

# AFE4405 Ultra-Small, Integrated AFE with FIFO for Wearable, Optical Heart-Rate Monitoring and Bio-Sensing

## 1 Features

- Transmitter:
  - Supports Common Anode LED Configuration
  - Dynamic Range: 100 dB
  - 8-Bit Programmable LED Current to 50 mA (Extendable to 100 mA)
  - Programmable LED On-Time
  - Simultaneous Support of 3 LEDs for Optimized SpO<sub>2</sub>, HRM, or Multi-Wavelength HRM
- Receiver:
  - Supports 2 Time-Multiplexed Photodiode Inputs
  - 24-Bit Representation of the Current Input from the Photodiode in Twos Complement Format
  - Individual DC Offset Subtraction DAC ( $\pm 15.75\text{-}\mu\text{A}$  Range) at TIA Input for Each LED, Ambient
  - Digital Ambient Subtraction at ADC Output
  - Transimpedance Gain: 10 k $\Omega$  to 2 M $\Omega$
  - Dynamic Range: 100 dB
  - Dynamic Power-Saving Mode to Reduce Receiver Current to 200  $\mu\text{A}$
- Pulse Frequency: 5 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
- FIFO with 240 Sample Depth:
  - Programmable Partitioning Across Phases
- I<sup>2</sup>C, SPI Interfaces: Selectable by Pin
- Operating Temperature Range:  $-20^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$
- 2.6-mm x 2.1-mm DSBGA, 0.4-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) for Wearables, Hearables
- Heart-Rate Variability (HRV)
- Pulse Oximetry (SpO<sub>2</sub>) Measurements
- Maximum Oxygen Consumption (VO<sub>2</sub> Max)
- Calorie Expenditure

## 3 Description

The AFE4405 is an analog front-end (AFE) for optical bio-sensing applications, such as heart-rate monitoring (HRM) and saturation of peripheral capillary oxygen (SpO<sub>2</sub>). The device supports three switching light-emitting diodes (LEDs) and up to two photodiodes. 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 stored in a 240-sample first in, first out (FIFO) block with programmable depth. The FIFO depth can be partitioned to accommodate the phases that must be stored. The FIFO can be read out using either an I<sup>2</sup>C or a SPI interface. The AFE also has a fully-integrated LED driver with an 8-bit current control. The device has a high dynamic range transmit-and-receive circuitry that helps with the sensing of very small signal levels.

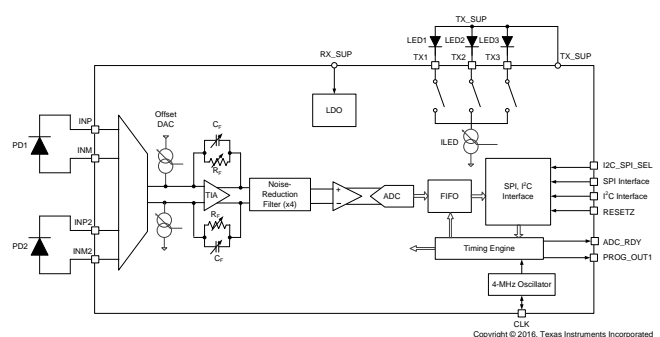
To request a full data sheet or other design resources: [request AFE4405](#)

### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
AFE4405	DSBGA (30)	2.60 mm x 2.10 mm

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

### Simplified Block Diagram



## 4 Revision History

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

<b>Changes from Revision B (May 2016) to Revision C</b>	<b>Page</b>
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- |  |   |
|--|---|
| • Changed the <i>Mechanical Packaging</i> images ..... | 4 |
|--|---|

<b>Changes from Revision A (May 2016) to Revision B</b>	<b>Page</b>
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- |   |   |
|---|---|
| • Added link to request full data sheet ..... | 1 |
|---|---|

<b>Changes from Original (April 2016) to Revision A</b>	<b>Page</b>
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- |                               |   |
|-------------------------------|---|
| • Released to production..... | 1 |
|-------------------------------|---|

## 5 Device and Documentation Support

### 5.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 5.2 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.

### 5.3 Trademarks

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### 5.4 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.

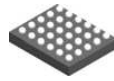
### 5.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 6 Mechanical, Packaging, and Orderable Information

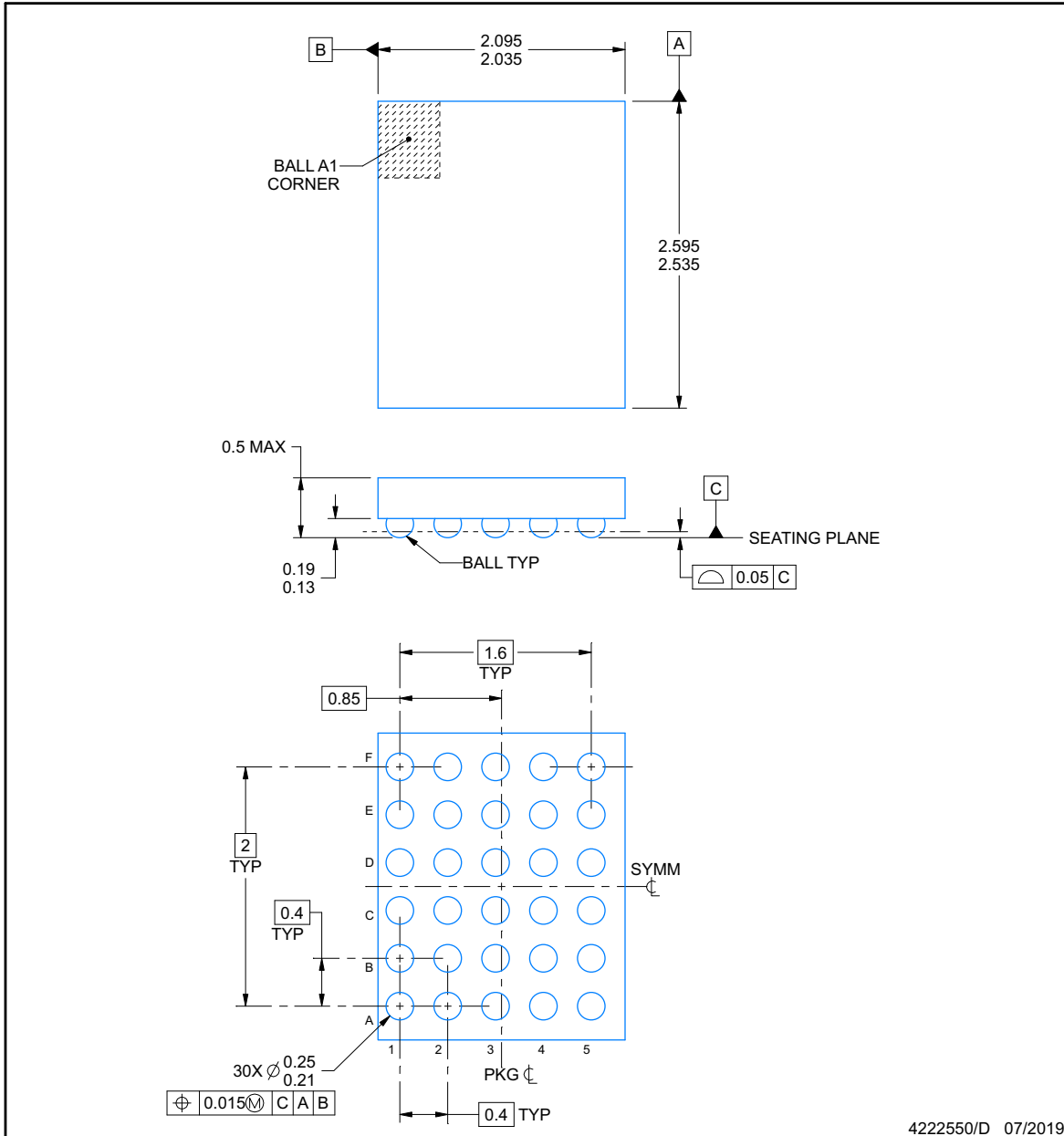
The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand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



**YZ0030-C01**

**PACKAGE OUTLINE**  
**DSBGA - 0.5 mm max height**

DIE SIZE BALL GRID ARRAY



NOTES:

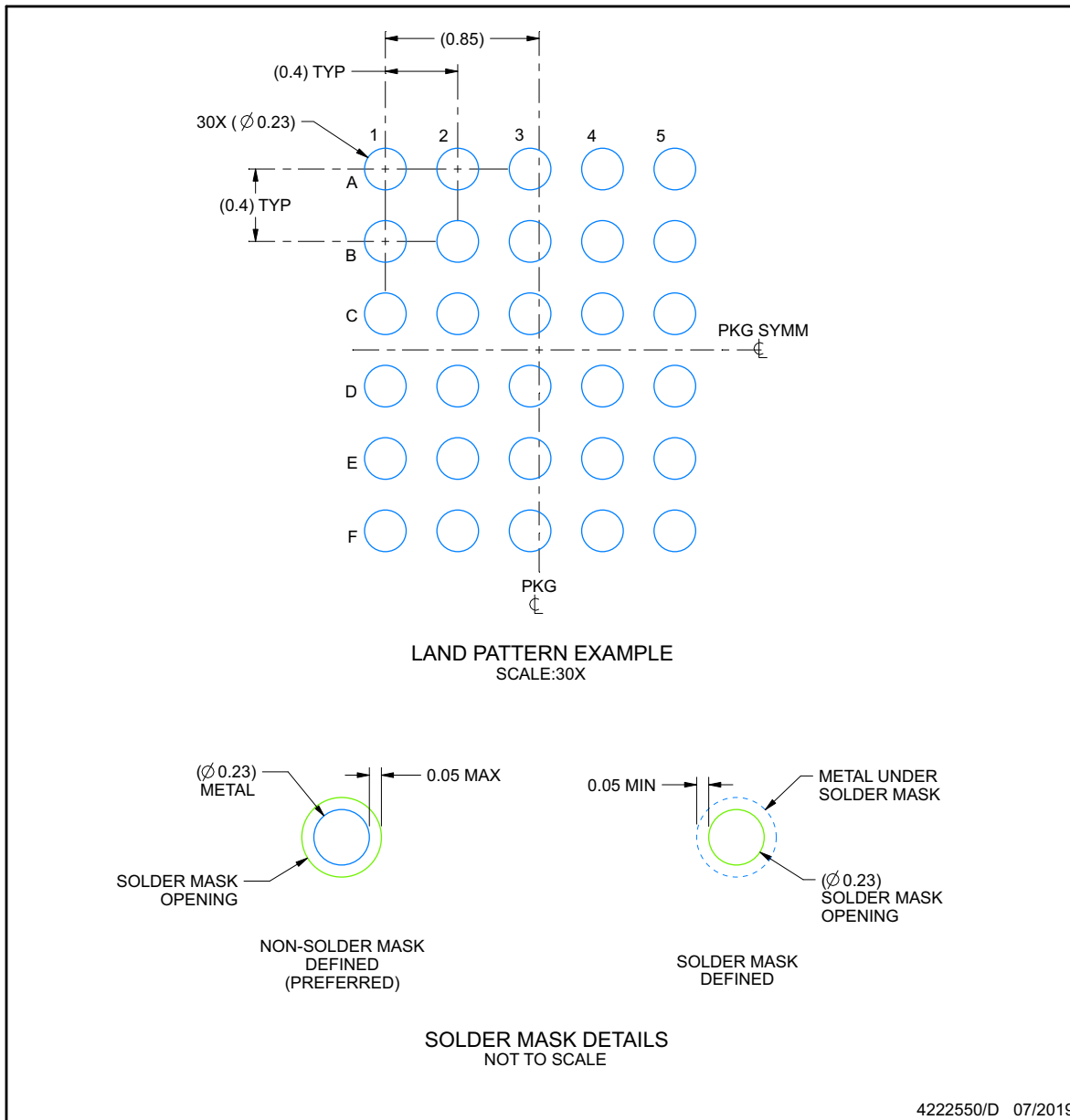
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

## EXAMPLE BOARD LAYOUT

**YZ0030-C01**

**DSBGA - 0.5 mm max height**

DIE SIZE BALL GRID ARRAY



NOTES: (continued)

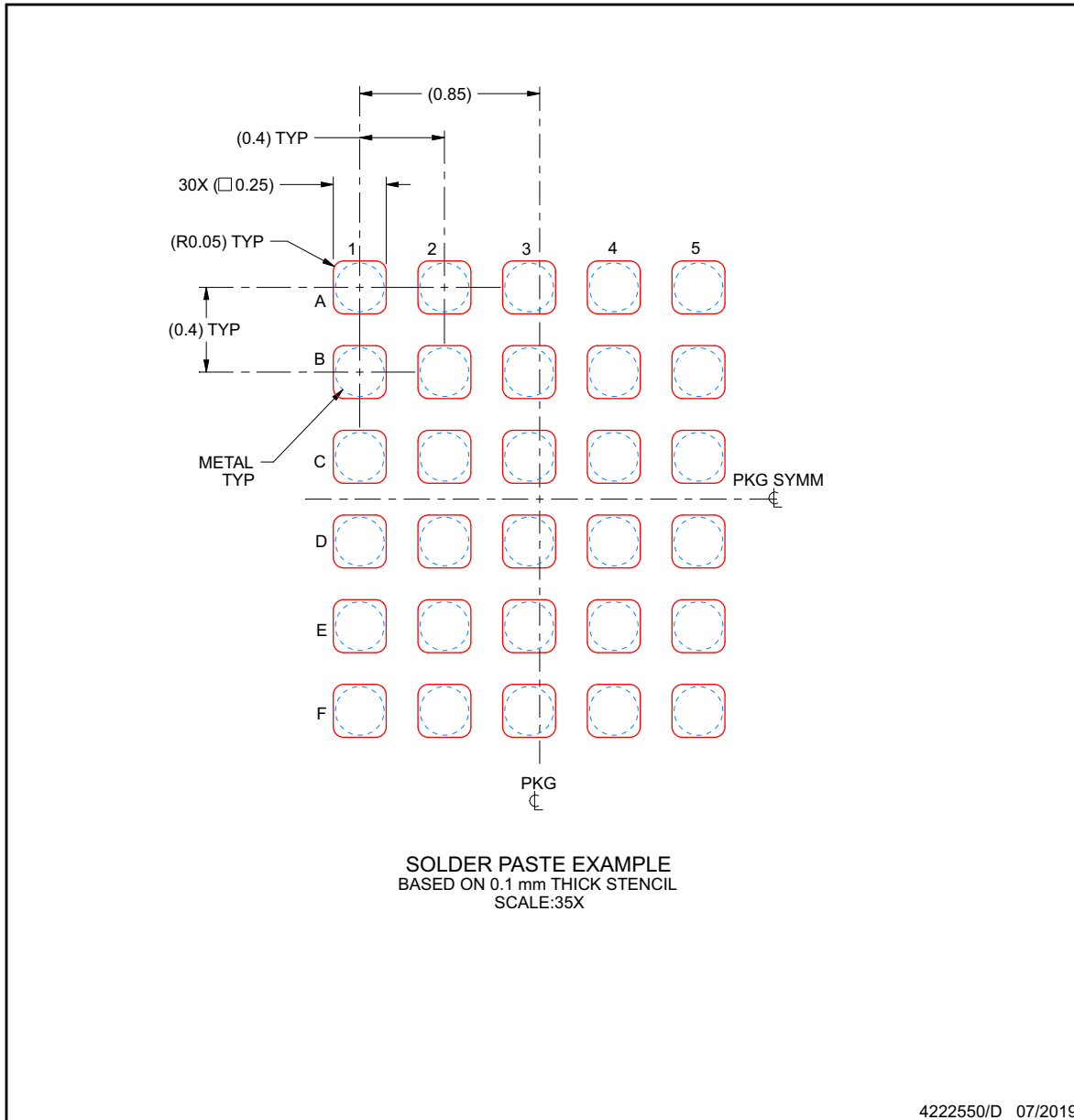
- 3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. See Texas Instruments Literature No. SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).

**EXAMPLE STENCIL DESIGN**

**YZ0030-C01**

**DSBGA - 0.5 mm max height**

DIE SIZE BALL GRID ARRAY



NOTES: (continued)

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

**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">AFE4405YZR</a>	Active	Production	DSBGA (YZ)   30	3000   LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-20 to 70	AFE4405
AFE4405YZR.A	Active	Production	DSBGA (YZ)   30	3000   LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-20 to 70	AFE4405

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
AFE4405YZR	DSBGA	YZ	30	3000	180.0	8.4	2.16	2.66	0.6	4.0	8.0	Q1



**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
AFE4405YZR	DSBGA	YZ	30	3000	210.0	185.0	35.0

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