

Arrangement of contact pairs for compensating near-end crosstalk for an electric plug connection

The invention relates to an arrangement of
5 contact pairs for compensating near-end crosstalk for
an electric plug connection.

Because of magnetic and electric coupling
between two contact pairs, one contact pair induces a
current or influences electric charges in adjacent
10 contact pairs, so that crosstalk occurs. In order to
avoid near-end crosstalk, the contact pairs may be
arranged to be very far apart from one another, or
shielding may be arranged between the contact pairs.
However, if the contact pairs have to be arranged very
15 close alongside one another for design reasons, the
measures described above cannot be carried out, and
near-end crosstalk has to be compensated.

The most widespread electric plug connection
for symmetrical data cables is the RJ-45 plug
20 connection, which is known in various embodiments,
depending on the technical requirement. Known RJ-45
plug connections in Category 5 have, for example,
between all four contact pairs, a crosstalk attenuation
value of > 40 dB at 100 MHz transmission frequency.
25 Because of the unfavorable contact allocation in the
RJ-45, the design gives rise to increased crosstalk,
particularly in the plug, between the two pairs 3, 6
and 4, 5, because of the nested arrangement of the
latter, and this restricts use at high transmission
30 frequencies. However, the contact allocation cannot be
changed for reasons of compatibility with the previous
plugs. Because of this unfavorable design arrangement,
special measures are already necessary in order to
achieve near-end crosstalk values of > 40 dB at 100 MHz
35 in Category 5. All the known measures leave the plug
untouched and provide the improvement in the near-end

crosstalk by means of compensation measures in the socket.

A known practice here is the crossing of a pair, as a result of which antiphase crosstalk is generated downstream of the crossed area. For this purpose, EP 0 525 703 A1 describes the practice of crossing the two lines 4 and 5, and WO 94/06216 describes the practice of crossing the two lines 3 and 6 on circuit boards. Twisting wires of different pairs is also known, from EP 0 601 829 A2. Compensation by means of direct additional capacitances with respect to the next-but-one contact is to be found in EP 0 692 884 A1. One solution for the compensation, by means of contacts which have been lengthened and bent over many times to make them cross, is described by EP 0 598 192 A1, where the compensation is produced downstream of the crossover by the continuing contacts and insulation displacement terminals.

The common factor in all the known solutions is compensation measures in the socket, but the distance between the crosstalk area and the effective compensation area is too great. In order to implement the spring forces and in order to guide the moveable contacts safely in the socket, these contacts are designed to be relatively long, so that a crossover on a circuit board is set too far away from the lengthened fixed contacts or twisted connecting wires. The gain resulting from these known compensation measures is therefore restricted, so that plug connectors for 200 MHz cannot be implemented using these known solutions, since the near-end crosstalk at higher frequencies cannot be adequately compensated.

The invention is therefore based on the technical problem of providing an arrangement of contact pairs for an electric plug connection having at least two contact pairs which are nested inside one another, especially for an RJ-45 plug connection, for higher transmission frequencies with adequate crosstalk attenuation. A further technical problem is the

provision of an electric plug connection for high transmission frequencies which is downward compatible with the known Cat 5 plug connectors.

5 The solution to the technical problem is given by the features of patent claims 1 and 8. As a result of arranging the crossover point in the spring-mounted part of the contacts of the socket, the location of the compensation is shifted into the vicinity of the location where the near-end crosstalk is generated,
10 namely the contact area, so that considerably higher limiting frequencies are achievable. As a result of the coupled position of the contacts in the connecting area of the plug, the tolerances which occur as a result of the fitting of the wires are reduced in such a way
15 that, in conjunction with the contact arrangement for the socket, higher transmission frequencies are achievable, but the arrangement is still also compatible with Cat 5. Further advantageous refinements of the invention are given by the subclaims.

20 In a further preferred embodiment, the crossover point is placed directly downstream of the contact area, which has the effect of a minimum distance between the crosstalk zone and the compensation zone, so that phase shifts because of
25 propagation times are negligible.

In a further preferred embodiment, the contacts of the nested contact pairs are led in parallel in the contact area, the inner contacts being oriented in the opposite direction to the outer contacts, which has the
30 effect of inductive decoupling of those subareas of the inner contacts through which no current flows. Following this, the inner contacts are crossed and bent through 180° and again designed to be parallel to the first subarea. The effect of this is that, directly
35 downstream of the crossover point, the crosstalk generated changes its sign and compensation of the crosstalk from the contact area takes place.

In order to produce adequate spring forces, the contacts of the nested contact pairs are then bent at

an acute angle and led in parallel to a connection area. For the purpose of decoupling, and consequently in order to limit the compensation area, the inner contacts are once more bent away from the outer
5 contacts before the connection region, and again led parallel to the outer contacts.

In order to reduce the crosstalk from the outer contacts of the nested contact pairs to the contact pairs which are not nested in one another, the latter,
10 in the contact area, are led in the same direction and parallel to the inner contacts, are bent into a decoupled position and are then led to the connection area parallel to the contacts of the nested contact pairs.

In order to improve the compensation gain, the crosstalk in the plug is deliberately selected to be greater and is then compensated again, the compensation zone preferably dividing into two subareas, namely a compensation zone in the socket and a compensation zone
15 at the connection area of the plug, for which purpose the inner contacts are likewise crossed.
20

In a further preferred embodiment, the inner contacts in the compensation zone of the plug are designed with a lower line impedance than in the
25 crosstalk zone, so that, between the contacts of the nested contact pairs, it is predominantly capacitive coupling which takes place, which compensates for the predominating proportion of the capacitive coupling in the area of the transition between plug and socket,
30 where those parts of the contacts of the socket and plug through which no current flows have a capacitive effect.

The outer contact pairs, which are not nested inside one another, are led parallel to one another,
35 these being led in the opposite direction to the contacts of the nested contact pairs in the contact area for the purpose of decoupling. For improved decoupling in relation to the contacts of the socket,

the outer contacts have an indentation adjacent to the contact area.

The invention will be explained in more detail below with reference to a preferred exemplary embodiment. In the figures:

- Fig. 1 shows a contact arrangement of an RJ-45 plug connection (prior art),
- Fig. 2 shows an illustration of the couplings which occur for an arrangement according to Fig. 1,
- Fig. 3. shows a perspective illustration of the nested contact pairs for an RJ-45 socket,
- Fig. 4 shows a side view of the arrangement according to Fig. 3,
- Fig. 5 shows a side view of the four contact pairs for an RJ-45 socket,
- Fig. 6 shows a schematic illustration of the nested contact pairs in the connection area for an RJ-45 plug,
- Fig. 7a shows a model of two homogenous lines in relation to near-end crosstalk,
- Fig. 7b shows a model according to Fig. 7a with single compensation,
- Fig. 7c shows a model according to Fig. 7a with dual compensation,
- Fig. 8 shows frequency curves of the models according to Figs. 7a-c,
- Fig. 9 shows an arrangement of the contacts according to Fig. 6 with crossover and compensation,
- Fig. 10 shows a side view of all four contact pairs for the RJ-45 plug,
- Fig. 11 shows a first perspective view of the contact arrangement according to Fig. 5,
- Fig. 12 shows a second perspective view of the contact arrangement according to Fig. 5,

Fig. 13 shows a third perspective view of the contact arrangement according to Fig. 5,

5 Fig. 14 shows a first perspective view of the contact arrangement according to Fig. 10, and

Fig. 15 shows a second perspective view of the contact arrangement according to Fig. 10.

10

Fig. 1 illustrates the pin allocation for an RJ-45 plug connection. The RJ-45 plug connection comprises four contact pairs 1, 2; 3, 6; 4, 5; 7, 8. For this purpose, the associated contacts of a contact
15 pair are not always located directly alongside one another, instead the two central contact pairs 3, 6 and 4, 5 are nested inside one another, the consequence of which is particularly severe crosstalk. In the case of four contact pairs, there are six couplings between the
20 contact pairs, these being illustrated schematically in Fig. 2, the thickness of the line symbolizing the strength of the coupling.

Since previous approaches to the solution only use compensation measures in the socket to reduce the
25 crosstalk and retain the crosstalk in the plug, it is not possible for the crosstalk in the plug to be reduced as desired in order to improve the plug connector, for reasons of the desired downward compatibility with Cat 5 plug connections. The
30 improvements therefore have to be initially carried out primarily in the socket. The text below presents individual measures which are all severally and jointly essential to the invention.

Fig. 3 illustrates a perspective view of the
35 central, nested contact pairs 3, 6 and 4, 5. In order to improve the compensation gain in the socket, the distance between the contact area 10, where the contacts of the plug make contact with those of the socket, and the compensation area is reduced in size.

To this end, the crossing of the contacts 4 and 5, which is known in principle, is displaced into the moveable part of the contacts of the socket. As can be seen from Fig. 3, the crossover 11 is carried out
5 directly adjacent to the contact area 10, the compensation area following directly downstream of the crossover 11.

The functioning of the compensation of the contact arrangement according to Fig. 3 will now be
10 explained in more detail with reference to Fig. 4, which illustrates a side view of Fig. 3. The contacts 3 and 6 of the spread pair are designed to be parallel and completely identical, go away to the left from the contact area 10 in a first subarea 31, 61, change into
15 a straight part 33, 63 after a bend 32, 62 and end on the right in a connection area 90, which may be a circuit board, for example.

The contacts 4 and 5 of the central pair run parallel to the contacts 3 and 6 in the contact area
20 41, 51 and go away to the right in the opposite direction and make a bend of 180° 42, 52, where the two contacts cross, that is to say, as viewed from above, contact 4 takes the place of contact 5 and contact 5 takes the place of contact 4. Following the crossover
25 11, the two contacts 4 and 5 run parallel to each other and parallel to the contact sections 31 and 61. After another bend 44, 54, the contacts 4 and 5 are located in the same plane as 3 and 6.

Compensation begins directly downstream of the
30 crossover 11 or bend 42, 52, as a result of the parallelism of the contact areas 31, 61, 43, 53 and 33, 63, 45, 55. In order to limit the compensation area, the two contacts 4 and 5 leave the compensation zone by way of a bend 46, 56 and end in a decoupled manner in
35 the connection area 90.

In order to achieve the necessary spring forces, the contact sections 31, 32 and 41, 42, 43, 44 as well as 51, 52, 53, 54 and 61, 62 are moveable, while the others are located in a fixed manner in the

socket. As a result of the displacement of the crossover 11 into the moveable part of the contacts, the crosstalk area and the compensation are located very close to one another.

5 As a result of the contacts being led in opposite directions from the contact area, contacts 3 and 6 to the left, contacts 4 and 5 to the right, the crosstalk in the contact area 31, 41, 51, 61 is restricted to the electrical component, since the
10 currents flowing in opposite directions barely influence one another here.

 Fig. 5 illustrates the complete contact arrangement for the socket of an RJ-45 plug connection. In order to optimize the crosstalk in relation to the
15 outer contact pairs 1, 2 and 7, 8, no deliberate compensation is necessary in the socket in order to achieve compatibility with Cat 5. For this reason, the crosstalk to the outer pairs is minimized. In order to reduce the crosstalk in the contact area of the socket,
20 between the contacts 3 and 1, 2 and, respectively, 6 and 7, 8, the contacts 1, 2, 7, 8 are designed in the opposite directions to the adjacent contacts 3, 6. The outer contact pairs 1, 2 and 7, 8 are led further at a level between the two pairs 3, 6 and 4, 5, in a
25 virtually decoupled position.

 Because of the requirement for compatibility, a corresponding degree of crosstalk between the pairs 36 [sic] and 4 5 [sic] must be maintained in an improved plug. As a result of the known, conventional, direct
30 fitting of the wires to the contacts in the case of previous Cat 5 plugs, relatively large tolerances in the crosstalk occur, depending on the position of the wires, but this is still sufficient to satisfy the values of Cat 5. In order to use the plug at still
35 higher frequencies, a few improvements still have to be made in the plug.

 In Fig. 6, the contacts 203, 206; 204, 205 of the nested contact pairs are illustrated in plan view. The contacts 203, 204, 205, 206 run completely parallel

to one another. Only at the connection area 214 are the contacts 204, 205 and 203, 206 drawn apart from one another, so that these are largely decoupled in the connection area 214 because of the distance between the contact pairs. This may be achieved, as illustrated in Fig. 6, by bending the contact pairs over in opposite directions, or simply bending over one contact pair. The action of the contact arrangement of the improved plug is to restrict the previously usual large tolerances in the crosstalk, and to fix the crosstalk at a lower tolerance value which still satisfies Cat 5 and is matched to the compensation in the socket. Fixing the crosstalk at a defined value is carried out by means of contacts which are inserted firmly into a plastic body and which, in order to produce the necessary crosstalk, run parallel. In order to restrict cable influences to a great extent when they are being connected to the contacts, the contacts are first drawn apart, in order to delimit the crosstalk zone unequivocally, and the wires are fitted in a virtually decoupled position. Undefined positions of the wires as a result of unwound twisting thus have hardly any further influence on the crosstalk values.

Together with the socket previously described, a plug of this type produces considerably better values for the near-end crosstalk at higher transmission frequencies, which has also been confirmed by measurement. In order to improve the frequency response further, the crosstalk in the plug between the contact pairs 203, 206 and 204, 205 is deliberately selected to be higher and is corrected again by subsequent compensation. In this case, the compensation is selected such that the plug again provides the necessary values for Cat 5. Before the implementation in the contact arrangement is described, the effect principle on which it is based will be explained in more detail. Together with the contact arrangement previously described for the socket, the overall plug connector behaves like a crosstalk zone having two

compensation zones, namely one in the socket and one in the plug, which provides a considerably better compensation gain than simple compensation, as will be explained below with reference to a simple arrangement of two coupled dual lines in Figs. 7a-c.

Up to a specific limit, the near-end crosstalk between two parallel homogeneous lines according to Fig. 7a rises at 20 dB/decade, and therefore behaves like a high-pass filter of first order. If this crosstalk is compensated, for example by means of a second line section according to Fig. 7b, one line pair having been crossed for this purpose, a limiting curve for the near-end crosstalk which, given optimum equalization, rises at 40 dB/decade, is obtained. This limiting curve is explained in graphic terms by the average d between the crosstalk zone and compensation zone, so that the signal running through the compensation zone has a propagation time which is greater by twice the distance d . This leads to an additional frequency-dependent phase shift, which has the effect of a deviation from the desired 180° for canceling the crosstalk. A distance $d = \lambda/4$ has the effect of an additional phase reversal, simply because of the doubled path length, so that in this case the resulting crosstalk is twice as great as that of the uncompensated crosstalk zone. A more precise analysis finds that a gain is given only for a distance $d < \lambda/12$ in the case of compensation of this type.

For a compensation gain of 20 dB, a tenth of this distance is needed, that is to say about $d = \lambda/120$. For a frequency of 200 MHz, depending on the material of the surrounding plastic, this results in a wavelength of about 1 m, that is to say a distance d of about 8 mm is needed for this. The example shows how the dimensions of the plug connector determine the limits of the compensations. A dimension of 8 mm can hardly be bettered in the RJ-45 plug connector, for mechanical reasons, and in addition a gain of 20 dB is inadequate.

If the compensation area is divided into two equal parts, and these are displaced upstream and downstream of the crosstalk area, an arrangement according to Fig. 7c is obtained. The subdivision
5 results in two compensation signals, whose average propagation time is identical to the average propagation time in the crosstalk zone. There is thus no longer any frequency-dependent phase shift, the phase difference between the crosstalk signal and the
10 compensation signal remaining at 180° , a symmetrical construction being assumed. As a result, considerably better values for the compensation gain are obtained. For exact equalization, a limiting curve of the near-end crosstalk of 60 dB/decade is achievable. This
15 limit is clearly brought about by the fact that the magnitude of the compensation decreases at the high frequencies as a result of the geometrical separation of the two compensations. If the distance between the two compensations is $1.5 d = \lambda/4$, that is to say
20 $d = \lambda/6$, then the two have opposite signs and the compensation is ineffective. The limiting frequency at which the compensation becomes ineffective is twice as high as in the case of single compensation. Together with the higher slope of the near-end crosstalk curve, the gain of this type of compensation can be seen in
25 Fig. 8. The frequency curves in Fig. 8 could be confirmed by measurement using a four-way ribbon cable.

Fig. 9 illustrates the contact arrangement for the inner contacts 203, 204, 205, 206. In order to
30 produce the previously described dual compensation, the two inner contacts 204, 205 are designed to be crossed, the crosstalk zone 211 being located to the right of the crossover point 212, and the compensation zone 213 being located to the left of the crossover point 212,
35 and forming the first part of the compensation, while the second compensation area is located in the socket. In addition, the contacts 203, 204, 205, 206 have a low line impedance in the compensation zone 213, as compared with the crosstalk zone 211, this being

implemented, for example, by means of different diameters or shapes of the contacts. As a result, there is predominantly capacitive coupling [lacuna] the two contact pairs in the compensation zone. This
5 compensates for the predominant proportion of the capacitive coupling in the area of the transition between plug and socket, where those contact ends of the plug through which no current flows and, above all, those of the socket have a capacitive effect. As a
10 result of this measure, the plug connector obtains the necessary good values for far-end crosstalk, even for this frequency range. Alternatively, the measure with the different line impedances can also be placed or divided up downstream of the crossover in the socket.
15 From a production point of view, the implementation of these capacitances is easier to bring about in the stamped contacts in the plug, however, than in the bush, whose contacts are produced from wire.

Fig. 10 illustrates the complete contact
20 arrangement for the plug. For the purpose of decoupling between the inner contacts 203, 206, 204, 205 and the outer contacts 201, 202, 207, 208, the outer contacts run in opposite directions in the contact area 210. As can be seen, the current flows from top to bottom in
25 the outer contacts, from bottom to top in the inner contacts. All the contacts are designed to have radii at their contact ends, in order to improve the making of contact with the mating contacts of the socket. In addition, the outer contacts 201, 202, 207, 208 have
30 indentations 215 directly adjacent to the contact area 210, these serving for better decoupling with the contacts of the socket. The outer contacts 201, 202, 207, 208 are led further from the contact area 210 to the connection area 214 so that they are parallel to
35 the inner contacts 203, 206, 204, 205 and in a different plane, such that decoupling takes place between the inner and outer contacts. The cable connections in the connection area are made in pairs and are separated physically from one another by a

2 x 2 arrangement similar to a matrix, so that cable influences because of undefined twisting are low.

Figs. 11-13 illustrate various perspective views of the contact arrangement for a socket having a circuit board 91 and the fitted insulation displacement contacts 92. The contacts are illustrated in the non-installed state, that is to say without the socket body. If the contact set is installed in a socket body (not illustrated), the eight contacts will be parallel and under the necessary prestress. The soldering eyes on the circuit board for the contacts 1, 2 and 4, 5 and 7, 8 are offset, in order to maintain the necessary minimum distance here for the creep paths.

Figs. 14 and 15 illustrate the contact arrangement for the plug, in perspective view, the contacts 201-208 being designed to have penetration connections 216 in the connection area 214. The contacts 203-206 of the two nested contact pairs are designed to extend over an area in the compensation zone 213, in order to reduce the line impedance in comparison with the crosstalk zone 211. In addition, contacts 201-208 are designed to have in the contact area 210 hooks 217 which are used for the purpose of fastening in a plug body (not illustrated).

List of designations

1	Contact (socket)	201	Contact (plug)
2	Contact (socket)	202	Contact (plug)
3	Contact (socket)	203	Contact (plug)
4	Contact (socket)	204	Contact (plug)
5	Contact (socket)	205	Contact (plug)
6	Contact (socket)	206	Contact (plug)
7	Contact (socket)	207	Contact (plug)
8	Contact (socket)	208	Contact (plug)
10	Contact area (socket)	210	Contact area (plug)
11	Crossover point (socket)	211	Crosstalk zone (plug)
31	Subarea of contact 3	212	Crossover point (plug)
32	Subarea of contact 3	213	Compensation zone (plug)
33	Subarea of contact 3	214	Connection area (plug)
41	Subarea of contact 4	215	Indentation (plug)
42	Subarea of contact 4	216	Penetration connections
43	Subarea of contact 4	217	Hook
44	Subarea of contact 4		
45	Subarea of contact 4		
46	Subarea of contact 4		
51	Subarea of contact 5		
52	Subarea of contact 5		
53	Subarea of contact 5		
54	Subarea of contact 5		
55	Subarea of contact 5		
56	Subarea of contact 5		
61	Subarea of contact 6		
62	Subarea of contact 6		
63	Subarea of contact 6		
90	Connection area (socket)		
91	Circuit board		
92	Insulation displacement contact		

Arrangement of contact pairs for compensating near-end crosstalk for an electric plug connection



Patent Claims:

- 5
1. An arrangement of contact pairs for a socket of an electric plug connection, having at least two contact pairs which are nested inside one another, especially for an RJ-45 plug connection, it being possible for the contacts, towards the connection area, to be arranged to be partly fixed and, towards the contact area, to be arranged in a sprung manner in a socket body, and at least two contacts of the nested contact pairs being led so that they cross, wherein the crossover point (11) of the contacts (4, 5) is located in the spring-mounted subarea of the contacts (4, 5).
- 10
2. The arrangement as claimed in claim 1, wherein the crossover point (11) directly adjoins the contact area (10).
- 15
3. The arrangement as claimed in claim 2, wherein, in a first subarea (31, 61, 41, 51), the contacts (3, 6) are led from the common contact area (10) in the opposite direction and parallel to the contacts (4, 5), following this, in a second subarea (42, 52), the contacts (4, 5) are then turned through 180° and crossed and, in a following subarea (43, 53), are again led parallel to the first subarea (31, 61, 41, 51).
- 20
4. The arrangement as claimed in claim 3, wherein, in a following area (32, 62, 44, 54), the contacts (3, 6; 4, 5) are bent and then led in parallel.
- 25
5. The arrangement as claimed in claim 4, wherein, in an area (46, 56), the contacts (4, 5) are bent over toward the connection area (90) and are led in a position in which they are decoupled from the contacts (3, 6) and parallel to the latter.
- 30
6. The arrangement as claimed in one of claims 3 to 5, wherein, in the area (41, 51), the contact pairs
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(1, 2; 7, 8) which are not nested in one another are led in the same direction and parallel to the contacts (4, 5), are bent in the area of the crossover point (11) and are then led to the connection area (90) parallel to the contacts (3, 6; 4, 5).

7. A socket for an electric plug connection, comprising a socket body and a set of contacts, wherein the contacts (1, 2; 3, 6; 4, 5; 7, 8) are designed as an arrangement as claimed in one of claims 1 to 6.

10 8. An arrangement of contact pairs for a plug of an electric plug connection, having at least two contact pairs which are nested inside one another, especially for an RJ-45 plug connection, wherein, between a contact area (210) and a connection area (214), the nested contacts (3, 6; 4, 5) are designed to be parallel to one another and uncrossed, in order to form a defined crosstalk zone (211), and, at the connection area (214), the two contact pairs (3, 6; 4, 5) are led in a position in which they are decoupled from one another.

9. The arrangement as claimed in claim 8, wherein, in the area of the crosstalk zone (211), the contact length and/or the distance between the contacts (3, 6; 4, 5) is/are selected such that a degree of crosstalk which is greater than a Cat 5 plug is established.

10. The arrangement as claimed in claim 9, wherein, between the crosstalk zone (211) and the connection area (214), the contacts (204, 205) are crossed and form a compensation area (213).

30 11. The arrangement as claimed in claim 10, wherein the line impedances of the contacts (203, 206; 204, 205) in the compensation area (213) are lower than in the crosstalk area (211).

12. The arrangement as claimed in claim 11, wherein the contacts (203, 206; 204, 205) are designed to extend over an area in the compensation area (213).

13. The arrangement as claimed in one of claims 8 to 12, wherein the contacts (201, 202; 207, 208) are designed to be parallel to one another and, in the



contact area (210), are led in the opposite direction to the contacts (3, 6; 4, 5).

14. The arrangement as claimed in claim 9, wherein, the contacts (201, 202; 207, 208) have an indentation
5 (215) adjacent to the contact area (210).

15. A plug for an electric plug connection, comprising a plug body and a set of contacts, wherein [lacuna] are designed as an arrangement as claimed in one of claims 8 to 14.

