

## Description

Wire-free transmission of power and data for a modular peripheral system

5       The present invention relates to an electronic controller of modular design, in particular a stored-program controller or peripheral units, in each case for controlling and/or monitoring a technical process.

10       Controllers of modular design of the type described at the beginning are generally known in the prior art. The individual modules are supplied with electrical power from a supply source via electrical connections, with which either the electrical power is fed to each individual module or else with which the electrical power is fed to a first module, which itself  
15       passes on this power to an adjacent module. The passing on of the electrical power to all the modules of the electronic controller of modular design is carried out by means of connecting elements which are essentially of the same type. The same applies to the data flow which is  
20       provided between the modules. The data flow then runs via connecting elements which make contact with the individual modules with a further connecting element, said further connecting element bringing about, for example, the electrically conductive connection to a bus.

25       Methods for the wire-free transmission of power and/or data are generally known in the prior art, in particular in the communications field. However, it is not known to use such a method for the transmission of power and/or data between modules or peripheral units of  
30       a control device which controls and/or monitors a technical process. In such equipment, the transmission of power and/or data is carried out by means of suitable electrically

conductive connections. In particular, the concept of the serial or parallel bus is widespread here.

5 A disadvantage with the connections which are known in the prior art between such modules is the mechanical or atmospheric stressing of the contact elements which are arranged in the connecting elements and which have been used to date to bring about a detachable, electrically conductive connection. The repeated formation of contacts with such a module results in  
10 considerable mechanical stresses for the individual contact elements, which may cause a contact element to bend, for example. If a bent contact element does not bring about the desired electrical connection, intended functions which are to be controlled by the module are  
15 not carried out. This may lead to the operating personnel or the electrical system being put at risk, or even give rise to damage to the technical system itself or else to damage to the products which are fabricated using the technical system. It is also conceivable that in a  
20 mechanically damaged contact element the electrically conductive connection is produced only sporadically so that disadvantageous effects may occur in the same way as those already previously described. In this case, an additional aggravating factor is that the fault caused by  
25 the mechanical damage to the contact element can be found only with great difficulty, since it occurs only from time to time.

Furthermore, it is conceivable that when a contact element is damaged mechanically, undesired con-  
30 tacts may also be brought about to other contact elements. The disadvantageous effects already described may also occur in this case.

However, the contact elements are put at risk not only by mechanical influences but also by atmospheric  
35 influences.

In the case of oxidations of the contact elements, the electrically conductive connection of the contact elements which are correctly in mechanical contact with one another is no longer ensured. There is  
5 either no electrically conductive connection any more at all or else only a sporadic electrically conductive connection, with the disadvantages already described above.

A particular advantage of the electronic controller according to the invention is that it becomes possible to exchange individual modules of the controller in  
10 a particularly simple way or else to add or remove individual modules of this controller. Since the individual modules do not have any contact elements via which  
15 the electrical power or the data flow is fed in, the addition of a module can be effected simply by means of the suitable spatial arrangement of this module with respect to the modules which are already present in the electronic controller of modular design. When a module is  
20 removed, it is simply taken out of the controller, and after the removal all that has to be ensured is that the remaining modules have the correct spatial arrangement. The removal and addition of modules of such a controller can thus also be carried out by untrained personnel, or  
25 personnel who have only had a small amount of training.

A further advantage for the modules of the controller according to the invention is that the modules can be encapsulated much better in their housings than has been previously the case with modules known in the  
30 prior art. Correspondingly, the modules of the controller according to the invention are distinguished by a very high degree of protection. Since the known modules have until now always had connection elements or contact elements which were in contact with the electronics  
35 contained in the module, complete encapsulation of the electronics contained in the module has been impossible until now. However, in this way the

electronics which are contained in the known module are subjected to disruptive environmental influences, for example dust or atmospheric stresses. The controller according to the invention is thus suitable in an outstanding way for use in rough industrial environments. For this reason, it is, for example, also conceivable no longer to arrange an electronic controller according to the invention in a protective switching cabinet, as in the past, but instead to arrange it directly in the spatial proximity of the equipment, system or system component which is controlled or monitored by the electronic controller. The connection of individual modules to the peripherals which are to be controlled or monitored can then be made, for example, by means of special connecting elements which can be screwed tight, for example, to the module and which thus have, for example, a similar or else the same degree of protection as the module. The controller according to the invention is thus also particularly suitable for use in automation systems with a decentralized structure.

In the course of the increasing miniaturization of the electronic components which are used in a module of such an electronic controller, it is often the case with the electronic controllers which are known in the prior art that the spatial dimensions of the individual modules are predefined to a considerable degree by the spatial dimensions of the connecting elements. In the case when, for example, a parallel bus is used, neither the minimum dimension of an individual conductor track of such a bus or the minimum distance between the individual conductor tracks of this bus must be undershot. This also results in a lower limit for the dimension of the connecting elements which are to be used, thus also defining the dimensions of the modules. Transformers which are arranged in order to transmit the power and/or the data into the modules of the controller according to the invention can also often be given smaller spatial dimensions than in comparison with the previously required

connecting elements. In this way, the spatial requirement of the individual modules, and thus overall also the spatial requirement of the electronic controller, can be reduced. In view of this, it is also advantageously possible to use a controller according to the invention decentrally in the direct proximity of the peripheries which are to be controlled or monitored. However, even with a conventional arrangement in a switching cabinet, the achievable savings of space are a considerable advantage.

The object of the invention is therefore to specify a controller of modular design, in which a power and/or data transmission between the individual modules, for example modules or peripheral equipment, takes place in a wire-free fashion.

This object is achieved for the electrical controller of modular design, according to the preamble of claim 1 in that the electrical power is fed conductively into just one module and starting from this module power is supplied to the other modules using wire-free electromagnetic means, and that the data flow is also transmitted via the same electromagnetic means. For this purpose, each module has at least one transmitter for generating an electromagnetic field, the transmitter forming a data source and/or power source, and the receiver forming a data sink and/or power sink, so that the data source and/or power source transmits data and/or power to other, in particular adjacent, module units, and that the data sink and/or power sink receives data and/or power from other, in particular adjacent, modules.

The coupling of the modules is carried out here for example in a serial structure, in a star-shaped structure or else in a ring structure. This reveals a further advantage of the electronic controller according to the invention, this being that the modules can be arranged in virtually any desired topology.

The coupling of the modules may be selected here to correspond to the advantages or disadvantages associated with the different topologies. The advantage of a serial or tree-shaped structure is the ease with which individual modules can be inserted into or removed from this structure. However, the data throughput rate drops severely if too many modules are connected. The result of a module failing is usually only that this module can no longer be addressed. In the case of a star-shaped topology, the data flow runs via a central module that passes on the data appropriately as a function of a given destination address. The advantage of such a topology is the ease with which it can be expanded and the fact that a failure of a module entails virtually no faults in the system as a whole. However, a failure of the central module leads to a total failure.

Further advantages and inventive details emerge from the following description of an exemplary embodiment, with reference to the drawings and in conjunction with the subclaims. In particular:

FIG. 1 shows an electronic controller of modular design, FIG. 2 shows modules of an electronic controller of modular design, between which power and/or data is transmitted in a wire-free fashion, FIG. 3 shows the passing on of power and data from a master module to further modules.

FIG. 1 shows a stored-program electronic controller MS of modular design. In the modular controllers known from the prior art, the passing on of electrical signals, i.e. the transmission of power and/or data, is carried out over suitable electrically conductive connections. Between the modules KM, M, AM of the modular controller MS according

to FIG. 1 there is no electrically conductive connection whatsoever. The transmission of power and/or data is carried out by means of electromagnetic fields.

For this purpose, each module, with the exception  
5 of a master module KM and a terminating module AM, has at least one data and/or power source (not illustrated in FIG. 1) and one data and/or power sink. In the case of the master module KM, from which the transmission of data and/or power originates, one data and/or power source is  
10 sufficient. In the case of the terminating module AM, in which the transmission of data and/or power ends, one data and/or power sink is sufficient. The master module KM is supplied with power from an external power source via contact elements (not illustrated in FIG. 1). In the  
15 exemplary embodiment according to FIG. 1, the firing module AM has connection elements AE for interacting with the controlled or monitored technical process. In different refinements, it is, of course, also conceivable that, in addition or as an alternative, other modules KM,  
20 MM' also have these connection elements AE.

The description is continued below with a transmission of data between a data source and a data sink. In all cases this also covers the transmission of power between a power source and a power sink. In this context,  
25 data source and power source and data sink and power sink may be the same physical elements.

FIG. 2 shows a possible way of implementing the transmission of data from a module M to the adjacent module M'. The first module M contains, as data source,  
30 a coil SP with a suitable number of turns, a U-shaped, ferromagnetic element FE being located in the coil SP. The adjacent module M' also has as data sink a coil SP' with a suitable, in this case identical number of turns,

a U-shaped, ferromagnetic element FE being again located in the coil SP'. The data source S is designated as transmitter S below, and the data sink E as receiver E. Likewise, the coil SP for the transmitter S is designated as transmitter coil SP, and the coil SP' for the receiver E is designated as receiver coil SP'.

In this context it is particularly important to state that there is no preferred direction for the transmission of the data of the electronic controller of modular design, according to the invention. Merely for reasons of clarity, the description is continued in terms of a transmission of data with a device designated as transmitter S for generating an electromagnetic field and a device designated as receiver E for detecting an electromagnetic field. Since transmitter S and receiver E are essentially of identical design, the device which is designated as transmitter S can, of course, also detect an electromagnetic field and, correspondingly, the device which is designated as receiver E can also generate an electromagnetic field. Therefore, in each case, a bidirectional transmission of power and/or data is possible, and the direction of the transmission of data can be controlled by the protocol used for the data transmission - specifically by means of control instructions which can be transmitted and identified using the protocol.

In the exemplary embodiment according to FIG. 2, transmitter S and receiver E are enclosed at least in part by a housing of the respective module M, M'. The arrangement of the module M which contains the transmitter S is selected with respect to the module M' which contains the receiver E to be such that the two modules M, M' are adjacent here and are arranged with respect to one another in such a way that one side of the module M with the transmitter S lies opposite one side of the module M' with the receiver E, so that the transmission link is thus as short as possible, as a result of which

the possible losses are also minimized. The losses can advantageously be minimized further if the parts of the housing of the modules M, M' which interrupt the magnetic circuit are themselves fabricated from a ferromagnetic material, in particular from the same ferromagnetic material from which the ferromagnetic elements FE of the respective modules M, M' are also fabricated. In a specific refinement (not illustrated in FIG. 2), the limbs, for example, of the ferromagnetic elements FE of the modules M, M' penetrate the housings of the respective modules M, M' so so that the end faces of the limbs of the ferromagnetic elements FE terminate flush with the outer contour of the housing of the respective module M, M', so that the distance between the two ferromagnetic elements FE is actually at a minimum and can only then be determined by the distance between the modules M, M'.

If current flows through the transmitter coil SP, a magnetic field is formed in the ferromagnetic core FE of the transmitter coil SP. If, as in the exemplary embodiment according to FIG. 2, the ferromagnetic cores FE of the transmitter coil SP and receiver coil SP' are arranged in such a way that they form a virtually continuous circuit, the magnetic flux density is restricted essentially to the magnetic circuit which is formed in this way. The current which flows through the transmitter coil SP thus induces a magnetic field in the magnetic circuit, which magnetic field itself in turn gives rise to an electric current in the receiver coil SP'. The current induced in the receiver coil SP' is proportional to the current flowing through the transmitter coil SP. If the receiver coil SP' and transmitter coil SP have the same number of turns and if the ferromagnetic cores FE of the respective coils SP, SP' are of the same material and if the ferromagnetic cores FE also have the same dimensions, the strength of the current which is induced in the receiver coil SP' is essentially that of the

current flowing through the transmitter coil SP. Thus, the wire-free transmission is suitable in the same way both for supplying power based on alternating current and for the wire-free transmission of signals so that, ultimately, information can also be transmitted in a wire-free fashion from one module M to the adjacent module M'.

The simultaneous transmission of power and data can take place, in one refinement of the invention which is not illustrated, by means of two transmitter coils and two ferromagnetic cores on the transmitter side which are arranged therein and two receiver coils with ferromagnetic cores at the receiver end which are respectively arranged in said receiver coils. However, a further possibility is also to use just one ferromagnetic element FE on the respective receiver and transmitter sides, two coils SPE, SPD, SPE', SPD' being provided in each case on this ferromagnetic element FE, one pair of coils SPE, SPE' for transmitting power and the other pair of coils SPD, SPD' for transmitting data. This arrangement is illustrated in FIG. 3.

It is to be noted once more at this point that the selection of designations which are as informative as possible for the individual components of the electronic controller of modular design according to the invention is not intended to specify a preferred direction for the transmission of power and/or data.

When an alternating current is transmitted with the transmitter coil SPE, a magnetic field which varies over time is thus formed in the ferromagnetic element FE, said magnetic field giving rise to an alternating current of the same frequency in the receiver coil SPE'. The data which are to be transmitted with the transmitter coil SPD also vary by necessity so that the magnetic field strength which is caused by the respective coil SPD is superimposed on the field strength caused by the transmitter coil SPE for the transmission of power.

The data are thus modulated onto the magnetic field caused by the transmission of power. By means of an appropriate filter F, the modulated data can be removed from the electromagnetic field again at the receiver end,  
5 so that data and power can also be tapped again separately at the receiver end.

FIG. 3 shows, by way of example, the passing on of power and data from a master module KM, which contains only one transmitter S in the exemplary embodiment, to a  
10 further module M, which has a receiver E which is arranged opposite the transmitter S of the master module KM, and also has its own transmitter S for passing on power and data. The power is fed to the master module KM from an external power source. The module M' which is  
15 adjacent to the first module M is illustrated only in part. It also has a receiver E which is arranged opposite the transmitter S of the first module M. If this subsequent module M' is the terminating module AM, a further transmitter S, analogous to the first module M, is not  
20 necessary. If further modules M, M' are also connected to this module M', this module M' also has a corresponding transmitter S for passing on power and data.

According to FIG. 3, the master module KM has, as component of the transmitter S, a U-shaped, ferromagnetic  
25 element FE. The module M has a corresponding ferromagnetic element FE as a component of the receiver E. The two limbs of the ferromagnetic elements FE face one another in such a way that the two U-shaped, ferromagnetic elements FE form a circular arrangement. On the basis of  
30 the U-shaped ferromagnetic elements FE, the windings of two coils SPE, SPD are mounted in each module. The first coil SPE within the master module KM is part of the circuit for the transmission of power, and the second coil SPD within the master module KM is part of the  
35 circuit for the transmission of data.

Accordingly, the first coil SPE' within the module M is part of the circuit for the supply of power of this module M and the second coil SPD' is part of the circuit for the evaluation and processing of data. This  
5 basic structure continues with further connected modules M', so that in each case the power or the data are also transmitted to further connected modules M'.

In the arrangement according to FIG. 3, the transmission of power and data takes place by means of  
10 one transmitter S and one receiver E in each case. Here, as already described, the signals with which the data are transmitted are modulated onto the signals with which the power is transmitted. In order to extract the data signals, the module M has a filter F. After the filtering,  
15 the data are available again in the form in which they were originally emitted by the transmitting module. In this form, they can then be processed by a logic system L. In the exemplary embodiment according to FIG. 3, the filter unit F and the logic unit L are  
20 integrated into an ASIC A. A conversion unit KE is also integrated into this ASIC A, said conversion unit KE being used to convert the data back into analog electrical signals so that it is possible to transmit them with the transmission elements S, E, which have already  
25 been described.

The circuit for supplying the module M with power has a capacitor C, which is connected parallel to the coil SPE' which is mounted on the ferromagnetic element FE of the receiver E, and a diode D. The diode D and  
30 capacitor C constitute a rectifier diode D with downstream buffer capacitor C in order to rectify again the alternating voltage which has been received for the supply of power. The transmission of power is usually carried out with "chopper frequencies" in the kHz range.

It should be noted once more that the transmitter S and receiver E, in which in each case the turns of one coil are applied in each case to a separate ferromagnetic element, can also be used for the transmission of power and data described above. Both modules M, M' would therefore contain two transmitters S and two receivers E, one of the elements being used for transmitting power and the other for transmitting data. In this case, the necessary filtering of the modulated data is dispensed with.

In contrast to the transmission of data by means of essentially inductive elements as described above, the transmission of data can also be carried out with essentially capacitive elements, for example, capacitors. Instead of the turns of one coil, which is applied to a ferromagnetic element FE, each module then has, for example, a plate of a plate capacitor as transmission device. The corresponding reception device in the adjacent module is the corresponding second plate of the plate capacitor. When a voltage is applied to the capacitor which is formed in this way, an electrical field is formed between the capacitor plates and can be used for the transmission of power and/or data, in a way completely analogous to the magnetic field described above.

In order to provide the possibility of implementing very different topologies, in embodiments which differ from the previously described exemplary embodiment it is also possible to arrange more than just one transmission device S or reception device E in each case in the individual modules. In addition, it is possible, for example, for the transmission of power and/or data which starts from the master module KM to take place not only in one direction but also in two directions, so that the master module KM has, for example, two data sources and/or power sources for the wire-free transmission of data and/or power. In the case of a ring-type

topology of the modules of the stored-program controller according to the invention, the master module KM also has of course a data sink and/or power sink.

## Patent claims

1. An electronic controller of modular design, in particular stored-program controller,
- the modules being supplied, in the first instance, with electrical power from a supply source, in particular a power system, and
  - a data flow being provided between the modules, characterized
  - in that the electrical power is fed conductively into just one module (KM), and starting from this module (KM) power is supplied to the other modules (M, M', AM) using wire-free electromagnetic means,
  - in that the data flow is also transmitted using the same electromagnetic means.
2. The controller as claimed in claim 1, characterized in that
- the modules (KM, M, M', AM) have at least one transmitter (S) for generating an electromagnetic field and/or a receiver (E) for detecting an electromagnetic field, the transmitter (S) forming a data source and/or power source, and the receiver (E) forming a data sink and/or power sink,
  - the data source and/or power source transmits data and/or power to other modules (M, M', AM), and the data sink and/or power sink receives data and/or power from other modules (KM, M, M').
3. The controller as claimed in claim 1 or 2, characterized in that the modules (KM, M, M', AM) are coupled in a serial structure.



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4. The controller as claimed in claim 1 or 2, characterized in that the modules (KM, M, M', AM) are coupled in a star-shaped structure.

5. A piece of electrical equipment according to one of the above claims, characterized in that the transmitter (S) and receiver (E) are enclosed at least in part by a housing, and in that the transmitter (S) and receiver (E) are spatially adjacent and are arranged with respect to one another in such a way that one side of the transmitter housing lies opposite one side of the receiver housing so that the transmission link is as short as possible.

6. A piece of electrical equipment as claimed in one of claims 1 to 5, characterized in that the electromagnetic fields are generated with essentially inductive elements, for example a coil with a ferromagnetic core.

7. A piece of electrical equipment as claimed in one of claims 1 to 5, characterized in that the electromagnetic fields are generated with essentially capacitive elements, for example a capacitor.

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