Flexible Flat Cable for High-speed Data Transmission

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Flexible flat cable is widely used for internal wiring in the electronic devices due to the advantage of its flat shape for high-density wiring compared with the wire harness. Increasing of electronic equipment processing large volume of signals at high speed accelerates the demand for a flat cable that transmits signals in high speed with low loss. Sumitomo Electric Industries, Ltd. has already developed and manufactured flat cables suitable for high-speed data transmission that conforms to the LVDS technology. To meet the market needs for higher transmission performance, the company has succeeded in producing a new flat cable. This cable consists of polyolefin based low dielectric loss adhesive and shows excellent transmission property.

Keywords: flexible flat cable, high-speed data transmission, adhesive, low dielectric loss insulation

1. Introduction

Flexible flat cables are high-density wiring materials widely used in electronic devices for electrical connection between printed circuit boards. Sumitomo Electric Industries, Ltd. has commercialized various types of flat cables for electronics and car electronics applications. The company has also developed and manufactured flat cables for LVDS*1 to meet customer needs for high-speed signal transmission applications.

With the rapid progress of technological development for flat panel displays, game consoles and other electronic equipment that support high-definition video images and moving image data, the needs for higher-speed, lower-loss signal transmission flexible flat cables are increasing.

This paper describes and discusses two types of new flexible flat cables that have been developed to meet the needs for higher transmission performance.

2. Flexible Flat Cables for High-Speed Data Transmission

2-1 Construction of flexible flat cables

As shown in **Fig. 1**, the flexible flat cables consist of rectangular conductors arranged in parallel and insulations laminated on both sides of conductors (insulation: base film with adhesive). With an overall thickness of 100 to 300 μm, these flexible flat cables ensure more space-saving, higher-density wiring than conventional wire harnesses*2.

The need for higher-speed data transmission is increasing as described above. To transmit data at a high rate of more than 100 Mbps, it is indispensable to control the characteristic impedance*3 for the flat cable consistent matching with the impedances of the circuit boards and connectors. Moreover a shield layer is also required to reduce the effects of external noises. The company has already commercialized a high-speed data transmission flat cable (Type I) having the construction shown in **Fig. 2**.

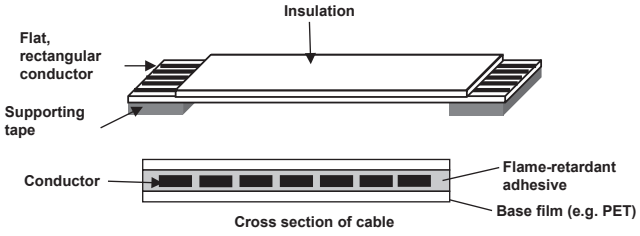


Fig. 1. Construction of flexible flat cable

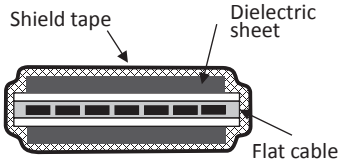
	Type I
UL AWM Style	20861 105˚C/60V
Flat cable adhesive	Polyester based (flame retardant)
Overall thickness of cable	0.74 mm
Characteristic impedance	90±10 Ω
Shield tape	Aluminum/PET laminated tape
Cross section construction of cable	

Fig. 2. Flexible flat cable for high-speed data transmission

The Type I flat cable consists of a flat cable using flame-retardant polyester based adhesive and a shield tape wrapping around the cable. In addition, a dielectric sheet is interposed between the flat cable and shield

tape to adjust the characteristic impedance.

This cable conforms to the LVDS technology, the most popular data transmission interface technology for flat panel displays.

For flat display interfaces, new data transmission technologies have been developed year after year to address the needs for higher-speed data transmission applications as shown in **Fig. 3**. To meet such needs, we determined to develop two types of new flat cables.

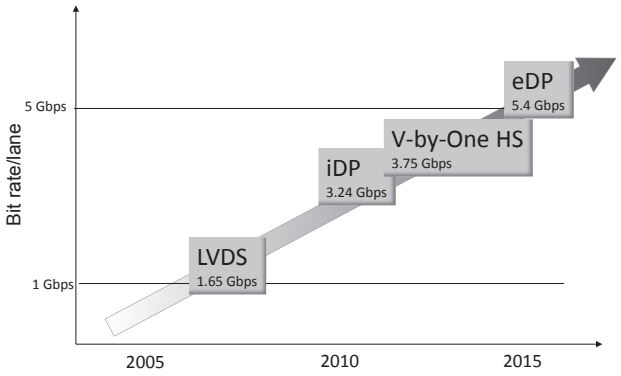


Fig. 3. Trend of high-speed interface technology development

The target performances of the newly developed flat cables are shown in **Table 1**. Besides characteristic impedance, insertion loss, and other transmission characteristics, we aimed to conform to the requirements for flame retardant and heat resistance specified in the UL standards*4.

Table 1. Target performances of new flexible flat cables

Item	Target performance
Characteristic impedance	100±10 Ω
Insertion loss	−25 dB/m (7.5 GHz)
Conductor adhesion force	10 N/cm min.
Flame retardance	Pass UL vertical flame test (VW-1)
Heat resistance	Pass UL80˚C rated heat resistance test

2-2 Development of low dielectric loss insulation

To enhance the transmission characteristics performance of a cable, both impedance matching and reduction of insertion transmission loss are indispensable. The insertion loss is the sum of conductor loss and dielectric loss. Since these losses increase in proportion to the square root of the dielectric constant of the insulation covering the conductor, the dielectric constant of the adhesive must be reduced.

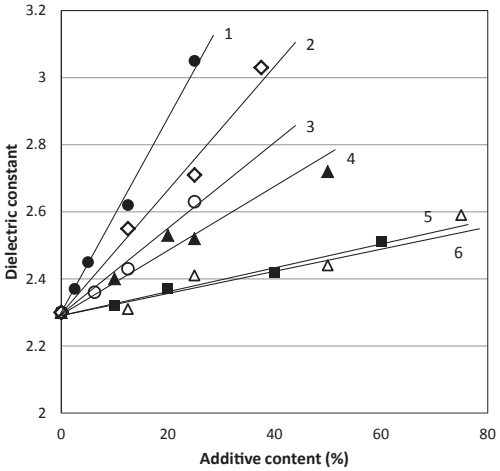
The flame-retardant polyester based adhesives are widely used for the insulation tape of general purpose flat cables. The reason is that the above polyester based adhesives have superior adhesion properties to both conductor and polyethylene terephthalate (PET) films, flexibility and lamination processability. However, the polyester based adhesives are unsuitable for high-speed data transmission applications since their dielectric constant is generally more than 3.

Table 2 shows the dielectric constants of typical adhesives. Among these, we chose the polyolefin based adhesive focusing on its dielectric properties and processability and promoted the development of a new adhesive formulation.

Table 2. Dielectric constants of typical adhesives

Adhesive	Dielectric constant 1 MHz
Polyester	3.1 - 4.0
Polyamide	3.0 - 3.4
Epoxy resin	3.3 - 4.0
Polyurethane	3.2 - 3.9
Polyolefin	
Polyethylene	2.3 - 2.4
Polypropylene	2.2 - 2.3

To satisfy the flame retardant specification of the new flat cable it is necessary to formulate flame retardant to the polyolefin based adhesive. A pigment and filler are also added to the adhesive as needed. However, addition of a flame retardant and pigment to the adhesive often increases its dielectric constant. **Fig. 4** shows



1. Titanium oxide, 2. Nitrogen-based flame retardant,
3. Antimony trioxide,
4. Metal hydroxide, 5. Phosphorus flame retardant,
6. Halogen flame retardant

Fig. 4. Amount of flame retardant vs. dielectric constant of adhesive

the results of investigation on the effects of various additives on the dielectric constant of a polyethylene based adhesive.

This figure shows that the dielectric constant of adhesive increases along with the amount of each additive. In particular, addition of a small quantity of titanium oxide (pigment) or antimony trioxide (flame retardant) increases significantly the dielectric constant of the adhesive. The effect of flame retardants on increasing the dielectric constant of the adhesive differs considerably depending on their chemical structures. A nitrogen-based flame retardant and metal hydroxide, both are typical halogen-free flame retardants, increase notably the dielectric constant of the adhesive. In contrast, a phosphorus based flame retardant and halogen based flame retardant moderately increase the dielectric constant of the adhesive.

Based on the above investigation results, we developed an adhesive with a low dielectric constant that conforms to the flame retardant and other specifications of the UL standards. In practice, we determined the most suitable types and amounts of flame retardant, pigment and filler to be added to the polyolefin based adhesive.

2-3 Design of new flat cables

(1) Flexible flat cable for high-speed data transmission (Type II)

The Type II cable (shown in **Fig. 5**) is produced by replacing the polyester based adhesive used in the Type I cable with a polyethylene based adhesive. Different from the Type I cable which is wrapped completely with a shield tape, the Type II cable has only one side shield tape. Thus the overall thickness of the cable is reduced, enhancing its flexibility, although its shielding characteristics are somewhat sacrificed.

(2) Flexible flat cable for high-speed data transmission (Type III)

Along with the down-sizing of electronic equipment, the internal temperature increases. Accordingly, the needs for higher heat-resistant cables are expected to be increased. To meet such future needs, we have developed a polyolefin based adhesive for a higher heat-resistant cable (Type III) (**Fig. 5**). This adhesive has a dielectric constant equivalent to that of a polyethylene based adhesive. In Type III, the characteristic impedance are adjusted by controlling the thickness of adhesive and eliminating the dielectric tape results in a simple construction.

Further, dielectric constant distribution of thickness direction is optimized by adopting multi-layered adhesive. Moreover, as with the Type II cable, the single side shielded construction affords higher flexibility to the cable.

2-4 Properties of newly developed cables

The characteristic impedances, the frequency characteristics of insertion loss and eye patterns of the newly developed flexible flat cables were measured. The results are shown in **Figs. 6, 7 and 8**, respectively.

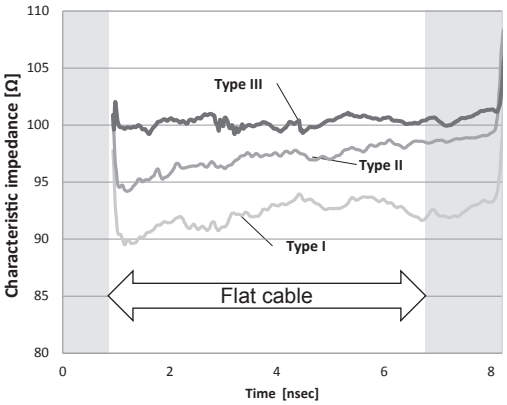


Fig. 6. Characteristic impedance

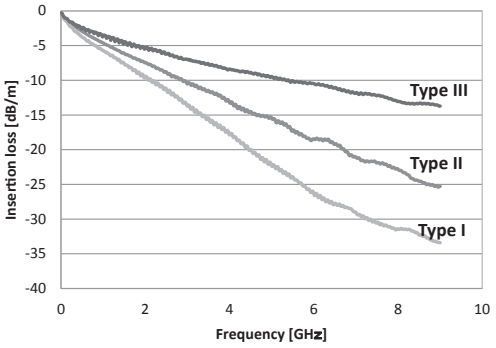


Fig. 7. Frequency characteristics of insertion loss

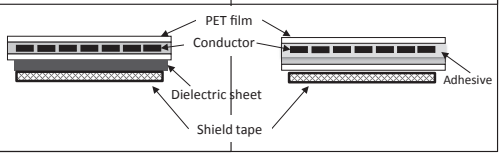
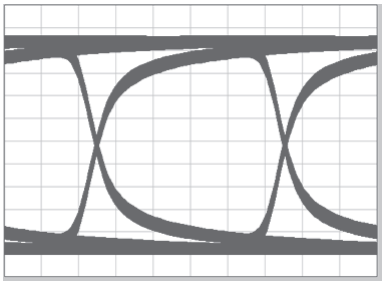
	Type II	Type III
Cable adhesive	Polyethylene besed flame-retardant adhesive	Special polyolefin based flame-retardant adhesive (multi-layered)
Cable thickness	0.35 mm	0.26 mm
Construction		

Fig. 5. Constructions of Type II and Type III cables



3.75 Gbps L=700 mm

Fig. 8. Eye pattern of Type III cable

These figures show that the characteristic impedances of both the Type II and Type III cables are within the specifications of 100±10 Ω and their insertion losses are improved significantly compared with the Type I cable. In particular, we confirmed that the Type III cable improved insertion loss remarkably in a higher frequency range.

The characteristics of the newly developed high-speed data transmission flexible flat cables are summarized in **Table 3**. Both the Type II and Type III cables have already obtained 80˚C rating UL approval. The Type III cable will also obtain 105˚C rating UL approval.

Table 3. Characteristics of high-speed data transmission flat cables

Item		Type II	Type III
Characteristic impedance		97±3 Ω	99±3 Ω
Insertion loss	7.5 GHz	-21 dB/m	-12 dB/m
Conductor adhesion strength	Annealed copper foil (thickness: 0.035 mm)	13 N/cm	17 N/cm
Flame retardance	Vertical flame test (UL1581VW-1)	Pass	Pass
Heat resistance	Flexible without delamination after exposed to 113˚C for 168 h	Pass	Pass

3. Conclusion

Sumitomo Electric has developed new types of flat cables for higher-speed data transmission applications. These cables ensure highly reliable data transmission with less loss than conventional cables, and have already been valued highly by users in the electronics industry. In the future, these new cables are expected to also be used for automotive electronic devices that are required to transmit data at higher speeds.

Technical Terms

∗1 LVDS: An abbreviation for low voltage differential signaling
∗2 Wire harness: A single cable consisting of a bundle of two or more wires
∗3 Characteristic impedance: The ratio of the voltage to the current of a magnetic wave propagating in a distributed constant circuit
∗4 UL standards: Standards established by Underwriters Laboratories Inc.

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