Development of EU2, a Surface-Mounted, Low-height Automotive Relay for Electrical Modules

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Abstract

Functions supporting automobile safety and comfort, such as powered windows, auto door locks and keyless entry systems contain various electrical modules. These modules are subjected to severe constraints regarding their overall sizes and their need to achieve thickness reductions from the viewpoint of diversification and high-density surface mounting of components on PC boards. For these reasons the aim to improve cost competitiveness is critical. Based on such a background, automotive relays for use in automotive electrical modules are also under increasing pressure regarding profile reduction and surface mounting issues.

In order to respond to these requirements, NEC TOKIN has developed a small-sized surface-mounted relay with the lowest profile among automotive twin relays worldwide that features a similar performance to the competing devices.

Keywords

automotive relay, surface mounted, low profile, size reduction
lead-free solder, ECU

1. Introduction

Automotive modules that use electric motors or polarized solenoid loads, such as the powered window and door lock, need to control forward/reverse motor operations by using two electromagnetic relays in an H-bridge circuit. In 1988 NEC TOKIN, developed and put into practical use the EN2 twin relay for use on PC boards. This device incorporates two pairs of magnetic make/break contacts in a single unit. Since that time, we have also developed the EP2, ET2 and subsequently the E2 relays and have made them available to the automobile industry.

Recently, automobiles are utilizing an increased number of ECUs (Electronic Control Units) in order to implement basic, environmental, comfort and safety performances. High-class vehicles may nowadays use as many as about 70 to 80 ECUs. This trend is making it difficult to secure suitable installation locations and to mount them in an optimum layout. Automobile manufacturers are dealing with this problem by reducing ECU sizes and are integrating them by assembling them according to their various functions. Under such constraints, a major automobile manufacturer has set a target maximum height for components to be mounted on the ECUs (mainly connectors, capacitors and relays). In addition, manufacturers also require surface-mounted components to feature lead-free solder compatibility from the viewpoint of high-density component packaging of the ECUs, minimization of manufacturing cost in ECU assembly and environmental performance.

To meet these requirements, we have developed and implemented the EU2 automotive twin relay for surface-mounting (**Photo 1** , Left). The device features the world's lowest height of the class at ≦8 mm, a volume of 1.87 cc and resistance to as high as 250°C thermal stress during surface-mount soldering, while at the same time maintaining the compact/space-saving features of the previous EX2. This paper is intended to introduce an outline of the design and features of the new EU2 twin relay.

Photo 1 The surface-mounted EU2 (Left) and the previous EX2 (Right).

2. Objectives of the EU2 Relay Development

In the development of the EU2 to meet market requirements, we set the objectives as listed below.

(1) Implementation of a minimum size among automotive twin relays.
- Relay height: Max. 8 mm (world's lowest height)
- Relay volume: Below 2.00 cc (excluding terminals)

(2) Maintenance of high performance and quality
- Equivalent performance to the EX2
- Minimized foreign matter production sources

(3) Implementation of resistance against the thermal stress of surface-mount soldering
- Minimized characteristic fluctuations (rate of change below 10%)
- Minimized external form change (top cover projection, below 0.2 mm)

(4) Securing reliability of solder connections
- No solder cracks after 1,000 heat shock cycles

3. Design Outline

3.1 Considerations for the Implementation of a Minimum Size among Automotive Twin Relays

Fig. 1 shows the configuration of the EU2 and **Fig. 2** shows its internal wiring. The EU2 consists of two subassemblies, each of which is formed by fitting the tongues extended from the yokes of a magnet block equipped with an armature and mobile-contact spring into the ST block. Also included are insert moldings of groups of stationary-contact terminals, the cover, and the base. The spool used as a component of the magnet block has terminals that are insert-molded on to it. The two assemblies are placed in the specified positions on the cover and the base is then fitted and sealed with epoxy resin. The terminals are coated with lead-free solder, bent in a gull-wing form and processed into a shape suitable for surface mounting. The application of insert molding to all of the components that have previously been finished by driving-in the terminal pins has enabled size reduction because of the elimination of the locking structure associated with driving-in the terminals and the space required for inserting jigs and tools. We were able to achieve the target relay height of below 8 mm and the target relay volume of below 2.00 cc (excluding terminals) due to the additionally adopted size reduction

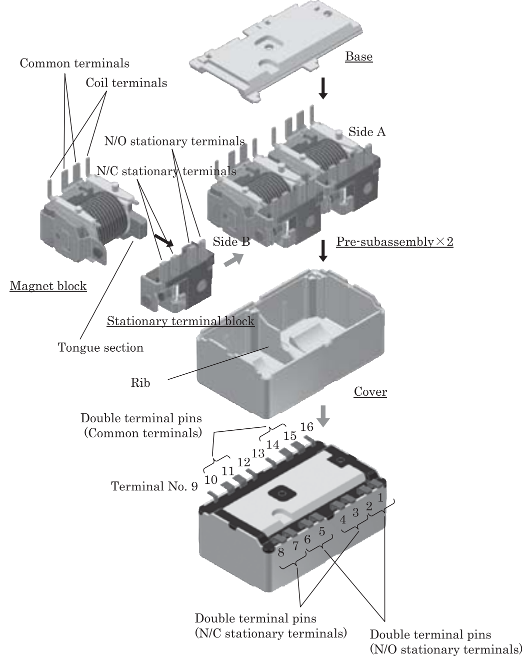

Fig. 1 Configuration of the surface-mount EU2.

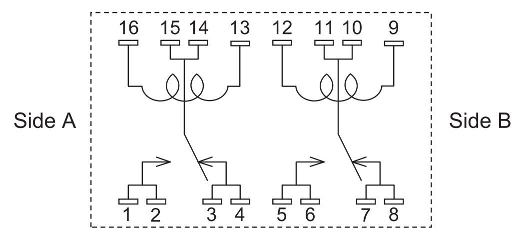

Fig. 2 Internal wiring of surface-mount EU2 (Top view).

measures. These include the adoption of the LCP (Liquid Crystal Polymer) material featuring excellent moldability that enables the small thickness of about 0.2 mm and the optimization of clearances between components.

3.2 Considerations for Maintenance of High Performance and Quality

In order to maintain an equivalently high performance to the previous EX2, it is essential to minimize any drop in the attractive force or spring load force that might accompany a size reduction. Regarding the issue of the attractive force, we have adopted an LCP material with excellent moldability in order to make it thin and have attached the coil terminals by insert molding. As this procedure has made it possible to reserve the coil winding space, we have obtained coil constants and magnetic attractive forces equivalent to those of the EX2. The spool used with the EU2 is shown in **Fig. 3** (Left). We were thereby able to maintain the required spring load force. We optimized the shape of the mobile-contact spring by applying infinite element analysis as shown in Fig. 3(Right). As a result, we succeeded in obtaining an equivalent performance to the EX2 as shown in **Table 1** .

To enable the continuation of our customary high quality performance, we eliminated our previous process of driving in the plastic components of the eight terminals, including the coil terminals, N/C stationary terminals and N/O stationary terminals and applied insert molding to all terminals. This procedure reduced the risk of foreign matter contamination when driving-in the terminals.

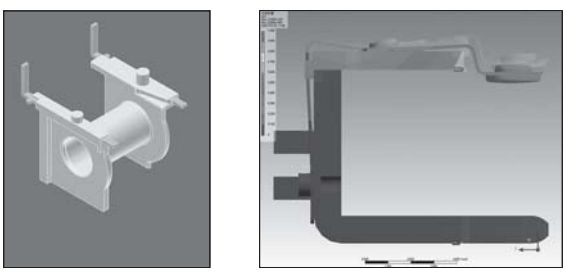

Fig. 3 Spool (Left) and example of finite element analysis (Right).

Table 1 Specifications of EU2 (In comparison with EX2).

Item	Specifications	
	EU2	EX2 (Comparison)
Dimensions	14(W) × 21(L) × 8(H)	12.1(W) × 13.6(L) × 13.7(H)
Volume (excl. terminals)	1.87cc	2.25cc
Weight	5.3 g typ.	6.4 g typ.
Contact form	1 Form C × 2	
Contact resistance	4 mΩ typ.	
Rated power consumption	0.96W	0.9W
Rated voltage	12 V DC	
Must operate voltage	≤6.5 V DC	
Must release voltage	≥0.6 V DC	≥0.9 V DC
Operate time	≤10 ms (excluding bounce)	
Release time, with diode	≤10 ms (excluding bounce)	
Insulation resistance	≥100 MΩ	
Withstanding voltage	≥500 V AC (per min.)	
Ambient temperature	-40 to +85°C	

3.3 Considerations for Implementation of Resistance against Thermal Stress of Surface–mount Soldering

The representative soldering method for surface mounting is the IRS (Infrared-rays Reflow Soldering). **Fig. 4** shows an example of soldering for surface mounting of this product that is compatible with lead-free solder. The temperatures mentioned in the figure represent those around the relay terminals on the PC board.

A surface-mounted relay is exposed to higher temperatures than the traditional inserted relays. In addition, the thermal capacity of the relay terminals should be large because the relay is required to have a high current-carrying performance. Thus, the temperature conditions of the relay terminals are higher and more severely constrained than hitherto because the lead-free solder previously used had a high melting point.

The major effects resulting from the exposure to severe temperature conditions include; 1) changes in the operating characteristics (voltage and time values) due to the change in the touch force of contacts caused by deformation of the plastic members, and; 2) deformation of the top cover due to an increase in the internal pressure of the relay.

To solve the above issues, we first selected a plastic material that matches the functions of the members. Namely, we adopted LCP (Liquid Crystal Polymer) with excellent continuous operation and thermal deformation temperature characteristics for all plastic members. We also reduced the changes in characteristics from before to after surface-mount soldering to within 10% as shown in **Fig. 5** . Furthermore, in order to reduce deformation due to high temperatures during surface

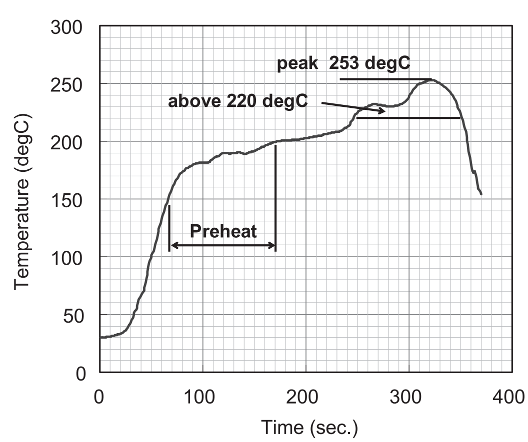

Fig. 4 Example of surface-mount soldering condition.

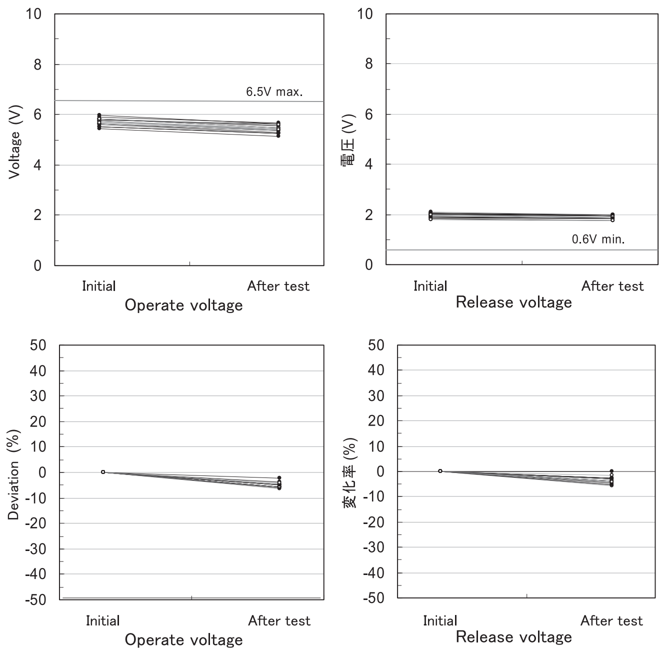

Fig. 5 Voltage characteristics before and after surface-mounting.

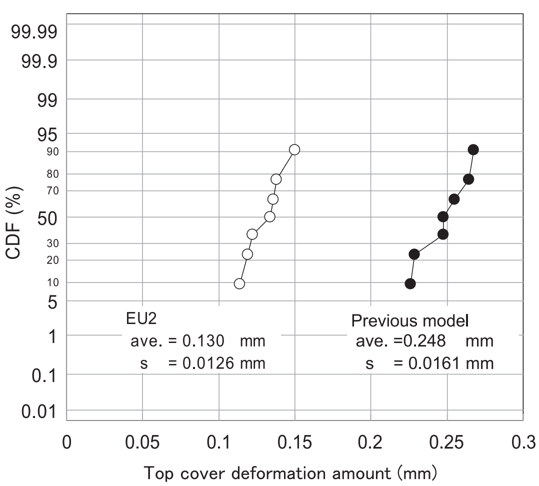

Fig. 6 Amount of top cover deformation after surface-mounting.

mounting, we adopted the material with the highest deflection temperature under load among the available LCPs and installed a rib on the top cover. As a result, the deformation of the cover has been reduced to within 0.2 mm as shown in **Fig. 6** .

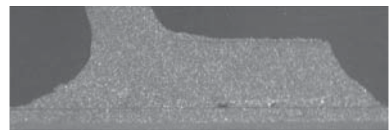

Photo 2 Example of solder joint cross-section after 1,000 cycles of heat shock testing.

3.4 Considerations for Securing Reliability of the Soldered Connection

Since many automotive relays are designed with large terminal cross-sections in order to achieve certain current-carrying performances there has been a fear that the long-term solder connection reliability would drop due to the rigidity of the terminals. To deal with this issue, we divided the terminals on the current-flow path of the EU2 relay, which are the N/C, N/O and common terminals, into double sized terminals as shown in Fig. 1. The double sized terminal design has made it possible to halve the rigidity of each terminal while maintaining the cross-section required for current carrying. The rigidity of the coil terminals are thus reduced to a sufficient level to prevent deformation during assembly; because the current flowing through them is less than 0.1 A.

To confirm the solder connection reliability of the EU2 that was designed as described above, we mounted it on a board, applied 1,000 cycles of heat shock testing under the conditions of 80°C/30 min. ⇔ -30°C/30 min,/cycle, and checked if any cracks or other irregularities were produced. The relay was mounted using lead-free solder. **Photo 2** shows an example of a cross-section of a terminal surface-mounted on a PC board after a thousand cycles. As shown here, we did not observe any production of cracks or other irregularities on the solder joint section of any terminal that experienced the 1,000-cycle testing.

4. Specifications of the EU2

Table 1 shows the main specifications of the EU2 in comparison with the EX2. As shown in the table, we have succeeded in developing and implementing a compact/low-height product with equivalent performance to that of the EX2. In particular, the height of the EU2 is no more than 8 mm and the volume (excluding terminals) of 1.87 cc is nearly 20% smaller than the 2.25 cc volume of the EX2.

Table 2 Results of EU2 reliability evaluation.

Item	Test Conditions	Result
Electrical life I	20°C, 14 V DC – 25 A, motor load (lock), ≥100,000 cycles	OK
Electrical life II	20°C, 14 V DC – 25 A/5 A, motor load (unlock), ≥100,000 cycles	OK
Mechanical life	20°C, 14 V DC, no load, ≥1,000,000 cycles	OK
High-temperature	85°C,192 hrs.	OK
Low-temperature	-40°C, 192 hrs.	OK
Heat shock	125°C/30 min. ⇔ -40°C/30 min, 1,000 cycles	OK
High temperature and high humidity	85°C, 85%RH, 192 hrs	OK
High temperature and high humidity cycling	MIL-STD-202F-106E, 10 cycles	OK
Vibration resistance (Misoperation)	10 to 300 Hz, 43.1 m/s^2	OK
Vibration resistance (Destructive failure)	10 to 500 Hz, 43.1 m/s^2, 192 hrs.	OK
Shock resistance (Misoperation)	98 m/s^2, 6 directions	OK
Shock resistance (Destructive failure)	980 m/s^2, 3 cycles, 6 directions	OK

5. Reliability Check

We also tested the EU2 with regard to the various reliability factors required for use in automotive electrical modules. As a result, we can confirm that the EU2 has sufficient reliability for use in automotive electrical modules as shown in **Table 2** .

6. Conclusion

As described above, we have developed and implemented the EU2, a surface-mount automotive twin relay with the world’s smallest size/lowest height of its class.

In the future we intend to advance the development of new products in a timely manner in order to meet the needs of the automotive electric module market.

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