

MAX32664

Ultra-Low Power Biometric Sensor Hub

General Description

The MAX32664 is a sensor hub family with embedded firmware and world-class algorithms for wearables. It seamlessly enables customer-desired sensor functionality, including communication with Analog Devices' optical sensor solutions and delivering raw or calculated data to the outside world. This is achieved while keeping overall system power consumption in check. The device family interfaces to a microcontroller host through a fast-mode slave I²C interface for access to raw and processed sensor data as well as field updates. A firmware bootloader is also provided.

The MAX32664 Version A supports the MAX30101/MAX30102 high-sensitivity pulse oximeter and heart-rate sensor for wearable health for finger-based applications. A master mode I²C interface for communication with sensors is provided.

The MAX32664 Version B supports the MAX86140/MAX86141 for wrist-based applications. A master mode SPI interface for communication with sensors is provided.

The MAX32664 Version C supports the MAX86140/MAX86141 for wrist-based applications and MAXM86161 for ear-based applications. The device provides either a master mode SPI or an I²C interface for communication with sensors.

The MAX32664 Version D supports the MAX30101/MAX30102 high-sensitivity pulse oximeter and heart-rate sensor for wearable health for finger-based applications. A master mode I²C interface for communication with sensors is provided. Version D also supports estimated blood pressure monitoring.

The wearable algorithms in the MAX32664 sensor hub support a directly connected accelerometer. They also allow feeding of X, Y, and Z samples from a host-connected accelerometer. This architecture provides robust detection and compensation of motion artifacts in captured samples.

The tiny form factor 1.6mm x 1.6mm WLP or 3mm x 3mm TQFN allows for integration into extremely small application devices.

Applications

- Wearable Fitness
- Hearables
- Wearable Medical
- Portable Medical
- Mobile Devices

Benefits and Features

- Biometric Sensor Hub Enables Faster Time to Market
- Finger-Based (Version A) Algorithms Measure:
 - Pulse Heart Rate
 - Pulse Blood Oxygen Saturation (SpO₂)
- Wrist-Based (Version B) Algorithm Measures:
 - Pulse Heart Rate
- Wrist-Based or Ear-Based (Version C) Algorithms Measure:
 - Pulse Heart Rate
 - Pulse Blood Oxygen Saturation (SpO₂)
- Finger-Based (Version D) Algorithms Measure:
 - Pulse Heart Rate
 - Pulse Blood Oxygen Saturation (SpO₂)
 - Estimated Blood Pressure
- Both Raw and Processed Data Are Available
- Basic Peripheral Mix Optimizes Size and Performance
 - One Slave I²C for Communication with a Host Microcontroller
 - One Master I²C for Communication with Sensors (Versions A, C, and D)
 - One Master SPI for Communication with Sensors (Versions B and C)
 - 32.768kHz RTC
 - FIFO Provides Minimal Host Interaction
 - Bootloader Facilitates Secure, Authenticated Firmware Upgrades

Simplified Block Diagram

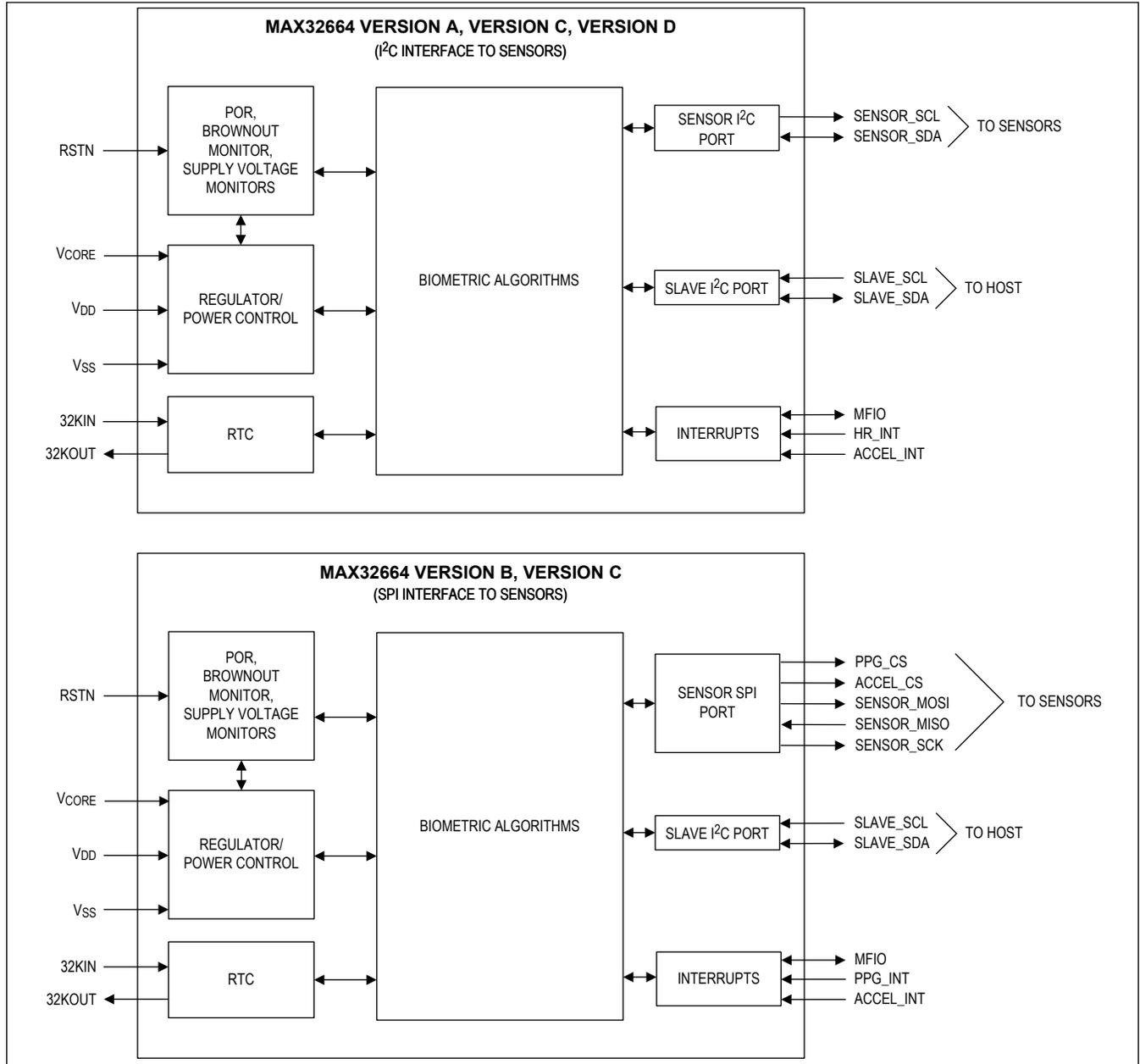


TABLE OF CONTENTS

| | |
|---|----|
| General Description | 1 |
| Applications | 1 |
| Benefits and Features | 1 |
| Simplified Block Diagram | 2 |
| Absolute Maximum Ratings | 7 |
| Package Information | 7 |
| 16 WLP | 7 |
| 24 TQFN-EP | 7 |
| Electrical Characteristics | 7 |
| Electrical Characteristics—I ² C | 9 |
| Electrical Characteristics—SPI | 9 |
| Pin Configuration MAX32664 Version A and Version D 16-WLP I ² C Interface to Sensors | 12 |
| Pin Descriptions MAX32664 Version A and Version D 16-WLP I ² C Interface to Sensors | 12 |
| Pin Configuration MAX32664 Version B and Version C 16-WLP SPI Interface to Sensors | 14 |
| Pin Descriptions MAX32664 Version B and Version C 16-WLP SPI Interface to Sensors | 14 |
| Pin Configuration MAX32664 Version A and Version D 24-TQFN I ² C Interface to Sensors | 16 |
| Pin Descriptions MAX32664 Version A and Version D 24-TQFN I ² C Interface to Sensors | 16 |
| Pin Configuration MAX32664 Version B and Version C 24-TQFN SPI Interface to Sensors | 18 |
| Pin Descriptions MAX32664 Version B and Version C 24-TQFN SPI Interface to Sensors | 18 |
| Pin Configuration MAX32664 Version C 16-WLP I ² C Interface to Sensors | 20 |
| Pin Descriptions MAX32664 Version C 16-WLP I ² C Interface to Sensors | 20 |
| Pin Configuration MAX32664 Version C 24-TQFN I ² C Interface to Sensors | 22 |
| Pin Descriptions MAX32664 Version C 24-TQFN I ² C Interface to Sensors | 22 |
| Detailed Description | 24 |
| Finger Heart Rate, SpO ₂ Algorithm (Version A) | 24 |
| Wrist Heart Rate Algorithm (Version B) | 24 |
| Wrist or Ear Heart Rate, SpO ₂ Algorithm (Version C) | 24 |
| Finger Heart Rate, SpO ₂ , Blood Pressure Algorithm (Version D) | 24 |
| Algorithm Selection and Evaluation | 24 |
| Interface to Host | 25 |
| Interface to the Sensors | 25 |
| Device Selection | 25 |
| Applications Information | 26 |
| Evaluation Platforms | 26 |
| Typical Application Circuits | 26 |
| MAX32664 VERSION A FINGER-BASED HEART RATE AND SpO ₂ MONITOR I ² C INTERFACE TO SENSORS | 26 |
| MAX32664 VERSION B WRIST-BASED HEART RATE MONITOR SPI INTERFACE TO SENSORS | 27 |
| MAX32664 VERSION C EAR-BASED HEART RATE AND SpO ₂ MONITOR I ² C INTERFACE TO SENSORS | 28 |

TABLE OF CONTENTS (CONTINUED)

MAX32664 VERSION C WRIST-BASED HEART RATE AND SpO₂ MONITOR SPI INTERFACE TO SENSORS . 29

MAX32664 VERSION D FINGER-BASED HEART RATE, SpO₂, BLOOD PRESSURE MONITOR I²C INTERFACE
TO SENSORS 30

Ordering Information 31

Revision History 33

LIST OF FIGURES

Figure 1. I²C Timing Diagram 10
Figure 2. SPI Master Mode Timing Diagram 11

LIST OF TABLES

Table 1. Evaluation Platforms 26

Absolute Maximum Ratings

| | | | |
|---|---------------------------------|---|-----------------|
| V _{DD} | -0.3V to +3.63V | Output Current (source) by Any Digital Pin..... | -25mA |
| 32KIN, 32KOUT | -0.3V to V _{DD} + 0.3V | Continuous Package Power Dissipation 24 TQFN-EP (multilayer board) T _A = +70°C (derate 16.3mW/°C above +70°C)... | 1305mW |
| All Digital Pins | -0.3V to V _{DD} + 0.3V | Operating Temperature Range | -40°C to +105°C |
| Total Current into All Digital Pins Combined (sink) | 100mA | Storage Temperature Range | -65°C to +150°C |
| V _{SS} | 100mA | Soldering Temperature (reflow) | +260°C |
| Output Current (sink) by Any Digital Pin..... | 25mA | | |

Note: All voltages with respect to V_{SS}, unless otherwise noted.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Information

16 WLP

| | |
|--|--|
| Package Code | W161K1+1 |
| Outline Number | 21-100241 |
| Land Pattern Number | Refer to Application Note 1891 |
| Thermal Resistance, Four-Layer Board: | |
| Junction to Ambient (θ _{JA}) | 66.34 °C/W |
| Junction to Case (θ _{JC}) | N/A |

24 TQFN-EP

| | |
|--|---------------------------|
| Package Code | T2433+2C |
| Outline Number | 21-100264 |
| Land Pattern Number | 90-100089 |
| Thermal Resistance, Four-Layer Board: | |
| Junction to Ambient (θ _{JA}) | 61.3°C/W |
| Junction to Case (θ _{JC}) | 2.2°C/W |

For the latest package outline information and land patterns (footprints), go to www.maximintegrated.com/packages. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--------------------------|------------------|--------------------------|------|-----|------|-------|
| POWER SUPPLIES | | | | | | |
| Supply Voltage | V _{DD} | | 1.71 | 1.8 | 3.63 | V |
| Power-Fail Reset Voltage | V _{RST} | Monitors V _{DD} | 1.63 | | 1.71 | V |
| Power-On Reset Voltage | V _{POR} | Monitors V _{DD} | | 1.4 | | V |

Electrical Characteristics (continued)

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|-----------------------|--|---------------------|--------|---------------------|---------------|
| DIGITAL I/O | | | | | | |
| Input Low Voltage for RSTN, SLAVE_SCL, SLAVE_SDA, SENSOR_SDA, SENSOR_MISO, PPG_INT, HR_INT, ACCEL_INT, MFIO | V_{IL} | | | | $0.3 \times V_{DD}$ | V |
| Input High Voltage for RSTN, SLAVE_SCL, SENSOR_SDA, SENSOR_MISO, PPG_INT, ACCEL_INT, MFIO, HR_INT, SLAVE_SDA | V_{IH} | | $0.7 \times V_{DD}$ | | | V |
| Output Low Voltage for SENSOR_SDA, SENSOR_SCL, SLAVE_SDA | V_{OL_I2C} | $V_{DD} = 1.71\text{V}$, $I_{OL} = 2\text{mA}$ | | 0.2 | 0.4 | V |
| Output High Voltage for SENSOR_SDA, SENSOR_SCL, SLAVE_SDA | V_{OH_I2C} | $V_{DD} = 1.71\text{V}$, $I_{OH} = -2\text{mA}$ | $V_{DD} - 0.4$ | | | V |
| Output Low Voltage for PPG_CS, ACCEL_CS, SENSOR_MOSI, SENSOR_SCK, MFIO | V_{OL} | $I_{OL} = 1\text{mA}$ | 0.4 | | | V |
| Output High Voltage for PPG_CS, ACCEL_CS, SENSOR_MOSI, SENSOR_SCK, MFIO | V_{OH} | $I_{OH} = -1\text{mA}$ | $V_{DD} - 0.4$ | | | V |
| Input Hysteresis (Schmitt) | V_{IHYS} | | | 300 | | mV |
| Input/Output Pin Capacitance for All Pins | C_{IO} | | | 4 | | pF |
| Input Leakage Current Low | I_{IL} | $V_{IN} = 0\text{V}$ | -500 | | +500 | nA |
| Input Leakage Current High | I_{IH} | $V_{IN} = 3.6\text{V}$ | -500 | | +500 | nA |
| Input Pullup Resistor to RSTN | R_{PU_VDD} | Pullup to $V_{DD} = 3.63\text{V}$ | | 10.5 | | k Ω |
| CLOCKS | | | | | | |
| System Clock Frequency | $f_{\text{SYS_CLK}}$ | | | 96 | | MHz |
| RTC Input Frequency | $f_{32\text{KIN}}$ | 32.768kHz watch crystal, $C_L = 6\text{pF}$, $\text{ESR} < 90\text{k}\Omega$, $C_0 < 2\text{pF}$ | | 32.768 | | kHz |
| RTC Operating Current | I_{RTC} | All power modes, RTC enabled | | 0.45 | | μA |

Electrical Characteristics (continued)

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|-------------------|----------------------|------------|-----|-----|-----|-------|
| RTC Power-Up Time | $t_{\text{RTC_ON}}$ | | | 250 | | ms |

Electrical Characteristics—I²C

(Limits are 100% tested at $T_A = +25^\circ\text{C}$ and $T_A = +105^\circ\text{C}$. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|---------------------|---|-----|-----|-----|---------------|
| FAST MODE | | | | | | |
| Output Fall Time | t_{OF} | From $V_{\text{OH(MIN)}}$ to $V_{\text{OL(MAX)}}$ | | 150 | | ns |
| Pulse Width Suppressed by Input Filter | t_{SP} | | | 75 | | ns |
| SCL Clock Frequency | f_{SCL} | | 0 | | 400 | kHz |
| Low Period SCL Clock | t_{LOW} | | 1.3 | | | μs |
| High Time SCL Clock | t_{HIGH} | | 0.6 | | | μs |
| Setup Time for Repeated Start Condition | $t_{\text{SU;STA}}$ | | 0.6 | | | μs |
| Hold Time for Repeated Start Condition | $t_{\text{HD;STA}}$ | | 0.6 | | | μs |
| Data Setup Time | $t_{\text{SU;DAT}}$ | | | 125 | | ns |
| Data Hold Time | $t_{\text{HD;DAT}}$ | | | 10 | | ns |
| Rise Time for SDA and SCL | t_{R} | | | 30 | | ns |
| Fall Time for SDA and SCL | t_{F} | | | 30 | | ns |
| Setup Time for a Stop Condition | $t_{\text{SU;STO}}$ | | 0.6 | | | μs |
| Bus Free Time Between a Stop and Start Condition | t_{BUS} | | 1.3 | | | μs |
| Data Valid Time | $t_{\text{VD;DAT}}$ | | 0.9 | | | μs |
| Data Valid Acknowledge Time | $t_{\text{VD;ACK}}$ | | 0.9 | | | μs |

Electrical Characteristics—SPI

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--------------------------------|------------------|------------|-----|--------------------|-----|-------|
| MASTER MODE | | | | | | |
| SPI Master Operating Frequency | f_{MCK} | | | | 48 | MHz |
| SPI Master SCK Period | t_{MCK} | | | $1/f_{\text{MCK}}$ | | ns |

Electrical Characteristics—SPI (continued)

(Timing specifications are guaranteed by design and not production tested.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|--------------------|------------|-------------|-------------|-----|-------|
| SCK Output Pulse-Width High/Low | t_{MCH}, t_{MCL} | | $t_{MCK}/2$ | | | ns |
| MOSI Output Hold Time After SCK Sample Edge | t_{MOH} | | $t_{MCK}/2$ | | | ns |
| MOSI Output Valid to Sample Edge | t_{MOV} | | $t_{MCK}/2$ | | | ns |
| MISO Input Valid to SCK Sample Edge Setup | t_{MIS} | | | 5 | | ns |
| MISO Input to SCK Sample Edge Hold | t_{MIH} | | | $t_{MCK}/2$ | | ns |

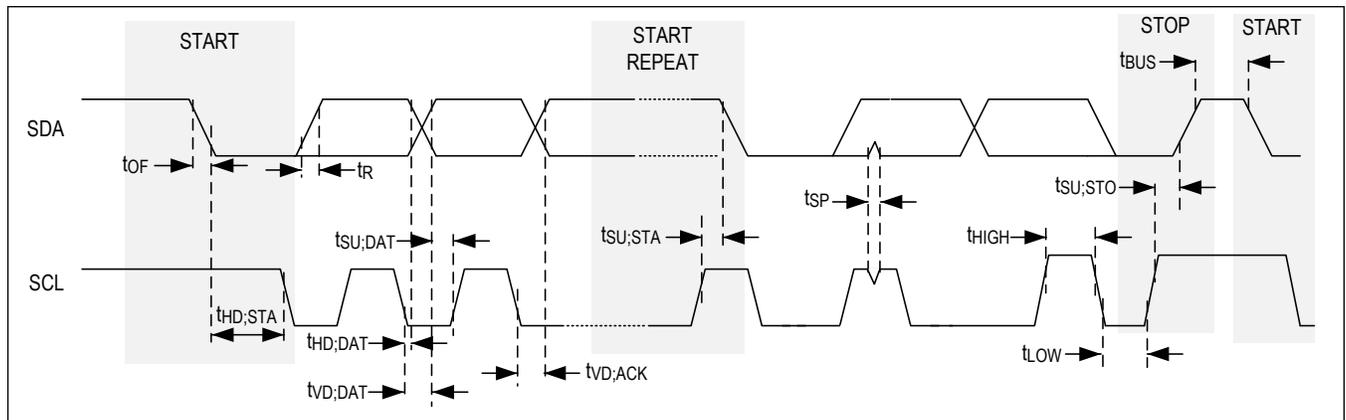


Figure 1. I²C Timing Diagram

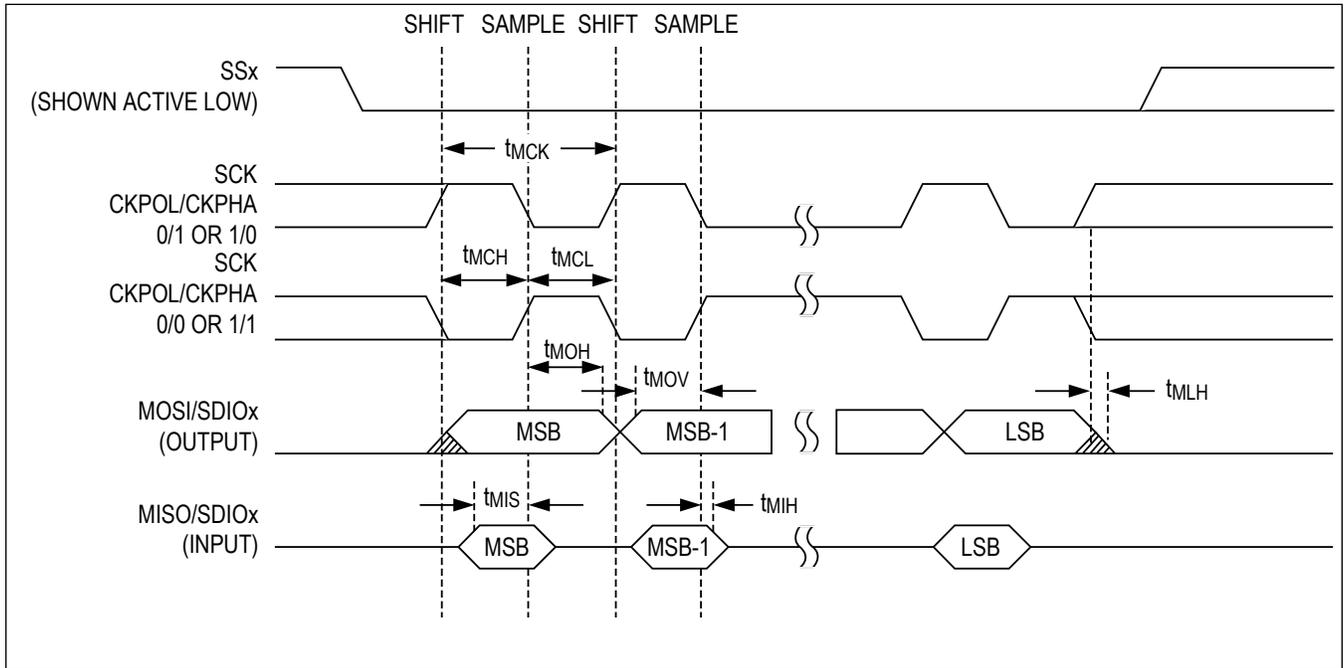
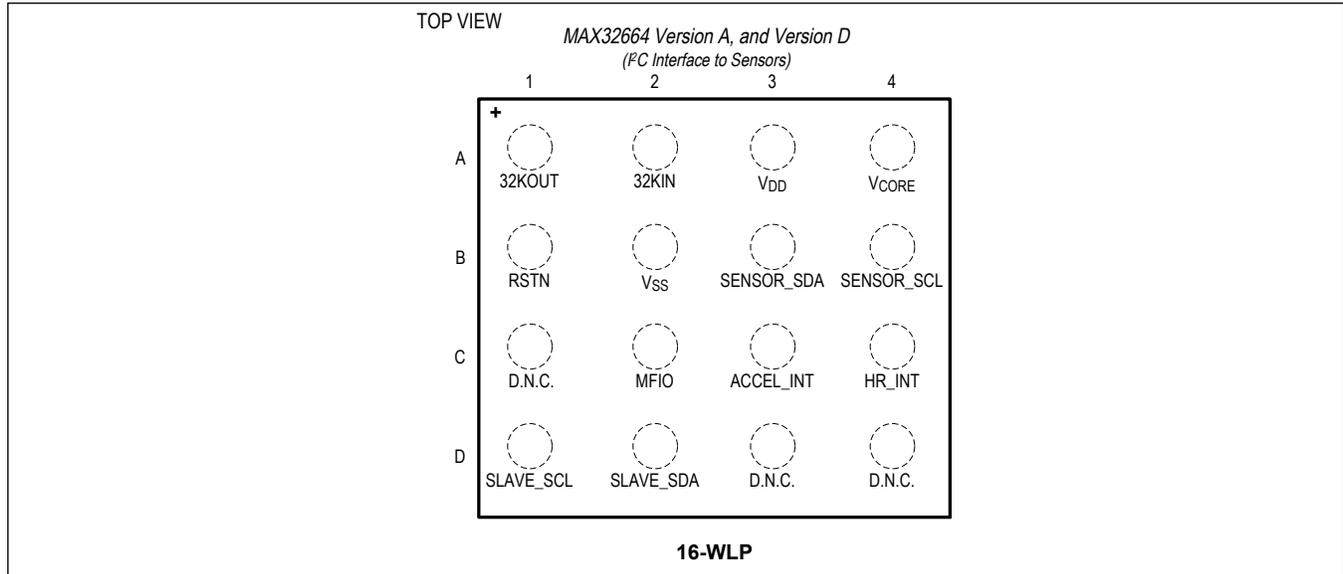


Figure 2. SPI Master Mode Timing Diagram

Pin Configuration MAX32664 Version A and Version D 16-WLP I²C Interface to Sensors

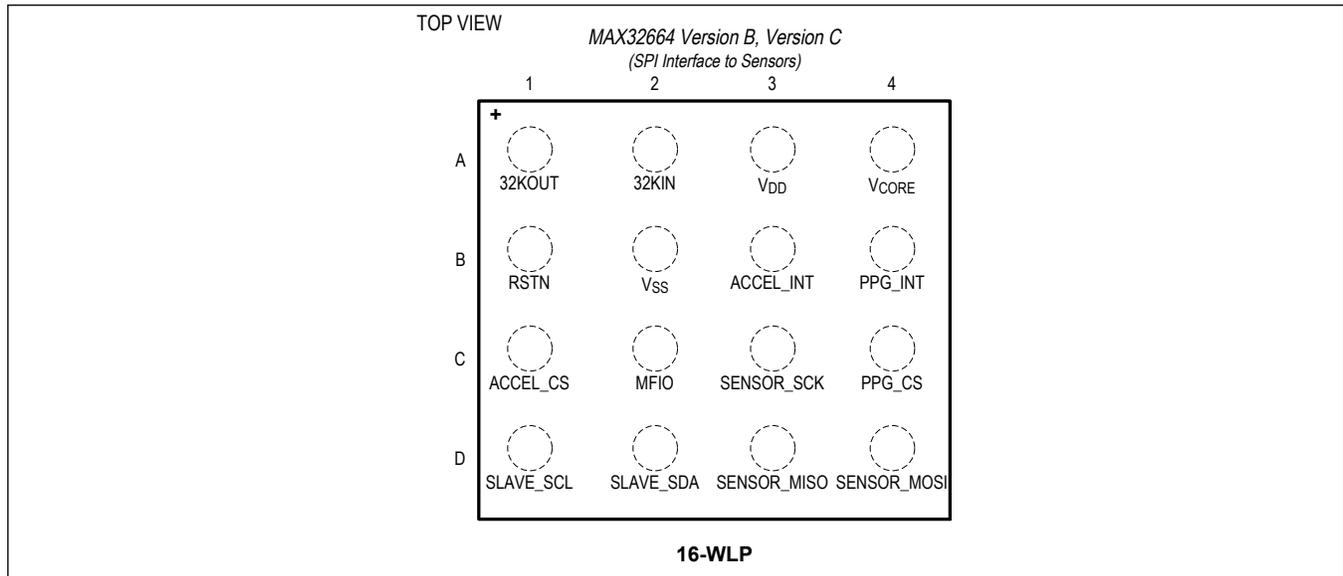


Pin Descriptions MAX32664 Version A and Version D 16-WLP I²C Interface to Sensors

| PIN | NAME | FUNCTION MODE | FUNCTION |
|--------------|-------------------|-------------------------------------|--|
| | | Signal Name | |
| POWER | | | |
| A3 | V _{DD} | Digital Supply Voltage | This pin must be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. The device operates solely from this one power supply pin. |
| A4 | V _{CORE} | Core Supply Voltage | V _{CORE} must always be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. Do not connect this device pin to any other circuits. |
| B2 | V _{SS} | Digital Ground | |
| CLOCK | | | |
| A2 | 32KIN | 32.768kHz Crystal Oscillator Input | Connect a 32.768kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, an external clock source can be driven on 32KIN if the 32KOUT pin is left unconnected. |
| A1 | 32KOUT | 32.768kHz Crystal Oscillator Output | |
| RESET | | | |
| B1 | RSTN | Reset | External System Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin is internally connected with an internal pullup to the V _{DD} supply as indicated in the Electrical Characteristics table. Add a noise snubber circuit as close as possible to the device, with component values shown in the Typical Application Circuits . |

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-----------------------|------------|--|--|
| | | Signal Name | |
| I²C | | | |
| D1 | SLAVE_SCL | I ² C Slave Clock | This is the I ² C slave SCL that should be connected to the host I ² C master SCL. |
| D2 | SLAVE_SDA | I ² C Slave Data | This is the I ² C slave SDA that should be connected to the host I ² C master SDA. |
| B4 | SENSOR_SCL | I ² C Sensor Clock | This is the I ² C master SCL that should be connected to the I ² C slave SCL on the slave sensors. |
| B3 | SENSOR_SDA | I ² C Sensor Data | This is the I ² C master SDA that should be connected to the I ² C slave SDA on the slave sensors. |
| INTERRUPTS | | | |
| C4 | HR_INT | Heart Rate/PPG Monitor Interrupt Input | This pin connects to the heart rate/PPG monitor sensor interrupt output. |
| C3 | ACCEL_INT | Accelerometer Interrupt Input | This pin connects to the accelerometer sensor interrupt output. |
| C2 | MFIO | Multifunction I/O | MFIO asserts low as an output when the sensor hub needs to communication with the host; MFIO acts as an input and when held low during a reset, the sensor hub enters bootloader mode. |
| DO NOT CONNECT | | | |
| C1, D3, D4 | D.N.C. | Do Not Connect | This pin is internally connected. Do not make any electrical connection, including V _{SS} , to this pin. |

Pin Configuration MAX32664 Version B and Version C 16-WLP SPI Interface to Sensors

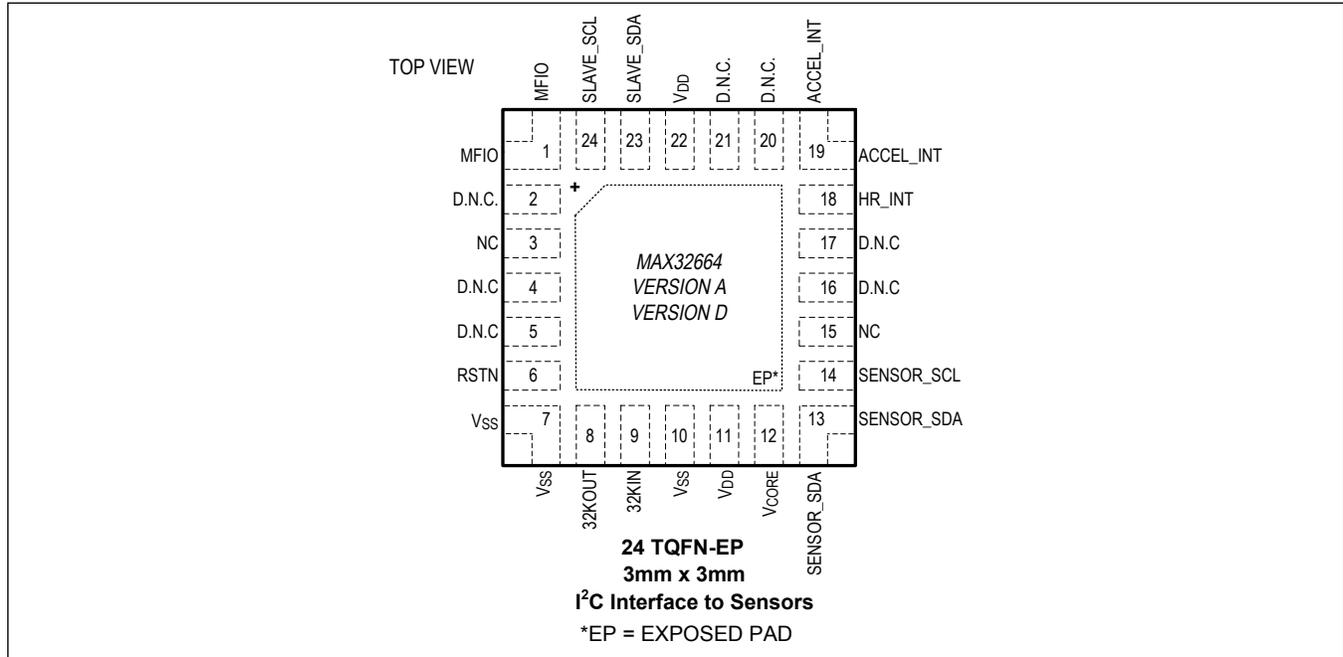


Pin Descriptions MAX32664 Version B and Version C 16-WLP SPI Interface to Sensors

| PIN | NAME | FUNCTION MODE | FUNCTION |
|--------------|-------------------|-------------------------------------|--|
| | | Signal Name | |
| POWER | | | |
| A3 | V _{DD} | Digital Supply Voltage | This pin must be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. The device operates solely from this one power supply pin. |
| A4 | V _{CORE} | Core Supply Voltage | V _{CORE} must always be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. Do not connect this device pin to any other circuits. |
| B2 | V _{SS} | Digital Ground | |
| CLOCK | | | |
| A2 | 32KIN | 32.768kHz Crystal Oscillator Input | Connect a 32.768kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, an external clock source can be driven on 32KIN if the 32KOUT pin is left unconnected. |
| A1 | 32KOUT | 32.768kHz Crystal Oscillator Output | |
| RESET | | | |
| B1 | RSTN | Reset | External System Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin is internally connected with an internal pullup to the V _{DD} supply as indicated in the Electrical Characteristics table. Add a noise snubber circuit as close as possible to the device, with component values shown in the Typical Application Circuits . |

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-----------------------|-------------|-------------------------------|---|
| | | Signal Name | |
| SPI | | | |
| C3 | SENSOR_SCK | SPI Master Clock for Sensors | This is the SPI master clock that should be connected to the sensor SPI SCK. |
| D3 | SENSOR_MISO | SPI Master In Slave Out | This is the SPI master in slave out that should be connected to the sensor SPI data output pin. |
| D4 | SENSOR_MOSI | SPI Master Out Slave In | This is the SPI master out slave in that should be connected to the sensor SPI data input pin. |
| C4 | PPG_CS | PPG Sensor Chip Select | This is the SPI master PPG sensor chip select output that should be connected to the SPI slave PPG sensor chip select input. |
| C1 | ACCEL_CS | Accelerometer Chip Select | This is the SPI master accelerometer chip select output that should be connected to the SPI slave accelerometer chip select input. |
| I²C | | | |
| D1 | SLAVE_SCL | I ² C Slave Clock | This is the I ² C slave SCL that should be connected to the host I ² C master SCL. |
| D2 | SLAVE_SDA | I ² C Slave Data | This is the I ² C slave SDA that should be connected to the host I ² C master SDA. |
| INTERRUPTS | | | |
| B4 | PPG_INT | PPG Sensor Interrupt Input | This pin connects to the PPG sensor interrupt output. |
| B3 | ACCEL_INT | Accelerometer Interrupt Input | This pin connects to the accelerometer sensor interrupt output. |
| C2 | MFIO | Multifunction I/O | The MFIO pin provides different functions. MFIO acts as an input and when held low during a reset, the sensor hub enters bootloader mode. The host asserts MFIO low when it needs to communicate with the sensor hub. |

Pin Configuration MAX32664 Version A and Version D 24-TQFN I²C Interface to Sensors

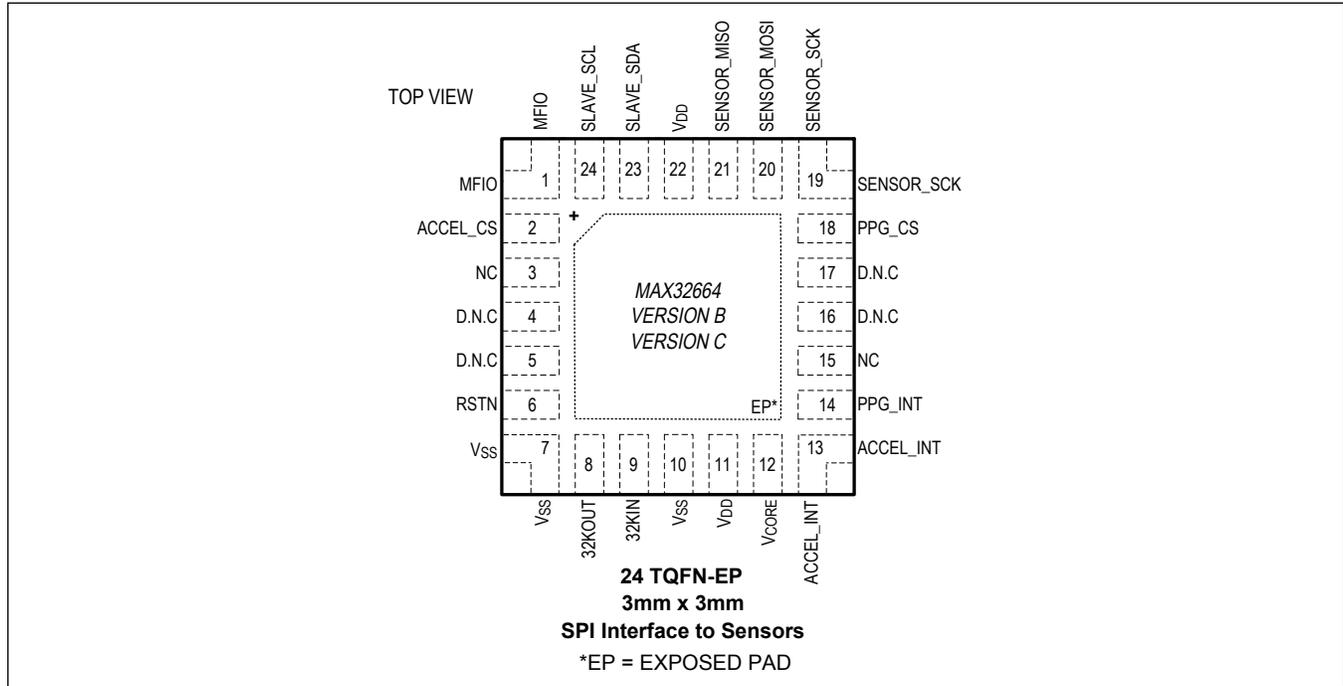


Pin Descriptions MAX32664 Version A and Version D 24-TQFN I²C Interface to Sensors

| PIN | NAME | FUNCTION MODE | FUNCTION |
|--------------|-------------------|-------------------------------------|---|
| | | Signal Name | |
| POWER | | | |
| 11, 22 | V _{DD} | Digital Supply Voltage | This pin must be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. The device operates solely from this one power supply pin. |
| 12 | V _{CORE} | Core Supply Voltage | V _{CORE} must always be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. Do not connect this device pin to any other circuits. |
| 7, 10 | V _{SS} | Digital Ground | |
| EP | EP | Exposed Pad | Exposed Pad (TQFN Only). This pad must be connected to V _{SS} . Refer to Application Note 3273: Exposed Pads: A Brief Introduction for additional information. |
| CLOCK | | | |
| 9 | 32KIN | 32.768kHz Crystal Oscillator Input | Connect a 32.768kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, an external clock source can be driven on 32KIN if the 32KOUT pin is left unconnected. |
| 8 | 32KOUT | 32.768kHz Crystal Oscillator Output | |

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-------------------------|------------|--|--|
| | | Signal Name | |
| RESET | | | |
| 6 | RSTN | Reset | External System Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin is internally connected with an internal pullup to the V _{DD} supply as indicated in the Electrical Characteristics table. Add a noise snubber circuit as close as possible to the device, with component values shown in the Typical Application Circuits . |
| I²C | | | |
| 24 | SLAVE_SCL | I ² C Slave Clock | This is the I ² C slave SCL that should be connected to the host I ² C master SCL. |
| 23 | SLAVE_SDA | I ² C Slave Data | This is the I ² C slave SDA that should be connected to the host I ² C master SDA. |
| 14 | SENSOR_SCL | I ² C Sensor Clock | This is the I ² C master SCL that should be connected to the I ² C slave SCL on the slave sensors. |
| 13 | SENSOR_SDA | I ² C Sensor Data | This is the I ² C master SDA that should be connected to the I ² C slave SDA on the slave sensors. |
| INTERRUPTS | | | |
| 18 | HR_INT | Heart Rate/PPG Monitor Interrupt Input | This pin connects to the heart rate/PPG monitor sensor interrupt output. |
| 19 | ACCEL_INT | Accelerometer Interrupt Input | This pin connects to the accelerometer sensor interrupt output. |
| 1 | MFIO | Multifunction I/O | MFIO asserts low as an output when the sensor hub needs to communicate with the host; MFIO acts as an input and when held low during a reset, the sensor hub enters bootloader mode. |
| DO NOT CONNECT | | | |
| 2, 4, 5, 16, 17, 20, 21 | D.N.C. | Do Not Connect | This pin is internally connected. Do not make any electrical connection, including V _{SS} , to this pin. |
| NOT CONNECTED | | | |
| 3, 15 | NC | Not Connected. This pin is not connected to the die and can be used to route any signal. | This pin is not connected to the die and can be used to route any signal. |

Pin Configuration MAX32664 Version B and Version C 24-TQFN SPI Interface to Sensors

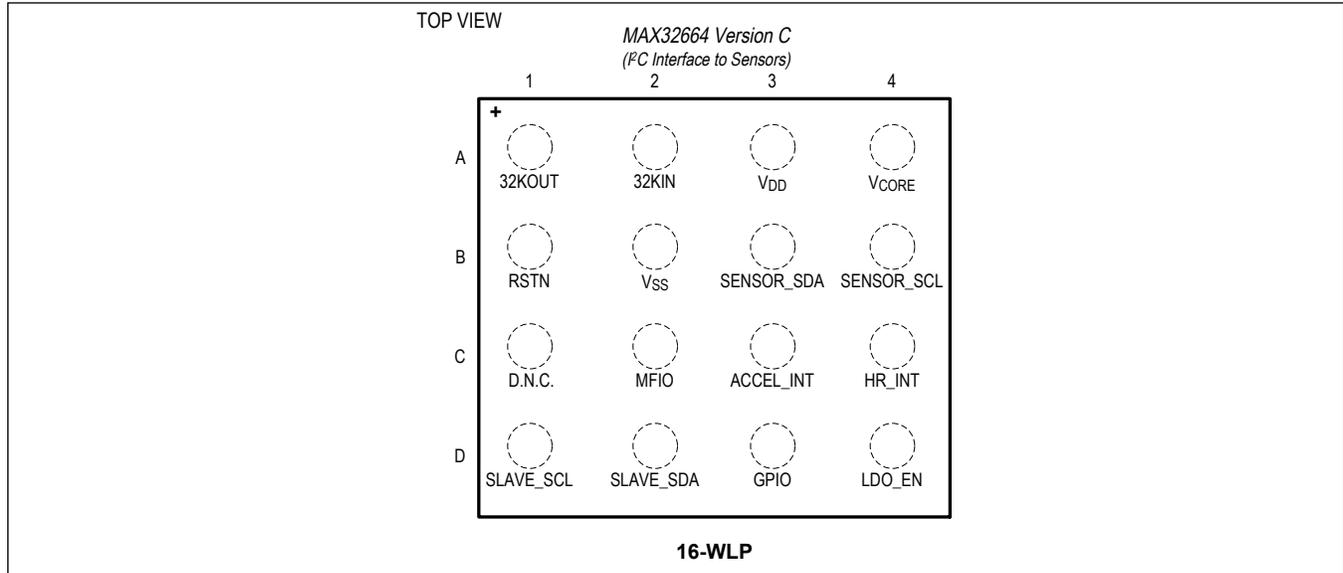


Pin Descriptions MAX32664 Version B and Version C 24-TQFN SPI Interface to Sensors

| PIN | NAME | FUNCTION MODE | FUNCTION |
|--------------|-------------------|-------------------------------------|---|
| | | Signal Name | |
| POWER | | | |
| 11, 22 | V _{DD} | Digital Supply Voltage | This pin must be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. The device operates solely from this one power supply pin. |
| 12 | V _{CORE} | Core Supply Voltage | V _{CORE} must always be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. Do not connect this device pin to any other circuits. |
| 7, 10 | V _{SS} | Digital Ground | |
| EP | EP | Exposed Pad | Exposed Pad (TQFN Only). This pad must be connected to V _{SS} . Refer to Application Note 3273: Exposed Pads: A Brief Introduction for additional information. |
| CLOCK | | | |
| 9 | 32KIN | 32.768kHz Crystal Oscillator Input | Connect a 32.768kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, an external clock source can be driven on 32KIN if the 32KOUT pin is left unconnected. |
| 8 | 32KOUT | 32.768kHz Crystal Oscillator Output | |

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-----------------------|-------------|--|--|
| | | Signal Name | |
| RESET | | | |
| 6 | RSTN | Reset | External System Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin is internally connected with an internal pullup to the V _{DD} supply as indicated in the Electrical Characteristics table. Add a noise snubber circuit as close as possible to the device, with component values shown in the Typical Application Circuits . |
| SPI | | | |
| 19 | SENSOR_SCK | SPI Master Clock for Sensors | This is the SPI master clock that should be connected to the sensor SPI SCK. |
| 21 | SENSOR_MISO | SPI Master In Slave Out | This is the SPI master in slave out that should be connected to the sensor SPI data output pin. |
| 20 | SENSOR_MOSI | SPI Master Out Slave In | This is the SPI master out slave in that should be connected to the sensor SPI data input pin. |
| 18 | PPG_CS | PPG Sensor Chip Select | This is the SPI master PPG sensor chip select output that should be connected to the SPI slave PPG sensor chip select input. |
| 2 | ACCEL_CS | Accelerometer Chip Select | This is the SPI master accelerometer chip select output that should be connected to the SPI slave accelerometer chip select input. |
| I²C | | | |
| 24 | SLAVE_SCL | I ² C Slave Clock | This is the I ² C slave SCL that should be connected to the host I ² C master SCL. |
| 23 | SLAVE_SDA | I ² C Slave Data | This is the I ² C slave SDA that should be connected to the host I ² C master SDA. |
| INTERRUPTS | | | |
| 14 | PPG_INT | PPG Sensor Interrupt Input | This pin connects to the PPG sensor interrupt output. |
| 13 | ACCEL_INT | Accelerometer Interrupt Input | This pin connects to the accelerometer sensor interrupt output. |
| 1 | MFIO | Multifunction I/O | This pin provides different functions. MFIO acts as an input and when held low during a reset, the sensor hub enters bootloader mode. The host asserts MFIO low when it needs to communicate with the sensor hub. |
| DO NOT CONNECT | | | |
| 4, 5, 16, 17 | D.N.C. | Do Not Connect | This pin is internally connected. Do not make any electrical connection, including V _{SS} , to this pin. |
| NOT CONNECTED | | | |
| 3, 15 | NC | Not Connected. This pin is not connected to the die and can be used to route any signal. | This pin is not connected to the die and can be used to route any signal. |

Pin Configuration MAX32664 Version C 16-WLP I²C Interface to Sensors

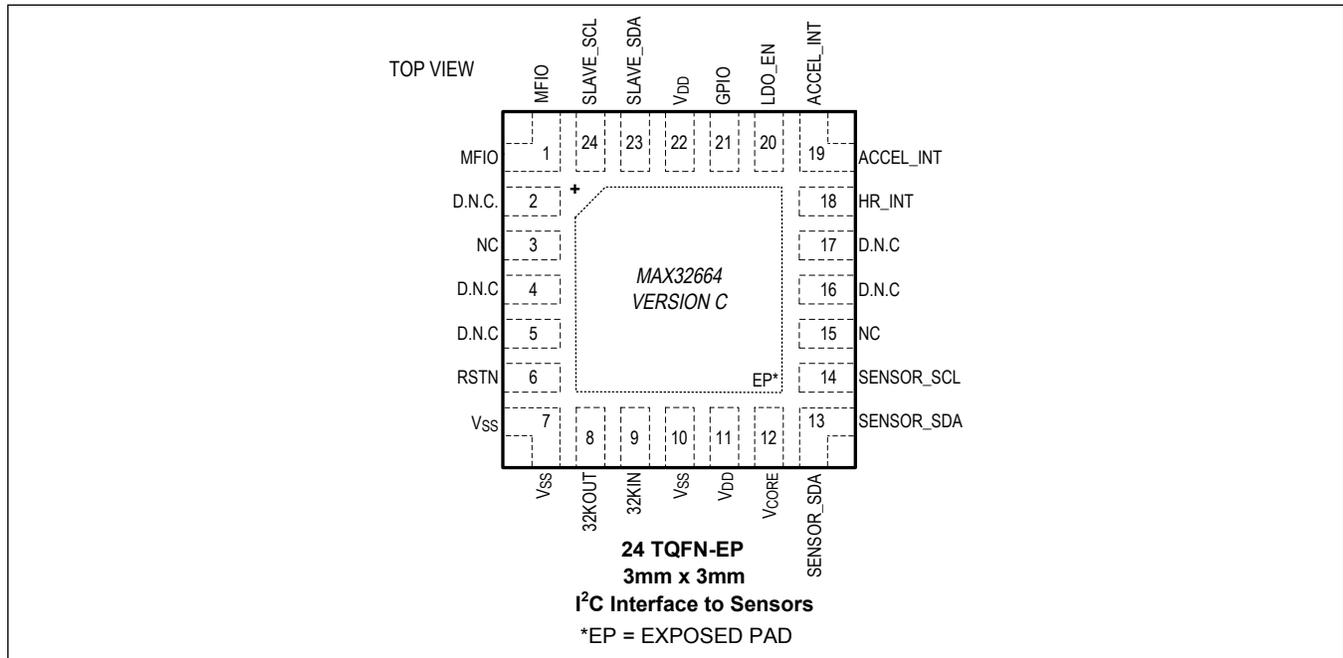


Pin Descriptions MAX32664 Version C 16-WLP I²C Interface to Sensors

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-----------------------|-------------------|-------------------------------------|--|
| | | Signal Name | |
| POWER | | | |
| A3 | V _{DD} | Digital Supply Voltage | This pin must be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. The device operates solely from this one power supply pin. |
| A4 | V _{CORE} | Core Supply Voltage | V _{CORE} must always be bypassed to V _{SS} with a 1.0µF capacitor as close as possible to the package. Do not connect this device pin to any other circuits. |
| B2 | V _{SS} | Digital Ground | |
| CLOCK | | | |
| A2 | 32KIN | 32.768kHz Crystal Oscillator Input | Connect a 32.768kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, an external clock source can be driven on 32KIN if the 32KOUT pin is left unconnected. |
| A1 | 32KOUT | 32.768kHz Crystal Oscillator Output | |
| RESET | | | |
| B1 | RSTN | Reset | External System Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin is internally connected with an internal pullup to the V _{DD} supply as indicated in the Electrical Characteristics table. Add a noise snubber circuit as close as possible to the device, with component values shown in the Typical Application Circuits . |
| I²C | | | |
| D1 | SLAVE_SCL | I ² C Slave Clock | This is the I ² C slave SCL that should be connected to the host I ² C master SCL. |

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-----------------------|------------|--|--|
| | | Signal Name | |
| D2 | SLAVE_SDA | I ² C Slave Data | This is the I ² C slave SDA that should be connected to the host I ² C master SDA. |
| B4 | SENSOR_SCL | I ² C Sensor Clock | This is the I ² C master SCL that should be connected to the I ² C slave SCL on the slave sensors. |
| B3 | SENSOR_SDA | I ² C Sensor Data | This is the I ² C master SDA that should be connected to the I ² C slave SDA on the slave sensors. |
| INTERRUPTS | | | |
| C4 | HR_INT | Heart Rate/PPG Monitor Interrupt Input | This pin connects to the heart rate/PPG monitor sensor interrupt output. |
| C3 | ACCEL_INT | Accelerometer Interrupt Input | This pin connects to the accelerometer sensor interrupt output. |
| C2 | MFIO | Multifunction I/O | The host asserts MFIO low when it needs to communicate with the sensor hub; MFIO acts as an input and when held low during a reset, the sensor hub enters bootloader mode. |
| GPIO | | | |
| D3 | GPIO | General-Purpose Input/Output | Open drain when programmed as output (active low). This device pin connects to the heart rate/PPG monitor sensor GPIO pin. |
| D4 | LDO_EN | LDO Enable Output | This pin connects to the heart rate/PPG monitor sensor LDO Enable pin. |
| DO NOT CONNECT | | | |
| C1 | D.N.C. | Do Not Connect | This pin is internally connected. Do not make any electrical connection, including V _{SS} , to this pin. |

Pin Configuration MAX32664 Version C 24-TQFN I²C Interface to Sensors



Pin Descriptions MAX32664 Version C 24-TQFN I²C Interface to Sensors

| PIN | NAME | FUNCTION MODE | FUNCTION |
|--------------|-------------------|-------------------------------------|---|
| | | Signal Name | |
| POWER | | | |
| 11, 22 | V _{DD} | Digital Supply Voltage | This pin must be bypassed to V _{SS} with a 1.0μF capacitor as close as possible to the package. The device operates solely from this one power supply pin. |
| 12 | V _{CORE} | Core Supply Voltage | V _{CORE} must always be bypassed to V _{SS} with a 1.0μF capacitor as close as possible to the package. Do not connect this device pin to any other circuits. |
| 7, 10 | V _{SS} | Digital Ground | |
| EP | EP | Exposed Pad | Exposed Pad (TQFN Only). This pad must be connected to V _{SS} . Refer to Application Note 3273: Exposed Pads: A Brief Introduction for additional information. |
| CLOCK | | | |
| 9 | 32KIN | 32.768kHz Crystal Oscillator Input | Connect a 32.768kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, an external clock source can be driven on 32KIN if the 32KOUT pin is left unconnected. |
| 8 | 32KOUT | 32.768kHz Crystal Oscillator Output | |

| PIN | NAME | FUNCTION MODE | FUNCTION |
|-----------------------|------------|--|--|
| | | Signal Name | |
| RESET | | | |
| 6 | RSTN | Reset | External System Reset (Active-Low) Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin is internally connected with an internal pullup to the V _{DD} supply as indicated in the Electrical Characteristics table. Add a noise snubber circuit as close as possible to the device, with component values shown in the Typical Application Circuits . |
| I²C | | | |
| 24 | SLAVE_SCL | I ² C Slave Clock | This is the I ² C slave SCL that should be connected to the host I ² C master SCL. |
| 23 | SLAVE_SDA | I ² C Slave Data | This is the I ² C slave SDA that should be connected to the host I ² C master SDA. |
| 14 | SENSOR_SCL | I ² C Sensor Clock | This is the I ² C master SCL that should be connected to the I ² C slave SCL on the slave sensors. |
| 13 | SENSOR_SDA | I ² C Sensor Data | This is the I ² C master SDA that should be connected to the I ² C slave SDA on the slave sensors. |
| INTERRUPTS | | | |
| 18 | HR_INT | Heart Rate/PPG Monitor Interrupt Input | This pin connects to the heart rate/PPG monitor sensor interrupt output. |
| 19 | ACCEL_INT | Accelerometer Interrupt Input | This pin connects to the accelerometer sensor interrupt output. |
| 1 | MFIO | Multifunction I/O | The host asserts MFIO low when it needs to communicate with the sensor hub; MFIO acts as an input and when held low during a reset, the sensor hub enters bootloader mode. |
| GPIO | | | |
| 21 | GPIO | General-Purpose Input/Output | Open drain when programmed as output (active low). This device pin connects to the heart rate/PPG monitor sensor GPIO pin. |
| 20 | LDO_EN | LDO Enable Output | This pin connects to the heart rate/PPG monitor sensor LDO Enable pin. |
| DO NOT CONNECT | | | |
| 2, 4, 5, 16, 17 | D.N.C. | Do Not Connect | This pin is internally connected. Do not make any electrical connection, including V _{SS} , to this pin. |
| NOT CONNECTED | | | |
| 3, 15 | NC | Not Connected. This pin is not connected to the die and can be used to route any signal. | This pin is not connected to the die and can be used to route any signal. |

Detailed Description

The MAX32664 is a sensor hub family with embedded firmware and algorithms for wearables. It seamlessly enables customer-desired sensor functionality, including communication with Analog Devices' optical sensor solutions and delivering raw or calculated data to the outside world. This is achieved while keeping overall system power consumption in check. The device family interfaces to a microcontroller host through a fast-mode slave I²C interface for access to raw and processed sensor data as well as field updates. The sampling is adjusted automatically by the algorithm to minimize power consumption and can be configured by the user as needed.

Finger Heart Rate, SpO₂ Algorithm (Version A)

The MAX32664 Version A communicates with the MAX30101/MAX30102 through I²C to perform finger-based heart rate and blood oxygen saturation (SpO₂) monitoring. The embedded algorithm uses digital filtering, pressure/position compensation, advanced R-wave detection, and automatic gain control to determine the heart rate in beats per minute while minimizing power. Also, the Analog Devices sensor hardware has built-in ambient light rejection to minimize background noise. SpO₂ results are reported as percentage of hemoglobin that is saturated with oxygen. The calibration values for SpO₂ configuration should be determined prior to deploying the end product. Use of an accelerometer is recommended to detect and compensate for the artifacts of motion on the algorithm.

Wrist Heart Rate Algorithm (Version B)

The MAX32664 Version B communicates with the MAX86140/MAX86141 through SPI to perform wrist-based heart rate measurements. The embedded algorithm uses digital filtering, distance/motion compensation, and advanced R-wave detection to determine the pulse rate in beats per minute. Power usage is minimized with automatic gain control. In addition, the Analog Devices sensor hardware provides additional features such as ambient light rejection, high signal-to-noise (SNR) ratio, and external LEDs for optimal placement. Use of an accelerometer is required to detect and compensate for the artifacts of motion on the algorithm.

Wrist or Ear Heart Rate, SpO₂ Algorithm (Version C)

The MAX32664 Version C communicates with the MAX86141 through SPI or to the MAXM86161 through I²C to perform wrist-based or ear-based heart rate and blood oxygen saturation (SpO₂) measurements. The embedded algorithm uses digital filtering, distance/motion compensation, and advanced R-wave detection to determine the pulse rate in beats per minute. Power usage is minimized with automatic gain control. SpO₂ results are reported as a percentage of hemoglobin that is saturated with oxygen. The calibration values for SpO₂ configuration should be determined before deploying the end product. In addition, the Analog Devices sensor hardware provides additional features such as ambient light rejection, high signal-to-noise (SNR) ratio, and external LEDs for optimal placement. Use of an accelerometer is required to detect and compensate for the artifacts of motion on the algorithm.

Finger Heart Rate, SpO₂, Blood Pressure Algorithm (Version D)

The MAX32664 Version D communicates with the MAX30101/MAX30102 through I²C to perform finger-based heart rate, blood oxygen saturation (SpO₂), and blood pressure monitoring. The embedded algorithm uses digital filtering, pressure/position compensation, advanced R-wave detection, and automatic gain control to determine the heart rate in beats per minute while minimizing power. Also, the Analog Devices sensor hardware has built-in ambient light rejection to minimize background noise. SpO₂ results are reported as percentage of hemoglobin that is saturated with oxygen. The calibration values for SpO₂ configuration should be determined before deploying the end product. Estimated blood pressure is reported for systolic and diastolic blood pressure. Blood pressure cuff measurements are used to set the blood pressure calibration data in the firmware. An accelerator is not required by the algorithm.

Algorithm Selection and Evaluation

During early stages of algorithm selection and evaluation, a user may wish to experiment with different versions of the MAX32664. To facilitate this, the MAX32664 Version Z was created. The MAX32664 Version Z contains only the bootloader and a Z encryption key. The Version Z encryption key is used as a generic key that allows multiple, Analog Devices-supplied algorithms to be accepted by the bootloader (not at the same time). For example, various Analog

Devices evaluation kits use the MAX32664 Version Z. This allows any of the versions of algorithm to be evaluated. In order to do this, a special version of the algorithms must be obtained from Analog Devices (Version A, B, C, or D algorithm with Z encryption key). Furthermore, it must be noted that the sensor interface/device pinout may be different between various algorithm versions, such as I²C vs. SPI. The MAX32664 Version Z is not intended for mass production.

Each production version (A, B, C, or D) has its own bootloader with encryption and an initial preprogrammed version of the firmware. If the user determines that performance of the initial preprogrammed firmware is not sufficient for their application, they can upgrade the firmware by going to the MAX32664 webpage [MAX32664 Ultra-Low Power Biometric Sensor Hub](#) to obtain the latest version of the firmware.

Interface to Host

The interface to the host is the I²C interface. The devices support one slave interface with the 7-bit address of 0x55. The MAX32664B and the MAX32664C provide a selectable address feature that can be accessed by the host through an I²C command. The following features for this interface are as follows:

- One slave for communication with a host
- RESTART condition
- Fast mode: 400kbps
- Internal filter to reject noise spikes
- Receiver FIFO depth of 8 bytes
- Transmitter FIFO depth of 8 bytes
- Firmware bootloader

Interface to the Sensors

The interface to the sensors is either a master SPI or a fast-mode I²C. Pullup resistors are required for the I²C.

Device Selection

See the [Ordering Information](#) table at the end of this data sheet for device selection by interface type.

Applications Information

Evaluation Platforms

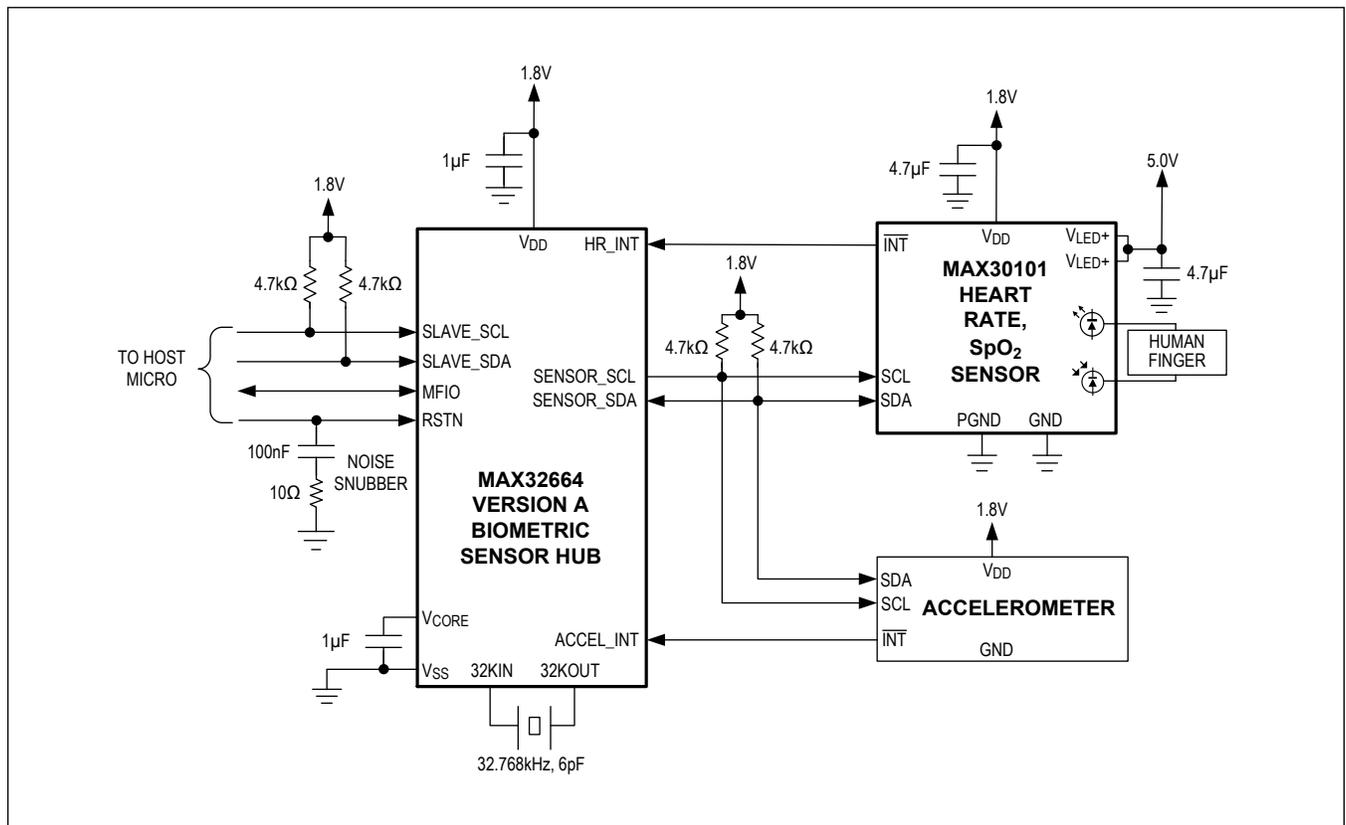
The actual device (IC) used in the evaluation platforms may be the MAX32664 Version Z preprogrammed with the corresponding algorithm. See the [Algorithm Selection and Evaluation](#) section for additional information.

Table 1. Evaluation Platforms

| DEVICE | PLATFORM |
|----------------------------------|---------------|
| MAX32664 Version A and Version D | MAXREFDES220# |
| MAX32664 Version B | MAXREFDES101# |
| MAX32664 Version C | MAXREFDES103# |

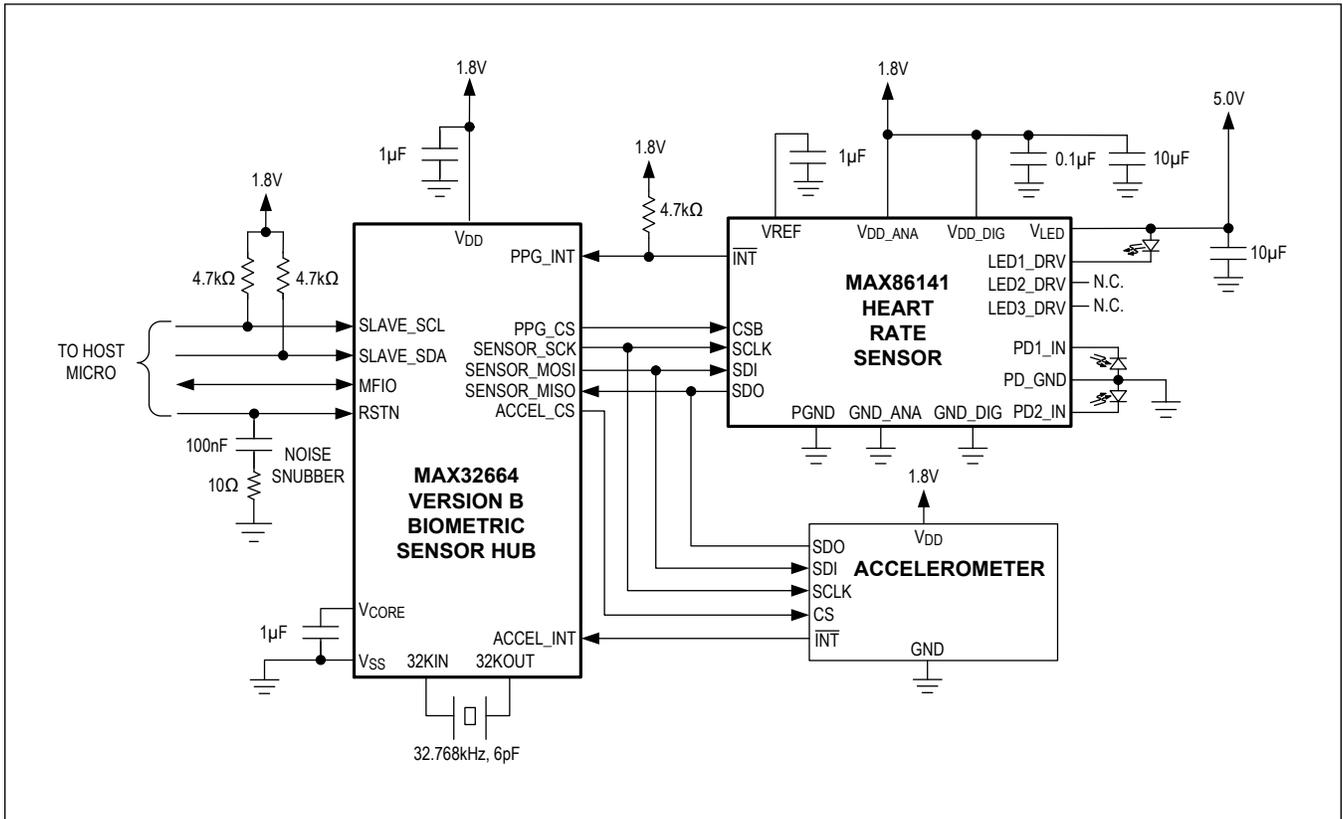
Typical Application Circuits

MAX32664 VERSION A FINGER-BASED HEART RATE AND SpO₂ MONITOR I²C INTERFACE TO SENSORS



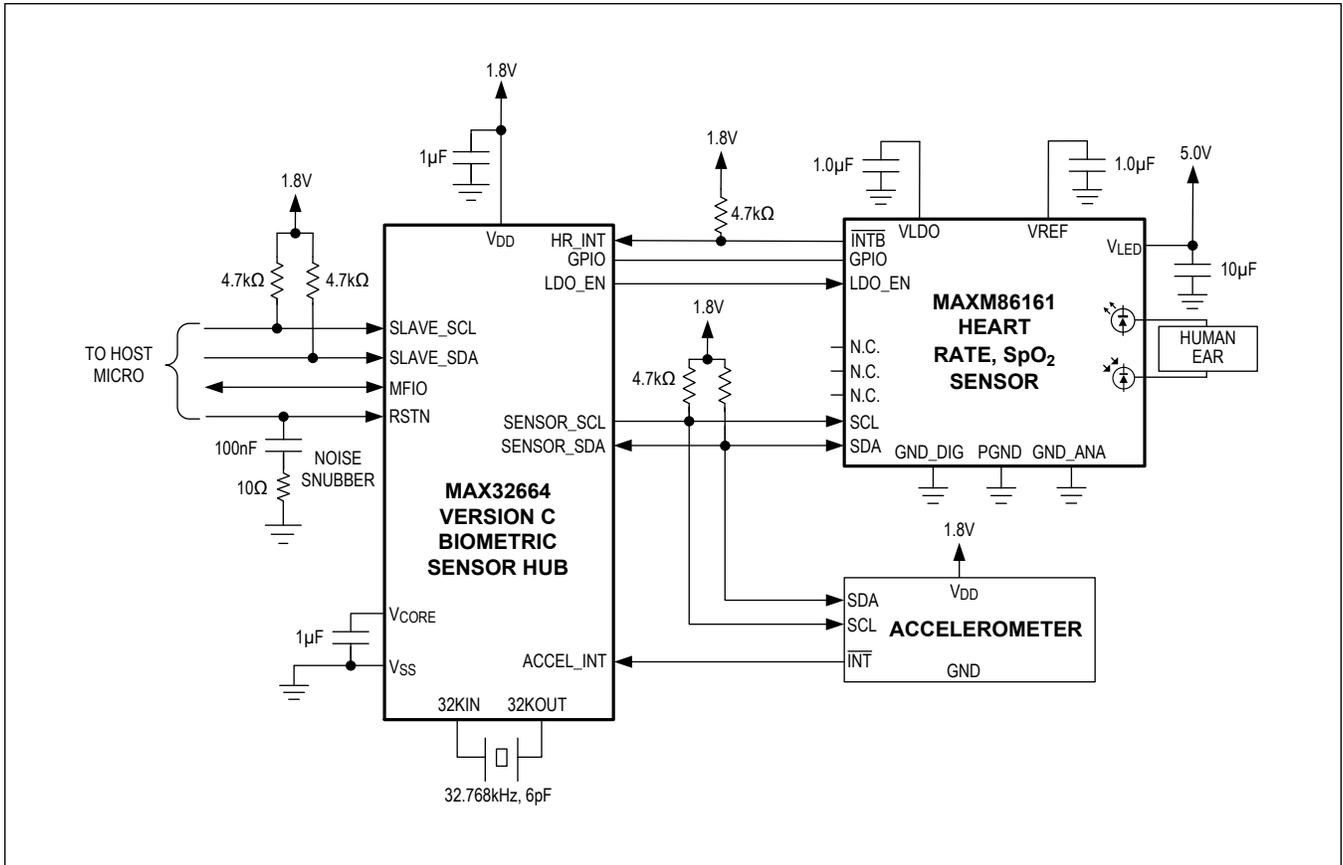
Typical Application Circuits (continued)

MAX32664 VERSION B WRIST-BASED HEART RATE MONITOR SPI INTERFACE TO SENSORS



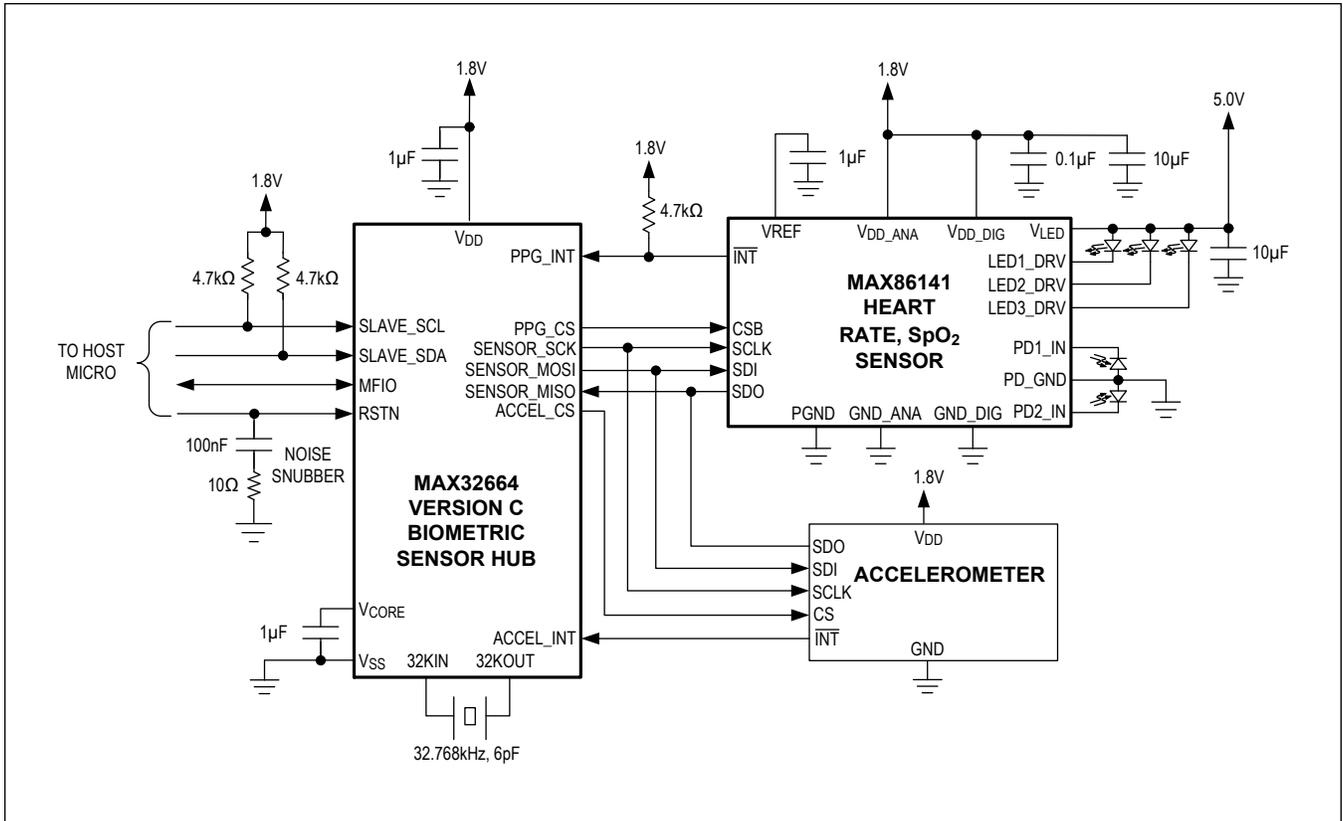
Typical Application Circuits (continued)

MAX32664 VERSION C EAR-BASED HEART RATE AND SpO₂ MONITOR I²C INTERFACE TO SENSORS



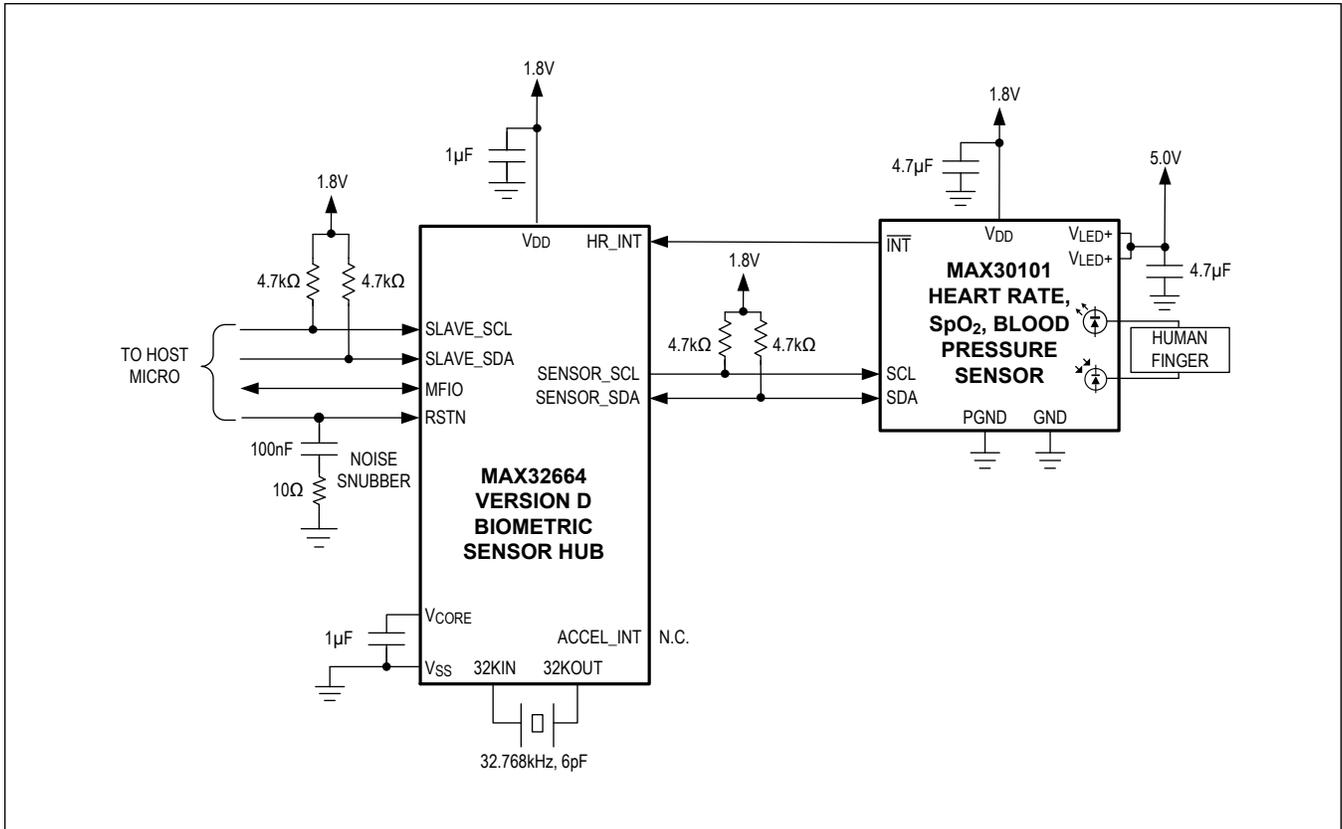
Typical Application Circuits (continued)

MAX32664 VERSION C WRIST-BASED HEART RATE AND SpO₂ MONITOR SPI INTERFACE TO SENSORS



Typical Application Circuits (continued)

MAX32664 VERSION D FINGER-BASED HEART RATE, SpO₂, BLOOD PRESSURE MONITOR I²C INTERFACE TO SENSORS



Ordering Information

| PART | VERSION | SENSOR INTERFACE | COMPATIBLE SENSORS | PIN-PACKAGE |
|----------------|---------|----------------------|----------------------------|---|
| MAX32664GWEA+ | A | I ² C | MAX30101 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWEA+T | A | I ² C | MAX30101 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWEB+ | B | SPI | MAX86140/141 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWEB+T | B | SPI | MAX86140/141 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWEC+ | C | SPI/I ² C | MAX86140/141, MAXM86161 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWEC+T | C | SPI/I ² C | MAX86140/141, MAXM86161 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWED+ | D | I ² C | MAX30101/102 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GWED+T | D | I ² C | MAX30101/102 | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GTGA+ | A | I ² C | MAX30101/102 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGA+T | A | I ² C | MAX30101/102 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGB+ | B | SPI | MAX86140/141 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGB+T | B | SPI | MAX86140/141 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGC+ | C | SPI/I ² C | MAX86140/141, MAXM86161 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGC+T | C | SPI/I ² C | MAX86140/141, MAXM86161 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGD+ | D | I ² C | MAX30101/102 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |
| MAX32664GTGD+T | D | I ² C | MAX30101/102 | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |

| | | | | |
|---------------|---|---|---|---|
| MAX32664GWEZ+ | Z | — | — | 16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch) |
| MAX32664GTGZ+ | Z | — | — | 24 TQFN-EP (3mm x 3mm x 0.75mm, 0.4mm pitch) |

+Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel. Full reel.

Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|-----------------|---------------|---|--|
| 0 | 4/18 | Initial release | — |
| 1 | 2/19 | Revised entire data sheet | 1–13 |
| 2 | 5/19 | Updated <i>General Description, Benefits and Features, Simplified Block Diagram, Pin Configurations, Pin Descriptions, Wrist Heart Rate SpO₂ Algorithm (Version C), Finger Heart Rate SpO₂ Blood Pressure Algorithm (Version D), Algorithm Selection and Evaluation, Typical Application Circuits, and Ordering Information</i> sections | 1, 2, 7–10, 14–16 |
| 3 | 4/20 | Updated <i>General Description, Benefits and Features, Absolute Maximum Ratings, Electrical Characteristics, Electrical Characteristics—I²C, Pin Description, Finger Heart Rate, SpO₂ (Version A), Wrist Heart Rate (Version B), Wrist or Ear Heart Rate, SpO₂ Algorithm (Version C), Finger Heart Rate, SpO₂, Blood Pressure Algorithm (Version D), Interface to Host, and Ordering Information</i> | 1, 7–9, 12–21, 27, 28 |
| 4 | 2/22 | Added HR_INT and SLAVE_SDA to VIL Electrical Characteristics. Added VOL Electrical Characteristics. Updated the link to the MAX32664 Ultra-Low Power Biometric Sensor Hub webpage located in the Algorithm Selection and Evaluation section. Updated the Interface to Host description. Added new Pin Configuration and Pin Descriptions for Version C I ² C to Sensors. Updated MAX32664 VERSION C EAR-BASED HEART RATE AND SpO ₂ MONITOR I ² C INTERFACE TO SENSORS Typical Application Circuit. Updated package measurements in Ordering Information table. | 8, 9, 12–14, 16, 17, 19–23, 25, 28, 31, 32 |