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_2, 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 (±15.75-µA Range) at TIA Input for Each LED, Ambient
  - Digital Ambient Subtraction at ADC Output
  - Transimpedance Gain: 10 kΩ to 2 MΩ
  - Dynamic Range: 100 dB
  - Dynamic Power-Saving Mode to Reduce Receiver Current to 200 µA
- 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^2C, SPI Interfaces: Selectable by Pin
- Operating Temperature Range: –20°C to +70°C
- 2.6-mm × 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_2) Measurements
- Maximum Oxygen Consumption (VO_2 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_2). 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^2C 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.

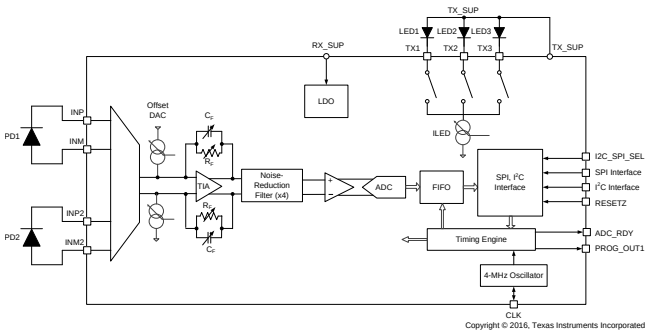
To request a full data sheet or other design resources: request AFE4405

Device Information(1)

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

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

Simplified Block Diagram



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4 Revision History

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

Changes from Revision B (May 2016) to Revision C	Page
• Changed the *Mechanical Packaging* images	4

Changes from Revision A (May 2016) to Revision B	Page
• Added link to request full data sheet	1

Changes from Original (April 2016) to Revision A	Page
• Released to production	1

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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

E2E is a trademark of Texas Instruments.
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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.

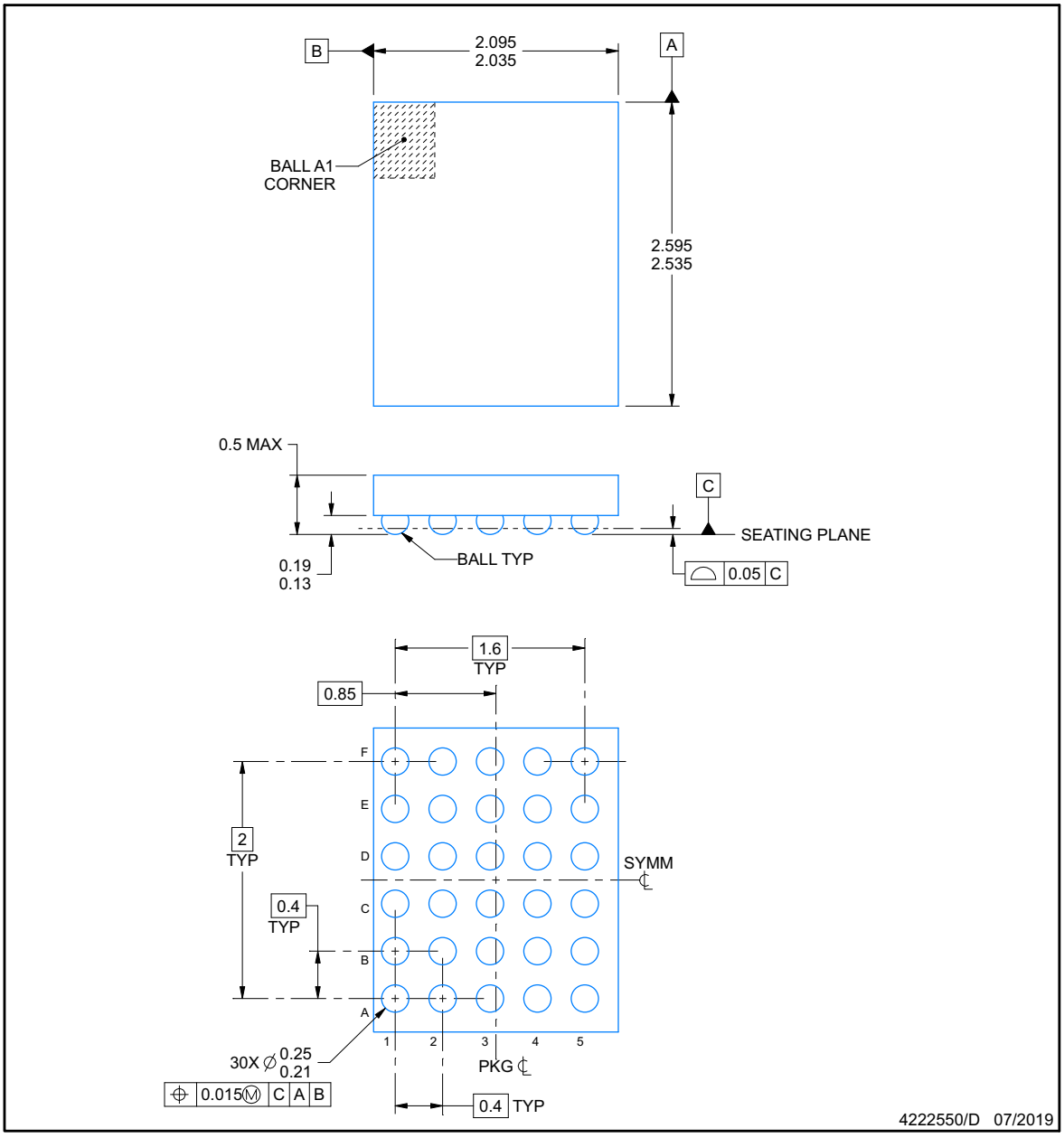
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PACKAGE OUTLINE

YZ0030-C01

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.

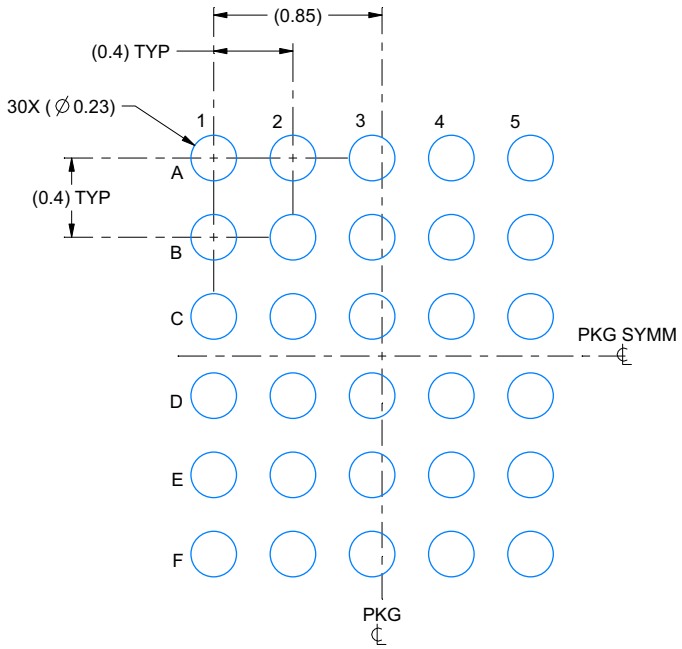
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EXAMPLE BOARD LAYOUT

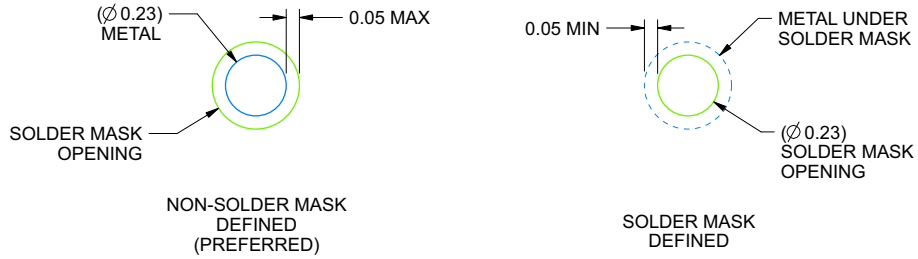
YZ0030-C01

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE
SCALE:30X



SOLDER MASK DETAILS
NOT TO SCALE

4222550/D 07/2019

NOTES: (continued)

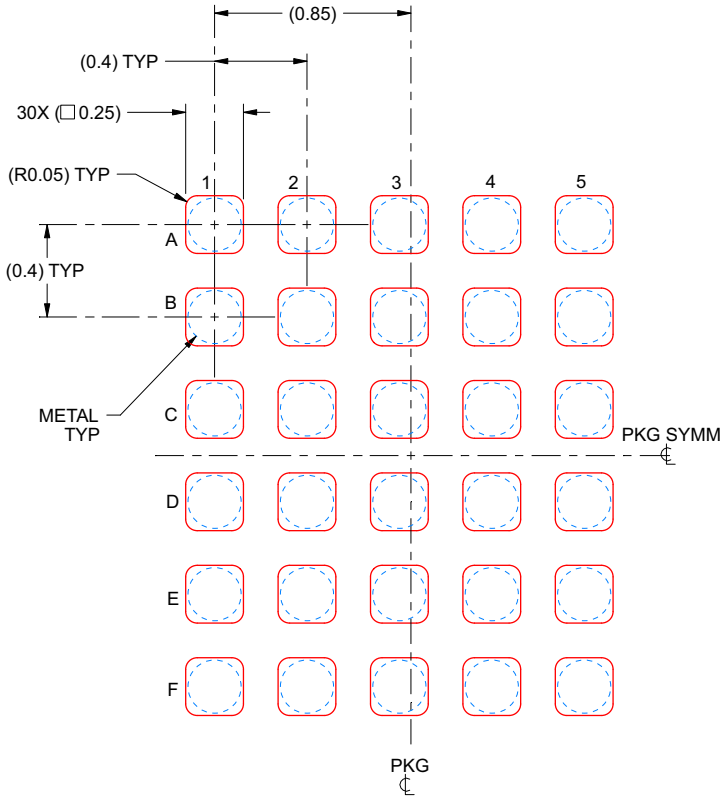
3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. See Texas Instruments Literature No. SNVA009 (www.ti.com/lit/snva009).

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EXAMPLE STENCIL DESIGN

YZ0030-C01 — **DSBGA - 0.5 mm max height**

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:35X

4222550/D 07/2019

NOTES: (continued)

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

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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
AFE4405YZR	ACTIVE	DSBGA	YZ	30	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-20 to 70	AFE4405	Samples

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(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.

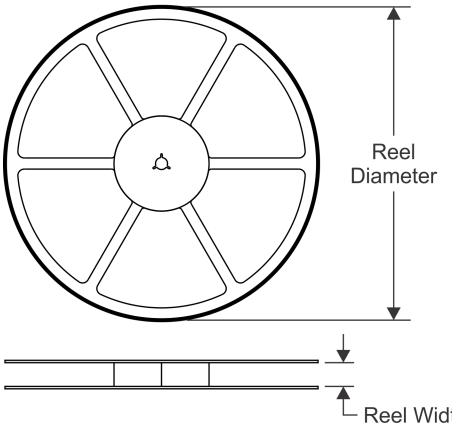
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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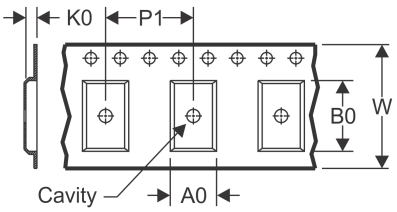
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

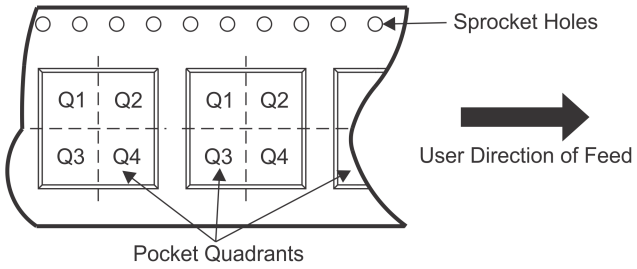


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

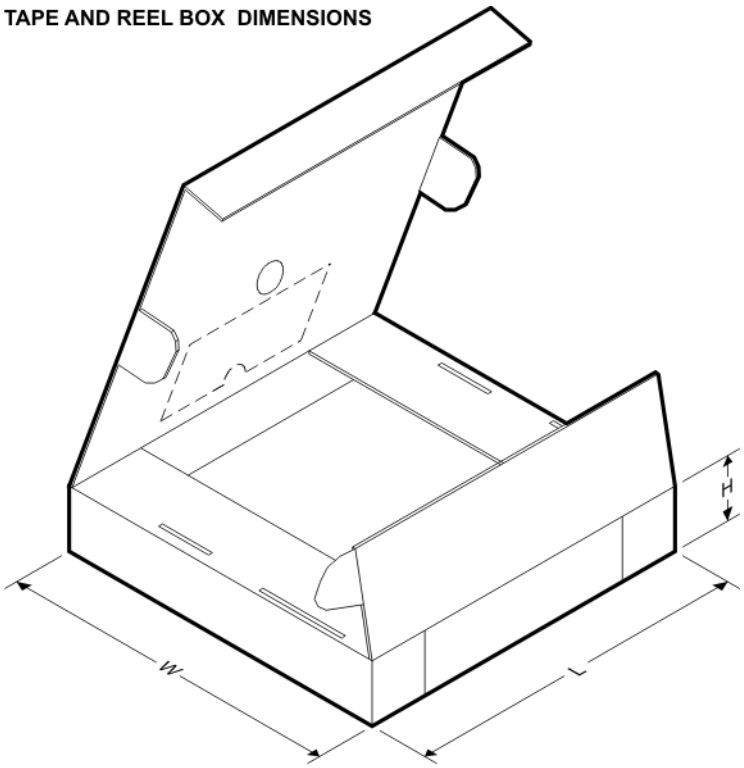
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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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