WHITE PAPER

- Enhancement of the solder-crack resistance of quartz devices -

1. Background

Quartz devices are used in various onboard electronic appliances such as car audio equipment, car navigation systems, engine controls, tire pressure monitoring systems (TPMS), power windows etc. As environmental tests for these onboard electronic appliances, repeated tests between high and low temperature (thermal cycle tests) are conducted. In particular, quartz devices used in a hostile and life-affecting environment such as engine controls and TPMS are subjected to the requirements for extremely severe thermal cycle resistance. Quartz devices are mounted on a printed circuit board with solder. However, the repetition of thermal cycles results in the problem of cracks in the solder that bonds the quartz device and the printed circuit board.

In this paper, the mechanism of the occurrence of solder cracks and countermeasures against them are explained. At the same time, Daishinku Corporation's quartz device, which has solved this problem in the industry as the first manufacturer of SMD-type ceramic package products, will be presented.

2. Mechanism of the occurrence of solder cracks

The coefficient of thermal expansion differs between the ceramic package forming a quartz device (hereinafter referred to as a "package") and the printed circuit board. As the thermal cycles repeat, this difference in the coefficient of thermal expansion causes the load to act on the soldered portion, with a crack occurring there. It is considered that a crack that has occurred in the outer regions of the soldered portion at low temperature extends into the soldered portion as the thermal cycle repeats. (Fig. 1)

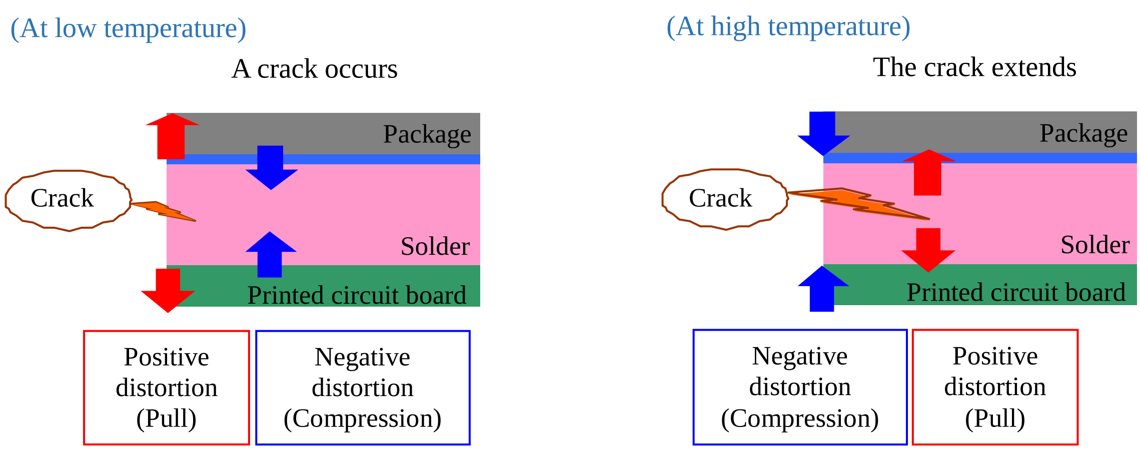
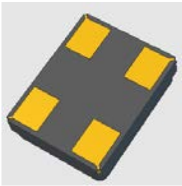


Fig. 1: Occurrence of a crack

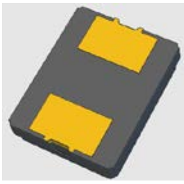
3. Countermeasures against solder cracks based on the terminal configuration

The configuration of terminals formed on a quartz device that provides the optimum condition is verified by simulation. To verify the method of allowing the stress to escape and the effect on the area occupied by terminals, simulations were conducted on the three patterns below.

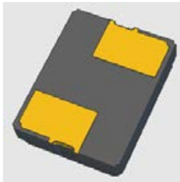
1) Ordinary product (product with four terminals)



2) Product with two terminals on each of opposite sides



3) Product with two diagonally opposite terminals



<Results of simulations>

1) Ordinary product (Product with four terminals)

2) Product with two terminals on each of opposite sides

3) Product with two diagonally opposite terminals

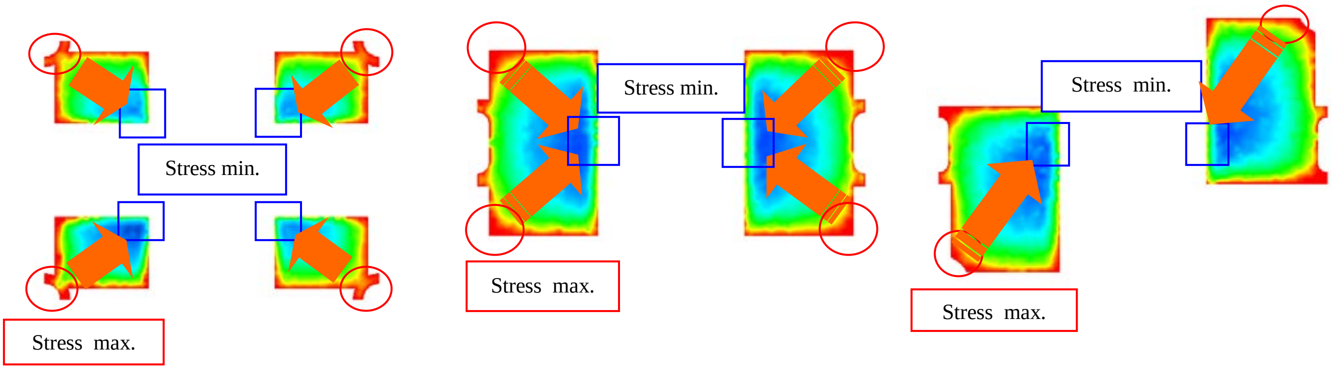


Fig. 2: Stress and the direction in which a crack extends

It has been clarified that a crack develops and extends from the location at which the stress is maximal (the part in red) to the location at which the stress is minimal (the part in blue). (Fig. 2) The results obtained with the different patterns are as follows:

Ordinary product (product with four terminals) - For all four terminals, a crack extends from the package corner toward the center.

Product with two terminals on each of opposite sides - A crack extends from the package corner toward the center. Compared with the product with four terminals, the distance over which a crack can extend is physically lengthened, and as a result, the life up to the electric fracture caused by a crack (hereinafter referred to as the “solder-based life”) becomes longer.

Product with two diagonally opposite terminals - Setting two terminals in a diagonally opposite configuration causes the location at which the stress is minimal to shift from the center of the long side of the terminal. This enables a crack to extend farther, with the solder-based life becoming even longer.

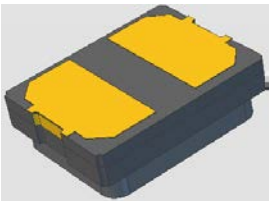
The results from these simulations have revealed that the solder-based life becomes the longest with a product with two diagonally opposite terminals. In other words, when the area occupied by terminals is the same, the configuration of two diagonally opposite terminals can be said to be the optimum condition for a countermeasure against a crack.

Solder-based life: Product with two diagonally opposite terminals >Product with two terminals on each of two sides >> Product with four terminals

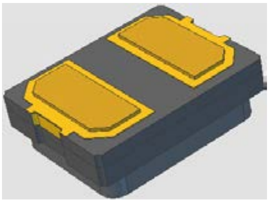
4. Countermeasures against solder cracks based on the formation of bumps

Next, the effectiveness of an improved product with two terminals on each opposite sides, in which bumps were formed on the terminals as a means of thickening the solder layer, was verified by simulation.

Product with two terminals on each of opposite sides (without bumps)

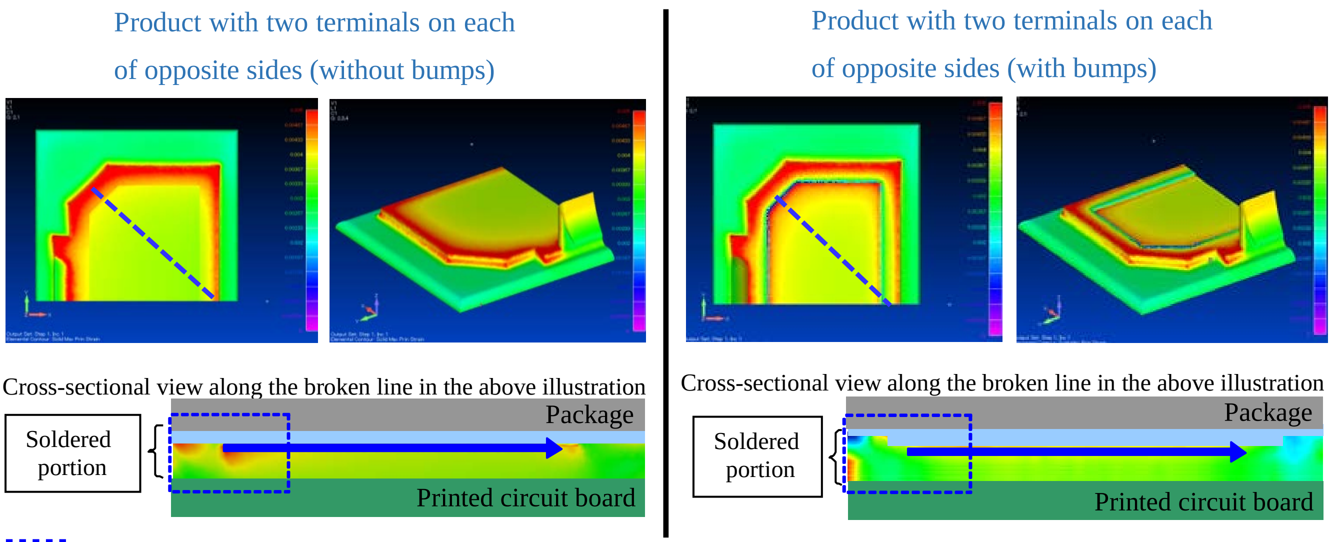


Product with two terminals on each of opposite sides (with bumps)



<Results of the simulation>

Shown below are the diagrams of distribution of the distortion acting on the soldered portion (the distortion expanding or contracting in the direction of the solder thickness). (Fig. 3)



: The contour diagrams for the outer regions of the soldered portion at high/low temperatures are shown below.

Note: A contour diagram is one with the zones between contour lines filled in with colors.

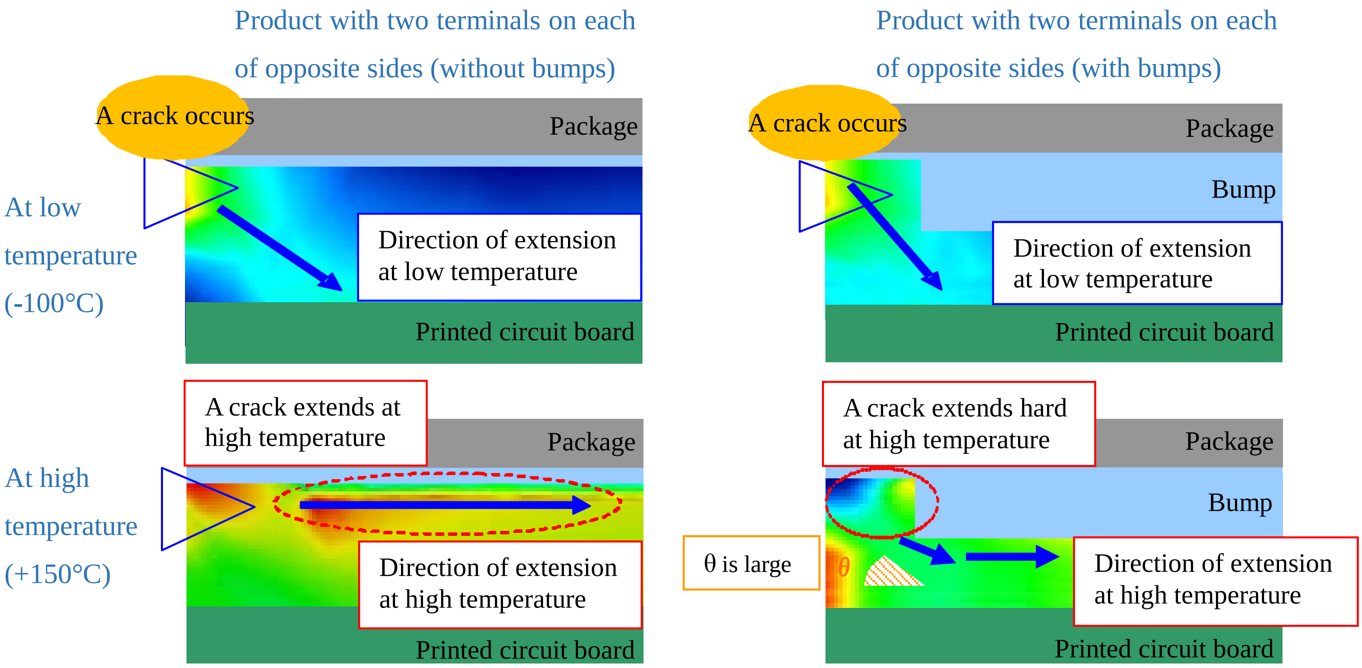


Fig. 3: Distribution of distortion in the outer region on the soldered portion at high temperature and at low temperature

1) Without bumps, the domain at which a crack occurs at low temperature is close to the one at which the distortion increases at high temperature; as a result, a crack extends easily.

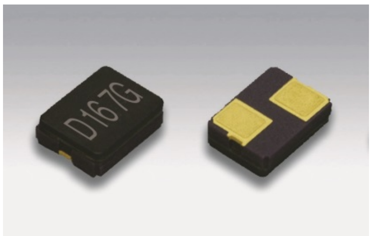
⇨ Forming bumps prevents a crack from extending in a straight line at high temperature, it is considered, and the extension after the occurrence of a crack is possibly restricted.

2) As considered from the result described in paragraph 1) above, the simulation has revealed that when the bumps are provided, a crack extends with an angle of θ with the direction of extension and, consequently, the crack extends hard toward the interior. It has been additionally clarified that the distortion in the outer regions at high temperature becomes negative (contracts) and that the formation of bumps at the terminal section is effective as a measure for lengthening the solder-based life.

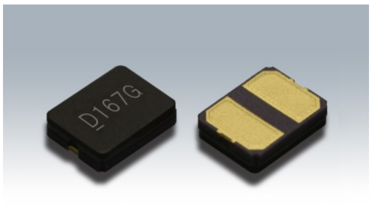
5. Summary

A solder crack occurs as a result of the distortion caused by the difference in the coefficient of thermal expansion between the package and the printed circuit board. The simulations described above have clarified, in terms of the effect of the terminal configuration, that the configuration of diagonally opposite terminals causes a crack to extend in a direction shifted from the central part of the long side with the solder-based life extending further. At the occurrence of a crack, the expansion of distortion causes a crack to expand and extend. With bumps formed, however, the distortion in the outer regions of the soldered portion becomes negative at high temperature, with the crack being prevented from extending. Furthermore, the presence of bumps causes a crack to extend in the direction of the bottom right. The mechanical fracture that matters with a solder crack is the failure to secure the electric connection due to peeling between the package and the printed circuit board. This is not affected by the possible extension of a crack in the direction of the bottom. The formation of bumps on the terminal enables these two effects to be obtained, which provides the product with high thermal cycle performance.

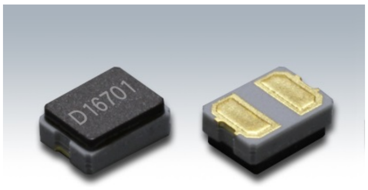
As described above, the configuration of two diagonally opposite terminals and the formation of bumps have allowed an effective countermeasure to be taken against the occurrence of a solder crack. Our company has developed products equipped with these countermeasures ahead of the industry, providing a wide selection of 3225- or 2016-size quartz crystals for onboard devices.



DSX320G



DSX320GE



DSX210GE

*Here’s a list of car-electronics-destined products including the models described above.

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