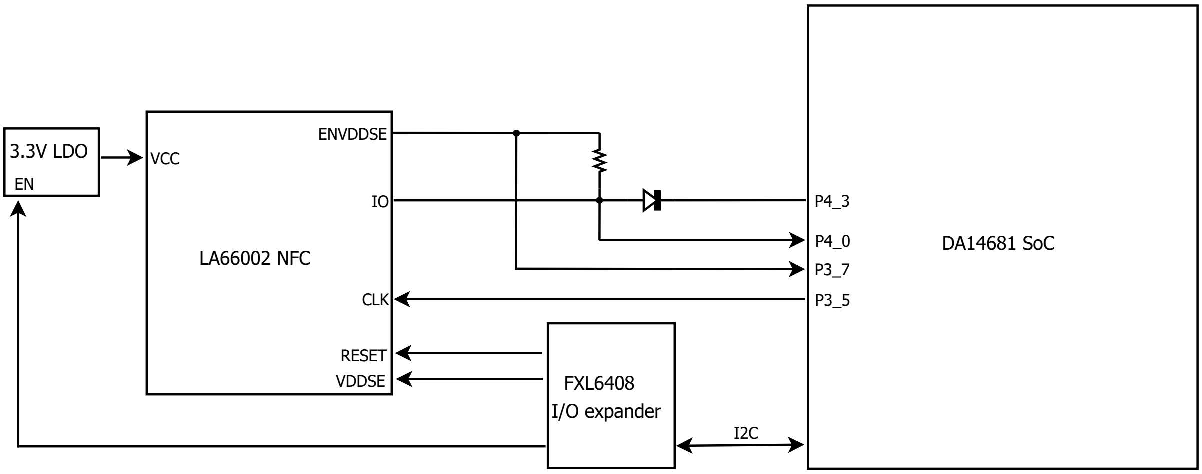

Figure 29: Block Diagram of the Host Communication Mode Implementation

The NFC module can be activated in Host Communication mode by raising ENVDDSE, providing a clock at the corresponding line and raising the RST line. Here, a 4 MHz clock is provided by the DA14681. Upon powering up and entering host mode successfully, the NFC module will output an Answer to Reset (ATR) message, after which protocol parameter negotiation and communication with the host can be initiated.

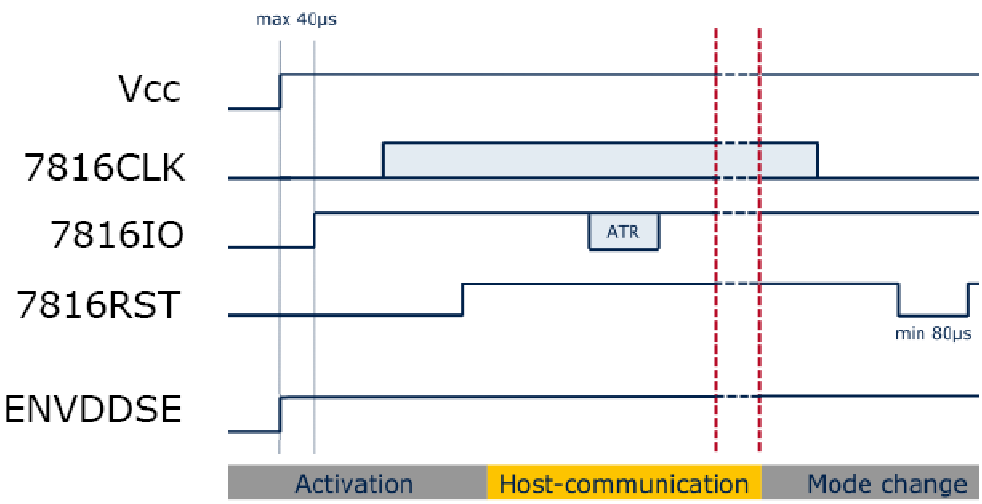

Figure 30: Voltage Levels of the NFC Module Pins – Host Communication Mode

In order to power up the NFC module in RF Communication (card emulation) mode, only power needs to be applied while the IO and RST lines are high impedance and the CLK and ENVDDSE signals are driven low.

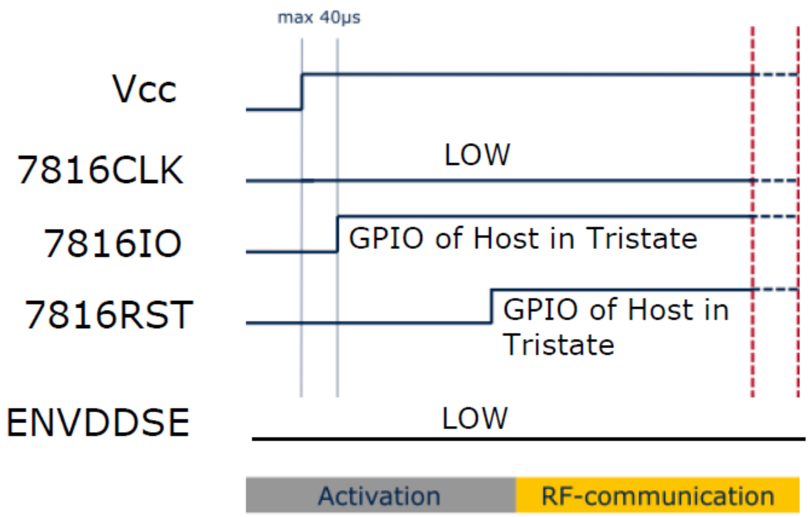

Figure 31: Voltage Levels of the NFC Module Pins – RF Communication Mode

The NFC module runs its own dedicated secure operating system and applications, and communicates with the host or reader via standard and application specific APDU (Application Protocol Data Unit) commands. The devices come pre-programmed with a sample application from the manufacturer. Other applications can also be loaded depending on the required function.

5.2 Capacitive Touch and Proximity Controller

The DA14681 wearable reference design is equipped with a capacitive touch and proximity controller SX9300 from Semtech. It operates in conjunction with two touch pads located at the top of the daughterboard. The controller has the ability to sense touch as well as proximity at a maximum distance of 20 mm from the two touch pads.

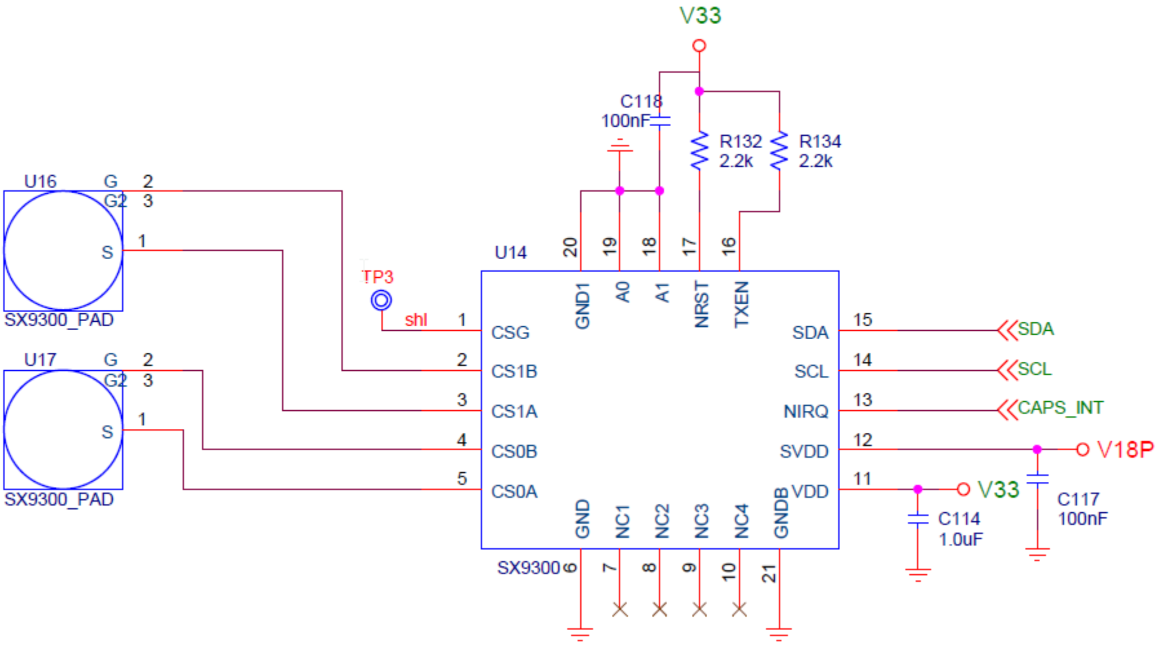

Figure 32: Capacitive Touch Controller Schematic

The capacitive touch sensors help the user to navigate through the various sensor readings that appear on the TFT display. The touch sensor is accessible by the DA14681 via the I2C interface.

The PCB touch pads are shown in Figure 35: they are oval shaped with a 10 mm pitch to ensure proper sensitivity. For optimum noise performance there is a dedicated shield pin (CS0A, CS1A). This shield, as shown in Figure 33, can be a simple copper area on a PCB below the sensor. It is used to protect it against potential surrounding noise sources and improve its global performance. It also brings directivity to the sensing, for example sensing objects approaching from top only. In addition, the touch pad shape should be a circle, oval or square. Any other shape with angles less than 90 degrees (see Figure 34) is not recommended.

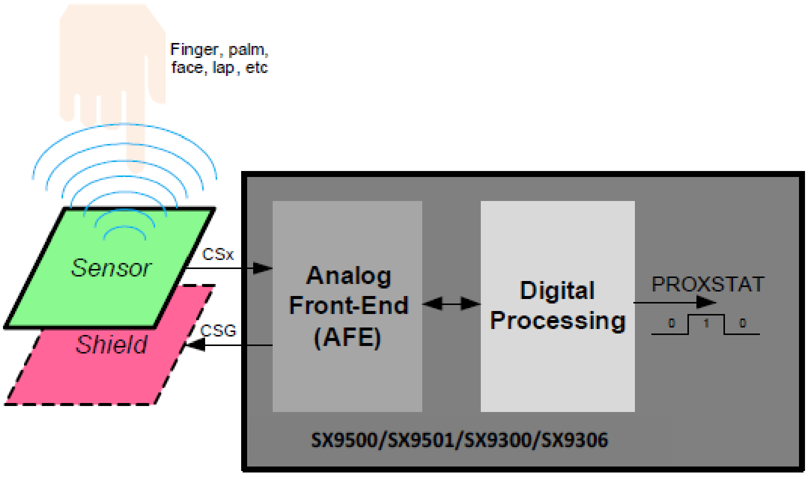

Figure 33: Shield Layer Function

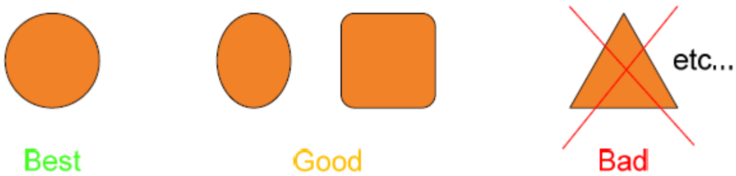

Figure 34: PCB Touch Pad Recommended Shapes

Figure 35: 680_RD_WEARABLE_PCB_TOUCH_BUTTONS_2X_VC -Top View

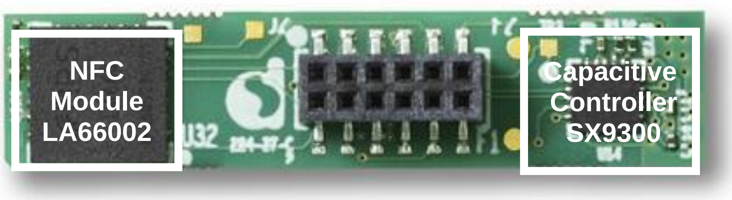

Figure 36: 680_RD_WEARABLE_PCB_TOUCH_BUTTONS_2X_VC - Bottom View

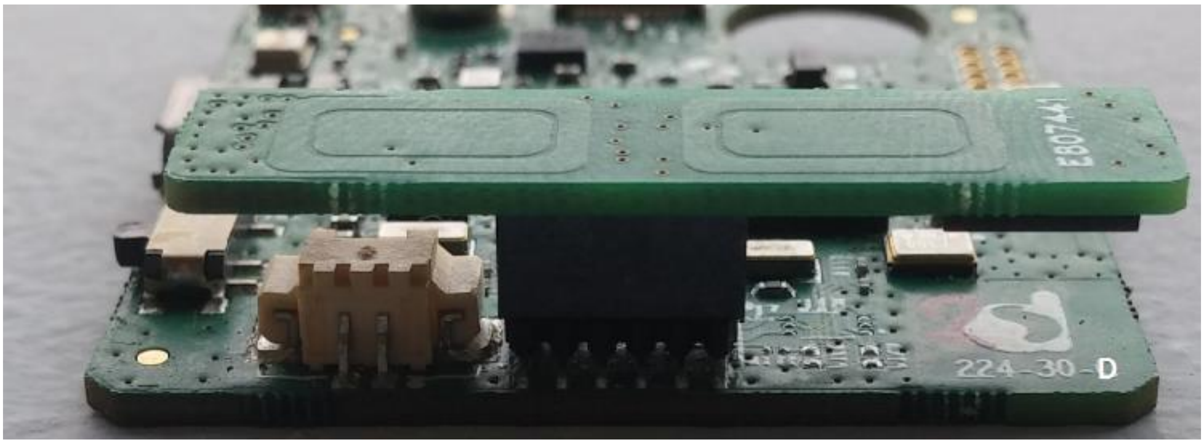

Figure 37: Touch Pad Daughterboard Attached to the Motherboard

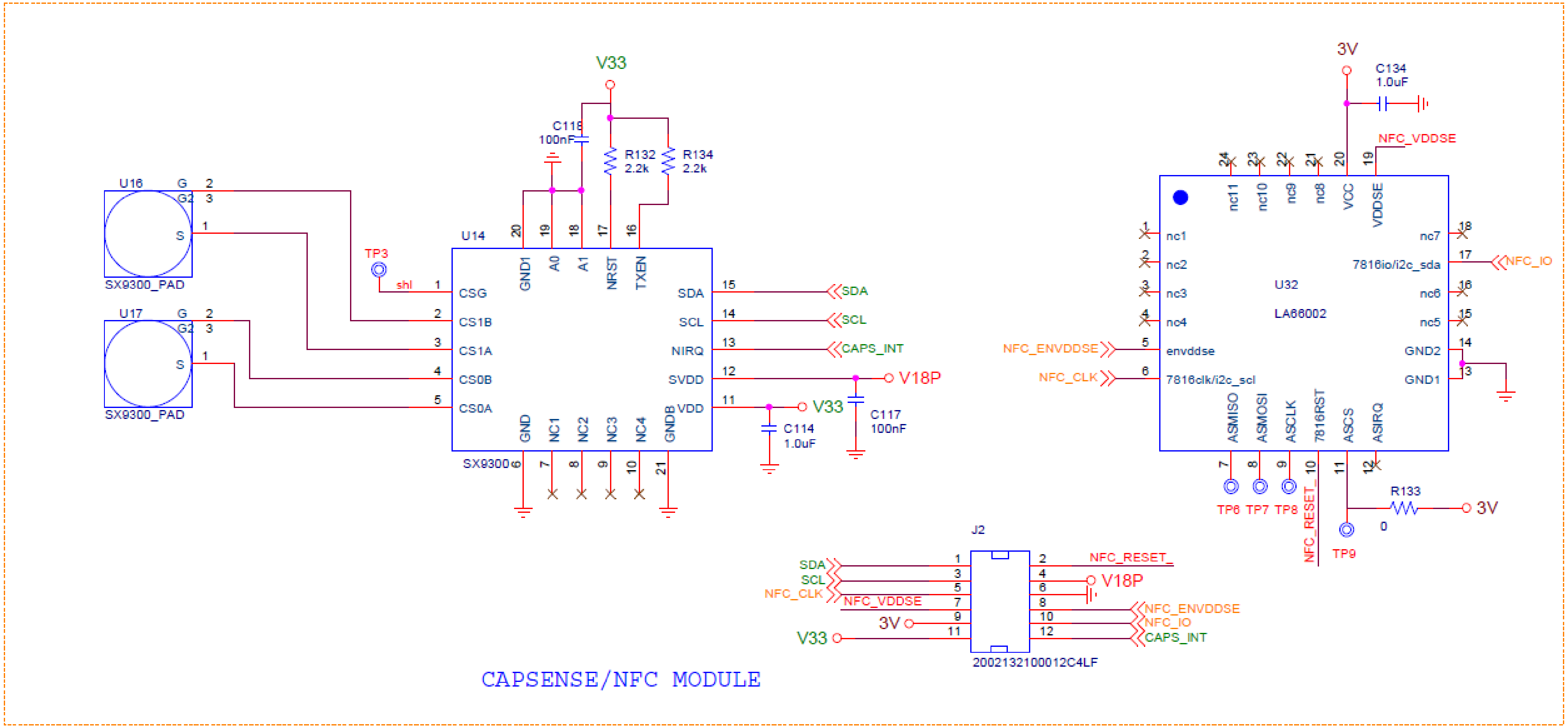

Figure 38: 680_RD_WEARABLE_PCB_TOUCH_BUTTONS_2X_VC - Daughterboard Schematic

6 Wearable Reference Design - PCB

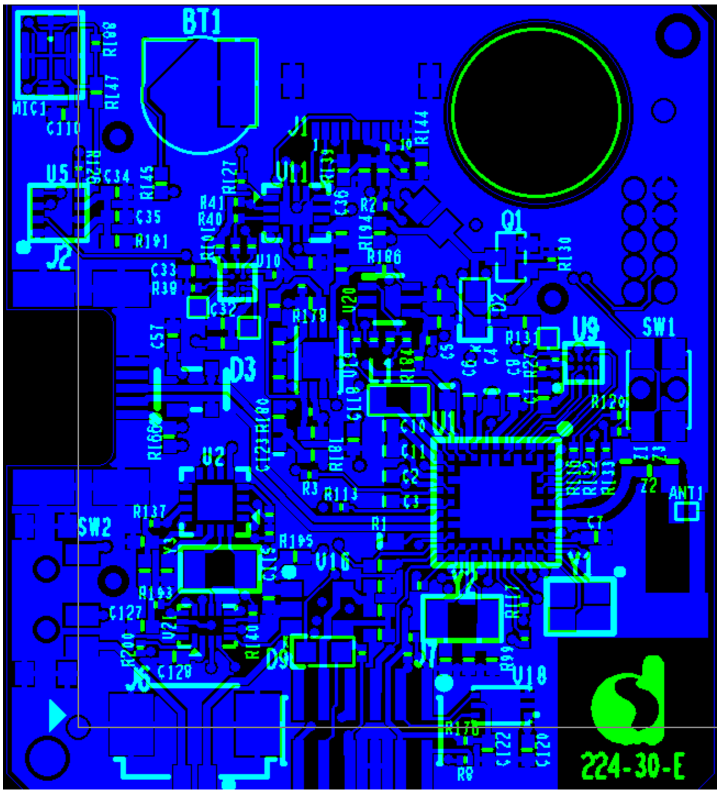

Figure 39: 680-RD-wearable-mb_vE – Motherboard (Top View)

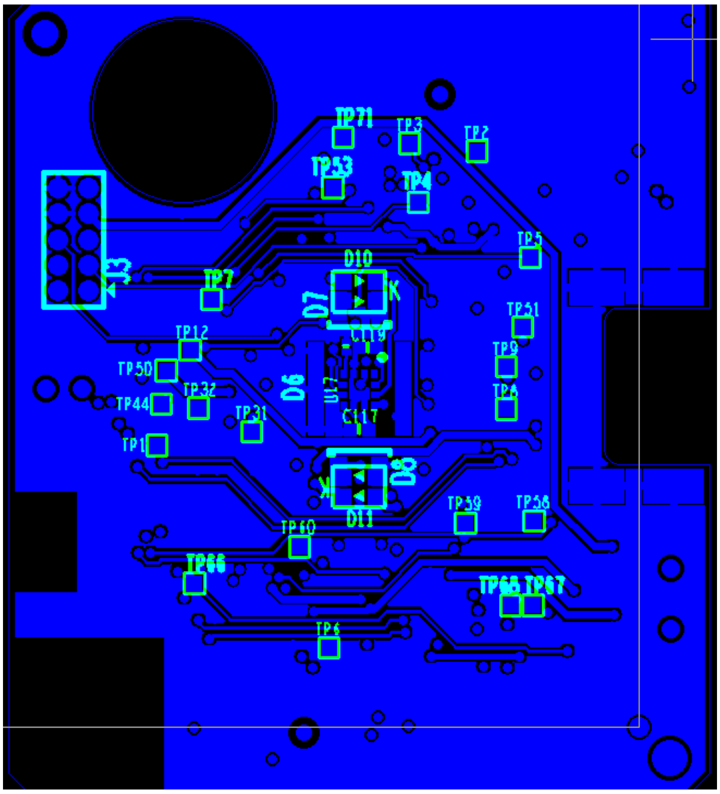

Figure 40: 680-RD-wearable-mb_vE – Motherboard (Bottom View)

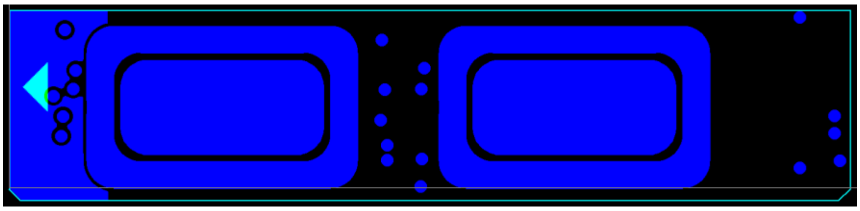

Figure 41: 680_RD_WEARABLE_PCB_TOUCH_BUTTONS_2X_VC – Daughterboard (Top View)

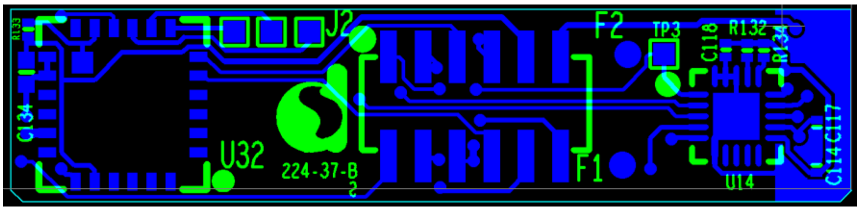

Figure 42: 680_RD_WEARABLE_PCB_TOUCH_BUTTONS_2X_VC – Daughterboard (Bottom View)

7 Power Consumption Measurements

The current measurements in this section have been obtained using the Agilent N6705B DC power analyzer. Figure 43 presents a simplified block diagram of the DA14681 wearable reference design, showing the various test points where the actual current measurements have been taken for each sensor and peripheral of the system.

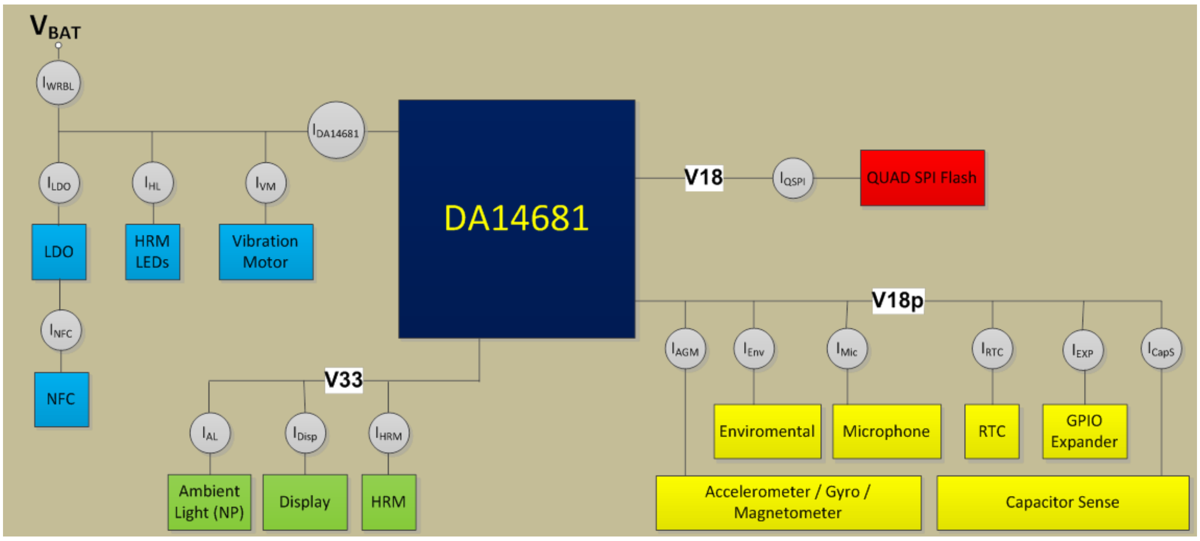

Figure 43: Current Measurement Test Points

Table 17: Current Consumption of Wearable Reference Design Sensors and Peripherals

System Component	Current consumption (µA)
DA14681 BLE SoC	3.41
QSPI Flash memory	0.38
LDO	0.06
TFT LCD display	0.05
HRM module (DI5115)	2.27
Environmental sensor (BME280)	0.12
Microphone	4.6
RTC	0.34
Accelerometer/Gyro (BMI160) and magnetometer (BMM150)	3.31
Capacitive touch controller (SX9300)	2.2
GPIO expander	1.2

The total average current consumption of the entire wearable reference design in sleep mode was measured to be 17.94 µA (advertising pulse period: 100 ms).

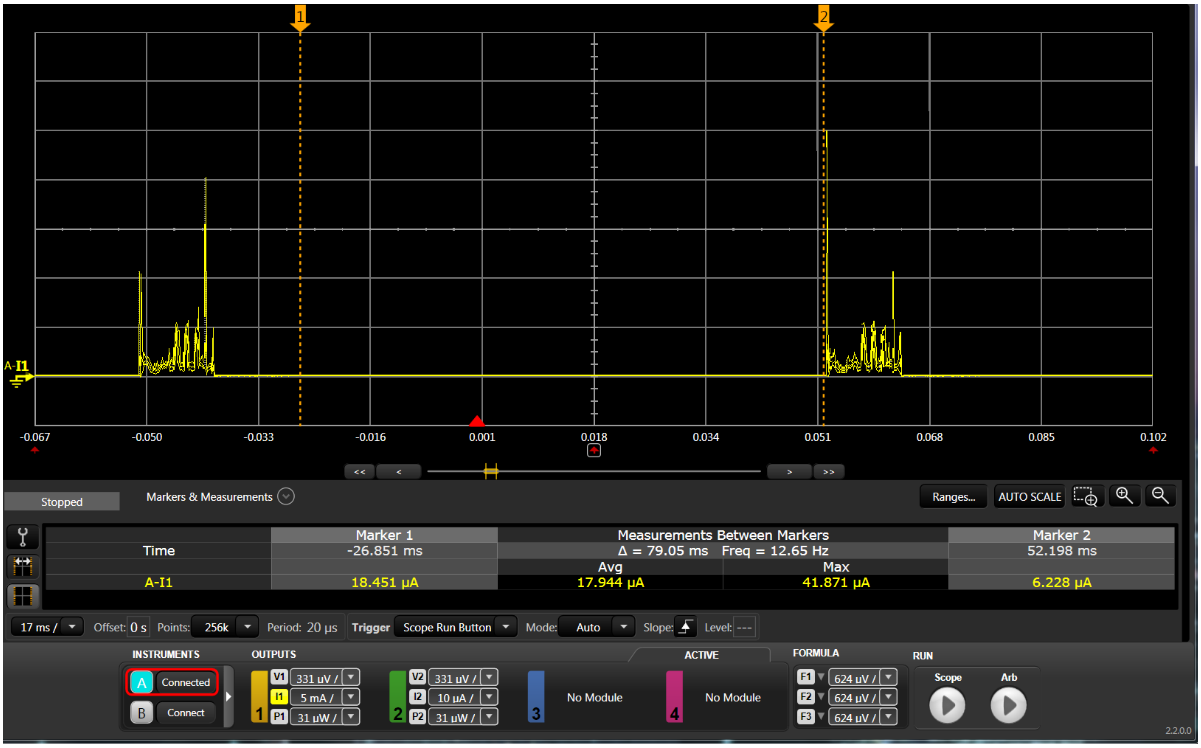

Figure 44: Actual Current Consumption Waveform (Sleep Mode) from DC Power Analyzer

The average current consumption in Advertising mode is approximately 250 µA. When the wearable device is connected to a host this goes up to 550 µA (advertising pulse period: 1 s).

8 Wearable Reference Design Enclosure

The main purpose of this wearable reference design was to fit inside a wrist watch type housing, so it can be used as fitness equipment. This section presents the enclosure that was developed for the wearable reference design.

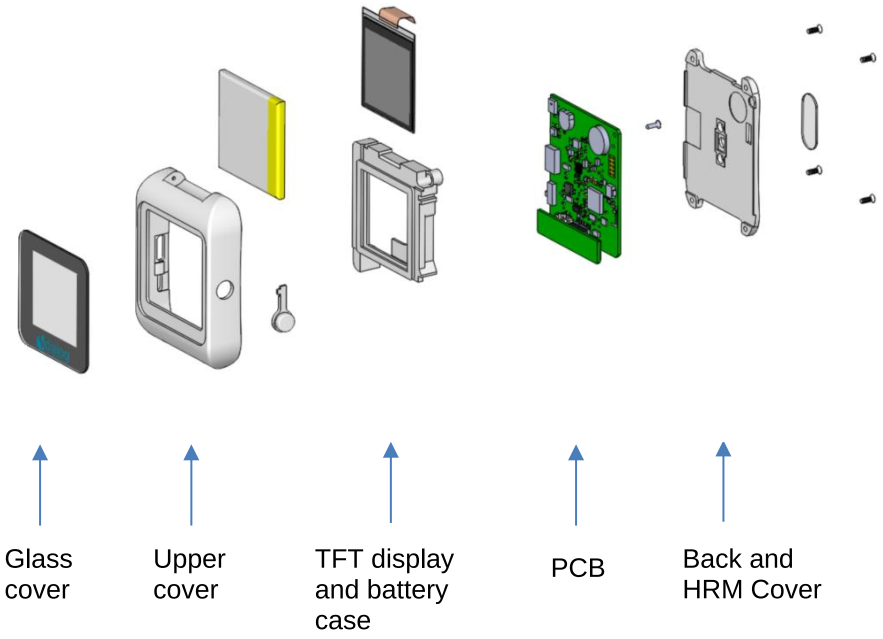

Figure 45: Wearable Reference Design Wnclosure – Exploded View

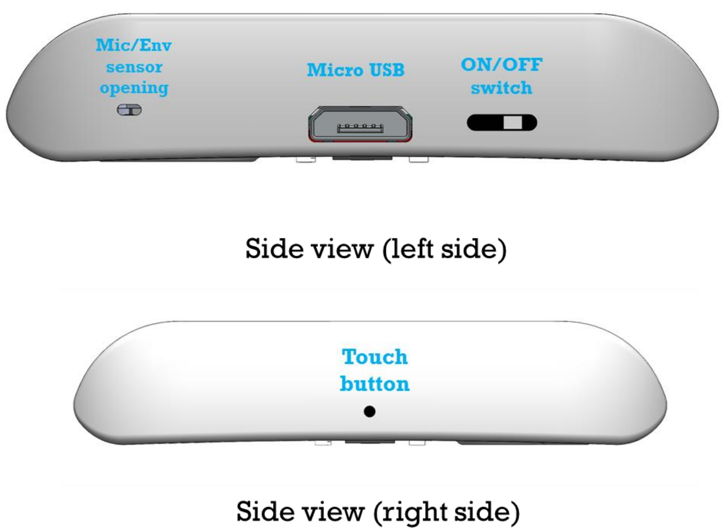

Figure 46: Wearable Reference Design Enclosure – Side View

Figure 47: Actual Enclosure – Top View

Figure 48: Actual Enclosure – Bottom View

Figure 49: Wearable Watch Placed on the Left Wrist

Revision History

Revision	Date	Description
1.3	24-Dec-2021	Updated logo, disclaimer, copyright.
1.2	06-Apr-2017	Text revision with regards to naming convention
1.1	08-Feb-2017	Text revision
1.0	17-Nov-2016	Initial version.

DA14681 Wearable Development Kit Hardware Manual

Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.