Click here for production status of specific part numbers.

MAX32664   Ultra-Low Power Biometric Sensor Hub

General Description

The MAX32664 is part of a sensor hub family with embedded firmware and algorithms for wearables. It seamlessly enables customer-desired sensor functionality, which includes communicating with Maxim's 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 I^2C interface for field updates as well as access to raw and processed sensor data.

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 I^2C 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. A master mode SPI interface for communication with sensors is provided.

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 I^2C interface for communication with sensors is provided.

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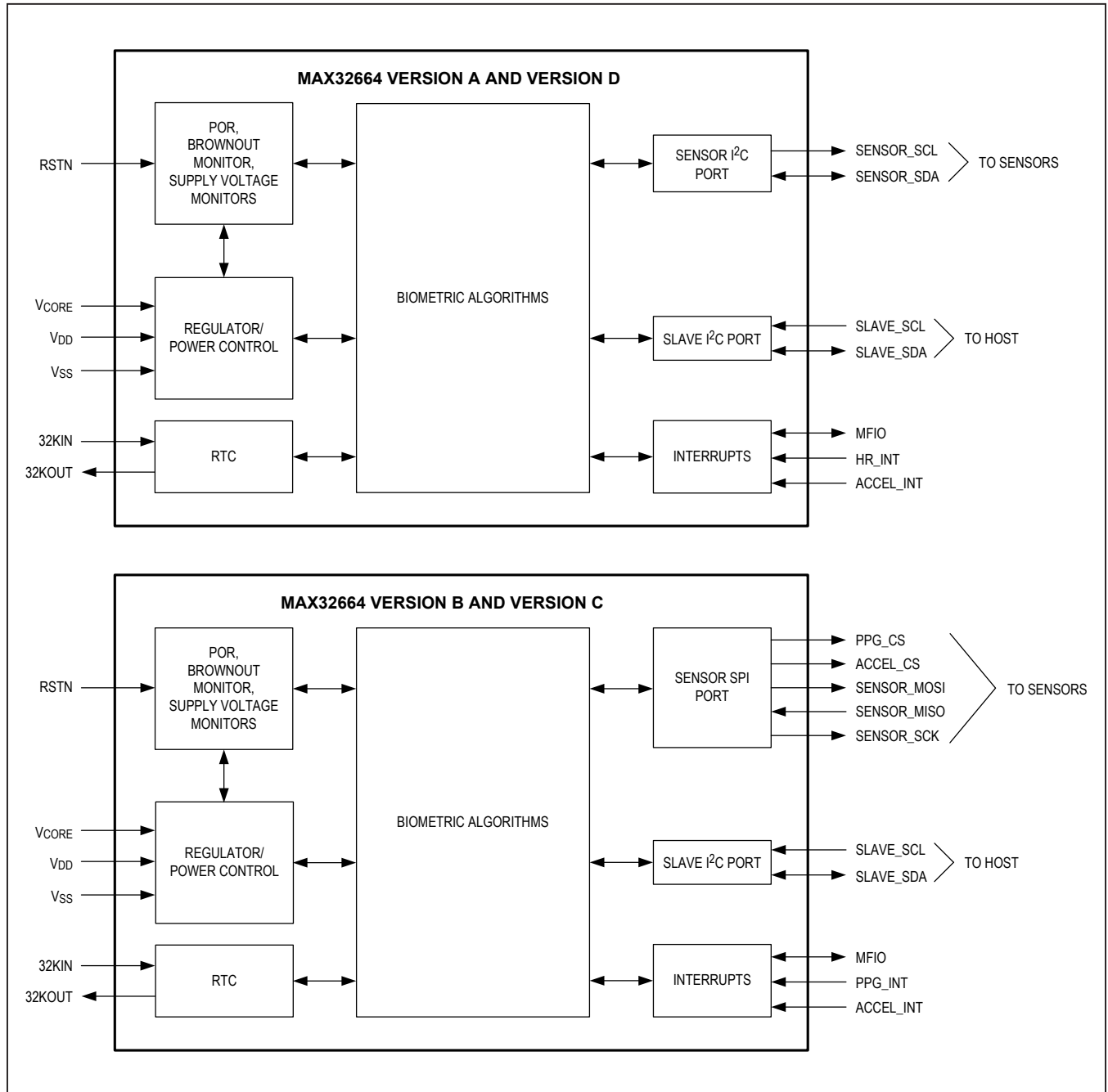
Applications

- 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 (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 I^2C for Communication with a Host Microcontroller
  - One Master I^2C for Communication with Sensors (Version A)
  - One Master SPI for Communication with Sensors (Version B)
  - 32.768kHz RTC
  - FIFO Provides Minimal Host Interaction
  - Bootloader Facilitates Secure, Authenticated Firmware Upgrades

Ordering Information **appears at end of data sheet.**

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Simplified Block Diagrams

MAX32664 VERSION A AND VERSION D

RSTN → POR, BROWNOUT MONITOR, SUPPLY VOLTAGE MONITORS

V$_{CORE}$, V$_{DD}$, V$_{SS}$ → REGULATOR/POWER CONTROL

32KIN, 32KOUT → RTC

BIOMETRIC ALGORITHMS

SENSOR I^{2}C PORT → SENSOR_SCL, SENSOR_SDA → TO SENSORS

SLAVE I^{2}C PORT → SLAVE_SCL, SLAVE_SDA → TO HOST

INTERRUPTS → MFIO, HR_INT, ACCEL_INT

MAX32664 VERSION B AND VERSION C

RSTN → POR, BROWNOUT MONITOR, SUPPLY VOLTAGE MONITORS

V$_{CORE}$, V$_{DD}$, V$_{SS}$ → REGULATOR/POWER CONTROL

32KIN, 32KOUT → RTC

BIOMETRIC ALGORITHMS

SENSOR SPI PORT → PPG_CS, ACCEL_CS, SENSOR_MOSI, SENSOR_MISO, SENSOR_SCK → TO SENSORS

SLAVE I^{2}C PORT → SLAVE_SCL, SLAVE_SDA → TO HOST

INTERRUPTS → MFIO, PPG_INT, ACCEL_INT

Absolute Maximum Ratings

(All voltages with respect to V_{SS}, unless otherwise noted.)

V_{CORE} ....-0.3V to +1.21V
V_{DD} ....-0.3V to +3.63V
32KIN, 32KOUT ....-0.3V to V_{DD} + 0.3V
RSTN ....-0.3V to V_{DD} + 0.3V
Total Current into All Digital Pins Combined (sink) 100mA

V_{SS} 100mA
Output Current (sink) by Any Digital Pin 25mA
Output Current (source) by Any Digital Pin ....-25mA
Operating Temperature Range......................... -40°C to +105°C
Storage Temperature Range........................... -65°C to +150°C
Soldering Temperature (reflow) ....+260°C

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})	2.2ºC/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
DIGITAL I/O						
Input Low Voltage for RSTN, SLAVE_SCL, SENSOR_SDA, SENSOR_MISO, PPG_INT, ACCEL_INT, MIFO	V_{IL}				$0.3 \times V_{DD}$	V
Input High Voltage for RSTN, SLAVE_SCL, SENSOR_SDA, SENSOR_MISO, PPG_INT, ACCEL_INT, MIFO	V_{IH}		$0.7 \times V_{DD}$			V
Output Low Voltage for SENSOR_SDA, SENSOR_SCL, SLAVE_SDA	V_{OL_I2C}	V_{DD} = 1.71V, I_{OL} = 2mA		0.2	0.4	V
Output High Voltage for SENSOR_SDA, SENSOR_SCL, SLAVE_SDA	V_{OH_I2C}	V_{DD} = 1.71V, I_{OH} = 2mA	$V_{DD} -$ 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} = 0V	-500		+500	nA
Input Leakage Current High	I_{IH}	V_{IN} = 3.6V	-500		+500	nA
Input Pullup Resistor to RSTN	R_{PU_VDD}	Pullup to V_{DD} = 3.63V		10.5		kΩ
CLOCKS						
System Clock Frequency	f_{SYS_CLK}			96		MHz
RTC Input Frequency	f_{32KIN}	32.768kHz watch crystal, C_L = 6pF, ESR < 90kΩ, C_0 < 2pF		32.768		kHz
RTC Operating Current	I_{RTC}	All power modes, RTC enabled		0.57		µA
RTC Power-Up Time	t_{RTC_ON}			250		ms

Electrical Characteristics—I2C

(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.)

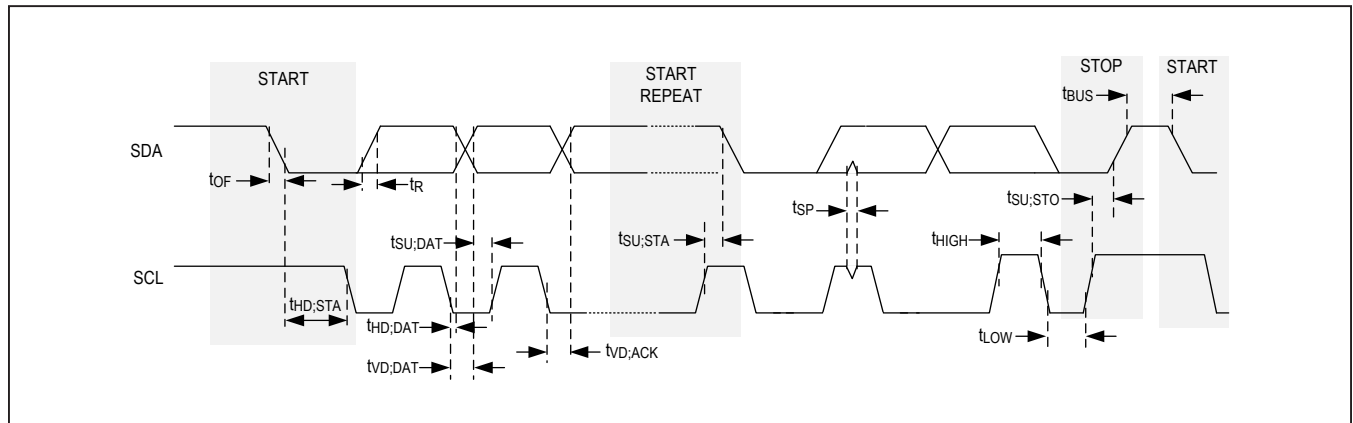| PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
FAST MODE						
Output Fall Time	t_{OF}	From $V_{OL\_I2C(MIN)}$ to $V_{OL\_I2C(MAX)}$		150		ns
Pulse Width Suppressed by Input Filter	t_{SP}			75		ns
SCL Clock Frequency	f_{SCL}		0		400	kHz
Low Period SCL Clock	t_{LOW}		1.3			µs
High Time SCL Clock	t_{HIGH}		0.6			µs
Setup Time for Repeated Start Condition	$t_{SU;STA}$		0.6			µs
Hold Time for Repeated Start Condition	$t_{HD;STA}$		0.6			µs
Data Setup Time	$t_{SU;DAT}$			125		ns
Data Hold Time	$t_{HD;DAT}$			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	$t_{SU;STO}$		0.6			µs
Bus Free Time Between a Stop and Start Condition	t_{BUS}		1.3			µs
Data Valid Time	$t_{VD;DAT}$		0.9			µs
Data Valid Acknowledge Time	$t_{VD;ACK}$		0.9			µs

Figure 1. I2C Timing Diagram

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}	f_{SYS_CLK} = 96MHz, $f_{MCK(MAX)}$ = $f_{SYS\_CLK}/2$			48	MHz
SPI Master SCK Period	t_{MCK}			$1/f_{MCK}$		ns
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
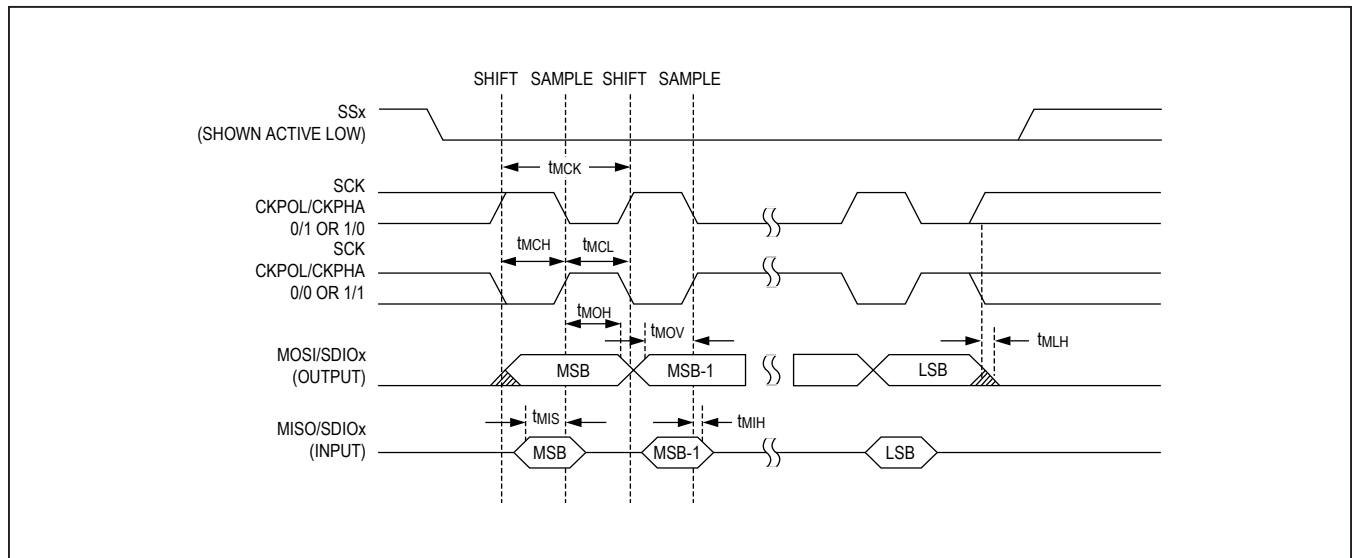
Figure 2. SPI Master Mode Timing Diagram

Pin Configurations
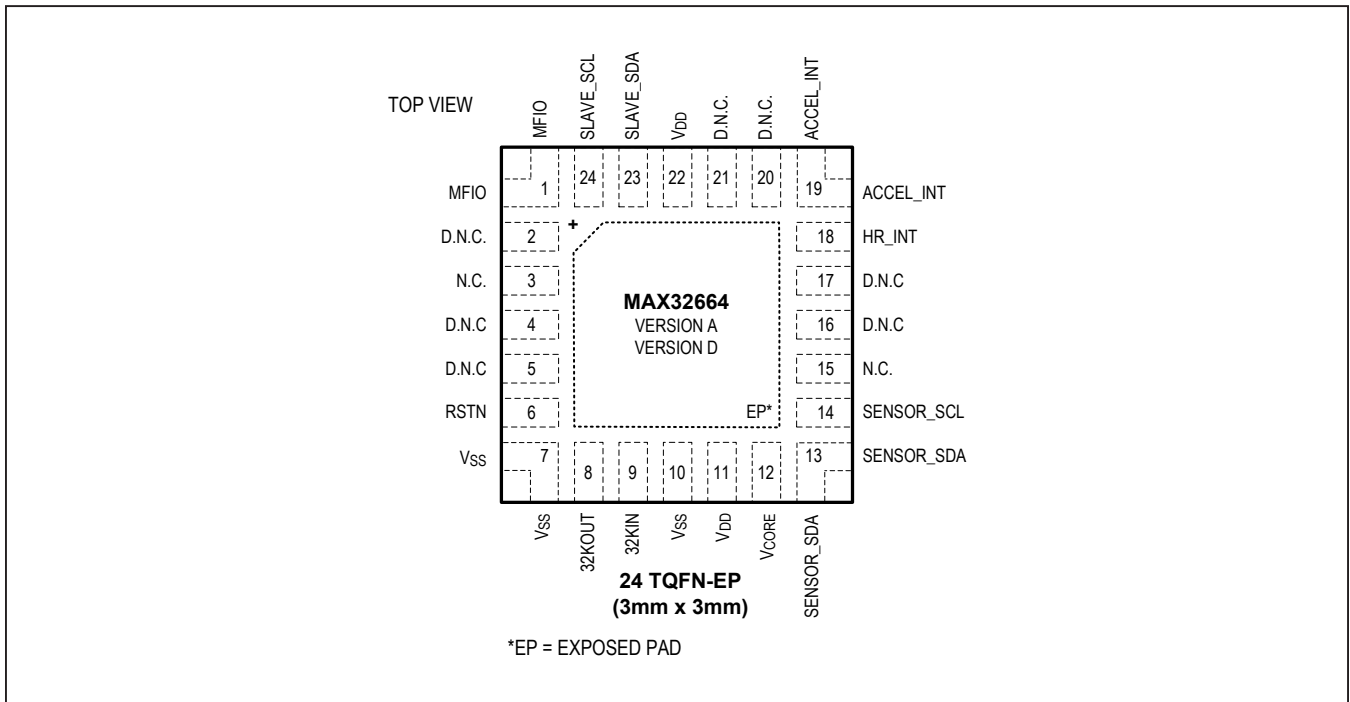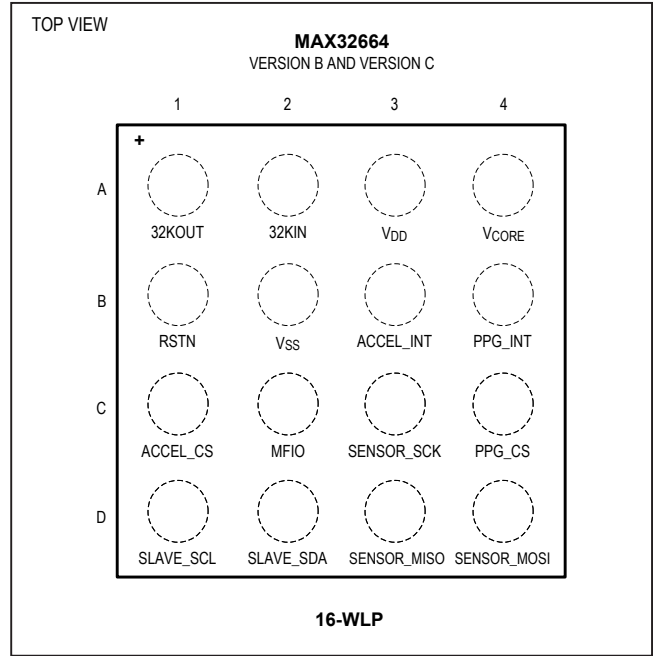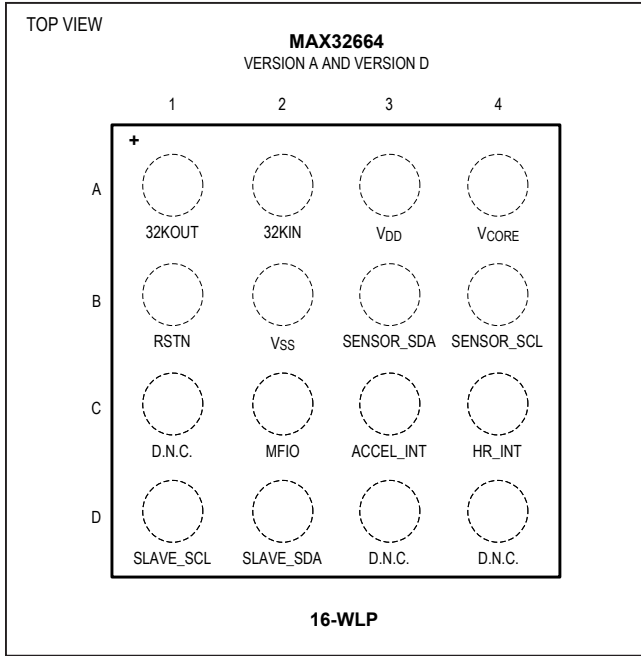
Pin Descriptions

BUMP (VERSION A AND D 16-WLP)	BUMP (VERSION B AND C 16-WLP)	PIN (VERSION A AND D 24 TQFN)	NAME	FUNCTION
POWER				
A3	A3	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.
A4	A4	12	V_{CORE}	Core Supply Voltage. This should be left open-circuit. This pin must always be bypassed to V_{SS} with a 1.0µF capacitor as close as possible to the package.
B2	B2	7, 10	V_{SS}	Digital Ground
—	—	—	EP	Exposed Pad (TQFN Only). This pad must be connected to VSS. Refer to Application Note 3273: Exposed Pads: A Brief Introduction for additional information.
CLOCK				
A2	A2	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.
A1	A1	8	32KOUT	32.768kHz Crystal Oscillator Output
RESET				
B1	B1	6	RSTN	Hardware Power 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 POR 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 and place a noise snubber circuit as close as possible to the device, with component values shown in the *Typical Applications Circuit*.
I2C				
D1	D1	24	SLAVE_SCL	I2C Slave Clock. This is the I2C slave SCL that should be connected to the host I2C master SCL.
D2	D2	23	SLAVE_SDA	I2C Slave Data. This is the I2C slave SDA that should be connected to the host I2C master SDA.
B4	—	14	SENSOR_SCL	I2C Sensor Clock. This is the I2C master SCL that should be connected to the I2C slave SCL on the slave sensors.
B4	—	13	SENSOR_SDA	I2C Sensor Data. This is the I2C master SDA that should be connected to the I2C slave SDA on the slave sensors.

Pin Descriptions (continued)

INTERRUPTS				
—	B4	—	PPG_INT	PPG Sensor Interrupt Input. This pin connects to the PPG sensor interrupt output.
C4	—	18	HR_INT	Heart Rate Monitor Interrupt Input. This pin connects to the heart rate monitor sensor interrupt output.
C3	B3	19	ACCEL_INT	Accelerometer Interrupt Input. This pin connects to the accelerometer sensor interrupt output.
C2	C2	1	MFIO	Multifunction IO. This pin provides different functions: MFIO asserts low as an output when the sensor hub needs to communicate with the host; the pin acts as an input and causes the sensor hub to enter bootloader mode if the MFIO pin is low during a reset.
DO NOT CONNECT				
C1, D3, D4	—	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.
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.
NOT CONNECTED				
—	—	3, 15	N.C.	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

MAX32664

The MAX32664 is part of a sensor hub family with embedded firmware and algorithms for wearables. It seamlessly enables customer-desired sensor functionality, which includes communicating with Maxim's 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 I^2C interface for field updates as well as access to raw and processed sensor data. The sampling of the sensors is derived from the 32.768kHz real-time clock. The sampling rate is user-configurable to minimize power consumption.

Finger Heart Rate Algorithm (Version A)

The MAX32664 Version A communicates with the MAX30101/MAX30102 through I^2C 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 Maxim Integrated 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 while using the end product.

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 power-minimized gain control. In addition, the Maxim Integrated sensor hardware provides additional features such as ambient light rejection, higher signal-to-noise (SNR) ratio, and external LEDs for optimal placement.

Wrist Heart Rate, SpO2 Algorithm (Version C)

The MAX32664 Version C communicates with the MAX86141 through SPI to perform wrist-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 power-minimized gain control. SpO2 results are reported as a percentage of hemoglo-

bin that is saturated with oxygen. The calibration values for SpO2 configuration should be determined while using the end product. In addition, the Maxim Integrated sensor hardware provides additional features such as ambient light rejection, higher signal-to-noise (SNR) ratio, and external LEDs for optimal placement.

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

The MAX32664 Version D communicates with the MAX30101/MAX30102 through I^2C 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 Maxim Integrated 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 while using 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.

Algorithm Selection and Evaluation

During early stages of algorithm selection and evaluation, a user can experiment with different versions of the MAX32664. The MAX32664 Version Z was created for this reason. 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, Maxim supplied, algorithms to be accepted by the bootloader (not at the same time). For example, various Maxim 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 Maxim (Version A algorithm with Z encryption key). Furthermore, it must be noted that the sensor interface/pinout can be different between various algorithm versions, such as I^2C vs. SPI. The MAX32664 Version Z is not intended for mass production.

Each production version (A,B,C,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 Maxim webpage** to obtain the latest version of the firmware.

Interface to Host

The interface to the host is the I^{2}C interface. It is a bidirectional, two-wire serial bus that provides a medium-speed communications network. It can operate as a one-to-one, one-to-many or many-to-many communications medium. These engines support standard-mode and fast-mode I^{2}C speeds. The devices support one slave interface with an address of 0x55. The following features for this interface are as follows:

- One slave for communication with a host
- Supports standard 7-bit addressing or 10-bit addressing
- RESTART condition
- Interactive receive mode
- Tx FIFO preloading
- Support for clock stretching to allow slower slave devices to operate on higher speed busses
- Fast mode: 400kbps
- Internal filter to reject noise spikes
- Receiver FIFO depth of 8 bytes
- Transmitter FIFO depth of 8 bytes

Interface to the Sensors

Serial Peripheral Interface

The serial peripheral interface (SPI) is a highly configurable, flexible, and efficient synchronous interface between multiple SPI devices on a single bus. The bus uses a single clock signal and multiple data signals, and one or more slave select lines to address only the intended target device. The SPI operates independently and requires minimal processor overhead.

I^{2}C

A master I^{2}C interface is a bidirectional, two-wire serial bus that provides a medium-speed communications network. It can operate as a one-to-one, one-to-many or many-to-many communications medium. These engines support standard-mode and fast-mode I^{2}C speeds. Pullup resistors are required for this interface. See the *MAX32664 Version A Heart Rate and SpO2 Monitor*.

Device Selection

See the *Ordering Information* for interface type device selection.

Applications Information

Evaluation Platforms

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

Table 1. Evaluation Platforms

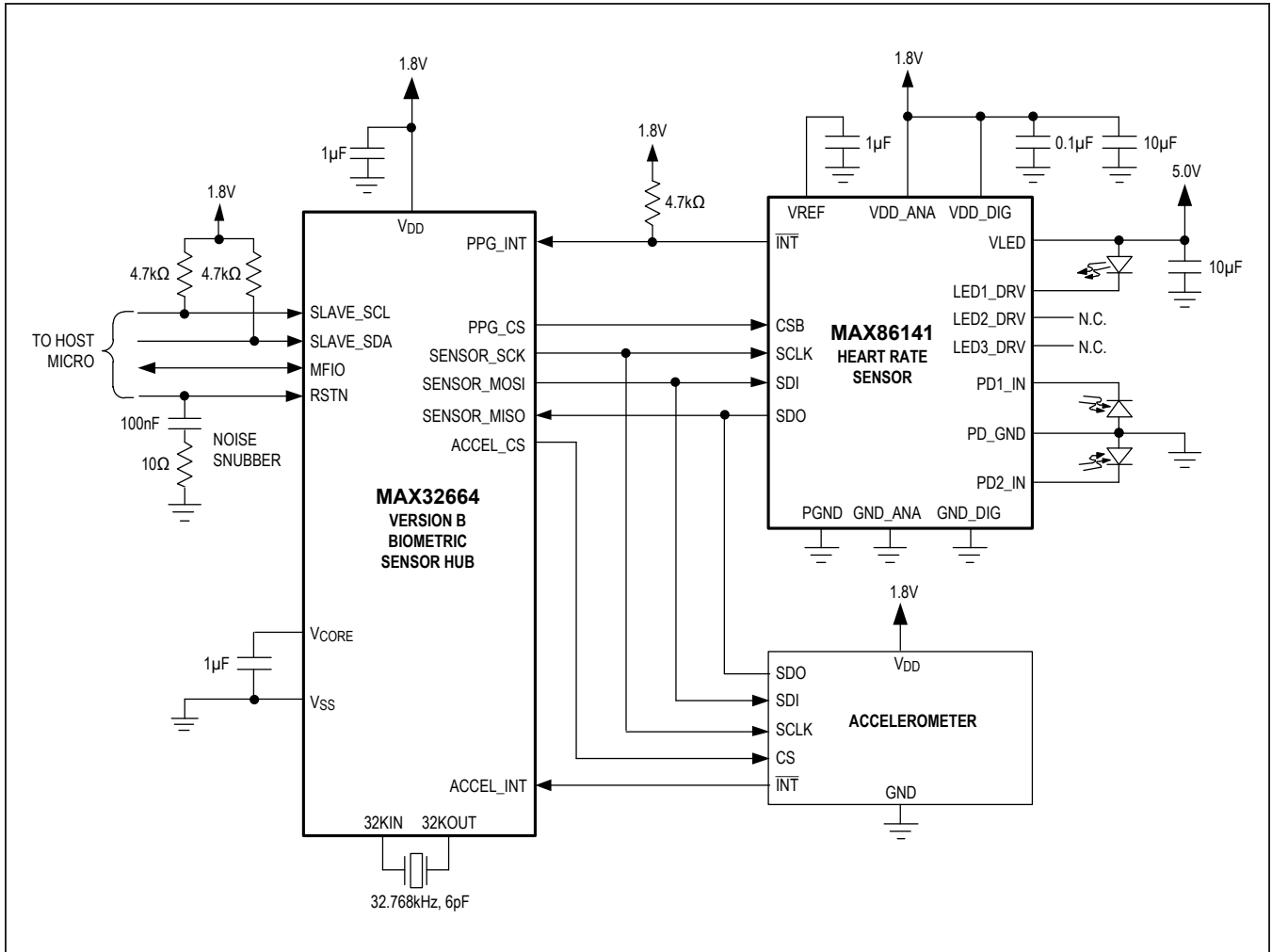| DEVICE	PLATFORM
MAX32664 Version A	MAXREFDES220#
MAX32664 Version B	MAXREFDES101#

Typical Application Circuits

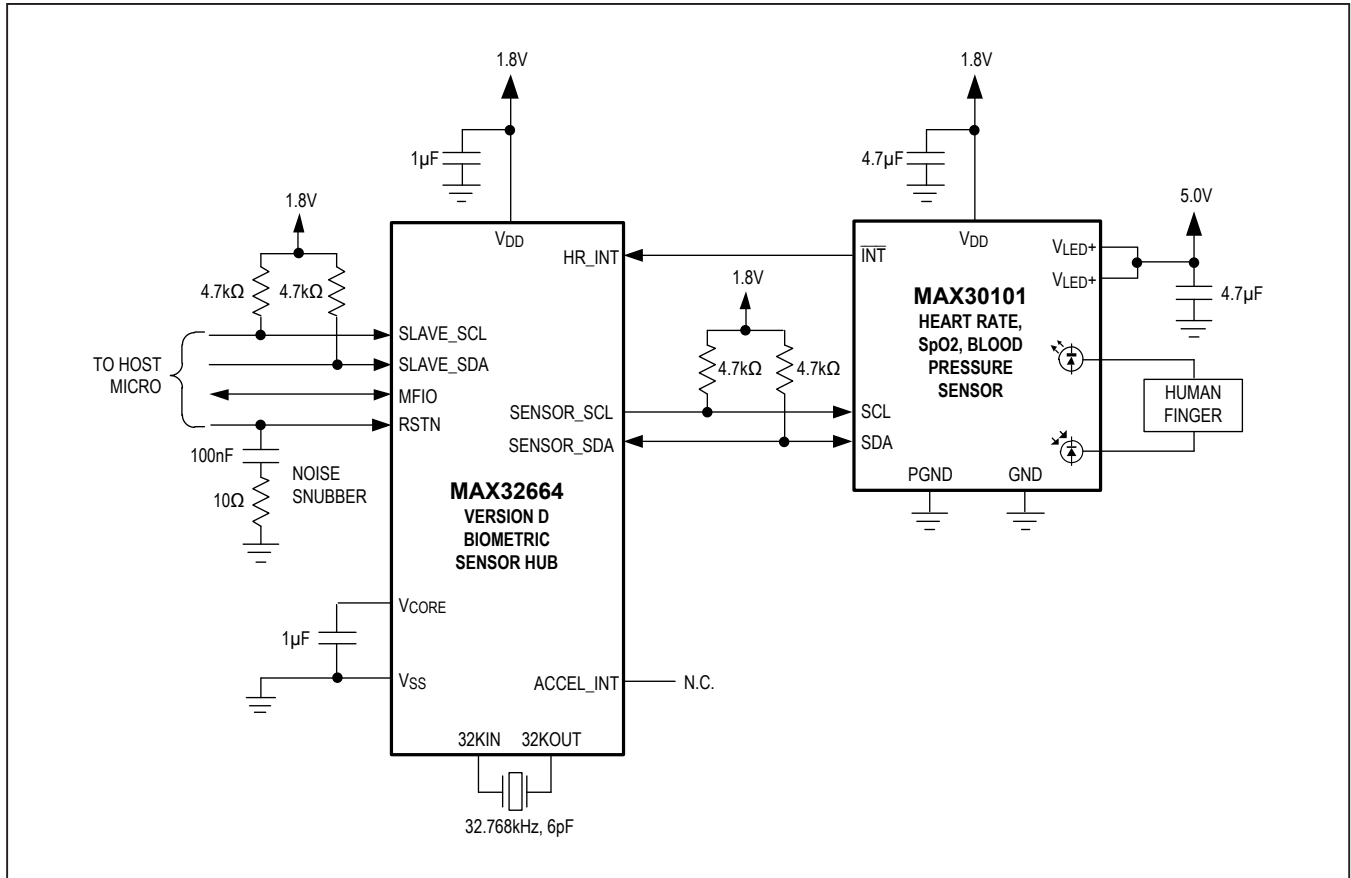### MAX32664 Version A Heart Rate and SpO2 Monitor
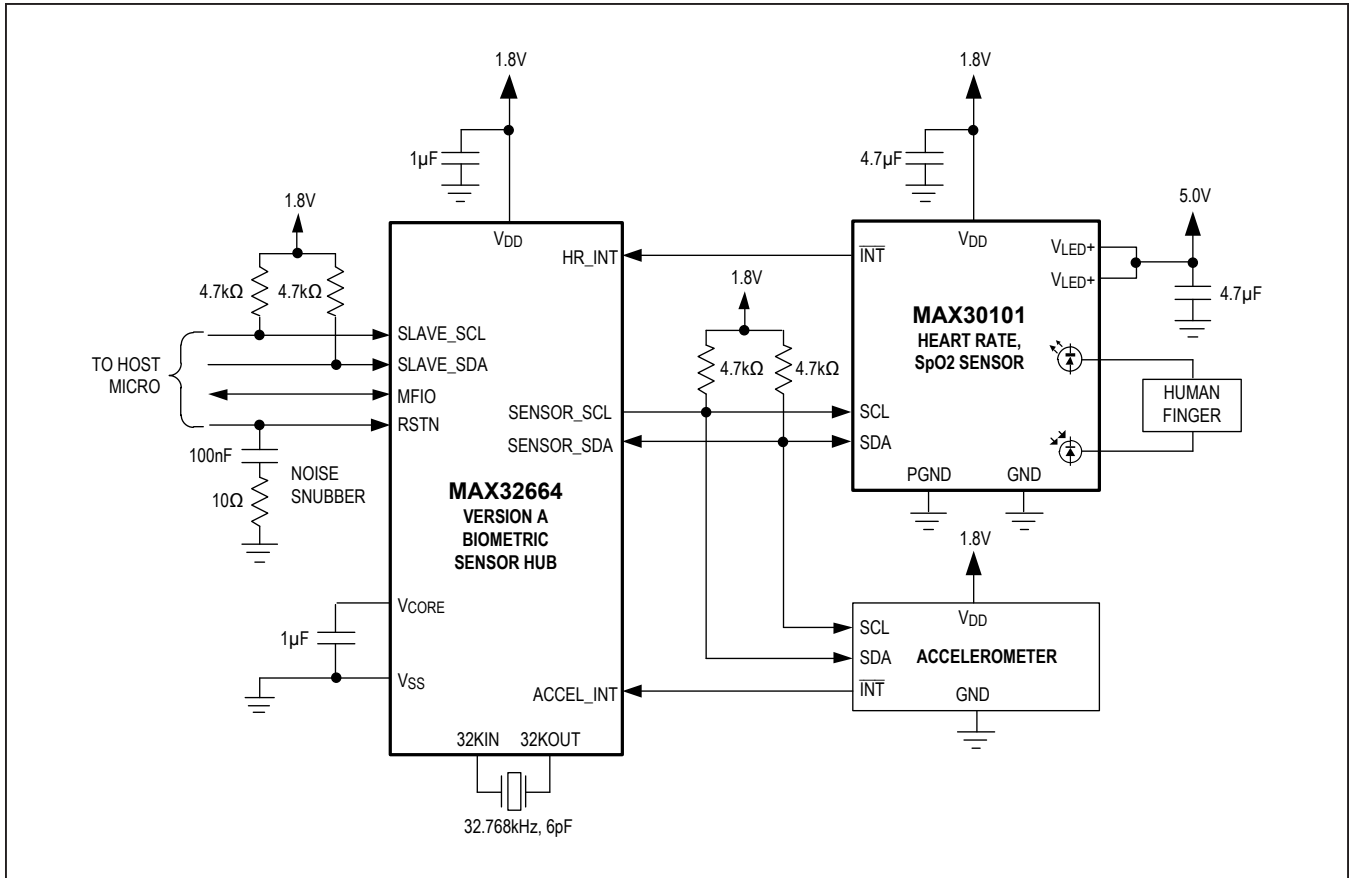
Typical Application Circuits (continued)

MAX32664 Version B Heart Rate Monitor

Typical Application Circuits (continued)

MAX32664 Version C Heart Rate and SpO2 Monitor

Typical Application Circuits (continued)

MAX32664 Version D Heart Rate, SpO2, Blood Pressure Monitor

Ordering Information

PART	VERSION	SENSOR INTERFACE	BOOT LOADER	PIN-PACKAGE
MAX32664GWEA+	A	I^{2}C	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWEA+T	A	I^{2}C	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWEB+	B	SPI	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWEB+T	B	SPI	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWEC+	C	SPI	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWEC+T	C	SPI	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWED+	D	I^{2}C	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GWED+T	D	I^{2}C	I^{2}C	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)
MAX32664GTGA+	A	I^{2}C	I^{2}C	24 TQFN-EP (3mm x 3mm x 0.75mm, 0.5mm pitch)
MAX32664GTGA+T	A	I^{2}C	I^{2}C	24 TQFN-EP (3mm x 3mm x 0.75mm, 0.5mm pitch)
MAX32664GTGD+*	D	I^{2}C	I^{2}C	24 TQFN-EP (3mm x 3mm x 0.75mm, 0.5mm pitch)
MAX32664GTGD+T*	D	I^{2}C	I^{2}C	24 TQFN-EP (3mm x 3mm x 0.75mm, 0.5mm pitch)
MAX32664GWEZ+	Z	—	—	16 WLP (1.6mm x 1.6mm x 0.65mm, 0.35mm pitch)

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

T = Tape and reel. Full reel.

*Future product--contact factory for availability.

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 *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* sections	1, 2, 7–10, 14–16