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ELECTRICAL CONNECTORS FOR SURFACE SOLDERLESS MOUNTING

The article describes the features of development, possibilities of manufacture and application of electrical connectors for surface mounting with flexible printed cables and elastomer liners. With regard to characteristics, manufacturability and, especially, mounting technological effectiveness, they can rival connectors with digital metal contacts.

Keywords: electrical connectors, solderless mounting, surface mounting, design of electronic equipment, contact joints, flexible printed cables, elastomeric liners.

No electrotechnical or radio engineering device can operate without connectors. There is a very large variety of designs of electrical connectors for the electronic devices, which meet almost any customers request. Very often the connectors ensure manufacturability issues of improving performance of manufacturing and installation of products.

The article focuses on such properties of connectors — the possibility of surface mounting with the implementation of solderless contact connections. Efficient designs oriented on batch fabrication of contacts and connectors assembly are introduced. Combining consumer needs and manufacturability suggests the prospect of use of such connectors for multi-contact electronic components.

Modern connectors can contain several hundred contacts, arranged with a relatively small interval of about 1 mm, and naturally, the simultaneous installation of such a large number of contacts into the holes and soldering of the contacts may cause some difficulties.

Importance of ensuring of manufacturability of connectors assembly caused the appearance of certain methods. The use of contact joints made by press-fit (press-in) technology [1—3] improves the performance only partially — there are no solder joints, but mounting into plated-through holes remains. Moreover, the size of contact connections makes the possibilities of their miniaturization very limited.

An original solution is the design of electrical connectors for surface solderless mounting proposed by the author earlier. The contact connection in such electrical connectors is ensured by mutual pressing of contact surfaces [3—5]. This design significantly improves manufacturability of the mounting and quality of the contact connection due to large contact area. In this case, the design of connectors simplifies owing to the use of the batch method of forming of contacts on a flexible printed cable (**FPC**). Pending this work the task was set to develop various types of electrical connectors designed for application in a variety of electronic devices with the use of FPC and elastomeric spring liners for solderless surface mounting, as well as to determine characteristics of such connectors experimentally. This article describes the results of these studies.

DESIGN OF ELECTRICAL CONNECTORS

The developed connectors are included to the group of low-frequency rectangular direct joint connectors, so in fact they consist of one part — a socket, while the terminal contacts of PCB of electronic modules or other similar structures serve as a plug.

The basis of the connector is made of contact groups manufactured according to the technology of flexible printed cables, and elastomeric liners, which function as group springs for contact elements.

Fig. 1 shows an electrical connector which is designed with the use of above-listed elements [6].

The plug is located in the rear part of the PCB *1* of electronic module and includes printed circuit contacts (lamellae) *2* and the slot *3*, which serves for the precise junction with the socket. The socket consists of a body *4* with a working cavity *7* and a bridge *6*, a cap *9*, made of plastic, an elastomeric liner *13* and an FPC *5* with printed contacts *8*. For fixing of the socket on the printed-circuit backboard there are latches *14* and fixing pin *10* with a hole *11* in its rear part for fixing the socket, for example, with a cotter pin. There also are pins *12*, which are used for accurate fixage of the sockets on the PCB.

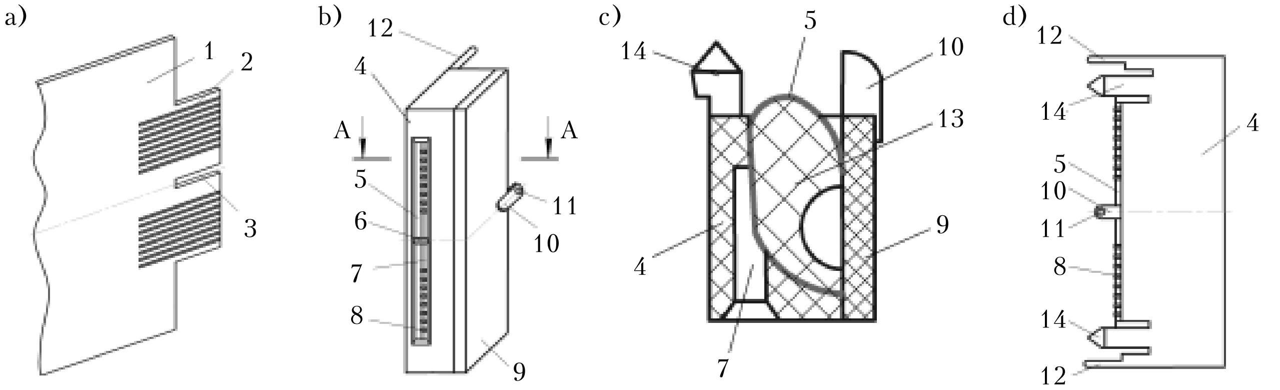

Fig. 1. Structural components of the electrical connector based on FPC and elastomeric liner (*a* — plug on the PCB; *b*, *c*, *d* — general view of the socket, its sectional view taken along A—A plane and its left-side view): *1* — PCB of the electronic module; *2* — printed contacts; *3* —guide groove; *4* — body; *5* — FPC; *6* — rail bridge; *7* — working cavity; *8* — printed contacts of socket; *9* — cap; *10* — fixing pin; *11* — fixing hole; *12* — drive pins; *13* — liner; *14* — catch

FPC is inserted into the socket body. FPC contacts project from the body in two planes: in one they contact with the PCB of the electronic module and in the other — with the printed-circuit backboard, as it is shown in **fig. 2**.

The junction is formed as follows. The plug of the PCB of the electronic module is inserted into the working cavity of the socket, and the rail bridge of the socket body enters the guide groove of the PCB, thereby providing an exact match of contacts. As the working cavity narrows, the distance between the FPC and the left wall of the body at a certain depth of the cavity becomes less than the thickness of PCB of electronic module, which ensures a reliable contact junction. At the same time the elastic liner acts as a group spring, creating a constant pressing force for contacts. Thus a gas-tight contact connection with a large effective contact area is formed.

The electrical connection between the socket FPC and the backboard with the use of the above-mentioned elastic liner is formed similarly in a different plane.

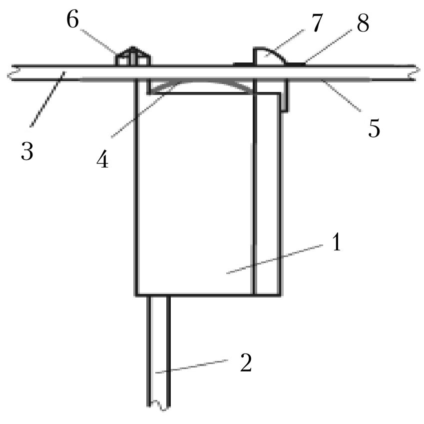

Fig. 2. Mechanical and electrical contact connection: *1* — socket; *2* — PCB of the electronic module; *3* — printed-circuit backboard; *4*, *5* — printed contacts on the socket's FPC and on the printed-circuit backboard respectively; *6* — catch; *7* — pin; 8 — cotter pin

TECHNOLOGY FEATURES OF ELECTRICAL CONNECTORS BASED ON FPC AND ELASTOMERIC LINERS

Parts of connectors are produced with the use of standard technologies, characteristic for manufacture of electronic equipment, namely, PCB manufacture, injection molding of thermoplastic plastic, molding of silicone rubber. In order to ensure low transitional contact resistance the appropriate metal coatings must be applied on the contact areas. It should be remembered that there are two places of contact in the socket (zones A and B in **fig. 3**): a plug connection with the PCB of electronic module and a virtually permanent connection with the backboard. The choice of coating is determined by the use conditions.

In this case it is possible to perform a very simple in terms of manufacturing local coating of FPC contacts. This enables rational use of precious metals.

A particular attention should be payed to the method of producing socket contacts. It is similar to the technology of producing single- or double-sided flexible PCB, which usually applies high-efficiency equipment. This allows to obtain any number of contacts by batch method for an entire connector simultaneously.

On the other hand, the manufacturing of the FPC is possible with the use of dimensional electrochemical processing, which allows to receive a double-composite structure, since there is no adhesive to glue the foil to the insulating film substrate [7]. Such FPC has unique operational performance, which are determined by characteristics of polyimide instead of adhesive, which is present in all known structures of FPC.

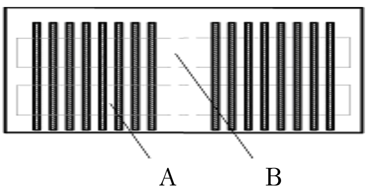

Fig. 3. Design of FPC with contact groups and local coating zones *A* and *B*

Assembly operations for sockets manufacturing are performed by simple methods without any fitting.

Mounting of sockets on the backboard runs without soldering — by clamping contact surfaces. Mechanical fastening under certain conditions can be carried out with the use of such an effective method as latching and locking with a cotter pin (see fig. 2).

EXPERIMENTAL INVESTIGATION OF CHARACTERISTICS OF THE CONNECTORS

The connectors were studied both as a whole, with respect to all the structure, and by the most important constituent elements which determine quality performance and manufacturability of the connectors.

Choice of material for elastomeric liner

Elastomeric liner being a part of the socket serves as a group spring, which provides the necessary pressure at the contact joints, thereby providing the required transient contact resistance. In this terms, a very important feature of the liner is the working temperature range in which the elasticity and hardness should be varied insignificantly. The residual deformation in this case should not considerably progress over time.

The analysis of characteristics for different materials has revealed that mixtures based on siloxane rubbers are the most appropriate for the liners. Such materials are good electrical insulators and ensure functionality of the liner in the temperature range from −60 to 250°C and at humidity up to 98%.

The analysis of the range of above-mentioned compounds has shown that ИРП-1265, ИРП-1338 siloxane mixtures and a composition consisting of ИРП-1265 and ИРП-1266 mixtures most fully meet the requirements.

To determine relative residual deformation of components made of these mixtures accelerated tests were carried out for two types of samples in the air in compressed state at 100, 150 and 200°C:

— standard samples (cylinders of 10 mm both in diameter and length);

— samples, the form and size of which match with socket liners.

On the basis of the test results the guarantee term for liners has been calculated, which made 17,5 years for the selected rubber compounds.

Test results for the samples of second type are shown in **fig. 4**.

Here, the relative residual deformation of compression was given by

$$C = \frac{h_0 - h}{h_0 - h_s} \cdot 100\%,$$

where h_0, h — thickness (width) of liners before and after testing, respectively;

h_s — thickness (width) of a device used for the test which provided compression of the liners.

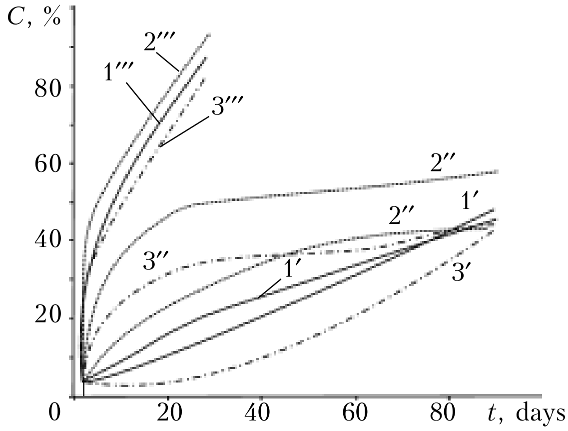

Fig. 4. Time dependence o f relative residual deformation of liners made of different compressed materials at different temperatures:
1 — ИРП-1265, *2* — ИРП-1338; *3* — silicon composition; «′» — 100°C; «″» — 150°C; «‴» — 200°C

Analysis of the obtained data considering the technological properties of all tested compounds showed that the best material for the liner is the silicone composition based on mixtures of ИРП-1265 and ИРП-1266.

Calculation of the contact resistance of connectors

An important quality index of the connectors is the transitional contact resistance. It is not only its nominal value that is important, but also its possible changes during the operational process and the tests. The most convenient way to control the transitional contact resistance is by means of measurement. It is impossible, however, to measure the transitional contact resistance R_p directly. This can be done as follows. Having used a part of the conacts for the measurements — let us call them the output contacts — we shall obtain resistance R_m, which comprises the output contacts resistance R_k and the transitional resistance R_p.

With a certain approximation R_k can be regarded as a constant during the operational process and the tests. Therefore, having measured or calculated R_k, we can determine transitional contact resistance by the formula

$$R_p = R_m - R_k. \quad (1)$$

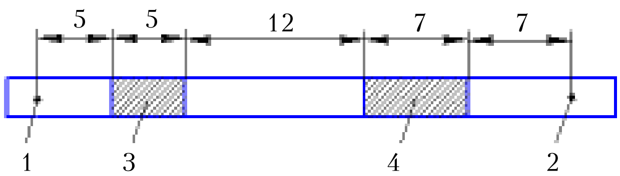

Fig. 5. Geometric model of the contact connection between the backboard, the socket FPC and the electronic module PCB:
1, *2* — resistance measurement points on the backboard and the electronic module PCB, respectively; *3*, *4* — areas of contact between the socket FPC and the backboard and between the socket FPC and the electronic module PCB, respectively

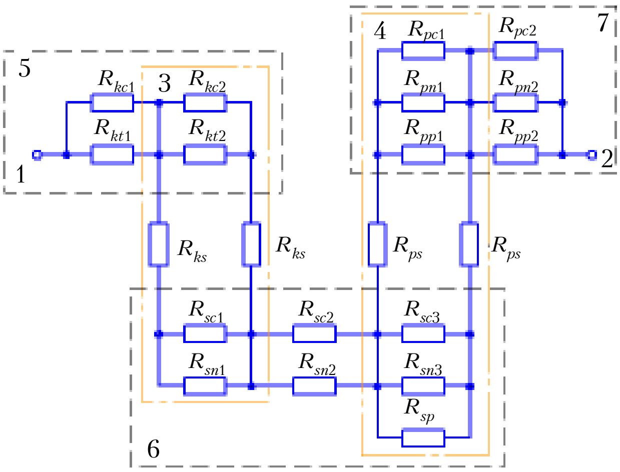

Fig. 6. Electrical circuit of contact connection of the socket FPC (*6*), the backboard (*5*) and the electronic module PCB (*7*)
(*1*, *2*, *3*, *4* — same as in fig. 5)

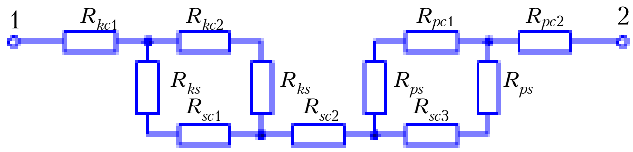

Fig. 7. Simplified electrical circuit of the contact connection

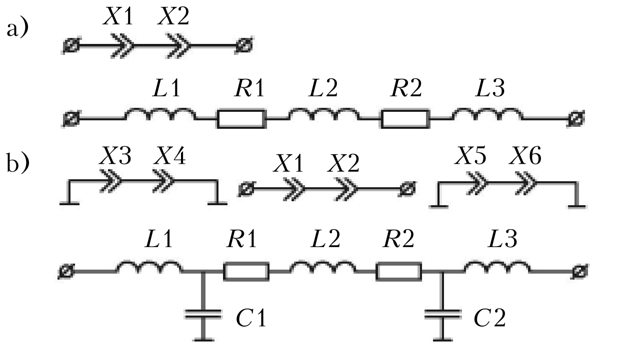

Fig. 8. Connection circuits and their equivalent circuits without earthed terminals (*a*) and with contiguous earthed cntacts (*b*)

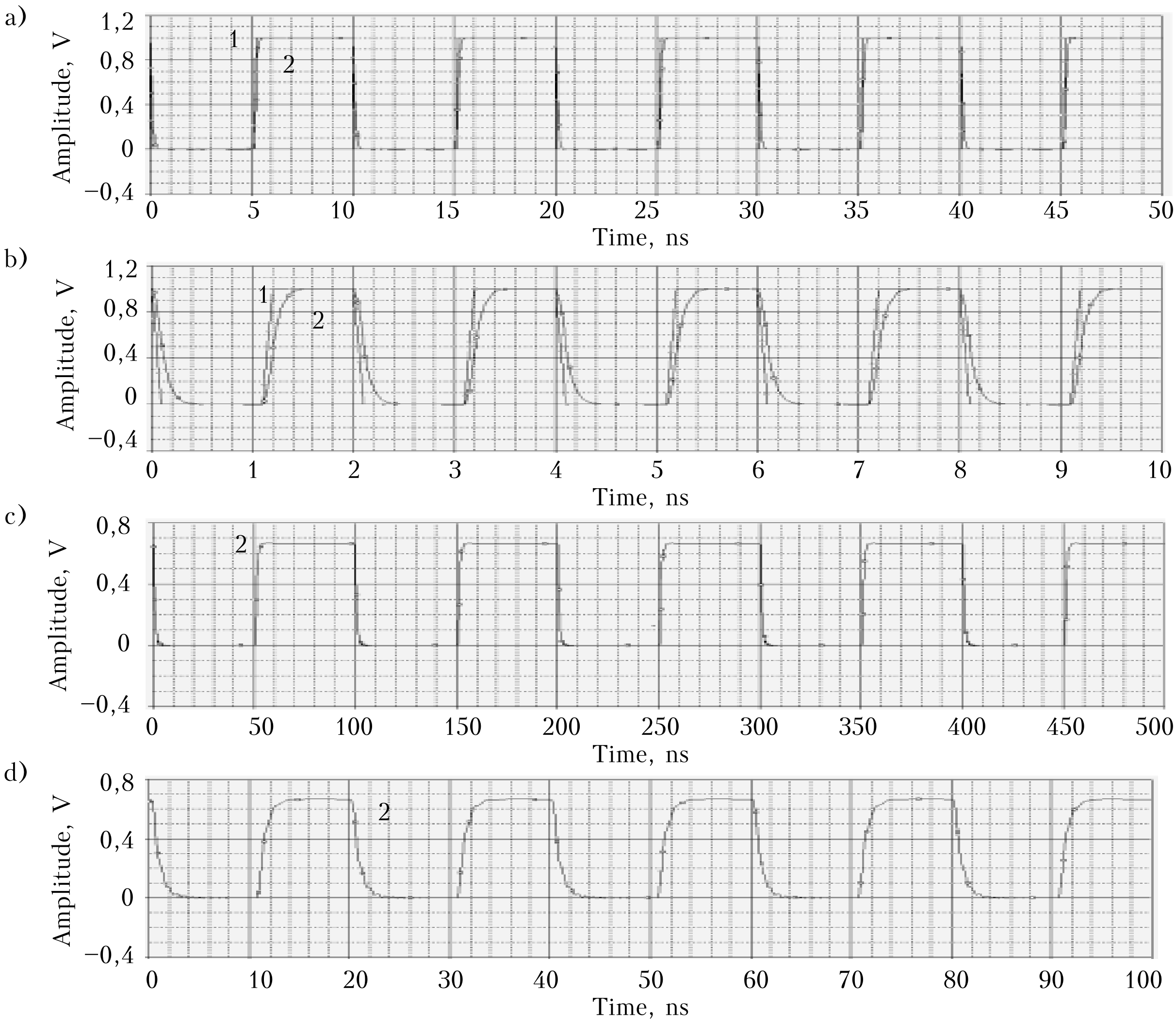

Fig. 9. Passage of pulse signal through the contacts connected as shown in fig. 8, *a* (100 MHz (*a*) and 500 MHz (*b*)), and according to fig. 8, *b* (10 MHz (*c*) and 50 MHz (*d*)):
1 — input signal; *2* — output signal

In order to calculate the contact resistance R_k let us consider a geometrical model of the contact connection from fig. 2 given in **fig. 5** and its equivalent electrical circuit in **fig. 6**.

The figure contains the following designations: R_{kc1}, R_{kc2}, R_{kt1}, R_{kt2} — resistance of base metal (copper) and the coating (e. g., tin alloy), respectively, in contact zones (**CZ**) of the backboard; R_{pc1}, R_{pc2}, R_{pn1}, R_{pn2}, R_{pp1}, R_{pp2} — resistance of copper, nickel sublayer and coating layer (e. g., palladium), respectively, in CZ on electronic module PCB; R_{sc1}, R_{sc2}, R_{sc3}, R_{sn1}, R_{sn2}, R_{sn3}, R_{sp} — resistance of copper, nickel sublayer and coating layer (e. g., palladium), respectively, in CZ on FPC; R_{ks}, R_{ps} — transitional resistance of contacts "backboard — FPC" and "FPC — electronic module PCB", respectively.

Given that the layers and sublayers of coatings forming CZ have small thickness and high resistivity compared to the base metal (copper foil), these contact resistance components may be neglected. As a result, the equivalent electrical circuit acquires the form shown in **fig. 7**. This diagram can be used for practical calculations of the contact resistance of the connection in question.

Modeling of connectors as a current line

As large number of plug connections in modern electronics are supposed to transmit high-frequency signals, it is advisable to do researches on low-frequency connectors (to which the investigated connectors are referred) in terms of their possible use for the transmission of high-frequency signals (more than 3 MHz). To this effect, there has been performed a modeling of transmission of a pulse signals of different frequency through the contact connections in question. For this purpose two connection circuits and their equivalent electrical circuits, presented in **fig. 8** ($X1...X6$ — contact connections; $R1$, $R2$ – contact resistance, including transitional contact resistances ($R1=R2=0{,}019\,\Omega$); $L1...L3$ – contact inductance $L1=L2=L3=24$ nH); $C1$, $C2$ – capacity ralative to adjacent contacts ($C1=C2=1{,}1$ pF)), have been used [8].

The effect of contact connections as irregularities in the current lines on the transmission are simulated with P-Spice program. The simulation results are given in **fig. 9**.

Analysis of the output signals given in fig. 9, *a* and *b*, and their comparison with the input ones allows to speak about their negligible distortion even at ultra-high frequency (500 MHz). The results given in fig. 9, *c* and *d*, show that the signal contacts being surrounded by the earthed contacts allows to improve their noise immunity to crosstalk signals.

However a dramatic distortion of the signal is noticeable at relatively lower frequencies.

ISSUES OF SYSTEM USE OF FPC-BASED CONNECTORS

The connector shown in fig. 1 and 2 serves as a switching device between the electronic modules of the first level by means of the backboard. However, the capabities of the FPC-based connector

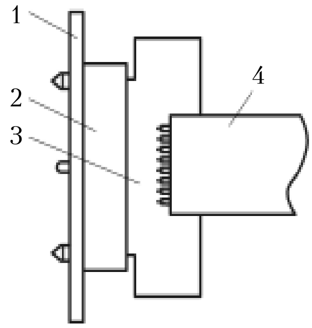

Fig. 10. Design of the electrical contacts for external connections and connections between second level modules: *1* — backboard; *2* — socket; *3* — plug; *4* — ribbon cable or FPC

come to more than this. Let us consider constructive decisions for different types of connectors.

Design of the connector that plugs into the backboard from the outer side for external connections and the connections between second level modules is shown in **fig. 10**.

This version of the socket in the main has the same constructive solution as the one described above, i. e. it is mounted on the surface of the backboard by clamping (no soldering), saving it is mounted from the outer side. Socket *2* is connected with other modules or with external circuits by means of plug *3*, based on a rigid PCB, on which a ribbon wire (cable), a round cable, a harness, an FPC can be mounted.

A possiblility for two-way connection of first level electronic modules to the backboard with sockets is shown in **fig. 11**. Such design of electrical connections with the possibility of using two-way access to electronic equipment allows to create flexible layout diagrams and to efficiently use the volume of electronic devices for arrangement of PCB-based electronic modules.

A connecting device which is mounted on the surface of the PCB by clamping is shown in **fig. 12**. Operating principle and design of the

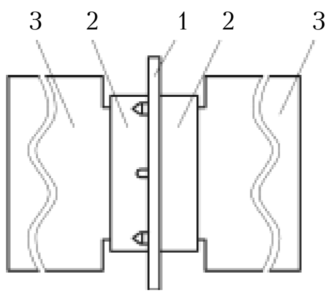

Fig. 11. Two-way connection of first level electronic modules to the backboard: *1* — backboard; *2* — socket; *3* — electronic module PCB

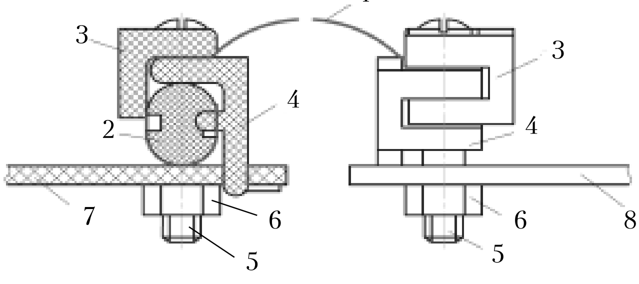

Fig. 12. Electrical connection by clamping of two PCB: *1* — FPC; *2* — elastomeric liner; *3*, *4* — insulators cases; *5* — screw; *6* — nut; *7* — PCB1; *8* — PCB2

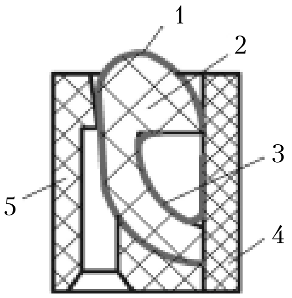

Fig. 13. Cross-section of the socket with an additional metal spring:
1 — FPC; *2* — elastomeric liner; *3* — spring; *4* — case; *5* — cover

device are described in [5]. Connections can be made both within a single PCB and to connect two PCB located relative to each other in any planes. The figure shows the connection of two circuit boards *7* and *8* by means of such a device. For a better perception of the image units of one PCB are shown in cross-section.

Here we shall present a few other constructive solutions for FPC-based connectors with improved quality performance and greater capability.

Previously in the study the issue of selecting an elastomeric liner material was dealt with. One of the key external factors affecting the quality is operation temperature increase, which makes the residual deformation accumulate in the liners. This results in significant weakening of the pressure between the contacts, and, therefore, in increase of transitional contact resistance.

For embodiments of connectors for application at high temperatures, a constructive version of the socket may be offered, in which, except for elastomeric liner, a metallic spring is used for reliability improvement [9].

A cross section of a modified socket, similar to that shown in fig. 1 is shown in **fig. 13**. If during the operation of the connector the residual deformation is accumulated in the liner, the metal spring compensates its waning effect.

It is possible to significantly improve the performance of the connectors by duplicating the number of contacts with a certain increase in thickness of the socket. This option opens when two FPC and two elastomeric liners are used in one socket — bilateral arrangement of contacts, including the terminal contacts (lamellae) on the electronic module PCB (**fig. 14**).

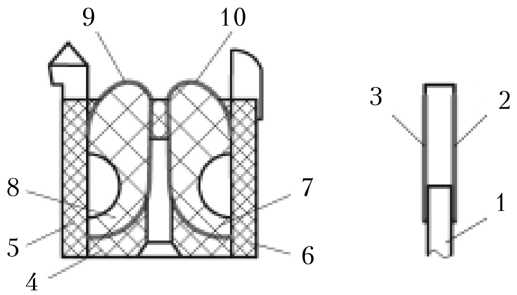

Fig. 14. The construction of connector with bilateral contacts layout:
1 — plug; *2*, *3* — terminal printed contacts (lamellae); *4* — socket body; *5*, *6* — covers; *7*, *8* – elastomeric liners; *9*, *10* — FPC

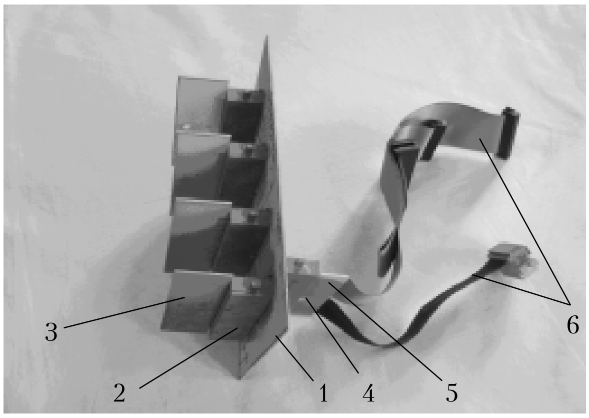

Fig. 15. Experimental model that implements the inter-unit electrical connections:
1 — backboard; 2 — socket for electronic module PCB connection; *3* — fragment of electronic module PCB; *4* — socket for external connections; *5* — plug; *6* — ribbon cables with connectors

Product design and engineering of FPC-based connectors and elastomeric liners are realized to a certain extent in the samples shown in **fig. 15**. Here the backboard *1* with sockets *2* provides electrical connections between first level electronic modules, which are presented by fragments of PCB *3*. In its turn, the connection of the backboards as components of second level electronic modules, as well as their external connection is performed by socket *4*, plug *5* and, for instance, wire cable connections *6*. Besides, the socket *4* is mounted on the surface of PCB1 similarly to socket *2*.

Contact arrangement pitch, mm	Number of contacts	Maximum intensity of contact current, A	The maximum voltage, V		Contact resistance, mΩ, max
			working	test	
5	13	4	400	1600	10
2,5	26	2	250	1200	20
1,25	52	1,2	150	800	40

In this sample were used sockets and the plugs with a contacts arrangement pitch (which defines the dimension type of connector) of 1,25, 2,5 and 5 mm and with the surfaces of working parts coated with palladium. According to test results, the main parameters of the connectors are within the range of values given in the **table**. At these current values the connectors superheat temperature does not exceed 20°C.

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The proposed designs are oriented on batch fabrication of contacts and connectors assembly. The research results has shown the feasibility of manufacturing and appliation of electrical connectors based on the FPC and elastomeric liners, which, due to their technical characteristics, manufacturability and, espesially, mounting technological effectiveness, can rival connectors with digital metal contacts.

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Ефименко А. А. **Электрические соединители для поверхностного непаяного монтажа**.

Ключевые слова: электрические соединители, непаяный монтаж, поверхностный монтаж, проектирование электронных устройств, контактные соединения, гибкие печатные кабели, эластомерные вкладыши.

В статье рассмотрены особенности создания, возможность изготовления и применения электрических соединителей для поверхностного монтажа на основе гибких печатных кабелей и эластомерных вкладышей. По своим техническим характеристикам, а также технологичности изготовления и, особенно, монтажа, они способны составить конкуренцию соединителям с дискретными металлическими контактами.

Украина, Одесский национальный политехнический университет.

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Єфіменко А. А. **Електричні з'єднувачі для поверхневого непаяного монтажу**.

Ключові слова: електричні з'єднувачі, непаяний монтаж, поверхневий монтаж, проектування електронних пристроїв, контактні з'єднання, гнучкі друковані кабелі, еластомірні вкладиші.

У статті розглянуто особливості створення, можливість виготовлення та застосування електричних з'єднувачів для поверхневого монтажу на основі гнучких друкованих кабелів та еластомерних вкладишів. За своїми технічними характеристиками, а також технологічністю виготовлення та, особливо, монтажу, вони здатні скласти конкуренцію з'єднувачам з дискретними металевими контактами.

Україна, Одеський національний політехничний університет.

НОВЫЕ КНИГИ

НОВЫЕ КНИГИ

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Сделан исчерпывающий анализ важных аналоговых компонентов и вопросов их практического применения при проектировании линейных схем. Более тысячи рисунков облегчают восприятие материала. Книга содержит подробное описание компонентов аналоговых схем для практикующих разработчиков, проверенные практическим внедрением примеры проектов основных типов линейных схем, советы по чтению технических описаний и выбору коммерческих операционных усилителей, в ней рассмотрены вопросы проектирования печатных плат. Издание будет полезно в качестве учебного материала или справочного пособия для инженеров, занимающихся разработкой аналоговых и аналого-цифровых устройств.