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Segmented control arrangement

The present invention is directed to a system arrangement with differential data communication for fault-tolerant and electromagnetically compatible control of a plurality of execution units. In this context, the present invention advantageously allows execution units to be controlled in such a way that, among other things, both a high so-called common-mode stability and a high fail-safety are achieved, even with a large number of execution units. Furthermore, the present invention is directed to a method for operating or manufacturing the proposed system arrangement. Furthermore, a computer program product is proposed with control instructions which execute the method or operate the device.

WO 2017/162 323 A1 shows an efficient control arrangement and a control method, wherein sequentially arranged execution units are controlled by means of a command unit.

WO 2018/103 880 A1 shows a compact light-emitting diode arrangement, which can be used generically, but is particularly advantageous for use in a vehicle due to its compact design.

WO 2017/153 026 A1 shows a method for brightness compensation in at least one light-emitting diode.

DE 20 2013 103 146 U1 shows a device system with several devices for distributed arrangement along escape routes or traffic routes.

US 2014/333 207 A1 shows a protocol for exchanging status messages in a lighting system.

US 8,492,983 B1 shows methods and systems for controlling lighting units.

DE 10 2016 125 290 A1 shows methods and a device for concatenated control and/ or programming of several integrated circuits.

US 2010/ 0188972 A1 shows a communication system with ring topology.

EP 2 663 028 A1 shows a communication system that increases fault tolerance due to a fault line.

US 2011/0309746 A1 shows a system arrangement with light-emitting diodes for use in an automobile.

DE 20 2016 008 325 U1 shows a communication system with a command unit and several control units.

US 2004/160 199 A1 shows a light arrangement with differently designed and configured light sources.

According to conventional methods, a variety of possibilities are known for addressing control units that are connected in series. There are generic approaches, which can be disadvantageous in specific application scenarios, or very special approaches, which can no longer be used generically. For example, the so-called CAN bus is known, which was developed with regard to cable harnesses and is intended in particular to implement networking of control units.

In general, the complexity of the CAN protocol is significantly greater than ISELED (registered trademark) and therefore more expensive. But the most important disadvantage of CAN and LIN is that they do not offer a natural (automatic) addressing possibility due to the bus architecture. Here the address must be configured. With ISELED (execution units) and also with the segmented ISELED (line driver unit and execution units) there is a physically given order and from this follows the one possibility to assign addresses automatically.

Various execution units are known from the prior art, which typically operate as a so-called slave or client and receive commands from a higher-level instance, which is typically referred to as the master. The execution units then implement these commands. The state of the art shows different architectures or topologies for this, how corresponding execution units together with their control units are to be arranged.

However, the state of the art has the problem that, depending on the application scenario, different requirements are made and, overall, it has to be weighed up whether an energy-efficient process with a higher susceptibility to faults is to be provided, or a process that consumes more energy but is more fault-robust. In addition, the dimensions of the intended location of such an architecture must be considered. Some arrangements are not suitable for large-area deployment and can therefore only be implemented on individual circuit boards. Other architectures, on the other hand, can be installed over a large area of several meters and consequently have to fulfill completely different requirements than system arrangements on individual circuit boards.

The state of the art also addresses the problem of electromagnetic compatibility (EMC). This can lead to interference, which can either be prevented from the outset or rectified afterwards. In addition, malfunctions can occur when individual components fail due to the effects of force or heat, resulting in consequential failures. This is a particular problem if units are connected in series and one unit receives commands from its predecessor. In the case of so-called daisy chaining, problems can arise if individual components are not switched through in the event of a failure. This means that the underlying subchain is cut off from the communication flow and consequently fails. There are also very special requirements for a system arrangement that is to be installed in an automobile. An automobile is generally a high-priced product on which the customer is always dependent. Consequently, the customer will not tolerate a high level of susceptibility to faults and, in addition, the components to be controlled are often safety-relevant. Susceptibility to faults plays an overriding role here, as the customer only wants to call on customer service in exceptional situations and the functionality of safety-critical units must also be guaranteed.

Consequently, it is a task of the present invention to provide a system arrangement for controlling execution units which is fault-tolerant in the broadest sense and can also be provided with little technical effort. With respect to fault tolerance, particular attention is paid to electromagnetic compatibility and fail-safety. Furthermore, it is an object of the present invention to propose a method for providing or operating the proposed system arrangement. Furthermore, a computer program product with control instructions is to be proposed, which executes the method and/or operates the system arrangement.

The task is solved with the features of the independent patent claims. Further advantageous embodiments are given in the subclaims.

Accordingly, a system arrangement with differential data communication is proposed for use in automobiles for fault-tolerant and electromagnetically compatible control of a plurality of execution units of the system arrangement, comprising a command unit and a plurality of line driver units, wherein the plurality of execution units is segmented into a plurality of respective serial sub-chains, wherein each sub-chain comprises at least two execution units along a first data line, and in each case one line driver unit is connected directly upstream of each subchain and exactly one subchain is connected directly downstream of each line driver unit, and differential modulation is always provided when driving the multiplicity of execution units, and the line driver units being coupled to one another in serial communication by means of a second data line, and the first line driver unit connected in series being coupled in communication to the command unit by means of the second data line, wherein each of the first data line and the second data line is an electrical data line, each of which is adapted to carry current at all times.

One of the advantages of the proposed invention is that, in order to increase system-wide fault tolerance, the proposed segmentation also enables automatic address assignment. According to the invention, the large number of execution units, each of which is preceded by only one line driver unit per segment, results in a positive ratio between the number of execution units and the number of line driver units. This allows automatic addressability, unlike CAN/LIN, with maximum fault tolerance and minimum complexity

due to the simple protocol. The serial arrangement enables automatic addressability or address assignment, so that the execution units can each be addressed by means of their own address.

The command unit sends commands as a master. A command contains for example a command, i.e. what is to be done e.g.: "set pulse width modulation PWM red channel"), and optionally a parameter (e.g. = 255) and preferably an address. This address addresses one or more execution units. The execution units have a unique address, which is automatically derived from their physical location.

Thus, it is possible to provide a method step that automatically assigns an address to each of the execution units depending on the physical arrangement of the respective execution units within the proposed system arrangement. The physical arrangement may take into account in which sub-chain the respective execution unit is arranged. This may take into account which line driver unit is upstream of the respective execution unit.

The commands are typically distributed by all line driver units to all execution units. This means that there is no need for filtering or processing in the line driver units. The execution units then decide whether or not to execute the command according to their own address and the address contained in the command. Typically, they execute the command if they themselves are addressed by means of the address.

The present invention makes it possible in an advantageous manner to control execution units in such a way that both a high so-called common-mode stability and a high reliability are achieved, even with a large number of exe-

cution units. It is also possible to use line drivers that are optimal, for example, for differential electrical physical media. Due to the segmentation, a small number of line driver units is required compared to the total number of execution units, so that it is possible to work here with more current/power consumption and higher complexity of the chip than with the execution units.

An alternative to bus solutions such as CAN/LIN is thus proposed which, among other things, solves the described problem of the lack of automatic addressing. Segmentation with the aid of line driver units, the possibility of passive switching and optimization of the physical layer (common mode and electrically differential or op-tical) now solve the problem of susceptibility to interference.

The proposed system arrangement is fault-tolerant, among other things, because the execution units are segmented and consequently arranged in partial chains. Serial sub-chains are thus created, with the individual execution units being connected in series. Thus, in the event of a failure of an execution unit, impairments occur only within the subchain in which the failing execution unit is arranged. Compared with the state of the art, this offers the advantage that a large number of further execution units connected in series do not fail, but only execution units in the same segment fail. This can also be achieved by merely switching through the execution units in the event of a failure.

The execution units are serially coupled, which is preferably bidirectional. It is thus possible for the execution units to receive commands from the line driver unit and then implement them. A command can be an instruction or a readout or a setting of a parameter. For example, the execution units can be

provided as light-emitting diode units that control individual light-emitting diodes. Light emitting diodes are typically provided as red, green and blue light emitting diodes, although a white light emitting diode may also be provided. The execution units thus implement the commands of the line driver unit and are also capable of providing a return value. Thus, it is possible that the line driver unit instructs the execution unit to read out a sensor, and by means of bidirectional communication, the execution unit can return a read-out temperature value of the sensor.

Since according to the invention there are several sub-chains or segments, a fault does not affect the entire sub-chain, as is shown in the prior art, and according to the invention also not all sub-chains, but only one (the affected) sub-chain, but rather the reliability is increased by the fact that separate and individually controllable sub-chains are formed. In a non-exhaustive enumeration, the sub-chains include at least one execution unit, with each sub-chain being preceded by a line driver unit. Also, fault tolerance is provided by the line driver units passing signals in the event of an inactive state. Passing through generally describes the passing on of signals without processing them. Consequently, no logic is implemented or processing steps are performed within the failed element. Instead, a signal that is present at an input is output again at the output without any processing.

Electromagnetic compatibility when driving a large number of execution units can be achieved, among other things, by always providing differential modulation, i.e. the line is actively driven even if no command is transmitted. This eliminates the need for a steep edge that occurs when the line driver is switched on and off. According to the invention, it is possible to implement the proposed topology in such a way that a cable connection (electrically differential) is established at least between the line driver units. Consequently,

the data line is not implemented as conventionally on a printed circuit board, but merely the individual sub-chains are arranged on a printed circuit board, and the resulting printed circuit boards can be communicatively coupled by means of a cable connection (electrically differential) via the respective line driver unit. Thus, it is particularly advantageous that the number of sub-chains therefore scales, since any number of line driver units can be connected in series and a sub-chain of execution units is communicatively arranged or coupled to each line driver unit.

In general, the number of execution units or line driver units to be operated is limited by the address space, i.e. the number of units that can be addressed. Since the address space can be selected arbitrarily, the number of units to be installed also scales.

The proposed system arrangement also provides, among other things, a command unit that ultimately controls the individual execution units. This is typically not done directly, but via the line driver units. Thus, the command unit generates commands and transmits them to the execution units via the respective line driver units or receives parameters and values from the execution units via the line driver units. Thus, the command unit represents a higher-level instance with respect to the line driver units and can consequently be referred to as a master unit. In this case, the line driver units behave as slave units or client units. Since the line driver units are connected upstream of the subchains, i.e. the execution units, and the line driver units transmit the commands to the respective subchains, the line driver units behave in this aspect like master units with respect to the execution units. The execution units then assume the role of the slave unit or client unit.

For example, the proposed system arrangement is in the form of a light-emitting diode chain. The command unit issues a specific pattern that is to be implemented by means of the individual light-emitting diodes. For this purpose, the command unit controls the individual line driver units, which then pass on the command to the respective sub-chain. The line driver units can not only pass on the command, but also adapt the command independently. The individual execution units ultimately implement the command and control individual LEDs, for example. These may again be the red, green and blue light-emitting diodes, although a white light-emitting diode may also optionally be provided. The execution units can also be other actuators such as motors, matrix LEDs, sensors, temperature sensors, light sensors or buttons.

The first data line is the data line which forms partial chains. Thus, the first data line connects the individual execution units and connects this chain of execution units to exactly one line driver unit. Thus, the data line first comprises a line driver unit, to which an execution unit is connected. Optionally, further execution units are serially connected to this execution unit. There is again no restriction on the number of execution units, but only the underlying address space is selected accordingly. The address space does not have to be completely exhausted, but rather the address space merely represents an upper limit for the number of execution units to be installed.

The second data line connects the line driver units to each other serially and preferably bidirectionally. As the first unit, the command unit is connected to the second data line, and then at least one line driver unit follows.

Since the individual sub-chains have their own data line, the first data line can be said to be of a data line according to a first type. In general, there are

as many first data lines as there are sub-chains. If, for example, there are three sub-chains, exactly three line driver units are installed and three sub-chains are formed, with a data line of the first type being present within each sub-chain. Consequently, there are exactly three first data lines in this case. The distinction between first and second data lines makes it possible to design the respective first data lines differently from the second data line, which is typically present only once. Thus, the first data line can be arranged on a printed circuit board in each case and the second data line can be present as a cable, for example. This results in a particularly advantageous flexible structure, which is particularly suited to the application scenario in the automobile.

According to one aspect of the present invention, the line driver unit upstream of a sub-chain acts as a master unit for the at least one execution unit of that sub-chain, and the at least one execution unit acts as a slave unit with respect to that line driver unit. This has the advantage that the execution units can receive commands from the line driver unit and the commands are then passed through or executed by the execution units. Thus, the line driver unit provides a command that is passed through the sub-chain and is executed and passed on by each execution unit. Furthermore, it is also possible to address a single execution unit by means of an address, so that the corresponding command is addressed by the line driver unit to this one specific execution unit through the chain. Once the command has been executed, it is also possible to transmit a result from the respective execution unit back to the preceding execution unit and then provide the final result to the line driver unit. For this case, bidirectional communication within the subchain is advantageous. The command is advantageously issued by the command unit and passed on to the execution units via the line driver units, typically unchanged.

According to another aspect of the present invention, the command unit acts as a master unit for the line driver units, and the line driver units act as a slave unit with respect to the command unit. This has the advantage that a single command or sequence of commands can be created by the command unit and transmitted to the line driver units. The line driver units thus receive this command or these commands and, if necessary, forward them unchanged or adapted to the execution units. Here, too, it is possible for the line driver units to be addressed individually by means of an address and, if necessary, also to output return values to the command unit.

According to another aspect of the present invention, the first data line and/or the second data line are bidirectional. This has the advantage that commands or signals are transmitted in both directions, and consequently both the execution units can transmit return values to the line driver units and the line driver units can transmit signals to the command unit. In particular, the individual units can communicate with each other. Preferably, both data lines are bidirectional, although it is also possible for only the first data line to be bidirectional, or for the second data line to be bidirectional. Since there are several data lines of the first type, it is also possible that the individual first data lines are designed differently. Typically, however, all first data lines are configured in the same way.

According to another aspect of the present invention, signals on the second data line are modulated with a larger amplitude than signals on the first data line. This has the advantage that greater distances can be traversed without error by means of the second data line. A higher amplitude makes the distinction between zero and one clearer, so the signal modulation is less error-prone. Thus it is possible to implement the first data line on a printed circuit

board and to implement the second data line by means of a cable line, which is then also modulated accordingly with a larger amplitude due to the greater distance.

According to another aspect of the present invention, signals on the second data line are modulated with an amplitude 10 times greater than signals on the first data line. This has the advantage that, surprisingly, this value is particularly advantageous and the signals on the first data line can be modulated particularly efficiently and the signals on the second data line are modulated less efficiently but are much more error robust. Surprisingly, it was recognized in accordance with the invention that precisely the proposed value is particularly suitable for defining the ratio of the amplitude of the second data line to the first data line.

According to another aspect of the present invention, the first data line and/or the second data line is a electrical data line. This has the advantage that several options can be provided, which in turn can be selected depending on the application scenario. According to the invention, an electrical data line is preferably implemented.

According to another aspect of the present invention, the first data line and/or the second data line is an electrical data line which always carries current. This has the advantage that differential transmission is always possible, and consequently there is no disadvantage of a particularly steep edge while current is applied. Rather, there is always a current present and settling is prevented. Thus, the proposed method is also insensitive with respect to electromagnetic interference. Furthermore, it is advantageous to choose such an embodiment because a cable connection can be implemented which has to overcome larger distances of several meters.

According to a further aspect of the present invention, a line driver unit together with a sub-chain is arranged on a separate printed circuit board. This offers the advantage that the line driver units together with the execution units and the respective first data line can be optimized for short distances and consequently can also be arranged on a single printed circuit board. This also reduces the susceptibility to faults, since the execution units are segmented and individual sub-chains are addressed separately by means of printed circuit boards.

According to a further aspect of the present invention, the line driver units are each configured such that signals on the second data line are passed through the respective line driver unit when the line driver unit is in an inactive state. This offers the advantage that if one line driver unit fails, the other line driver units connected in series can still receive commands and also send signals back. Thus, the defective line driver unit is merely blanked and corresponding signals are passively routed through. Consequently, no processing of signals takes place in the defective line driver unit, although this line driver unit also does not interrupt the further chain. It is therefore advantageous that, in the case of a defective line driver unit, only one subchain of several subchains fails.

According to a further aspect of the present invention, the execution units are each configured as a light-emitting diode, a motor, a sensor, a temperature sensor, a light sensor, a pushbutton or a switch. This has the advantage that different execution units can be provided, with a light emitting diode being particularly preferred according to the present invention. The light-emitting diode can in turn have individual units that emit red, green or blue. In general, however, it is also possible to mix the individual execution units in such

a way that, for example, light-emitting diodes are present and, within the same chain, sensors are also present. Furthermore, one sub-chain can be formed of light-emitting diodes and another sub-chain of sensors. Preferably, however, all execution units are of the same design.

According to another aspect of the present invention, the execution units are arranged to provide at least one piece of status information to the line driver unit. This has the advantage that the line driver unit can instruct that a certain value is read out, and then this instruction is passed through the partial chain to the addressed execution unit and this execution unit returns the requested value again via the other execution units. Bidirectional communication is particularly advantageous here.

The task is also solved by a method with differential data communication for use in automobiles for fault-tolerant and electromagnetically compatible control of a plurality of execution units, comprising provision of a command unit and a plurality of line driver units, wherein the plurality of execution units is segmented into a plurality of respective serial sub-chains, wherein each sub-chain comprises at least two execution units along a first data line, and in each case one line driver unit is connected directly upstream of each subchain and exactly one subchain is connected directly downstream of each line driver unit, and in which, when driving the plurality of execution units , differential modulation is always provided and the line driver units are coupled to one another in serial communication by means of a second data line, and the first line driver unit connected in series is coupled in communication to the command unit by means of the second data line, wherein the first data line and the second data line are provided as one electrical data line each, each of which always carries current.

The task is also solved by a computer program product with control instructions that execute the method or operate the proposed system arrangement.

According to the invention, it is particularly advantageous that the system arrangement provides structural features which functionally correspond to the process steps. Furthermore, method steps are proposed which can also be structurally replicated by the system arrangement with respect to the corresponding functionality. Thus, the method serves to operate the system arrangement and the system arrangement can execute the proposed method.

Further advantageous embodiments are explained in more detail with reference to the accompanying figures. They show:

Fig. 1: A subchain comprising a microcontroller and a plurality of prior art light emitting diode units connected in series;

Figs. 2A, 2B: a modulation of data as an example of application of the present invention;

Fig. 3: the proposed system arrangement in a block diagram relating to an aspect of the present invention; and

Fig. 4:A flowchart according to the proposed method for fault-tolerant and electromagnetically compatible control of a plurality of execution units according to an aspect of the present invention.

Fig. 1 shows a microcontroller on the left side, which acts as a command unit, for example. In addition, several execution units are arranged by means of bidirectional communication, which are implemented here as LED controllers. This is shown by the reference sign MLED CTRL. With regard to some application scenarios, the state of the art has the disadvantage that with the failure of one controller, all other controllers connected in series also fail because communication is prevented.

Fig. 1 shows a possible design of a system or communication arrangement according to the state of the art. On the left side, the command unit is visible, which is connected to three control units. Since the three control units are connected in series, the command unit is directly connected to one control unit and indirectly connected to the other control units. The control units may be so-called multi-LED controllers. This is shown in the present Fig. 1 as MLED CTRL. The uniform reference sign is intended to make it clear in particular that the control units are typically of the same design. As can be seen, the light-emitting diodes are RGB (red, green, blue) light-emitting diodes. These are set up to adjust a specific color value by means of a mixing ratio of the individual light emitting diode units. Furthermore, it is apparent from the present figure that further components are to be provided as required. For example, it may be necessary to provide a power supply. However, it is also possible here to provide these components, for example the power supply, externally and merely connect them.

The data line is present as a plurality of data line segments, which are drawn as bidirectional arrows SIO1, SIO2. Control units can also be referred to as execution units. The MLED controller can also be referred to as an ISELED controller, as it can be used as an execution unit according to the invention.

Fig. 2A shows a modulation of data, where only in the active phase when commands are transmitted the data lines are differentially modulated. In the inactive phase, when no commands are transmitted, the current on both lines is switched off and both lines "fall" to a non-differential potential, which is typically assigned by a termination. At the transition from active phase (differential with high current consumption) to inactive phase (non-differential, no current consumption) there is a steep edge. In addition, a clocking is indicated by means of the vertical lines, which is used to read semantics from the signal. Preferably, the signal is read out within the clocking if the amplitude is maximally exhausted in order to achieve error robustness. The data shown can be synchronization data on the left side and a command on the right side.

In general, the dimensions and contents of Figs. 2A and 2B are merely exemplary and schematic. Other modifications may also be present.

Fig. 2A shows a disadvantage in the prior art, namely the steep slope on the left side, which is not electromagnetically compatible. Thus, such modulation is not very suitable for a cable connection. This modulation is suitable for a printed circuit board, which is why only the first data line can be transmitted in this way according to the invention. This is the case because a short connection prevails here and shielding is possible.

Fig. 2B shows a superimposed signal and consequently shows two characteristic curves. In contrast to figure 2A, the data line is always actively driven. The transmission of the command is done with a sequence of bits which are differentially modulated as in figure 2A. In contrast to Figure 2A, the data lines are not turned off after the command is transmitted and continue to transmit a differential idle pattern. This is an aspect of data modulation that can also be used according to the invention. It is particularly advantageous

that, according to the invention, without adaptation of the transmitter on the receiver side, not only is sampling avoided at such unfavorable times, i.e. when a signal strength is close to the threshold value, but sampling takes place at just maximum amplitude. This guarantees a sufficient distance of the signal strength from the threshold value at a measuring time, i.e. the sampling time. The sampling time is arranged temporally within a bit width, which determines within which time span the respective bit to be transmitted is coded. Thus the sampling time is to be selected in each case within this bit width and reads out in each case a bit allocation. The individual bit widths, which divide the serial bit data stream into individual bits, are typically equidistant in time. An idle pattern is also called an idle pattern.

Samples typically performed may involve sampling times at the temporal midpoint of a bit width. For example, when changing from a coded zero to a coded one, the signal strength increases towards the beginning of the bit width, reaches its maximum approximately in the middle of the bit width, and drops thereafter if a zero is to be coded subsequently. Thus, the center of a bit width can be selected as a reference point of a suitable sampling time point.

Fig. 3 shows the proposed structure of a system arrangement, where the command unit BE is present as a microcontroller. This command unit BE is communicatively coupled to a plurality of line driver units LTE. The command unit BE is connected to the serially connected line driver units LTE by means of the second data line. For this purpose, each line driver unit LTE has three interfaces, namely interfaces A, B and C. As shown, a line driver unit LTE communicates with a sub-chain of execution units AE. These execution units AE are also connected in series and communicate by means of the first data line.

As also shown, several sub-chains are present, each sub-chain comprising a line driver unit LTE and at least one execution unit AE. Thus, several data lines of the first type are also present, with only three sub-chains, i.e. three first data lines, being drawn.

The proposed system scales, which is characterized by the fact that points are drawn between the second partial chain and the third partial chain. These points make clear that here several partial chains can be present in indefinite number. The number is limited only by the address space. In the lower right corner of the present Fig. 3 it is shown that different numbers of execution units AE can be provided, which is also indicated by dots. Here, too, the address space is decisive for the number of execution units AE.

In the present Fig. 3, the respective first data line is drawn horizontally and the second data line is drawn vertically. The second data line also refers to the connection between command unit BE and the plurality of line driver units LTE. Overall, the horizontal sub-chains can be arranged on a printed circuit board respectively, while a cable connection can be implemented between the vertical connection. Thus, longer distances of several meters can be covered vertically. Vertical and horizontal in the present context refers only to the figure, whereby the skilled person will recognize that the actual implementation is carried out as required.

Fig. 4 shows a schematic diagram of a method with differential data communication for use in an automobile for fault-tolerant and electromagnetically compatible control of a plurality of execution units AE, having a command unit BE provided 100 and a plurality of line driver units LTE, the plurality of execution units AE being segmented into a plurality of respective serial sub-

chains, each sub-chain having at least two execution units AE along a first data line, 101 and in each case a line driver unit LTE being connected directly upstream of each subchain 102 and exactly one subchain being connected directly downstream of each line driver unit LTE, and differential modulation always being provided when driving the plurality of execution units AE, and the line driver units LTE being communicatively coupled to one another in series by means of a second data line 103 and the first line driver unit LTE connected in series being communicatively coupled to the command unit BE by means of the second data line 104, wherein the first data line and the second data line are provided as one electrical data line each, each of which always carries current.

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1. A system arrangement with differential data communication for use in automobiles for fault-tolerant and electromagnetically compatible control of a plurality of execution units (AE) of the system arrangement, comprising:
   - a command unit (BE) and a plurality of line driver units (LTE), wherein
   - the plurality of execution units (AE) is segmented into a plurality of respective serial sub-chains, each sub-chain having at least two execution units (AE) along a first data line, and in each case one line driver unit (LTE) is connected directly upstream of each sub-chain and exactly one sub-chain is connected directly downstream of each line driver unit (LTE), and differential modulation is always provided when driving the plurality of execution units (AE); and
   - the line driver units (LTE) are communicatively coupled in series with one another by means of a second data line, and the first line driver unit (LTE) connected in series is communicatively coupled to the command unit (BE) by means of the second data line, the first data line and the second data line in each case being an electrical data line which is in each case set up to always carry current.

2. The system arrangement according to claim 1, characterized in that the line driver unit (LTE) connected upstream of a subchain is set up to act as a master unit for the at least one execution unit (AE) of this subchain, and the at least one execution unit (AE) is set up to act as a slave unit with respect to this line driver unit (LTE).

3. The system arrangement according to claim 1 or 2, characterized in that the command unit (BE) for the line driver units (LTE) is arranged to act as a master unit and the line driver units (LTE) are arranged to act as a slave unit with respect to the command unit (BE).

4. The system arrangement according to any of the preceding claims, characterized in that the first data line and the second data line are bi-directional.

5. The system arrangement according to any one of the preceding claims, characterized in that the system arrangement is arranged such that signals on the second data line are modulated with a larger amplitude than signals on the first data line.

6. The system arrangement according to any one of the preceding claims, characterized in that the system arrangement is arranged such that signals on the second data line are modulated with an amplitude 10 times greater than signals on the first data line.

7. The system arrangement according to one of the preceding claims, characterized in that in each case a line driver unit (LTE) together with a subchain is arranged on its own printed circuit board.

8. The system arrangement according to one of the preceding claims, characterized in that the execution units (AE) are each configured as a light-emitting diode, motor, sensor, temperature sensor, light sensor, button or switch.

9. The system arrangement according to any of the preceding claims, characterized in that the execution units (AE) are arranged to provide at least one status information to the line driver units (LTE).

10. A method with differential data communication for use in automobiles for fault-tolerant and electromagnetically compatible control of a plurality of execution units (AE), comprising:
- Providing (100) a command unit (BE) and a plurality of line driver units (LTE), wherein.
- the plurality of execution units (AE) is segmented (101) into a plurality of respective serial sub-chains, each sub-chain having at least two execution units (AE) along a first data line, and in each case one line driver unit (LTE) is connected directly upstream (102) of each sub-chain and exactly one sub-chain is connected directly downstream of each line driver unit (LTE), and differential modulation is always provided when driving the plurality of execution units (AE); and
- the line driver units (LTE) are serially communicatively coupled (103) to each other by means of a second data line, and the first series-connected line driver unit (LTE) is communicatively coupled (104) to the command unit (BE) by means of the second data line, wherein the first data line and the second data line are provided as a respective electrical data line, each of which always carries current.

11. A computer program product comprising control instructions which perform the method of claim 10 when caused to execute on a computer.

Abstract

The present invention is directed to a system arrangement for fault-tolerant and electromagnetically compatible control of a plurality of execution units. In this context, the present invention advantageously allows to control execution units in such a way that a high so-called common-mode stability is achieved as well as a high reliability even with a large number of execution units. Furthermore, the present invention is directed to a method for operating or manufacturing the proposed system arrangement. Furthermore, a computer program product is proposed with control instructions which execute the method or operate the device.

Figure 3