

AFE4404 Ultra-Small, Integrated AFE for Wearable, Optical, Heart-Rate Monitoring and Bio-Sensing

1 Features

- Transmitter:
 - Supports Common Anode LED Configuration
 - Dynamic Range: 100 dB
 - 6-Bit Programmable LED Current to 50 mA (Extendable to 100 mA)
 - Programmable LED On-Time
 - Simultaneous Support of 3 LEDs for Optimized SPO₂, HRM, or Multi-Wavelength HRM
- Receiver:
 - 24-Bit Representation of the Current Input from a Photodiode in Twos Complement Format
 - Individual DC Offset Subtraction DAC at TIA Input for Each LED and Ambient Phase
 - Digital Ambient Subtraction at ADC Output
 - Programmable Transimpedance Gain: 10 k Ω to 2 M Ω
 - Dynamic Range: 100 dB
 - Dynamic Power-Saving Mode to Reduce Current to Less Than 200 μ A
- Pulse Frequency: 10 SPS to 1000 SPS
- Flexible Pulse Sequencing and Timing Control
- Flexible Clock Options:
 - External Clocking: 4-MHz to 60-MHz Input Clock
 - Internal Clocking: 4-MHz Oscillator
- I²C Interface
- Operating Temperature Range: –20°C to 70°C
- 2.6-mm \times 1.6-mm DSBGA Package, 0.5-mm Pitch
- Supplies: Rx: 2 V to 3.6 V, Tx: 3 V to 5.25 V, IO: 1.8 V to 3.6 V

2 Applications

- Optical Heart-Rate Monitoring (HRM)
- Heart-Rate Variability (HRV)
- Pulse Oximetry (SpO₂ Measurement)
- VO₂ Max
- Calorie Expenditure

3 Description

The AFE4404 is an analog front-end (AFE) for optical bio-sensing applications, such as heart-rate monitoring (HRM) and saturation of peripheral capillary oxygen (SpO₂). The device supports three switching light-emitting diodes (LEDs) and a single photodiode. The current from the photodiode is converted into voltage by the transimpedance amplifier (TIA) and digitized using an analog-to-digital converter (ADC). The ADC code can be read out using an I²C interface. The AFE also has a fully-integrated LED driver with a 6-bit current control. The device has a high dynamic range transmit and receive circuitry that helps with the sensing of very small signal levels.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
AFE4404	DSBGA (15)	2.60 mm \times 1.60 mm ⁽²⁾

(1) For all available packages, see the orderable addendum at the end of the datasheet.

(2) Refers to dimensions D \times E in [Figure 1](#).

4 Simplified Block Diagram

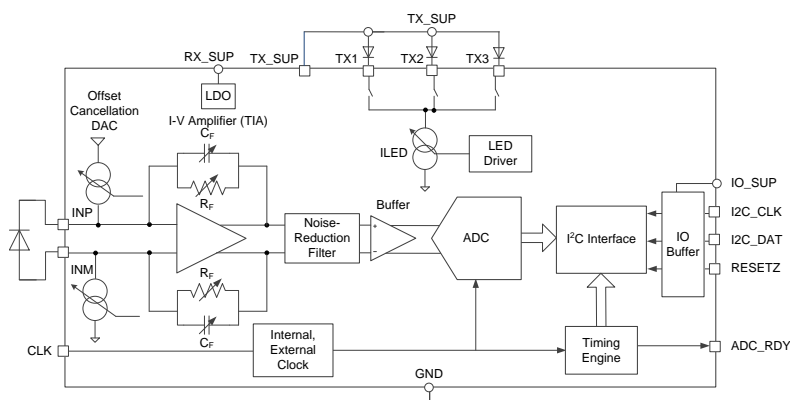


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5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

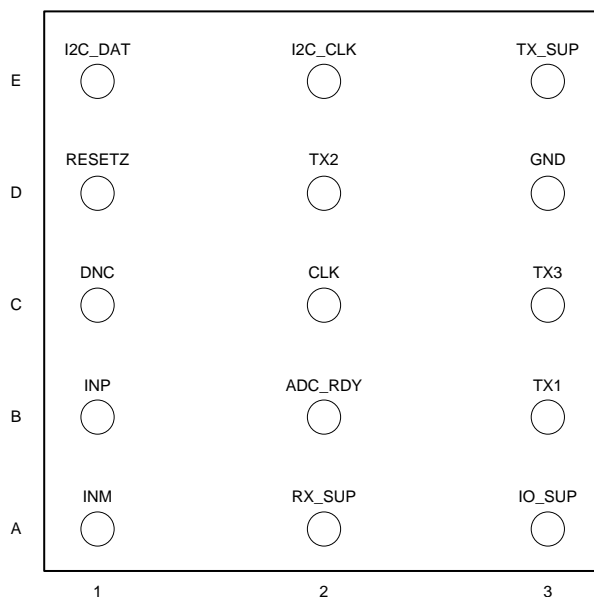
Changes from Original (May 2015) to Revision A	Page
• Added second footnote in <i>Device Information</i> table	1
• Changed <i>Simplified Block Diagram</i>	1

6 Device Comparison Table

PRODUCT	PACKAGE-LEAD	LED DRIVE CONFIGURATION	LED DRIVE CURRENT (mA, Max)	OPERATING TEMPERATURE RANGE	OPTIMIZED APPLICATION
AFE4400	VQFN-40	H-bridge, common anode	50	0°C to 70°C	Finger-clip pulse oximeters
AFE4490	VQFN-40	H-bridge, common anode	200	-40°C to 85°C	Clinical-grade pulse oximeters
AFE4403	DSBGA-36	H-bridge, common anode	100	-20°C to 70°C	Clinical pulse oximeter patches, wearables
AFE4404	DSBGA-15	Common anode	50	-20°C to 70°C	Wearable optical bio-sensing

7 Pin Configuration and Functions

**YZP Package
15-Ball DSBGA
Bottom View**



PRODUCT PREVIEW

Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
ADC_RDY	B2	Digital	ADC ready interrupt signal (output)
CLK	C2	Digital	Clock input or output, selectable based on register. Default is input (external clock mode). Can be set via a register to output the clock when the oscillator is enabled. ⁽¹⁾⁽²⁾
DNC	C1		Do not connect (leave floating)
GND	D3	Ground	Common ground for transmitter and receiver
I2C_CLK	E2	Digital	I ² C clock input, external pullup resistor to IO_SUP (for example, 10 k Ω)
I2C_DAT	E1	Digital	I ² C data, external pullup resistor to IO_SUP (for example, 10 k Ω)
INM	A1	Analog	Connect only to anode of photodiode ⁽³⁾
INP	B1	Analog	Connect only to cathode of photodiode ⁽³⁾
IO_SUP	A3	Supply	Separate supply for digital I/O. Must be less than or equal to RX_SUP. Can be tied to RX_SUP.
RESETZ	D1	Digital	RESETZ or PWDN: function based on (active low) duration of RESETZ pulse. ⁽⁴⁾ 25- μ s to 50- μ s duration = RESET active. For durations greater than 200 μ s, this pin functions as a power-down (PWDN) pin.
RX_SUP	A2	Supply	Receiver supply; 1- μ F decapacitor to GND
TX1	B3	Analog	Transmit output, LED1
TX2	D2	Analog	Transmit output, LED2
TX3	C3	Analog	Transmit output, LED3
TX_SUP	E2	Supply	Transmitter supply; 1- μ F decapacitor to GND

- (1) Depending on whether external clock mode or internal oscillator mode is used, extra series or shunt resistors are recommended on the CLK pin.
- (2) In both hardware power-down (PWDN) and software power-down (PDNAFE) modes, the CLK pin is driven by the AFE to 0 V. Therefore, if operating in external clock mode, take care to shut off the external clock to the AFE when in these power-down modes.
- (3) Maintain the indicated polarity of photodiode connections to the AFE input pins.
- (4) A RESET pulse must be applied after power-up to ensure that the registers are all reset to their default values.

8 Device and Documentation Support

8.1 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

8.2 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

8.3 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

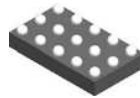
8.4 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

9 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

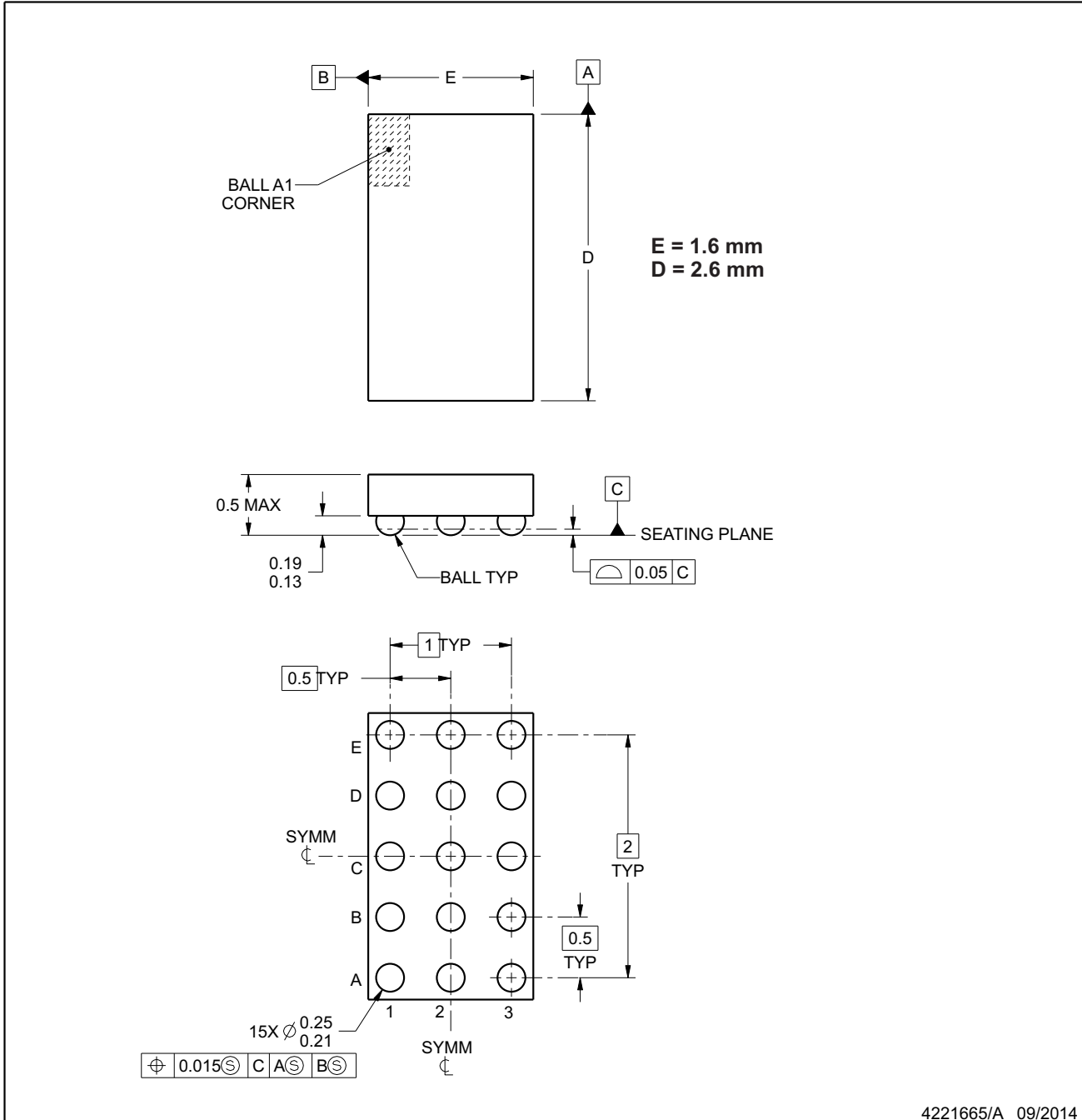


YZP0015

PACKAGE OUTLINE

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



NOTES:

NanoFree is a trademark of Texas Instruments.

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. NanoFree™ package configuration.

Figure 1. Package Outline

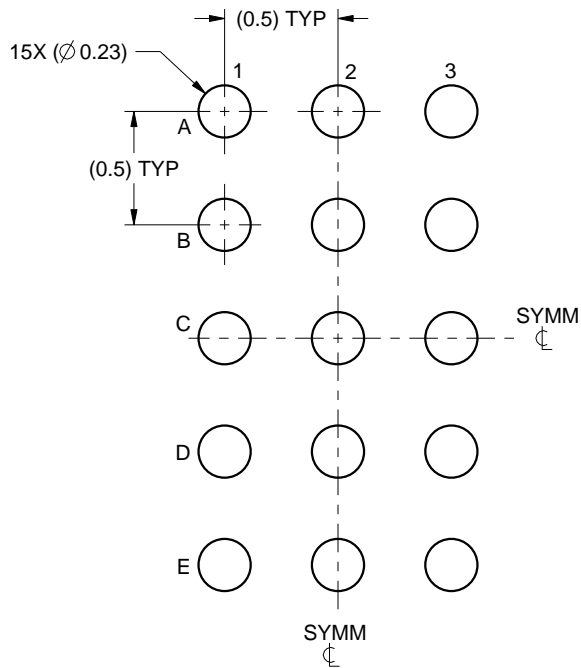
PRODUCT PREVIEW

EXAMPLE BOARD LAYOUT

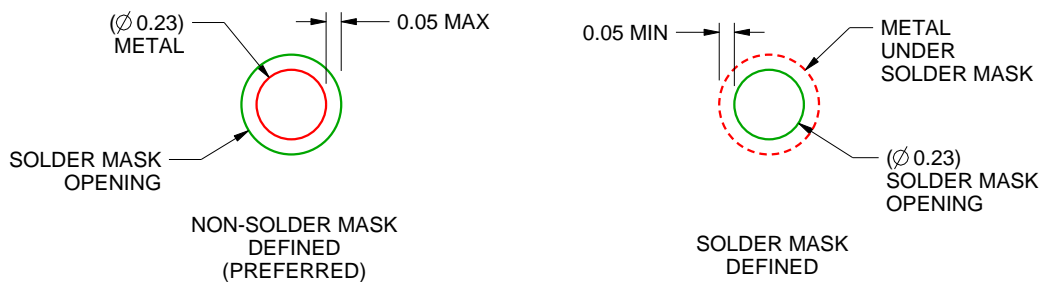
YZP0015

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE
SCALE:30X



SOLDER MASK DETAILS
NOT TO SCALE

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NOTES: (continued)

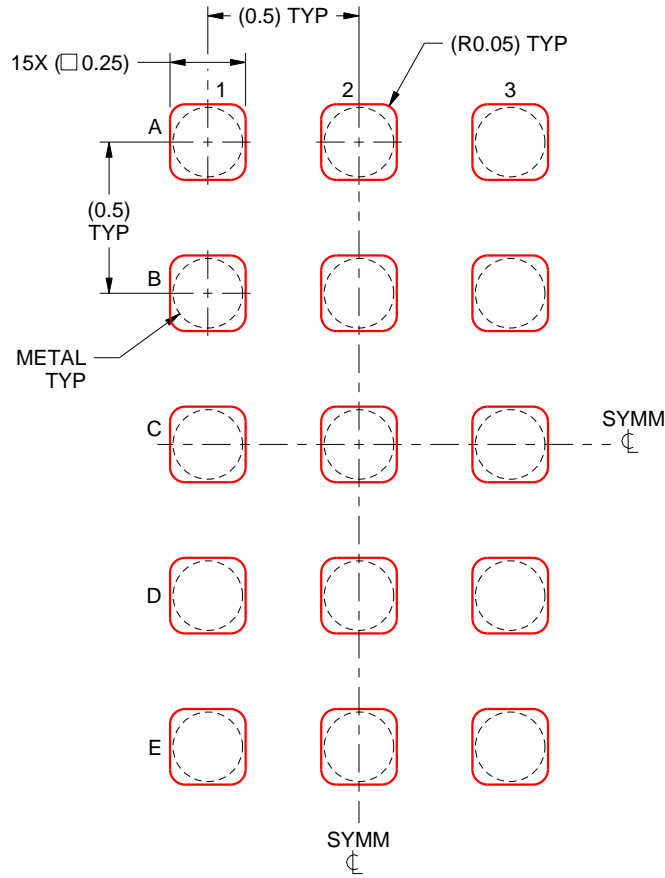
- 4. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SBVA017 (www.ti.com/lit/sbva017).

EXAMPLE STENCIL DESIGN

YZP0015

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:40X

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NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
AFE4404YZPT	PREVIEW	DSBGA	YZP	15	250	TBD	Call TI	Call TI	-20 to 70		

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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