AF-301

ULTRA-LOW POWER ANALOG FRONT END (AFE)

PRODUCT BRIEF

Revision B

CONTENTS

1. GENERAL DESCRIPTION

The Qorvo AF-301 represents ultra-low power and high SNR single-channel Analog Front-End devices (AFEs). It is designed to work with Qorvo's FT-401 force sensor to enable the best sensing solution. The AFE allows direct connection to a host processor via an industry standard I²C interface.

The AF-301 is designed for Always-On applications. They sample the sensing signals and off-load the host, allowing the host to remain asleep during tasks such as auto-calibration. In force applications, these AFEs can wake the system via an interrupt when a pre-defined force trigger level is achieved. In active mode, sampling at 100 Hz, the entire solution consumes only 5 µA. Depending on the sampling frequency, the solution has a low latency of 1 ms.

The AF-301 is available in a 9-pin CSP package (1.16 mm x 1.16 mm x 0.475 mm) and is used with Qorvo FT-401 Force sensor.

2. FEATURES

- Analog front end for FT-401 MEMS Force sensor
- Integrated instrumentation amplifier with programmable gain (up to x416)
- Sensor duty-cycle control
- Ultra-low power: 5 µA @ 100 Hz (sensor + AFE)
- Runtime auto-Calibration
- Auto-preload adjust on power-up
- Low latency: 1 ms
- Single channel differential input
- I²C slave interface
- Hardware and/or software programmable force trigger
- 9-Pin CSP, 1.16 mm x 1.16 mm x 0.475 mm

3. MARKETS

- Earbuds
- Wearables
- AR/VR

4. ORDERING INFORMATION

PART	OPERATING TEMP. RANGE	FEATURES	DESCRIPTION
AF-301Y00	0°C to +70°C	Consumer	5000pc 7-inch reel
AF-301Y00SR	0°C to +70°C	Consumer	300pc sample reel

Table 1: Ordering Information

5. PIN CONFIGURATION

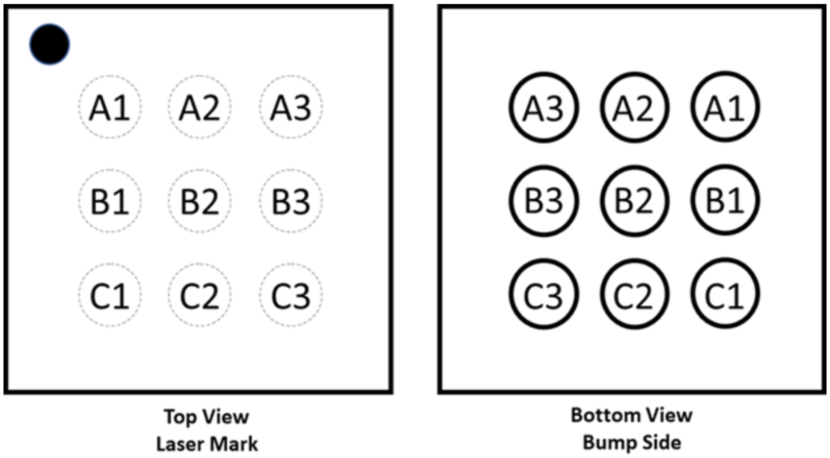

Figure 1: Pin Configuration

6. PIN DESCRIPTION

BUMP ID	PIN NAME	PIN DESCRIPTION
A1	DRV	Sensor Driver Voltage Output. This is an analog output designed to regulate power to the Qorvo analog force sensor.
A2	SNEG	Negative Input Terminal. Negative output of the force sensor connects to this input.
A3	SPOS	Positive Input Terminal. Positive output of the force sensor connects to this input.
B1	INTB	Interrupt Output. This active-low pin (can be programmed to be active-high) allows the AF-301 to wake-up the host. It is open drain.
B2	THR_ADR	I^2C Address Selection and hardware programmed threshold setting on boot up.
B3	GND	Ground. Ground terminal for AF-301. All signals are referred to this terminal
C1	SCL	Serial SCL Input. Serial I^2C clock input connecting the master clock.
C2	SDA	Serial Data I/O. Serial I^2C data pin allowing communications to/from the master. It is open drain.
C3	VDD	AF-301 Power Supply. This pin accepts supply voltage levels from 1.62 V to 3.63 V.

Table 2: Pin Description

7. ABSOLUTE MAXIMUM RATINGS

VDD to GND .... -0.3 V to +4 V
SPOS, SNEG to GND.. -0.3 V to +4 V
DRV to GND.. -0.3 V to VDD + 0.3 V
THR_ADR, SCL, SDA, INTB to GND.. -0.3 V to +4 V
Operating Temperature Range .... See Ordering Information
Storage Temperature..-65°C to +150°C
Lead Temperature (soldering 10s).. +260°C
Electrostatic Discharge Protection (ESD).. 2000 V (HBM), 500 V (CDM)

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.

8. APPLICATIONS INFORMATION

8.1 TYPICAL OPERATING CIRCUIT

Figure 2 depicts a button application utilizing the AF-301. The AFE generates an interrupt when the force applied to the force sensor reaches the programmed force threshold. The host processor can change the threshold by writing to the AFE using the I2C interface.

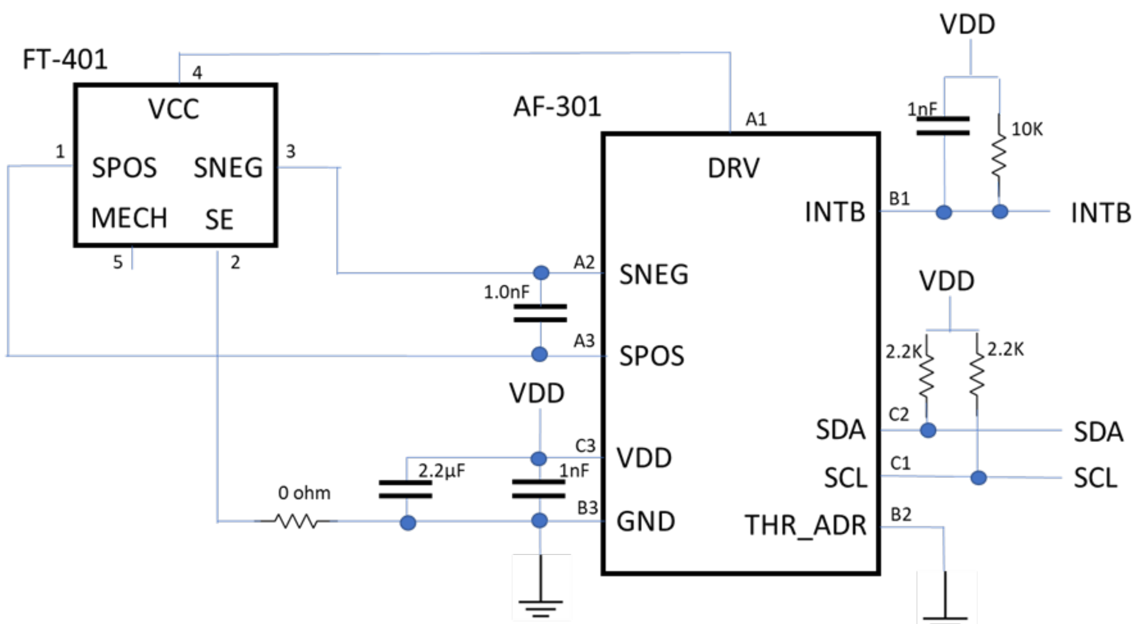

Figure 2: Button Application

8.2 POWER-UP SEQUENCE

The AF-301 AFE will be fully operational 10 ms after power is initially applied to the chip. After power-up, it enters active mode by default, see Figure 3.

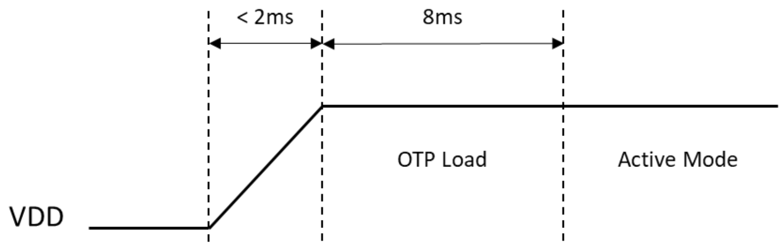

Figure 3: Power-up Ramp and Full Operation

8.3 DIGITAL INTERFACE - I²C SLAVE COMMUNICATIONS AND INTERRUPTS

The THR_ADR is used to choose between four I²C slave addresses at power-up to ensure that each device has a designated address. The four different addresses can be achieved by pulling the THR_ADR pin to either VDD directly, GND directly, connect it to VDD via a resistor or connect it to GND via a resistor. The resistor value must be from 5 kΩ to 25 kΩ. The four addresses and the associated THR_ADR connection is shown in Table 3.

THR_ADR CONNECTION	AFE I²C ADDRESS
THR_ADR = 5 kΩ to 25 kΩ to GND	0x44
THR_ADR = 5 kΩ to 25 kΩ to VDD	0x45
THR_ADR = GND	0x46
THR_ADR = VDD	0x47

Table 3: I2C Address Selection using THR_ADR

The AFE I²C addresses are 7-bit. Note that support for 10-bit I²C slave addressing and General-Call (broadcast) addressing are not available.

The supply voltage to the AFE should be less or equal to the IO voltage for the I2C and INTB. Figure 2 shows all voltage rails equal to the same value.

SDA and SCL signals are open-drain and must be pulled high for the bus to operate. This is typically done with ≥ 2 kΩ pull-up resistors (or greater for lower power operation), see Figure 2. Series resistors in the signal line paths are optional to protect the AFE input architecture from high-voltage spikes on the bus lines, minimize crosstalk, and undershoot events of the bus signals.

9. ELECTRICAL DESIGN, LAYOUT, PLACEMENT, HANDLING & PACKAGING INFORMATION

9.1 ELECTRICAL DESIGN AND BOARD LAYOUT CONSIDERATIONS

It is recommended to follow best layout practices involving sensitive sensor signal and the rest of the AFE signals. This includes proper matching of sensor signal line lengths to the AFE and balancing parasitic impacts on the differential sensor outputs.

Do not use vias directly under the AF-301 solder balls.

The AF-301 is a sensitive mixed-signal device and it is therefore recommended to reference any/all power on the sensor to a low-noise analog supply source. To achieve additional noise reduction, a differential capacitor with a value of 1 nF between SPOS and SNEG is recommended. For best noise rejection, ***place the differential capacitor close to differential inputs of the AF-301***.

Note the digital power supply section requires two bypass capacitors, 2.2µF & 1nF to reduce noise on the power supply when using the AF-301. Ensure that both of these capacitors are placed close to the AF-301.

The Sensor Enable (SE) pin on the sensor must be connected via a 0 ohm resistor directly to the grounded terminal of the bypass capacitors next to the AF-301. The 0 ohm resistor and the bypass capacitors should be ≤ 1mm away from the AF-301.

Route high-speed digital signal traces away from the sensitive analog traces. Keep signal lines short and free of 90° turns (steep angles/corners can cause undesired acid traps during the manufacturing process). Use 45° turns or rounded-edge-turns for all signal/power lines when designing with the Qorvo force sensing solutions.

9.2 PCB PLACEMENT – BEST PRACTICES

- Route sensitive signal and power lines away from high-speed clock and interface lines.
- Qorvo recommends greater than (or equal) 6 mil traces for all signals.
- Figure 4 shows an example of the AF-301 connected to the FT-401 sensor.

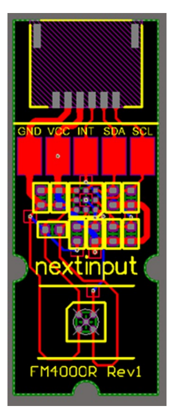

Figure 4: FM4000R Module Layout

- For applications using the FT-401 MEMS Force sensor in combination with the AF-301, place the nearest components at least 1 mm (**REQUIRED**) to 2 mm (RECOMMENDED) away from the FT-401 sensor.

9.3 FOOTPRINT AND SMT DETAILS

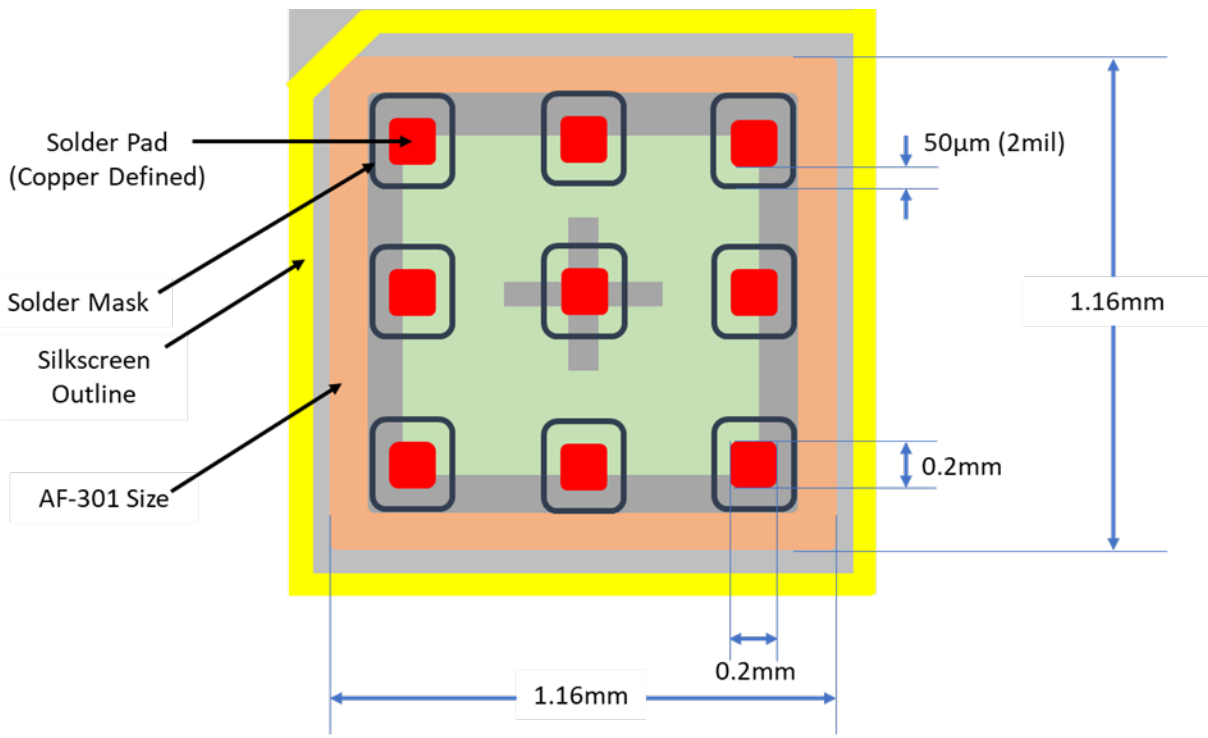

Figure 5: Must-Have Footprint

Figure 5 depicts the ***must-have*** footprint drawing for the AF-301 series and the details below must be followed for the SMT of the AFE onto a PCB/FPCB

1. Pad dimensions and type
    a. Rounded rectangle with dimensions **7.874 mil x 7.874 mil** (0.2 mm x 0.2 mm)
    b. Radius of the rounded square pad: **Corner radius of 0.05mm (not a circular pad)**
    c. Copper defined, ***not* solder-mask defined**
2. Solder paste stencil thickness: **4 mil** (100 µm)
3. Solder mask: **2 mil (50 µm) wider on all sides of the pad**
4. Solder Paste: **SAC405 or SAC305**

9.4 SMT PICK & PLACE GUIDELINES

9.4.1 NOZZEL CONSIDERATIONS

SMT assembly machines typically employ a vacuum nozzle for Pick & Place (P&P) operations. Not all equipment is the same, but there are some general guidelines to follow, for optimal performance/yield.

1. Select a vacuum nozzle only.
    a. DO NOT use mechanical grippers or collets, that contact the edges/sides of a WLCSP.
    b. DO NOT handle WLCSP parts with metal tweezers.
2. Prefer softer nozzle materials.
    a. Nozzle materials can vary (metal, ceramic, plastic, rubber), and certain equipment requires certain nozzle materials. If there's a choice, try to select a softer material, to avoid potential damage from mechanical shocks.
3. Select an appropriate nozzle tip shape.
    a. Nozzle tip shape can affect the amount of pressure applied to a single point on a WLCSP part.
    b. Nozzle tips should be circular, square/rectangular, and preferably with a vertical separator.
    c. The nozzle tip surface should be a single plane; do not use a nozzle with a protruded edge

Acceptable

NOT Acceptable

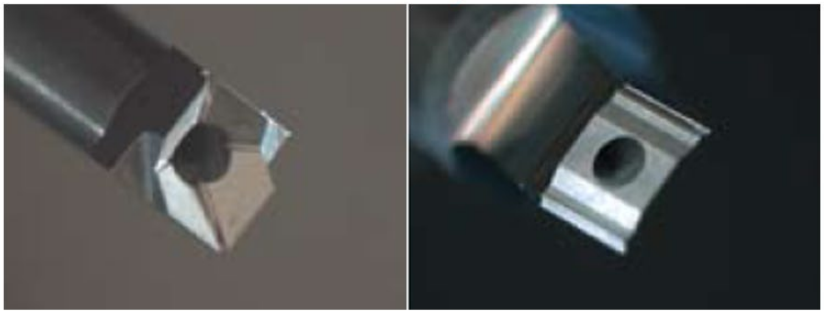

Figure 6: Acceptable vs. NOT Acceptable Tip Shapes

4. Select an appropriate nozzle tip size, for the part being placed.
    a. The largest tip dimension should be smaller than the size of the WLCSP part.
    b. The tip should account for the tolerance of the pick accuracy, so that it's not possible for the nozzle tip to contact the edge or the corner of a part.
    c. The tip size should be as large as possible, while satisfying the above 2 points.

9.4.2 PICK & PLACE OPERATION

The P&P operation consists of two key steps: picking a part out of the carrier tape pocket, and placement of that part onto a circuit board. Both operations are performed with some alignment tolerance: nozzle-to-part tolerance during the pick, and part-to-board alignment during the placement. Additionally, the placement should occur with as little force as possible, to press the die into place on the board.

WLCSP parts are shipped to customers in standard carrier tape & reel packaging. Parts sit in a pocket that is slightly larger than the size of the part. A part can move laterally inside the pocket, typically by less than 0.1 mm, but this varies by product.

1. If available, the P&P equipment should use a vision detection system to align the P&P nozzle to the center of the die, for every part picked.
2. If a vision alignment system isn't available, the nozzle size selection should account for the positional tolerance of the WLCSP part in the carrier tape pocket.

The die placement operation should be performed with a placement accuracy of better than 0.1 mm, but accuracies smaller than 0.05 mm are typical. The placement force should be as small as possible to make contact of the WLCSP solder bumps with the solder paste on the board.

1. A force contactless pickup is preferred, using only light physical contact, and allowing the vacuum to pick the part.
2. Prefer to use a "air-ejection" placement over a contact placement. A typical air-ejection pressure is 150 mbar.
3. If air placement isn't available, use a contact mode for the part placement. Ensure that both the pick and placement force is not larger than 2 N (200 gram). Placement forces should be measured periodically using a calibrated load, to ensure parts aren't placed with a force over this specification.

9.5 DEVICE HANDLING – BEST PRACTICES

- **Do not pick up the device with metal tweezers. Use vacuum pickup head.**
- Do not "snap" panelized, assembled PCBs
- Follow ESD-safe handling recommendations
    - store device in ESD sensitive containers (e.g. T&R, moisture-sealed)
    - handle devices only in ESD-safe work areas
    - persons /machines handling the device must be grounded to avoid potential ESD damage

9.6 ASSEMBLY INSTRUCTIONS

The AF-301 can be reflow-soldered using direct-chip-attachment (DCA) techniques to the circuit substrate (e.g. FR-4 or FPC). The chip should be soldered at normal reflow (Table 4) temperatures designed to support RoHS and Pb-free compliance (Figure 7). Reflow assembly houses should follow this profile closely but can chose more conservative ramp-up/down rates. To avoid damage to the device do not exceed maximum ratings of the qualification profile (e.g. T_{PMAX} = 260°C @ the top side of the CSP). Customers should consult with their assembly house/vendor for the appropriate temperature/reflow soldering profile.

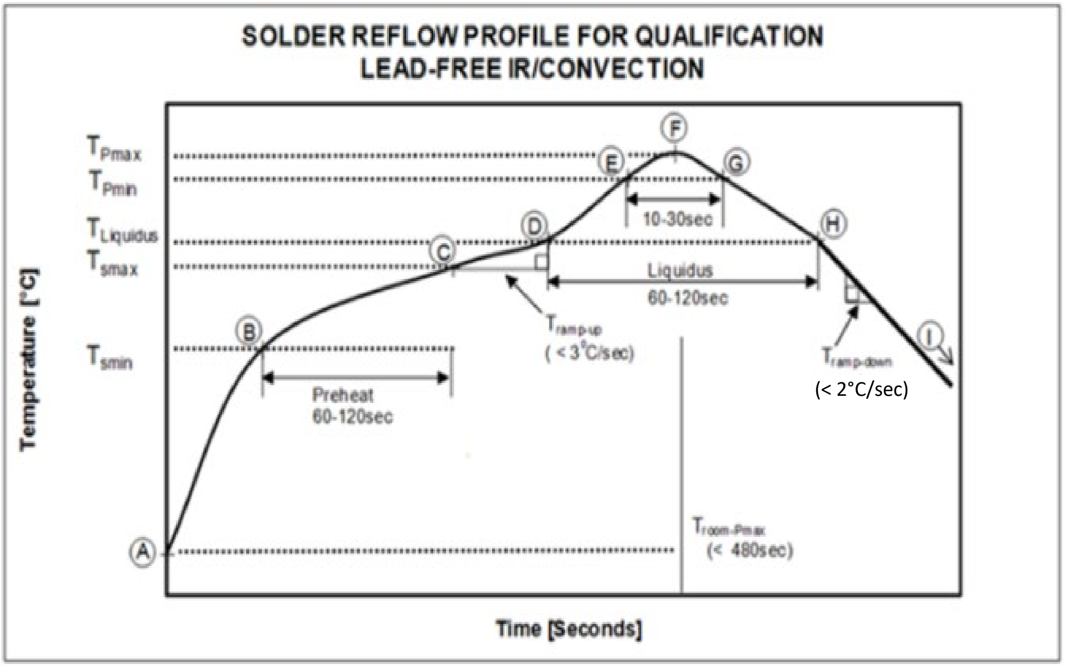

Figure 7: Pb-Free Soldering Profile for Reflow Assembly

Step	Parameter	Temperature [°C]	Time [s]	Maximum Rate [°C/s]
A	T_{ROOM}	25		
B	T_{SMIN}	150		
C	T_{SMAX}	200	$60 < t_{BC} < 120$	
D	$T_{LIQUIDUS}$	217		$r_{(TLIQUIDUS - TPMAX)} < 3$
E	$T_{PMIN\ [255°C,\ 260°]}$	255		$r_{(TLIQUIDUS - TPMAX)} < 3$
F	$T_{PMAX\ [260°C,\ 265°C]}$	260	$t_{AF} < 480$	$r_{(TLIQUIDUS - TPMAX)} < 3$
G	$T_{PMIN\ [255°C,\ 260°]}$	255	$10 < t_{EG} < 30$	$r_{(TPMAX-TLIQUIDUS)} < 2$
H	$T_{LIQUIDUS}$	217	$60 < t_{DH} < 120$	
I	T_{ROOM}	25		

Table 4: Reflow Assembly Temperature Profile

9.7 PACKAGING INFORMATION

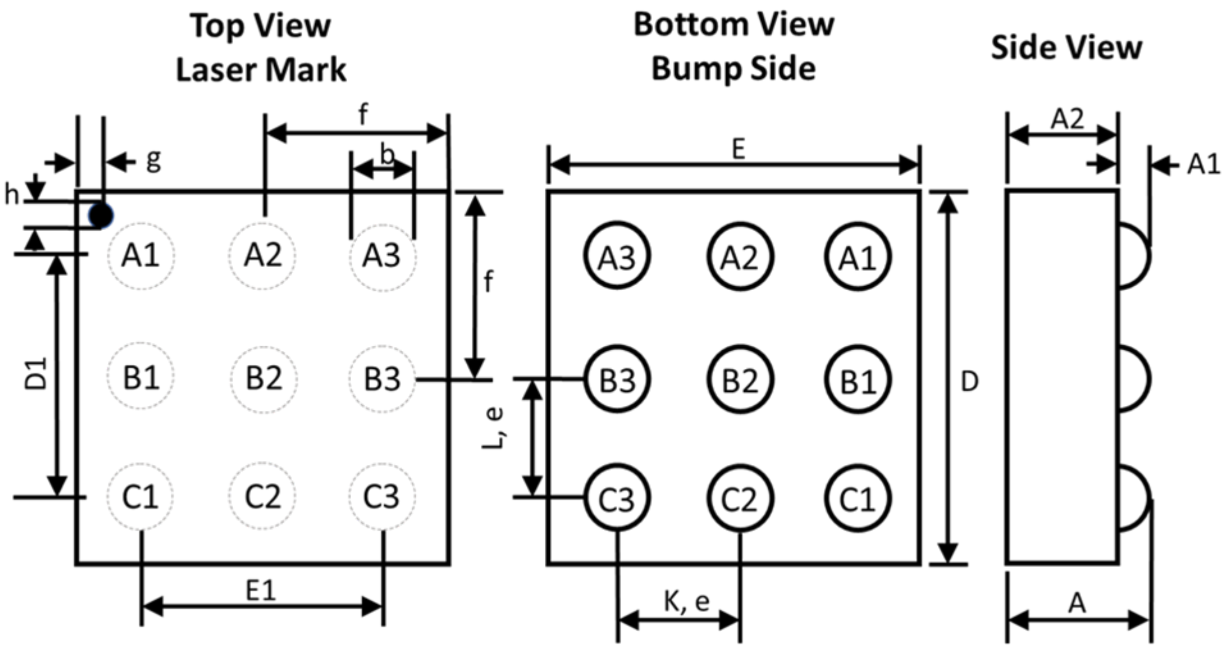

Figure 8: Package Dimensions

Info for 1.16 mm x 1.16 mm x 0.475 mm CSP				
Symbol	**Min.**	**Nom.**	**Max.**	**Notes**
A	0.435	0.475	0.515	Overall height
A1	0.137	0.157	0.177	Solder ball height
A2	0.298	0.318	0.338	Body thickness
D	1.12	1.16	1.20	Body size
D1	0.79	0.80	0.81	Solder ball footprint
E	1.12	1.16	1.20	Body size
E1	0.79	0.80	0.81	Solder ball footprint
9				Number of solder balls
b	0.18	0.21	0.24	Solder ball diameter; measured at the maximum solder ball diameter
e	0.395	0.400	0.405	Solder ball pitch
f	0.56	0.58	0.60	Package edge to center solder ball
g	0.10	0.15	0.20	Pin 1 ID to package edge
h	0.05	0.10	0.15	Pin 1 ID diameter
K	0.395	0.400	0.405	Center solder ball to corner solder ball (center), X
L	0.395	0.400	0.405	Center solder ball to corner solder ball (Center), Y

All dimensions are in mm unless otherwise specified; dimensions and tolerances conform to ANSI Y14.5M-1982.

For recommended footprint see Figure 5.

Table 5: Package Dimensions

9.8 DEVICE TOP MARK CODING

The top mark coding consists of 2 rows of letters and numbers printed on the top of the CSP package (Figure 9).

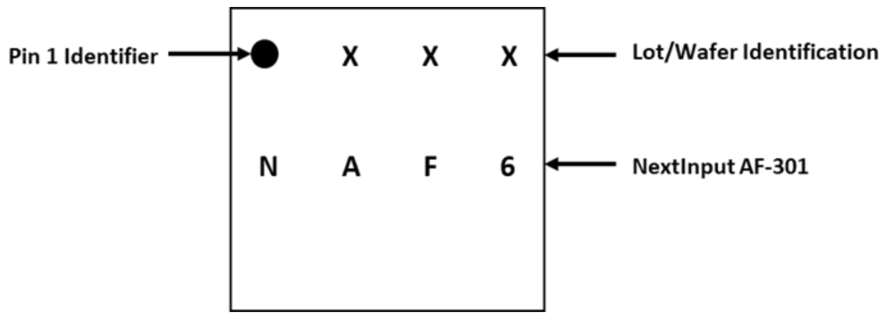

Figure 9: Top Mark

9.9 TAPE-AND-REEL (T&R) DETAILS/DIMENSIONS

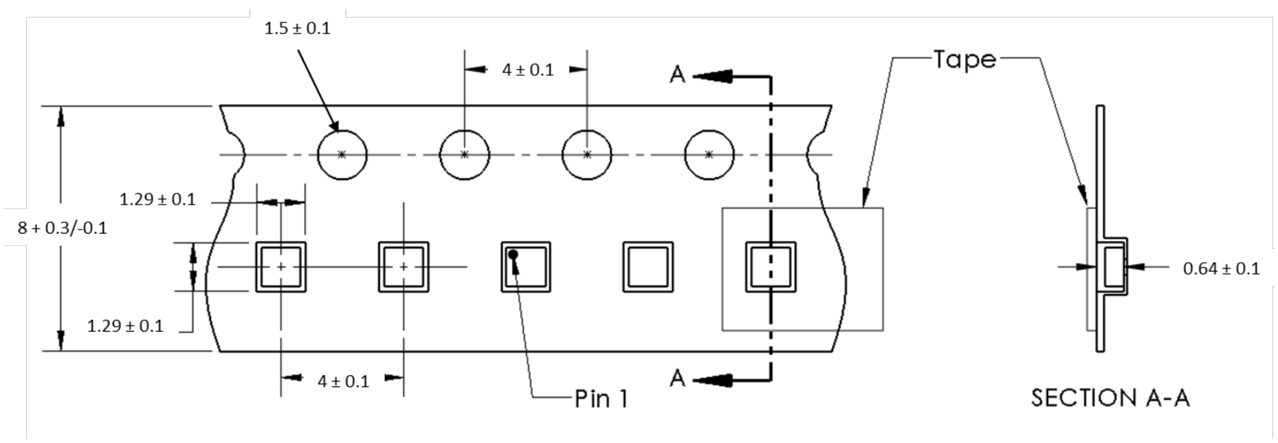

Figure 10: Tape-and-Reel Dimensions

Note that all dimensions and tolerances in this tape-and-reel diagram (Figure 10) are in mm.

Figures 11 depicts a tape reel sealed in an ESD-protective bag. The diameter of the sensor reel measures 7 inches (Radius = 3.5 inches) with reel thickness of 0.25 inches to comfortably host the tape. Each reel is stamped with the company logo, part number, lot number, and date code.

Figure 11: Example of Packaged Reel

10. RELIABILITY & ENVIRONMENTAL INFORMATION

The Qorvo AF-301 meets Level 1 (unlimited) Moisture Sensitivity Level (MSL) specifications.

Reliability and Environmental reports are furnished upon request.

11. REVISION HISTORY

REVISION NUMBER	REVISION DATE	DESCRIPTION/CHANGES	PAGES CHANGED
A	04/11/2022	Initial release	N/A
B	06/03/2022	Updated THR_ADR resistor range, added SMT pick & place guidelines	8, 24, 25