DF-880X SERIES

DIGITAL SENSOR

PRODUCT BRIEF

Revision E

CONTENTS

1. GENERAL DESCRIPTION

The Qorvo DF-880x Series is an ultra-low power and high SNR digital sensor. It's the world's first integrated force sensor with a built-in analog front-end. The sensor is designed to be the world's best single-chip force sensing solution. The digital output allows for a direct connection of the sensing solution output to a host processor via an industry standard I^2C interface.

The DF-880x sensor is also designed for "host-free" applications requiring autonomous force sensing from power-up, without the need for any I2C writes to initialize the part. To achieve this, a dual function pin allows for a force trigger threshold to be set using an external resistor. Several internal settings are factory programmable using OTP registers.

The Digital sensor is designed for Always-On applications. It offloads the host, allowing it to remain in a low-power state until woken up by the sensor through an interrupt when a pre-defined force threshold is achieved. The DF-880x has two modes of operation, a 12-bit ultra-low power mode and a 16-bit high performance mode.

The DF-880x includes factory calibration for sensitivity, automatic sensor offset correction, and programmable temperature correction in conjunction with an on-board temperature sensor.

2. FEATURES

- Integrated Digital Sensor with a built-in analog front-end
- Ultra-Low Power, 2 µA @ 15 Hz
- Integrated Instrumentation Amplifier with Programmable Gain (up to x416)
- Automatic offset correction
- Programmable temperature correction
- "Host-free" operation
- Low Latency, 1 ms
- I^2C Slave Interface
- Hardware and/or software Programmable Force Trigger
- 6-pin CSP, 1.33 mm x 1.33 mm x 0.22 mm

3. MARKETS

- General Purpose Solid-State Buttons
- Smart Phones and Tablets
- Automotive Smart Surfaces
- 3D Touch Displays
- Weight Scales, White Goods
- Wearables
- Gaming, Controllers
- Stylus, Touchpads, Smart Home, AR/VR

4. ORDERING INFORMATION

PART	OPERATING TEMP. RANGE	FEATURES	DESCRIPTION
DF-8800A00	-20°C to +70°C	Consumer	5000pc 7-inch reel
DF-8800A00SR	-20°C to +70°C	Consumer	300pc sample reel
DF-8800B00	-40°C to +85°C	Industrial	5000pc 7-inch reel
DF-8800B00SR	-40°C to +85°C	Industrial	300pc sample reel
DF-8800B00SQ	-40°C to +85°C	Industrial	25pc sample bag
DF-8805B00	-40°C to +85°C	Automotive Grade 3	5000pc 7-inch reel
DF-8805B00SR	-40°C to +85°C	Automotive Grade 3	300pc sample reel
DF-8805C00	-40°C to +105°C	Automotive Grade 2	5000pc 7-inch reel
DF-8805C00SR	-40°C to +105°C	Automotive Grade 2	300pc sample reel
DF-8800DK	N/A	N/A	Full Design Kit
DF-8800PCK	N/A	N/A	Design Kit, Sensor Module only

Table 1: Ordering Information

5. PIN CONFIGURATION

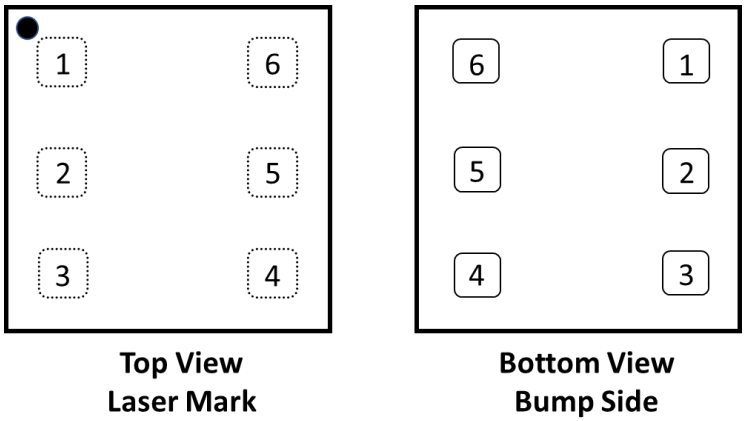


Figure 1: Pin Configuration

6. PIN DESCRIPTION

BUMP ID	PIN NAME	PIN DESCRIPTION
1	THR_ADR	I^2C Address Selection and hardware programmed threshold setting on boot up.
2	INTB	Interrupt Output. Open drain. This pin allows the DF-880x to wake-up the host.
3	SCL	Serial Clock Input. Serial I^2C clock input connecting the master clock.
4	SDA	Serial Data I/O. Open drain. Serial I^2C data pin allowing communications to/from the master.
5	VDD	DF-880x Power Supply. This pin accepts supply voltage levels from 1.62 V to 3.63 V.
6	GND	Ground. Ground terminal for DF-880x. All signals are referred to this terminal

Table 2: Pin Description

7. ABSOLUTE MAXIMUM RATINGS

VDD to GND (Power)	-0.3 V to +4 V
SCL to GND (Digital Input)	-0.3 V to +4 V
INTB to GND (Digital Output)	-0.3 V to + 4 V
THR_ADR, SDA to GND (Digital Input/output)	-0.3 V to +4 V
Applied Force (directly applied on top of sensor)	20N
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. APPLICATION INFORMATION

8.1 TYPICAL OPERATING CIRCUIT

Figure 2 shows a typical circuit for a button application utilizing the DF-880x. The Digital Force sensor generates an interrupt when the force applied to the sensor reaches the programmed force threshold. The host processor can change the threshold by writing to the sensor registers using the I2C interface.

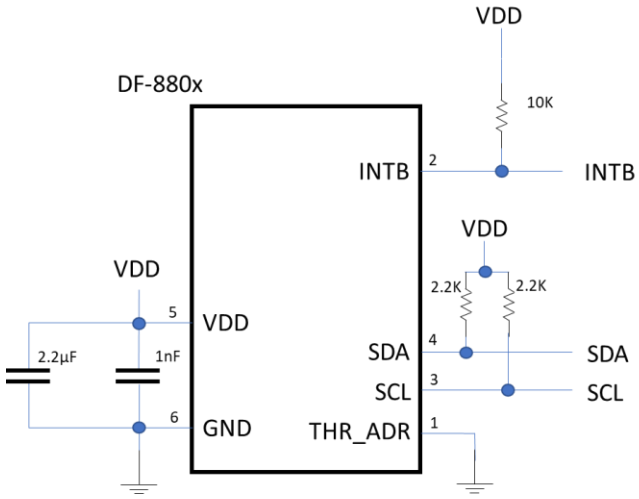


Figure 2: Typical Circuit for Button Application

8.2 POWER-UP SEQUENCE

The DF-880x series of digital sensors will be fully operational in < 10 ms after power is initially applied to the chip. After power-up, it enters active mode by default, see Figure 3.

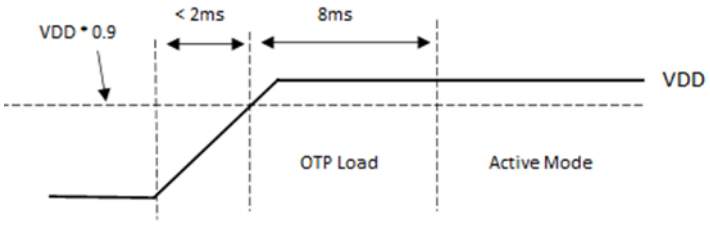


Figure 3: Power-up Ramp and Full Operation

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 range is between 3.3 kΩ to 50 kΩ. The four addresses and the associated THR_ADR connection is shown in Table 3.

THR_ADR CONNECTION	Sensor I²C ADDRESS
THR_ADR = 3.3 kΩ - 50 kΩ Resistor to GND	0x4C
THR_ADR = 3.3 kΩ - 50 kΩ Resistor to VDD	0x4D
THR_ADR = GND	0x4E
THR_ADR = VDD	0x4F

Table 3: I²C Address Selection using THR_ADR

The DF-880x I²C addresses are 7-bit. Note that support for 10-bit I²C slave addressing and General-Call (broadcast) addressing are not supported.

The supply voltage to the sensor 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 path are optional to protect the sensor input architecture from high-voltage spikes on the bus lines, minimize crosstalk, and undershoot events of the bus signals.

9. SOLUTION STACK-UP

The device is soldered onto a PCB, which is then bonded to the back of the surface where the force is to be detected. The DF-880x series force sensor can detect forces as light as a few grams. Figure 4 shows the stack-up for a single button application utilizing one sensor mounted to a PCB.

A 0.4mm thick FR4 PCB is recommended. For other PCB options and recommended adhesives, please contact Qorvo.

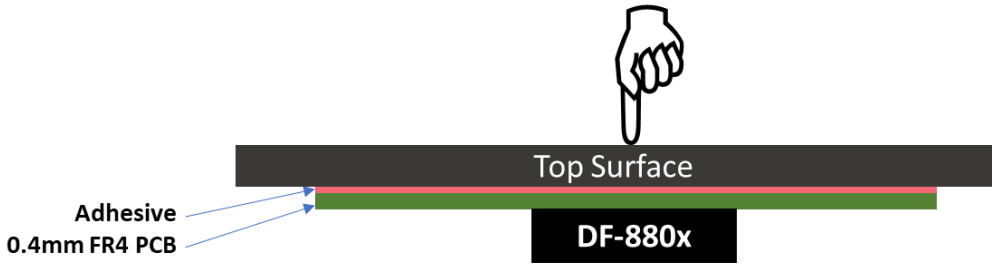


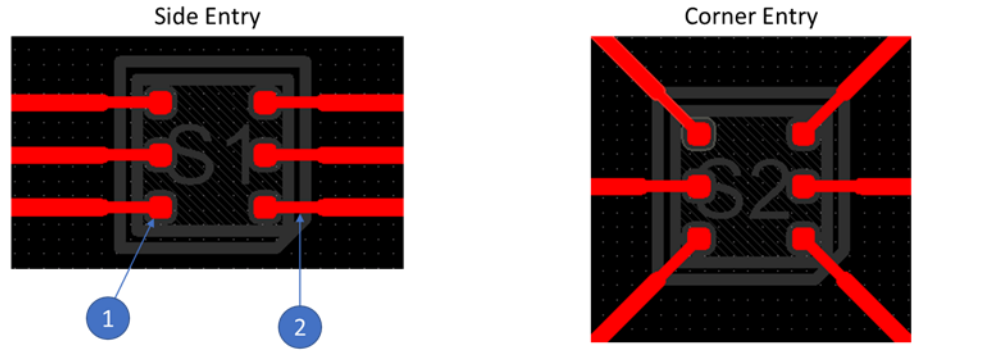
Figure 4: Stack-Up

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

10.1 ELECTRICAL DESIGN AND BOARD LAYOUT CONSIDERATIONS

- Two bypass capacitors required, 2.2uF & 1nF, to reduce noise on the power supply. Ensure that both of these capacitors are placed close to the DF-880x – ***REQUIRED***.
- Symmetrical routing improves sensor self-alignment (Figure 5-a) during assembly – ***REQUIRED***.
- Place the nearest components at least 0.3 mm (RECOMMENDED) away from the DF-880x series sensor.
- Do not use vias directly under the DF-880x solder balls. (Figure 5-b)
- Keep signal lines short (**REQUIRED**) 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
- Do not use glue/epoxy under or around the sensor – ***REQUIRED***.
- The sensor edge should be at least 0.25 mm from all edges of the PCB – ***RECOMMENDED***.
- If using a flexible PCB, a top hatched ground plane is required.
- Under-fill is not recommended. For harsh environments like salt spray please contact Qorvo for recommendations for materials for under-fill and glob top.
- For additional stability consider implementing “teardrop” routing into vias, pin pads and T-junctions; this increases the copper area and avoids steep angles in areas where multiple traces meet in a common point.
- It is recommended to run the sensor from an on-board analog power supply (e.g. low-noise LDO) for lowest noise.

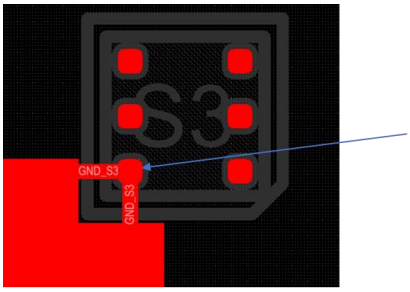
- Make the traces to all the pins the same width. Qorvo recommends greater than (or equal) 6 mils traces for all signals except the traces directly connected to bumps of DF-8800. These should be 4 mils traces for better reflow result.



1 → Pad Size: 0.2mm square pad with rounder corner.
Solder Mask: 0.05mm wider on all four sides of pad.
Copper defined, not solder mask defined pad.

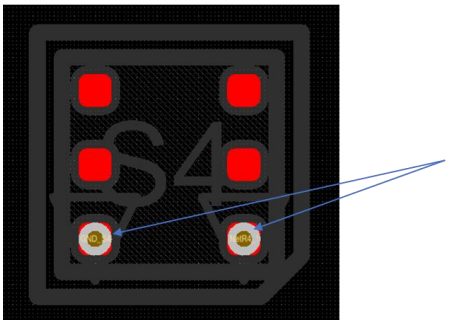
2 → Use 0.1mm trace-width (1/2 of pad size) at pad entry for minimum of 0.25mm length.
After 0.25mm: can increase trace width to 0.15mm.

Figure 5-a: Recommended Design/Layout Practice



Do not use multiple traces on same pads.
Do not use copper pouring or plane direct on device pad.

This will make routing non-symmetrical with other pads.



Do not use Via in pad or micro via (Blind via) direct on land area.

Figure 5-b: Avoid in Layout/Routing

10.2 FOOTPRINT AND SMT DETAILS

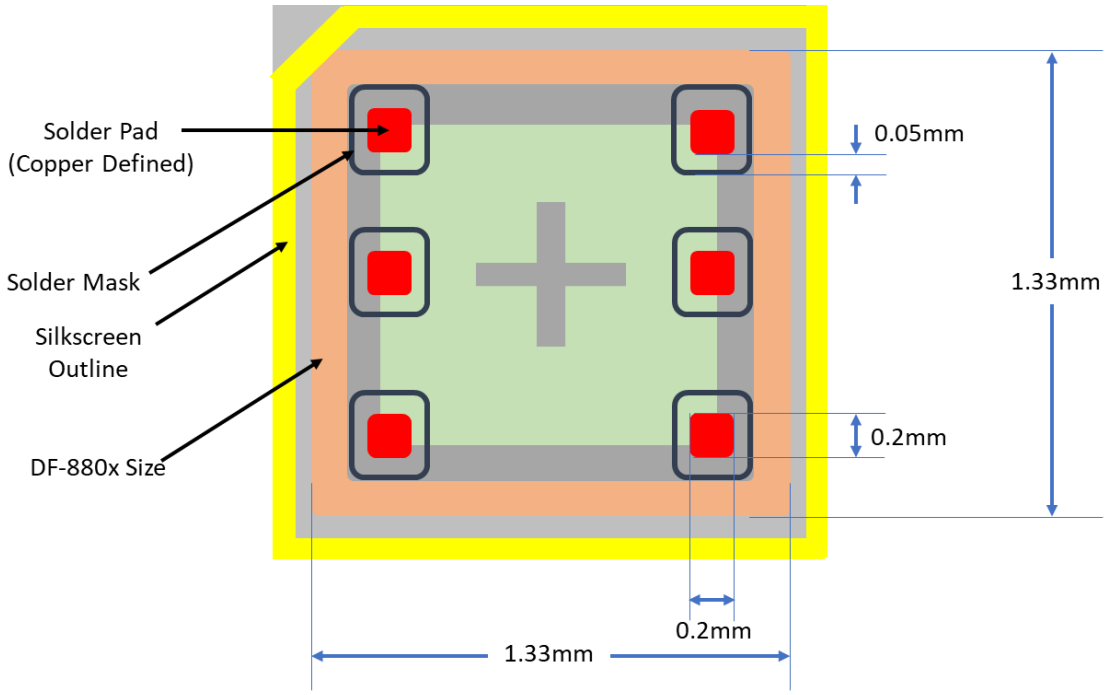


Figure 6: Must-Have Footprint

Figure 6 depicts the ***must-have*** footprint drawing for the DF-880x series and the details below must be followed for the SMT of the sensor 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: **Alpha OM 550 HRL1 (to reduce solution offset and TCO), SAC305 or SAC405**

10.3 SMT PICK & PLACE GUIDELINES

10.3.1 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

Figure 7: 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.

10.3.2 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 an "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.

10.4 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 sensors in ESD sensitive containers (e.g. T&R, moisture-sealed)
    - Handle devices only in ESD-safe work areas
    - Persons /machines handling the sensor must be grounded to avoid potential ESD damage

10.5 ASSEMBLY INSTRUCTIONS

The DF-880x 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 8). Reflow assembly houses should follow this profile closely but can choose more conservative ramp-up/down rates. To avoid damage to the force sensor 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.

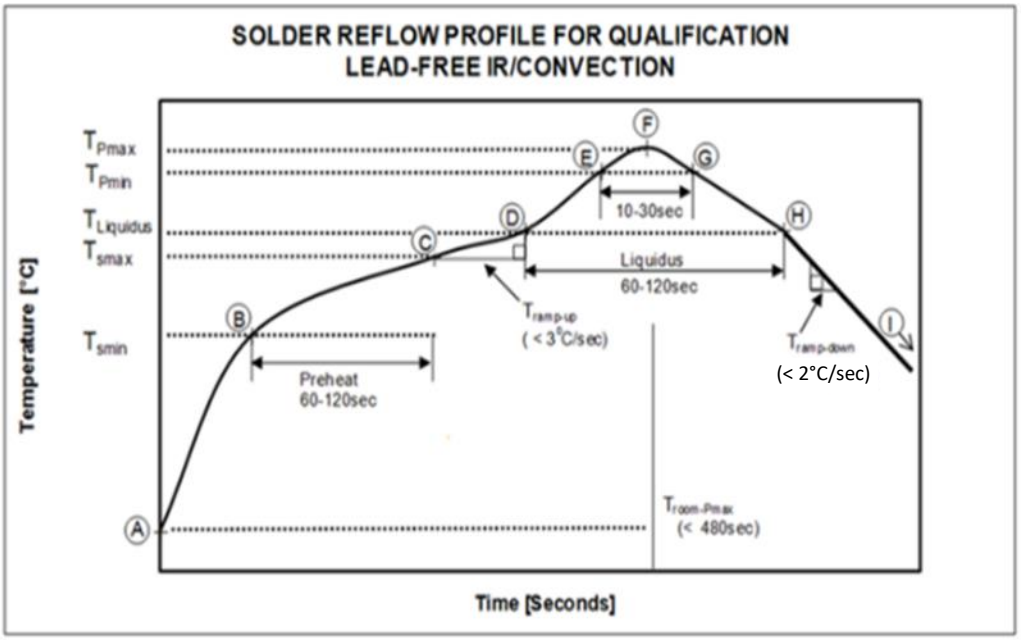


Figure 8: Pb-Free Soldering Profile for Reflow Assembly

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

10.6 PACKAGING INFORMATION LASER MARK

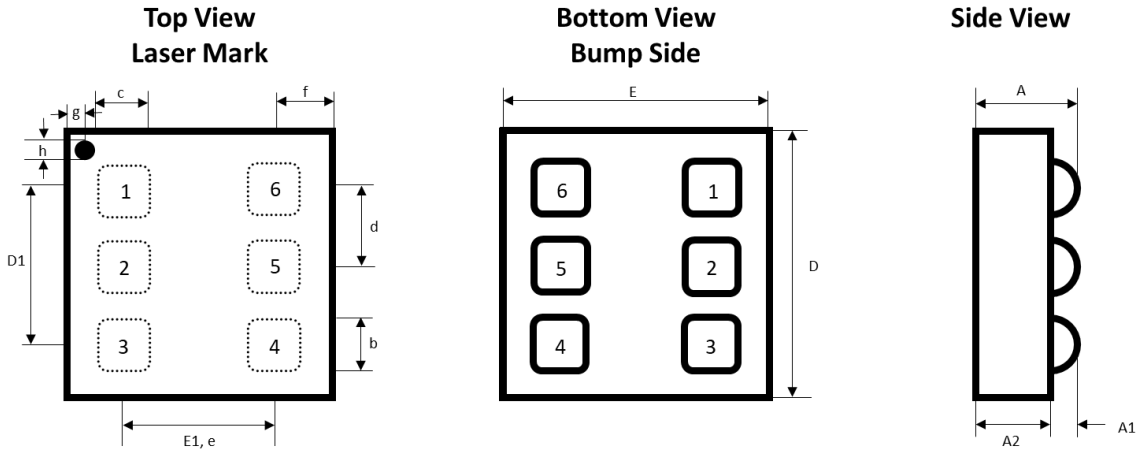


Figure 9: Package Dimensions

Info for 1.33 mm x 1.33 mm x 0.22 mm CSP				
Symbol	**Min.**	**Nom.**	**Max.**	**Notes**
A	0.190	0.220	0.250	Overall height
A1	0.055	0.075	0.095	Solder ball height
A2	0.135	0.150	0.165	Body thickness
D	1.280	1.330	1.380	Body size
D1	0.890	0.900	0.910	Solder ball footprint, Y
E	1.280	1.330	1.380	Body size
E1	0.890	0.900	0.910	Solder ball footprint, X
6				Number of solder balls
b	0.195	0.210	0.225	Solder ball diameter; measured at the maximum solder ball diameter, Y
c	0.195	0.210	0.225	Solder ball diameter; measured at the maximum solder ball diameter, X
d	0.440	0.450	0.460	Solder ball pitch, Y
e	0.890	0.900	0.910	Solder ball pitch, X
f	0.190	0.215	0.240	Package edge to solder ball center
g	0.100	0.150	0.200	Pin 1 ID to package edge
h	0.050	0.100	0.150	Pin 1 ID diameter

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

For Must have footprint see Figure 6.

Table 5: Package Dimensions

10.7 SENSOR TOP MARK CODING

The top mark coding consists of 3 rows of letters and numbers printed on the top of the CSP package (Figure 10).

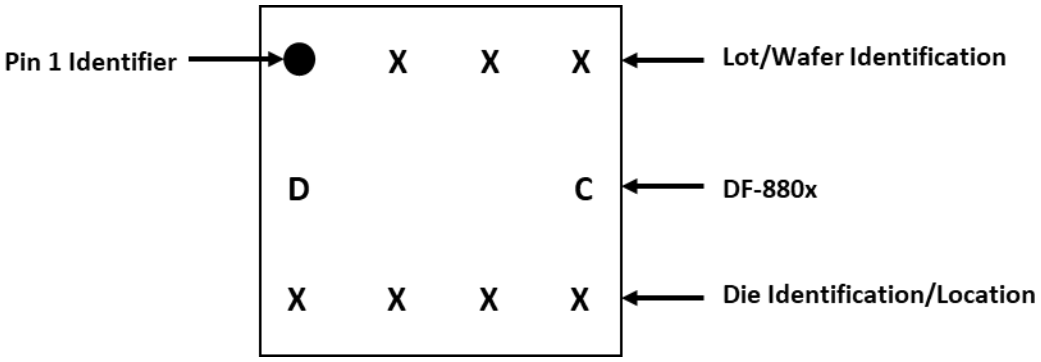


Figure 10: Top Mark

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

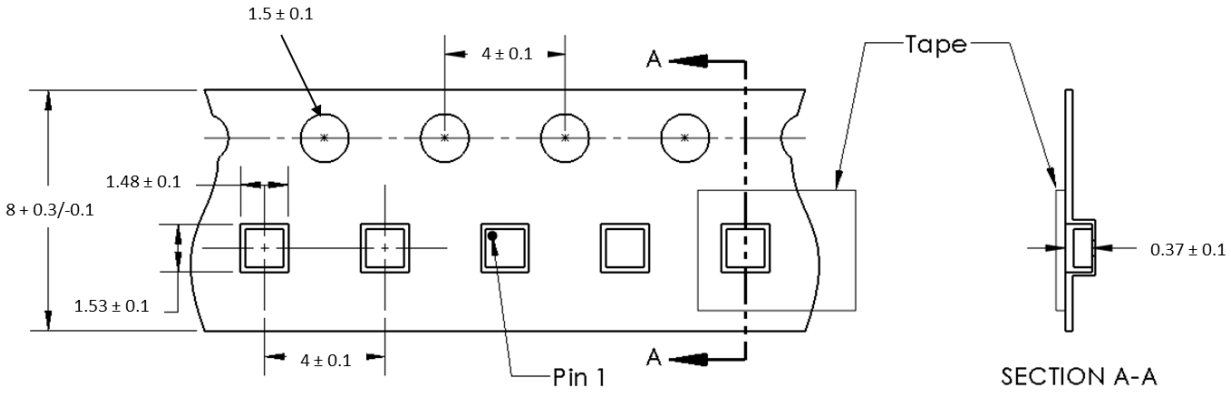


Figure 11: Tape-and-Reel Dimensions

Note that all dimensions and tolerances in this tape-and-reel diagram (Figure 11) are in mm.

Figure 12 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 12: Example of Packaged Reel

11. RELIABILITY & ENVIRONMENTALINFORMATION

The Qorvo DF-880x meets Level 1 (unlimited) Moisture Sensitivity Level (MSL) specifications.
Reliability and Environmental reports are furnished upon request.

12. REVISION HISTORY

REVISION NUMBER	REVISION DATE	DESCRIPTION/CHANGES	PAGES CHANGED
A	06/07/2021	New Release	N/A
B	05/31/2022	Updated THR_ADR resistor range, added SMT pick & place guidelines	6, 10, 11
C	11/16/2022	Added orderable p/n's for design kit Updated power-up, PCB layout, Sensor module pictures.	4, 6, 7, 8
D	04/17/2023	Sensor module image replaced. Traces' width info. updated.	8
E	05/05/2023	Sensor location's recommendation typo fixed. (sensor center → sensor edge) Solder Mask Tolerance Typo. Fixed (0.5mm → 0.05mm)	7, 8