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(54) **Method and apparatus for communicating on a lighting control bus**

(57) A method, a controller device and a computer program are provided for transmitting forward frames (601, 602, 701, 704, 709, 801, 805, 1201, 1205) from a controller of a first kind (400) on a lighting control bus (402) to which also controllers of a second kind (404) are allowed to be coupled. After transmitting a first forward

frame (701, 801, 1201) on the lighting control bus (402) the controller of first kind (400) waits for a delay (703, 708, 804) that is longer than a predefined longest settling time between frames applied by said controllers of second kind (404), before transmitting a second forward frame (704, 709, 805).

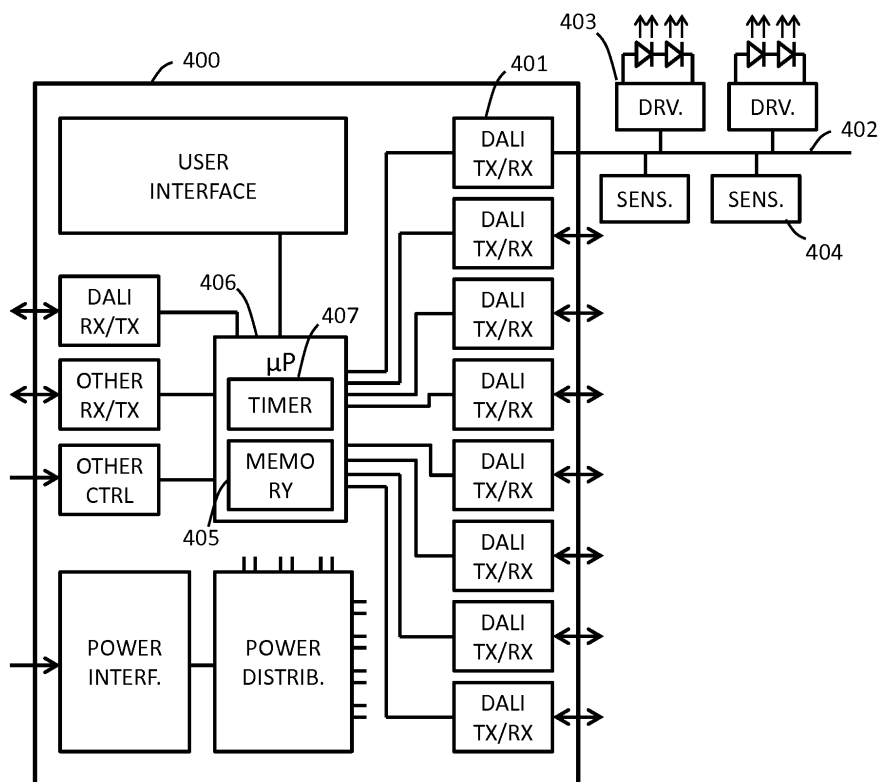


Fig. 4

Description

FIELD OF THE INVENTION

[0001] The invention concerns the field of sending and receiving messages on a bus used to control lighting devices. Especially the invention concerns a method and a device that enable reliable communications on a bus of said kind to which master devices of different capabilities have been connected.

BACKGROUND

[0002] Digital buses are known that can be used to control lighting devices. As an example, the IEC (International Electrotechnical Commission) standard number 62386 defines the DALI (Digital Addressable Lighting Interface) bus. The physical transmission medium of a DALI bus consists of two wires, and digital messages are transmitted on the bus in the form of bit sequences represented by voltage changes between higher and lower levels.

[0003] Access control that defines how the connected devices are allowed to use the bus for transmission differs depending on whether there is only one master device or where there are several master devices connected to the same DALI loop. A master device is one that is allowed to transmit on the bus spontaneously, while a slave device is only allowed to respond to queries from masters. The simplest DALI-controlled system has only one master, which is thus only required to operate in the so-called Single Central Master mode. If there are multiple masters, they are all assumed to operate in the Multi Master mode, which involves collision detection and avoidance as explained in the following with reference to figs. 1, 2, and 3.

[0004] Fig. 1 illustrates two consecutive forward frames 101 and 102, each followed by the corresponding stop bits. The time 103 between the end of the previous frame (excluding stop bits) and the beginning of the next frame is called the settling time. Its length depends on the priority of the message that the device transmitting in the latter frame 102 wants to transmit. The DALI standard defines a settling time of 12 milliseconds for the highest priority (priority 0) messages. The settling times become longer in steps of one millisecond with decreasing priority, so that the settling time for the lowest priority (priority 4) messages is 16 milliseconds. Fig. 2 illustrates how the beginning of the settling time coincides with the last voltage transition in the frame: if the final bit in the frame is a logic one, the voltage transition occurs in the middle of the bit period like in the left part of fig. 2. A logic zero as the final bit causes the last voltage transition to occur at the very end of the bit period like in the right part of fig. 2. The settling time between a forward frame carrying a query and a backward frame carrying a response thereto is shorter than any settling time between two consecutive forward frames.

[0005] Fig. 3 illustrates a collision detection method, which relies on the way in which signals are transmitted on the DALI bus. The DALI bus is normally held at the higher voltage, but a transmitting device may briefly short the two wires, drawing the bus to the lower voltage level. The lower voltage is the dominant state, meaning that of simultaneous states the lower voltage will prevail. A transmitting device operating in Multi Master mode may test the DALI bus eight microseconds before drawing the bus to the lower voltage level, and in the middle of each higher level bit. The arrows in fig. 3 illustrate the testing moments. If any test shows that the bus is actually not in the higher-voltage state, it means that some other device is transmitting a lower-level bit at the same time. Such a discovery causes the device which made it abort the current transmission attempt.

[0006] Problems may occur, however, if devices that operate in the Multi Master mode are connected to a DALI loop that already has a Single Central Master. The last-mentioned is not capable of collision detection; typically the transmission routine of a Single Central Master is a relatively simple one driven by just timer-based interrupts in the processor. Additionally a Single Central Master typically transmits very frequently, both to monitor the system and to resend information in case it was not received correctly the first time round. The Multi Masters may be for example presence sensors, in which case the frequent transmissions from the Single Central Master without collision detection increase the risk that the detection results from the sensors will only be reacted upon after considerable delays. The incapability of the Single Central Master to detect collisions may also lead to numerous incidents where the Single Central Master starts transmitting although one of the Multi Masters is transmitting already, which causes corruption of messages and generally unreliable operation of the lighting control bus.

SUMMARY

[0007] It is an objective of the present invention to provide a method and devices for arranging the communications on a digital lighting control bus so that master devices with different capabilities can co-exist along and communicate through the same bus without unnecessarily many collisions between their transmissions.

[0008] The objectives of the invention are reached with a method, control devices, and computer programs as defined by the respective independent claims.

[0009] According to an example embodiment, a method is provided for transmitting forward frames from a controller of a first kind on a lighting control bus to which also controllers of a second kind are allowed to be coupled. The method comprises, in the following order:

- transmitting a first forward frame on the lighting control bus,

- waiting for a delay that is longer than a predefined longest settling time between frames applied by said controllers of second kind, and
- transmitting a second forward frame on the lighting control bus.

[0010] According to another example embodiment, a controller device is provided for transmitting forward frames on a lighting control bus to which also controllers of another kind are allowed to be coupled. The controller device comprises a timer configured to trigger transmissions of said forward frames, wherein after the transmission of a first forward frame on the lighting control bus said timer is configured to trigger after a delay that is longer than a predefined longest settling time between frames applied by said controllers of the other kind.

[0011] According to yet another example embodiment, a computer program is provided for transmitting forward frames from a controller of a first kind on a lighting control bus to which also controllers of a second kind are allowed to be coupled. The computer program comprises machine-readable instructions stored on a non-transitory medium that, when executed by a processor, cause the implementation of

- transmitting a first forward frame on the lighting control bus,
- waiting for a delay that is longer than a predefined longest settling time between frames applied by said controllers of second kind, and
- transmitting a second forward frame on the lighting control bus.

[0012] The computer program may be embodied on a volatile or a non-volatile computer-readable record medium, for example as a computer program product comprising at least one computer readable non-transitory medium having program code stored thereon, the program code, which when executed by an apparatus, causes the apparatus at least to perform the operations described hereinbefore for the computer program in accordance with an example embodiment.

[0013] The exemplifying embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" and its derivatives are used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features described hereinafter are mutually freely combinable unless explicitly stated otherwise.

[0014] The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof,

will be best understood from the following detailed description of specific embodiments when read in connection with the accompanying drawings.

5 BRIEF DESCRIPTION OF DRAWINGS

[0015]

10 Fig. 1 illustrates two transmission frames on a DALI bus,

fig. 2 illustrates measuring a settling time from the last bit of a frame,

15 fig. 3 illustrates tests made on a DALI bus to detect collisions,

fig. 4 illustrates an example of a subnet controller device acting as a central controller,

20 fig. 5 illustrates an exemplary interface for connecting to a digital lighting control bus,

fig. 6 illustrates a prolonged settling time,

25 fig. 7 illustrates an example of transmitted forward frames,

fig. 8 illustrates an example of transmitted forward and backward frames,

30 fig. 9 illustrates a state diagram of a central controller,

35 fig. 10 illustrates a state diagram of a distributed controller,

fig. 11 illustrates a state diagram of another central controller, and

40 fig. 12 illustrates an example of transmitted forward frames.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

45 **[0016]** Fig. 4 illustrates schematically a controller device 400 for transmitting forward frames on a lighting control bus to which also controllers of another kind are allowed to be coupled. In particular, we may assume that the controller device 400 is a so-called subnet controller, the purpose of which is to control load devices coupled to the multitude (here: up to eight) of parallel DALI channels for which there are interfaces in the subnet controller. In a basic configuration the ballasts and drivers in said parallel DALI channels are not supposed to be individually addressed, which is very advantageous in many applications; for example it reduces commissioning and maintenance cost, as any faulty or outdated load devices

can be simply replaced. A known general example of the concept of a controller device is the 8-Subnet DALI Controller 478 available from the Lighting Controls division of the company Helvar in the United Kingdom.

[0017] Each DALI channel comprises a DALI transceiver interface, of which the interface 401 is shown as an example. The lighting control bus, here obviously a DALI bus 402, forming the communications backbone in that channel is shown schematically as a line coupled to the interface 401. If only load devices, such as LED drivers 403, are coupled to the DALI bus 402, the controller device 400 may operate as a Single Central Master without having to worry about collisions, because the load devices operate in the slave mode and consequently only transmit on the DALI bus 402 when asked to do so by the controller device. For the purpose of generality we may call the controller device 400 a controller of a first kind. The concepts of forward and backward frames are used here in the same sense as in the standards that define the DALI: a forward frame is one transmitted from a controlling device, containing light level information or a command, while a backward frame is a response transmitted by a device that received a forward frame containing a query or a write memory command.

[0018] Fig. 5 illustrates schematically a DALI transceiver interface. The two wires that constitute the physical transmission medium are coupled to the nodes 501 and 502 on the right. A full wave rectifier 503 couples them to a DALI reception block 504 and a DALI transmission block 505, of which the former essentially comprises a phototransmitter and the latter a photoreceiver. They implement galvanic isolation from the processor side, on which a phototransceiver block 506 is configured to convert light impulses from the phototransmitter into electric impulses to the processor 507. The phototransceiver block 506 is also configured to convert electric impulses from the processor 507 into light impulses that the photoreceiver in the DALI transmission block 505 will use to control a switch that couples the two wires of the DALI bus together. A DALI transceiver interface may also comprise a bus voltage connection for providing the two wires with their default potential difference, also known as the loop power. A bus voltage connection is not shown in fig. 5 to maintain graphical clarity, but a controller device 400 of the kind shown schematically in fig. 4 would typically have one for each output channel.

[0019] If galvanic isolation between the processor and the DALI bus is not required, the voltage variations occurring between the two wires of the DALI bus (or a rectified version thereof) can be coupled even directly to a receiving input of the processor. Similarly a transmitting output of the processor may be even directly coupled to the two wires of the DALI bus, or there may be only a simple voltage-converting buffer therebetween. Yet other forms of interfaces that are applicable in the general framework of the invention comprise e.g. wireless interfaces, in which the transmission and reception of signals take place wirelessly over what essentially takes the role

of a lighting control bus. In this sense the concept of a "bus" can be extended to cover also wireless interfaces; wireless transmissions on a particular frequency (and/or possibly using a particular spread spectrum scheme) can basically be received by all other devices that are within range and capable of operating on the same frequency and/or the same spread spectrum scheme, so they can be thought to pass through a "bus" that links all such devices together. Similarly to a bus, a medium access protocol is needed in such a wireless interface in order to keep the participating devices from making simultaneous or overlapping transmissions that would collide with each other.

[0020] The risk of collisions on the DALI bus 402 increases if there are also controller devices of another kind coupled to it. As examples of such other controllers of other kind (or: controllers of a second kind) we may assume that there are sensors 404 coupled to the DALI bus 402. We assume that the sensors 404 are basically configured to operate as Multi Masters, which means that they are capable of executing the access priority and collision detection routines predefined for use on the DALI bus 402.

[0021] An obvious way to adapt the operation of the controller device 400 to avoid collisions would be to program it to operate as a Multi Master. However, Multi Master type operation of the kind described earlier in this text requires extensive real time capability, which in this case should be accomplished in eight parallel channels independently of each other. Simultaneously the component costs and complicatedness of programming should be kept at a reasonable level, and the solution for collision avoidance should not contradict the existing standards (here: the DALI standard) of the lighting control bus.

[0022] Fig. 6 illustrates a principle of a method for transmitting forward frames from a controller of a first kind, such as the controller device 400 in fig. 4, on a lighting control bus to which also controllers of a second kind are allowed to be coupled. In the framework of fig. 4 the controllers of second kind would be the sensors 404 or other devices that can be coupled to the DALI bus 402 and that may operate as masters, i.e. transmit on the DALI bus 402 without having to be queried by the controller device. In fig. 6 we assume, in conformity with fig. 1 earlier and also in conformity with the DALI standard, that there are predefined settling times between frames applied by the controllers of second kind. In particular, in fig. 6 we assume that there are five settling times of predefined lengths defined for the controllers that operate as Multi Masters. The lengths of these predefined settling times are associated with transmission priority, so that the settling time for the highest priority (Priority 0) is the shortest, and the settling time for the lowest priority (Priority 4) is the longest.

[0023] The method illustrated in fig. 6 comprises transmitting a first forward frame 601 at a moment of time 603, and then waiting for a delay that is longer than the predefined longest settling time between frames applied by

the controllers of second kind. Only thereafter the second forward frame 602 is transmitted at a moment of time 604. In other words, if there was a controller of the second kind wishing to transmit a forward frame with any priority, it would have time to do so before the controller of the first kind begun transmitting the second forward frame 602.

[0024] On the other hand, the method involves transmitting a forward frame from a controller of the second kind only as a response to first having observed the transmission of a preceding forward frame on the lighting control bus. Each forward frame is transmitted from the controller of second kind after a predefined settling time has passed since the end of the preceding forward frame. The requirement of first observing a preceding forward frame does not, however, mean that the controllers of second kind (i.e. the Multi Masters) would operate in slave mode concerning their communications on the lighting control bus. The forward frame that a controller of second kind transmits is a true forward frame: it does not need to have anything to do with the contents of the preceding forward frame, and particularly it does not need to be a response to a query or command that was carried in the preceding forward frame.

[0025] Fig. 7 shows a simple practical example. The timeline marked SCM illustrates forward frames transmitted by a Single Central Master, or a controller of first kind, whereas the timeline marked MM illustrates forward frames transmitted by a Multi Master, or a controller of second kind. A first forward frame 701 is transmitted by the controller of first kind at a moment of time 702. After that the controller of first kind waits for a delay 703 that is longer than a predefined longest settling time between frames that is applied by the controllers of second kind, before transmitting a second forward frame 704. In this simplified graphical representation all delays are shown as beginning at the very end of the rectangular block that represents a frame with possible stop bits; in practice all delays would be measured in accordance with the appropriate standard, for example in the way illustrated in fig. 2 above for the DALI standard.

[0026] At moment 705 the controller of second kind comes up with a message that should be transmitted on the lighting control bus in the form of a forward frame. It cannot begin transmitting right away, because access to the bus is currently reserved by the controller of first kind. However, the second forward frame 704 transmitted by the controller of first kind serves in this case as the preceding frame for the controller of second kind: as a response to having observed the transmission of this preceding forward frame on the lighting control bus, the controller of second kind transmits its own forward frame 706 after a predefined settling time 707 has passed since the end of the preceding forward frame 704. It is possible that the controller of second kind selected the predefined settling time 707 among a number of predefined settling times in accordance with a priority of the forward frame 706 to be transmitted.

[0027] We may then briefly neglect the actual first forward frame 701 as it was introduced above, and call the frame 704 a first forward frame, assuming that the controller of first kind has then also a second forward frame to transmit. Although the controller of first kind does not have the sophisticated collision detection capabilities of a Multi Master, it is capable of detecting whether any of the controllers of second kind transmitted a forward frame at the expiry of a predefined settling time after the controller of first kind transmitted the first forward frame. In this case the controller of second kind did transmit the forward frame 706 after the predefined settling time 707. As a response to detecting this, the controller of first kind again waits - after the transmission of the forward frame 706 from the controller of second kind has ended - for a delay 708 that is longer than the predefined longest settling time between frames applied by the controllers of second kind, before transmitting what is now called the second forward frame 709. The delay 708 is preferably equal to the delay 703, so the time to wait after the transmission of the immediately previous forward frame on the bus has ended is the same regardless of whether said immediately previous forward frame came from the controller of first kind itself or some controller of second kind. Such an arrangement simplifies the operation of the timer in the Single Central Master.

[0028] Fig. 8 illustrates another example situation, this time with two Multi Masters (in general: controllers of the second kind) coupled to the same lighting control bus as the Single Central Master (controller of the first kind). We also assume that in this case at least some addressing is used on the bus, so that the Single Central Master can send queries and/or commands to individual other devices on the bus using an addressing scheme to indicate that other device or those other devices to which the query or command is destined. In fig. 8 the first frame 801 that the Single Central Master transmits contains a query to the first Multi Master (MM1), which responds by transmitting a backward frame 802 after a delay 803. In the DALI standard, which is used here as an example of a standard of a lighting control bus, the delay 803 between a forward frame that carried a query and the backward frame that carries a response to the query is shorter than any delay between two forward frames on the bus.

[0029] Following the principle mentioned earlier of keeping all inter-frame delays measured by the timer in the Single Central Master the same, the Single Central Master waits for a delay 804 (equal to the delays 703 and 708 above in fig. 7) before it sends the next forward frame 805. Meanwhile, at moments 806 and 807 respectively, both the first and second Multi Masters have independently come up with messages to be transmitted in forward frames. Also following the principles already described, the Multi Masters are not allowed to begin transmitting before they notice the transmission of a preceding forward frame from the Single Central Master. We also assume that the messages that the Multi Masters came up with at moments 806 and 807 respectively have different

priorities, with the priority in the second Multi Master (MM2) being higher.

[0030] As a response to having observed the transmission of a preceding forward frame 805 from the Single Central Master, any of the first and second Multi Masters could transmit its forward frame. Each Multi Master has selected its respective predefined settling time among a number of predefined settling times in accordance with a priority of the forward frame to be transmitted. The settling time 808 selected by the second Multi Master is shorter, so it transmits the forward frame 809 after the predefined settling time 808 has passed since the end of the preceding forward frame 805. The dashed rectangle shows the place on the timeline at which the first Multi Master would have transmitted its forward frame. However, the first Multi Master applies collision detection: before actively pulling the lighting control bus to a prevailing state at the beginning of a transmission, it tests whether the bus is already in the prevailing state. It is very much likely that it is, because the second Multi Master is already transmitting. As a response to detecting this in the collision detection test the first Multi Master aborts its current or intended transmission of forward frame and waits for another transmission opportunity.

[0031] The next transmission opportunity comes after the predefined settling time 810 (which the first Multi Master had selected based on a lower priority than what the second Multi Master selected for forward frame 809) has passed since the end of the forward frame 809, which thus now represents the concept "preceding forward frame". The first Multi Master transmits its forward frame 811, after which the bus is idle until the Single Central Master again transmits a forward frame at some later moment of time (not shown in fig. 8).

[0032] If the second Multi Master had a more complicated transaction to perform on the lighting control bus, requiring it to transmit more than one forward frame, the first Multi Master could have to wait longer for a transmission turn of its own. Namely, if the second Multi Master wanted to transmit another forward frame with same priority after the forward frame 809 shown in fig. 8, it would only wait for a delay equal to the delay 808 shown in fig. 8 before beginning the transmission of such further forward frame. When the first Multi Master tried to transmit its forward frame as illustrated with the reference designator 811 in fig. 8, it would again detect a collision and abort its current or intended transmission of forward frame, and then wait for another transmission opportunity.

[0033] The fact that any Multi Master can only send a forward frame after the Single Central Master has first spoken naturally means that there will be moments when a Multi Master would have something to send but it must first wait for a forward frame to come from the Single Central Master. This is not a big disadvantage, however, because a typical Single Central Master will make very frequent transmissions anyway, so it is unlikely that the Multi Masters would have to wait for any prohibitively long

periods. It should be noted that even a known DALI bus with several Multi Masters coupled to it would cause delays, because the other Multi Masters might simultaneously have forward frames to transmit.

[0034] The system depends very much on the Single Central Master: should it fail somehow, making it unable to transmit any forward frames, also the Multi Masters would be permanently kept from transmitting. Even this is not any significant drawback compared to other centrally controlled lighting systems, because a failure at the central controller would be likely to affect the system anyway; the addition that not even the associated Multi Masters can do anything does not make the situation any worse. Additionally an emergency mode can be programmed in the Multi Masters, much like the one defined in the DALI standard to account for possible failures during address allocation. Namely, according to the DALI standard all control devices that receive a command announcing the initialization of address allocation must remain in a no-transmission mode until they receive a termination command, unless more than 30 minutes have passed since the initialization command. In a similar way the Multi Masters may be programmed to respond to a prolonged silence from the Single Central Master by entering into a mode in which the Multi Masters can transmit forward frames without having to wait for a preceding forward frame from the Single Central Master. After such an exceptional freedom to transmit, the Multi Masters may be programmed to resume operation as described above (i.e. only transmitting forward frames after an immediately preceding other forward frame on the bus) if they receive a forward frame from the Single Central Master.

[0035] Fig. 9 illustrates a method to be executed by a Single Central Master, or a controller of the first kind, in the form of a state diagram. The drawing can also be read as an illustration of a computer program comprising machine-readable instructions that, when executed by a processor of a controller of the first kind, cause the implementation of the corresponding method.

[0036] The controller of first kind is at state 901 whenever it does not have any message ready that should be transmitted in a forward frame. The controller of first kind is free to transmit forward frames at its own initiative, so the completion of a message causes a transition to state 902, in which the controller of first kind waits for the correct moment to transmit. Typically some kind of a transmission routine has been predefined by programming, for example so that the controller of first kind transmits housekeeping messages on the lighting control bus according to a schedule, so in fig. 9 we assume that it remains in state 902 until the transmission routine produces a processor interrupt indicating a moment at which the forward frame can be transmitted. It is also possible that the controller of first kind goes immediately on to state 903.

[0037] State 903 thus corresponds to transmitting the ("first") forward frame on the lighting control bus, after

which an immediate transition to state 904 takes place. State 904 corresponds to waiting for a delay that is longer than a predefined longest settling time between frames applied by controllers of second kind that are coupled to the same lighting control bus as the controller of first kind. If, during the wait in state 904, the controller of first kind observes a transmission from another device on the bus, it goes to state 905, in which the transmission from the other device is received and any necessary actions are taken. The timer in the controller of first kind is reset, so that upon the return to state 904 the wait for the next possible transmission moment begins anew.

[0038] When the timer expires the controller of first kind is free to transmit its next ("second") forward frame on the bus. Naturally a transmission can only be made if there is something to transmit, so the transition from state 904 goes to state 901 in fig. 9. If the second forward frame is ready for transmission, the method proceeds immediately to state 902 and - since the expiration of the timer indicated the appropriate moment for transmitting and produced the appropriate processor interrupt - on to state 903 for transmitting the second forward frame. The controller of first kind may circulate through the states in the state diagram as long as it remains actively in control of the lighting control bus.

[0039] Fig. 10 illustrates a method to be executed by a Multi Master, or a controller of the second kind, in the form of a state diagram. The drawing can also be read as an illustration of a computer program comprising machine-readable instructions that, when executed by a processor of a controller of the second kind, cause the implementation of the corresponding method.

[0040] The controller of second kind is at state 1001 whenever it does not have any message ready that should be transmitted in a forward frame. The completion of a message causes a transition to state 1002, in which the controller of second kind waits for the correct moment to transmit. The controller of second kind is only allowed to transmit a forward frame only as a response to first having observed the transmission of a preceding forward frame on the lighting control bus. When such a preceding forward frame is observed, typically transmitted by the controller of first kind, the controller of second kind changes to a wait state 1003, in which it waits until a predefined settling time has passed since the end of the preceding forward frame. The controller of second kind may have selected said predefined settling time among a number of predefined settling times in accordance with a priority of the forward frame to be transmitted.

[0041] When the predefined settling time has passed, the controller of second kind changes to a transmission state 1004. Preferably it tests, before actively pulling the lighting control bus to a prevailing state, whether the lighting control bus already is in the prevailing state. Similar tests can be made not only before commencing the transmission but also during transmission, each time before actively pulling the lighting control bus to the prevailing state. As a response to detecting in the test that the light-

ing control bus already is in said prevailing state, the controller of second kind aborts the current or intended transmission of forward frame according to state 1005 and returns to state 1003 to wait for another transmission opportunity. If the transmission was completed without problems in state 1004, a transition to state 1001 occurs and the procedure starts anew.

[0042] Fig. 11 illustrates a variation to the method and computer program explained above with reference to fig. 9. The variation shown in fig. 11 is based on the assumption that the controller of first kind (the Single Central Master) may need to transmit two or more forward frames in succession on the lighting control bus without any of the controllers of second kind (the Multi Masters) transmitting their forward frames in between. This is accomplished by forbidding the controllers of second kind to use the shortest settling time (the one associated with the highest priority), and by programming the controller of first kind to use it instead of the previously explained delay that was longer than the predefined longest settling time used by the controllers of second kind.

[0043] In this description we use the designation "second forward frame" to indicate a forward frame that the controller of first kind (i.e. the Single Central Master) wants to transmit after a previous ("first") forward frame without any particular need to have it transmitted before the controllers of second kind (the Multi Masters) make any intervening transmissions. Correspondingly we use the designation "third forward frame" to indicate a forward frame that the controller of first kind wants to transmit after a previous ("first") forward frame with some particular need to have it transmitted before the controllers of second kind (the Multi Masters) make any intervening transmissions.

[0044] The states 901, 902, 903, 904, and 905 in fig. 11 are essentially the same as the correspondingly numbered states in fig. 9. As an addition there is the possibility of returning from state 904 back to state 903 for the immediate transmission of the next forward frame, on condition that there exists a next forward frame destined for immediately following transmission. This forward frame may be called a third forward frame as indicated above. In order to utilize the possibility shown in fig. 11 the method and computer program should comprise deciding, whether the third forward frame should be transmitted immediately after the first forward frame. As a response to deciding that said third forward frame should be transmitted immediately after the first forward frame, the method and computer program comprise waiting - after the transmission of the first forward frame in state 903 has ended - in state 904 for a delay that is shorter than a predefined shortest settling time between frames applied by the controllers of second kind, before transmitting said third forward frame upon return to state 903.

[0045] Fig. 12 is a schematic example of a case in which the method of fig. 11 is applied. The controller of first kind (the Single Central Master, SCM) transmits the first forward frame 1201. Simultaneously the first control-

ler of second kind (the first Multi Master, MM1) has come up, at moment 1202, with a message that should be transmitted in a forward frame. We assume that in the priority scale ranging from 0 (highest) to 4 (lowest), the message of the first Multi Master is of priority 2. At moment 1203 the second controller of second kind (the second Multi Master, MM2) comes up with a priority 1 message to be transmitted in a forward frame.

[0046] After the transmission of the first forward frame 1201 has ended, the Single Central Master waits for a delay 1204 that is shorter than a predefined shortest settling time between frames applied by the Multi Masters, before transmitting the third forward frame 1205. The first Multi Master had observed the transmission of the first forward frame 1201 and taken it as the preceding forward frame on the lighting control bus, preparing to transmit its own forward frame after the settling time corresponding to priority 2 had passed since the end of the first forward frame 1201. This means that the first Multi Master intends to transmit its forward frame at the moment indicated by the first dashed rectangle on its timeline. However, the transmission of the third forward frame 1205 comes in between, causing the first Multi Master to abort the intended transmission and to begin waiting for the appropriate settling time anew after the transmission of the third forward frame 1205 - which the first Multi Master now sees as the preceding forward frame on the lighting control bus - has ended.

[0047] Meanwhile also the second Multi Master has observed the transmission of the third forward frame 1205, which it takes as the preceding forward frame on the lighting control bus. The second Multi Master begins waiting for the settling time corresponding to priority 1 after the transmission of the third forward frame 1205 has ended. The higher priority means that this settling time is shorter than that applied by the first Multi Master, which means that the second Multi Master makes it to transmitting its forward frame 1206 as shown in fig. 12. The first Multi Master now intended to transmit its forward frame at the moment indicated by the second dashed rectangle on its timeline. This time the transmission of the forward frame 1206 from the second Multi Master comes in between, causing the first Multi Master to again abort the intended transmission and to begin waiting for the appropriate settling time anew after the transmission of the forward frame 1206 - which the first Multi Master now sees as the preceding forward frame on the lighting control bus - has ended. Eventually the first Multi Master makes it to transmitting its forward frame 1207 as shown in fig. 12.

[0048] Referring back to fig. 4, in order to make the controller device 400 transmit forward frames on the lighting control bus (the DALI bus 402) in accordance with the explanations above, it is most practical to store the appropriate machine-readable instructions to the memory 405 that the processor 406 uses to store its executable programs. In particular the timer(s) 407 that is/are configured to trigger transmissions of forward frames are

run as programmed processes. Each corresponding timer is configured to, after the transmission of a first forward frame on one of the lighting control buses coupled to the DALI interfaces on the right, trigger the transmission of a second forward frame on the same lighting control bus after a delay that is longer than a predefined longest settling time between frames applied by the controllers of other kind (for example the sensors 404). Similarly the timer 407 is configured to, as a response to any of said controllers of other kind transmitting a forward frame, trigger after the delay that is longer than a predefined longest settling time between frames applied by said controllers of other kind.

[0049] Another programmed process executed by the processor 406 may be a message priority evaluator that is configured to decide, whether a third forward frame should be transmitted immediately after the first forward frame. In that case the timer 407 is configured to, as a response to said priority evaluator deciding that said third forward frame should be transmitted immediately after the first forward frame, trigger - after the transmission of the first forward frame has ended - after a delay that is shorter than a predefined shortest settling time between frames applied by the controllers of other kind.

[0050] On each of the lighting control buses to the right the transmission of frames takes place independently of the other lighting control buses. Therefore the timer 407 is preferably configured to trigger transmissions of forward frames from one lighting control bus interface independently of the occurrence of forward frames in the other lighting control bus interfaces.

[0051] The exemplary embodiments described above do not constitute an exhaustive or limiting description of the scope of protection defined by the appended claims, but variations and modifications are possible. For example, in the description it has been assumed for simplicity that all Multi Masters have equal possibilities to transmit forward frames at priority-associated delays. One possible variation of the explained embodiments is that some Multi Masters have more priority classes enabled than others. Also it is possible to bind the Multi Masters' permission to transmit to some particular content of the first forward frame transmitted by the Single Central Master, so that it is not enough that the Single Central Master transmits a forward frame but it must transmit a forward frame with some particular contents before the Multi Masters can start their delay timers and prepare for their own transmissions.

Claims

1. A method for transmitting forward frames (601, 602, 701, 704, 709, 801, 805, 1201, 1205) from a controller of a first kind (400) on a lighting control bus (402) to which also controllers of a second kind (404) are allowed to be coupled, comprising, in the following order:

- transmitting a first forward frame (701, 801, 1201) on the lighting control bus,
 - waiting for a delay (703, 708, 804) that is longer than a predefined longest settling time between frames applied by said controllers of second kind (404), and
 - transmitting a second forward frame (704, 709, 805).
2. A method according to claim 1, **characterized in that** it comprises:
- detecting whether any of said controllers of second kind (404) transmitted a forward frame at the expiry of a predefined settling time after the controller of first kind (400) transmitted said first forward frame (701, 801, 1201), and
 - as a response to detecting that some of said controllers of second kind (404) transmitted a forward frame (706) at the expiry of a predefined settling time (707) after the controller of first kind (400) transmitted said first forward frame, waiting - after the transmission of the forward frame (706) from the controller of second kind (404) has ended - for a delay (708) that is longer than a predefined longest settling time between frames applied by said controllers of second kind (404) before transmitting said second forward frame (709).
3. A method according to any of claims 1 or 2, comprising:
- deciding, whether a third forward frame (1205) should be transmitted immediately after the first forward frame (1201), and
 - as a response to deciding that said third forward frame (1205) should be transmitted immediately after the first forward frame (1201), waiting - after the transmission of the first forward frame (1201) has ended - for a delay (1204) that is shorter than a predefined shortest settling time between frames applied by said controllers of second kind (404) before transmitting said third forward frame (1205).
4. A method according to any of the preceding claims, wherein the transmission of forward frames is made using frame lengths, bit timings, and bit-to-voltage-change mappings of the DALI standard.
5. A method for transmitting forward frames from a controller of a first kind (400) and at least one controller of a second kind (404) on a lighting control bus (402), comprising:
- applying a method according to any of the preceding claims to transmit forward frames (601, 602, 701, 704, 709, 801, 805, 1201, 1205) from said controller of first kind,
 - transmitting a forward frame (706, 809, 811, 1206, 1207) from said controller of second kind (404) only as a response to first having observed the transmission of a preceding forward frame (704, 805, 809, 1205, 1206) on the lighting control bus, and
 - transmitting each forward frame (706, 809, 811, 1206, 1207) from said controller of second kind (404) after a predefined settling time (707, 808, 810) has passed since the end of said preceding forward frame.
6. A method according to claim 5, comprising:
- at said controller of second kind (404), before actively pulling the lighting control bus (402) to a prevailing state, testing whether the lighting control bus (402) already is in said prevailing state, and
 - as a response to detecting in the test that the lighting control bus already is in said prevailing state, aborting (1005) the current or intended transmission of forward frame and waiting (1002) for another transmission opportunity.
7. A method according to any of claims 5 or 6, comprising:
- at said controller of second kind (404), selecting said predefined settling time (707, 808, 810) among a number of predefined settling times in accordance with a priority of the forward frame (706, 809, 811, 1206, 1207) to be transmitted.
8. A controller device (400) for transmitting forward frames (601, 602, 701, 704, 709, 801, 805, 1201, 1205) on a lighting control bus (402) to which also controllers of another kind (404) are allowed to be coupled, comprising a timer (407) configured to trigger transmissions of said forward frames, wherein after the transmission of a first forward frame (701, 801, 1201) on the lighting control bus (402) said timer (407) is configured to trigger after a delay that is longer than a predefined longest settling time between frames applied by said controllers of other kind (404).
9. A controller device according to claim 8, wherein said timer (407) is configured to, also as a response to any of said controllers of other kind (404) transmitting a forward frame, trigger after said delay that is longer than a predefined longest settling time between frames applied by said controllers of other kind (404).
10. A controller device (400) according to any of claims 8 or 9, comprising a message priority evaluator configured to decide, whether a third forward frame

(1205) should be transmitted immediately after the first forward frame (1201), wherein said timer (407) is configured to, as a response to said message priority evaluator deciding that said third forward frame (1205) should be transmitted immediately after the first forward frame (1201), trigger - after the transmission of the first forward frame (1201) has ended - after a delay (1204) that is shorter than a predefined shortest settling time between frames applied by said controllers of other kind (404). 5 10

11. A controller device according to any of claims 8 to 10, comprising a multitude of parallel lighting control bus interfaces (401), wherein said timer (407) is configured to trigger transmissions of forward frames from one lighting control bus interface (401) independently of the occurrence of forward frames in the other lighting control bus interfaces (401). 15

12. A computer program for transmitting forward frames (601, 602, 701, 704, 709, 801, 805, 1201, 1205) from a controller of a first kind (400) on a lighting control bus (402) to which also controllers of a second kind (404) are allowed to be coupled, the computer program comprising machine-readable instructions that, when executed by a processor (406), are configured to cause, in the following order, the execution of: 20 25

- transmitting a first forward frame (701, 801, 1201) at a moment of time indicated by a timer (407) in said controller of first kind (400), 30
- waiting for a delay (703, 708, 804) that is longer than a predefined longest settling time between frames applied by said controllers of second kind (404), and 35
- transmitting a second forward frame (704, 709, 805). 40

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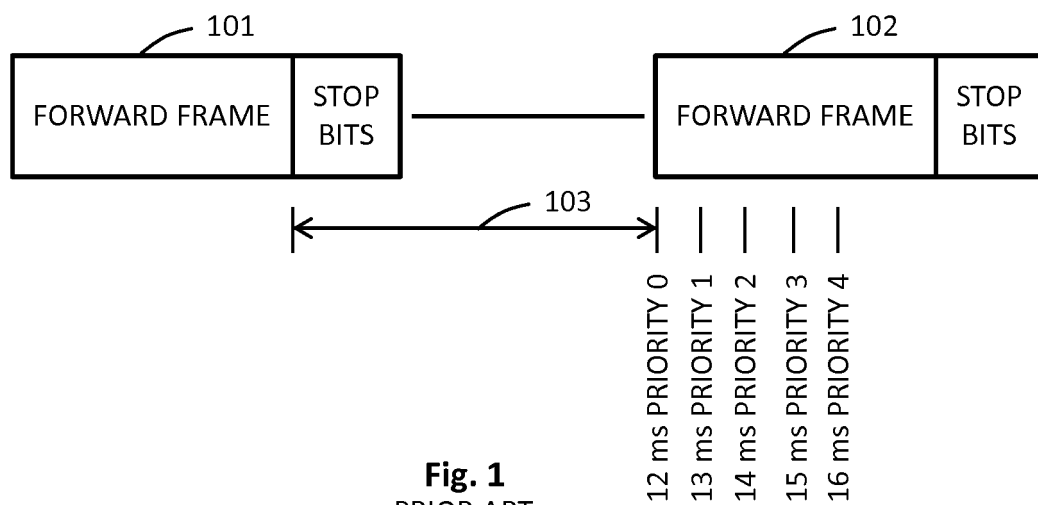


Fig. 1
PRIOR ART

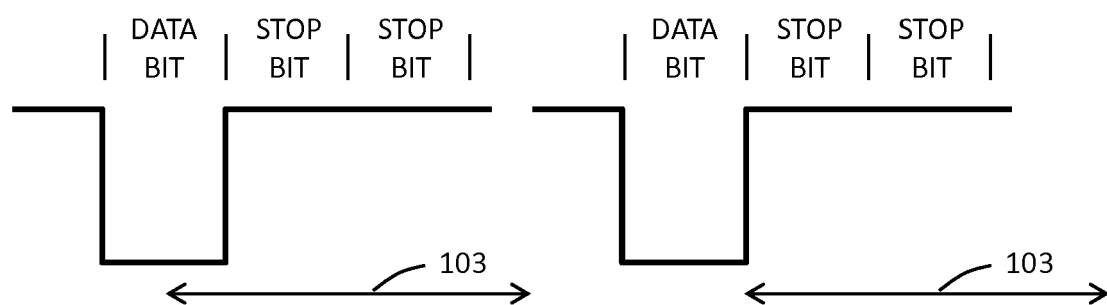


Fig. 2
PRIOR ART

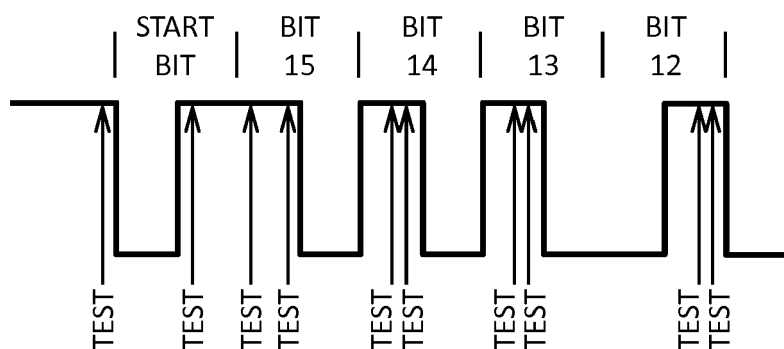


Fig. 3

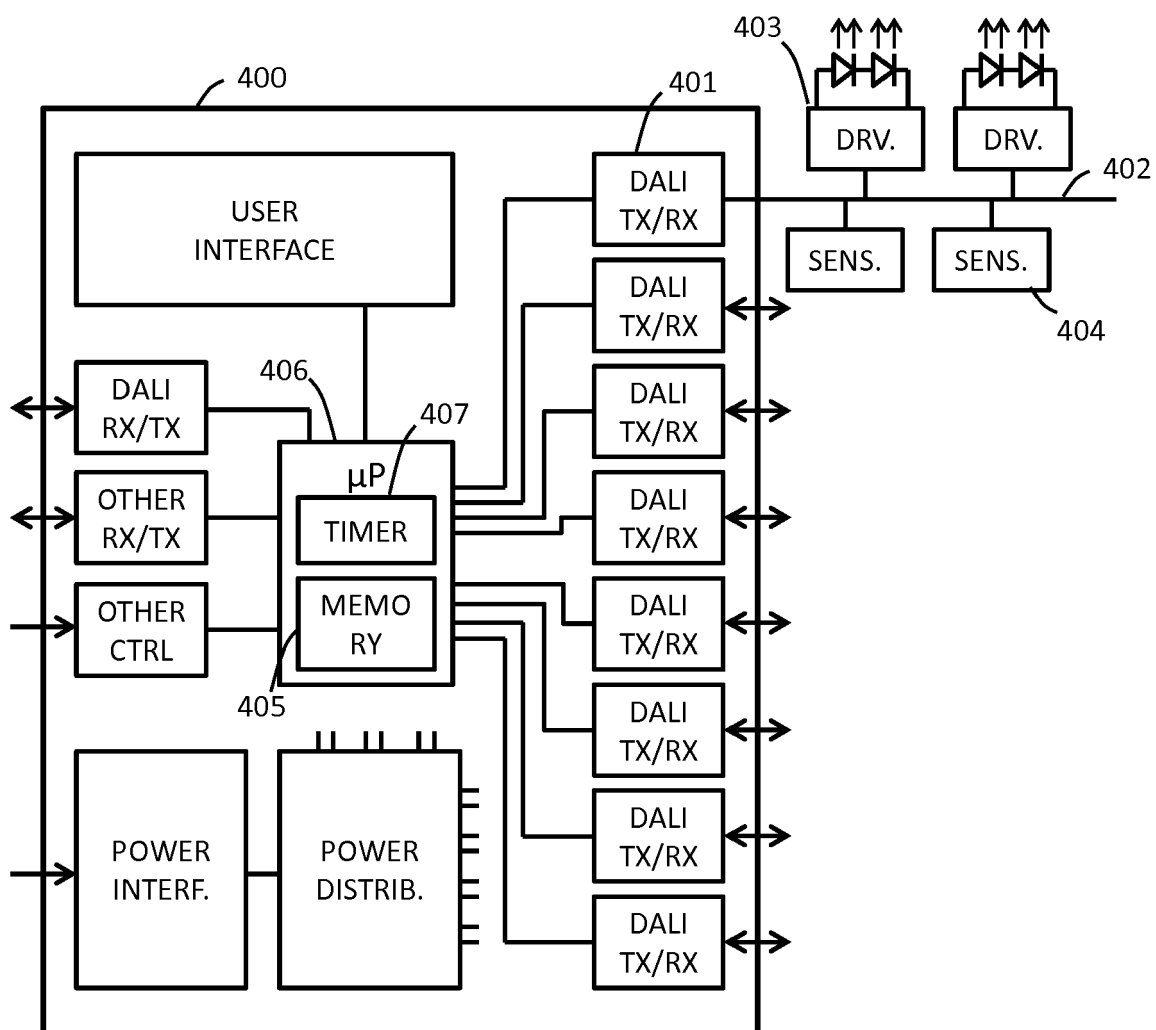


Fig. 4

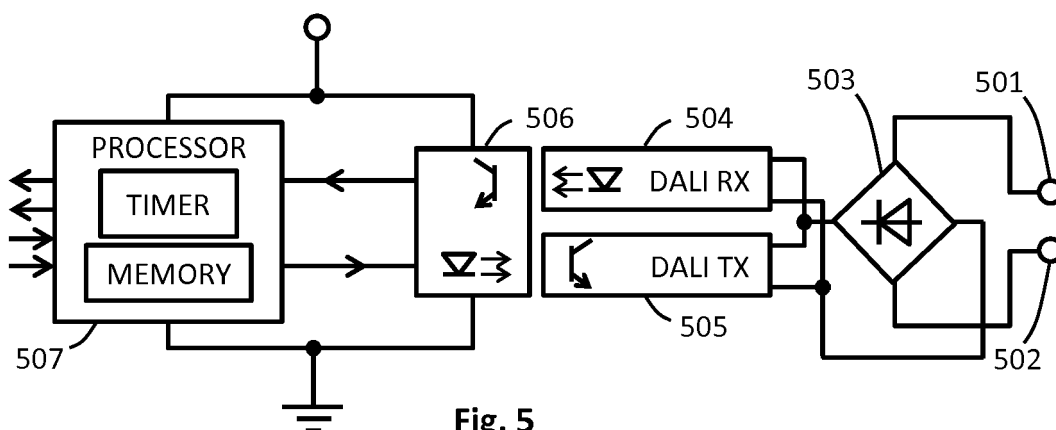


Fig. 5

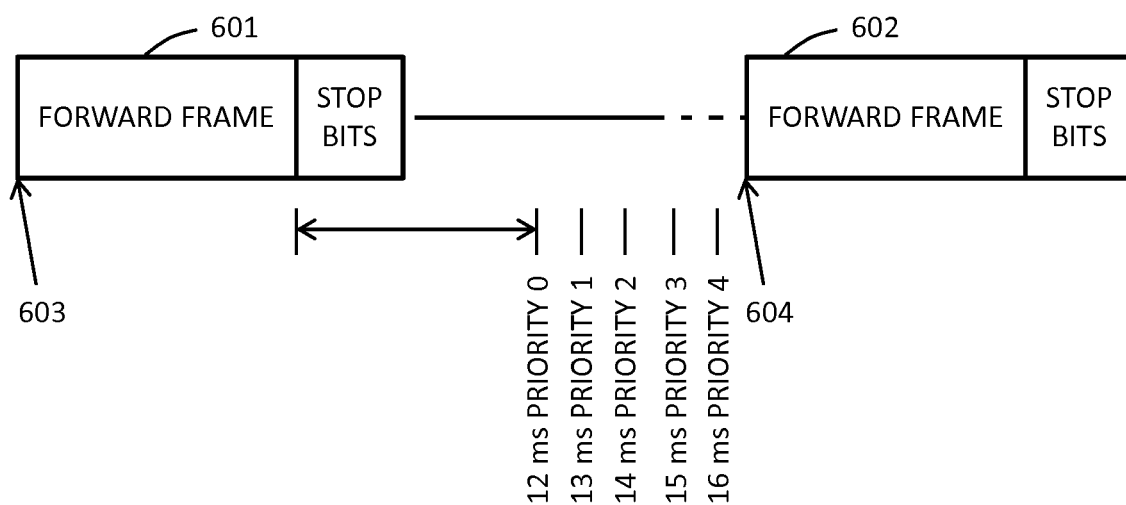


Fig. 6

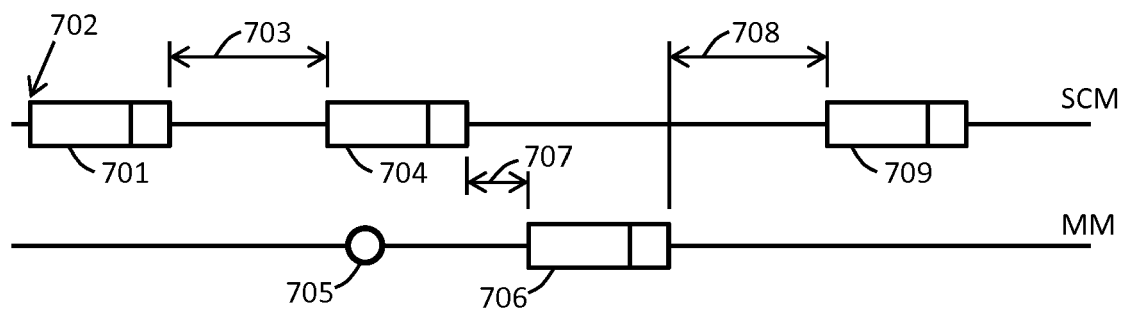


Fig. 7

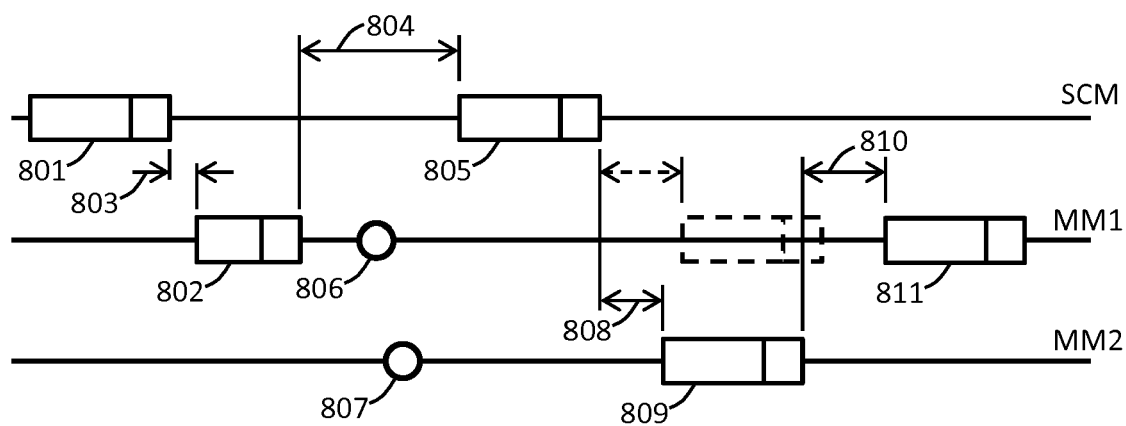


Fig. 8

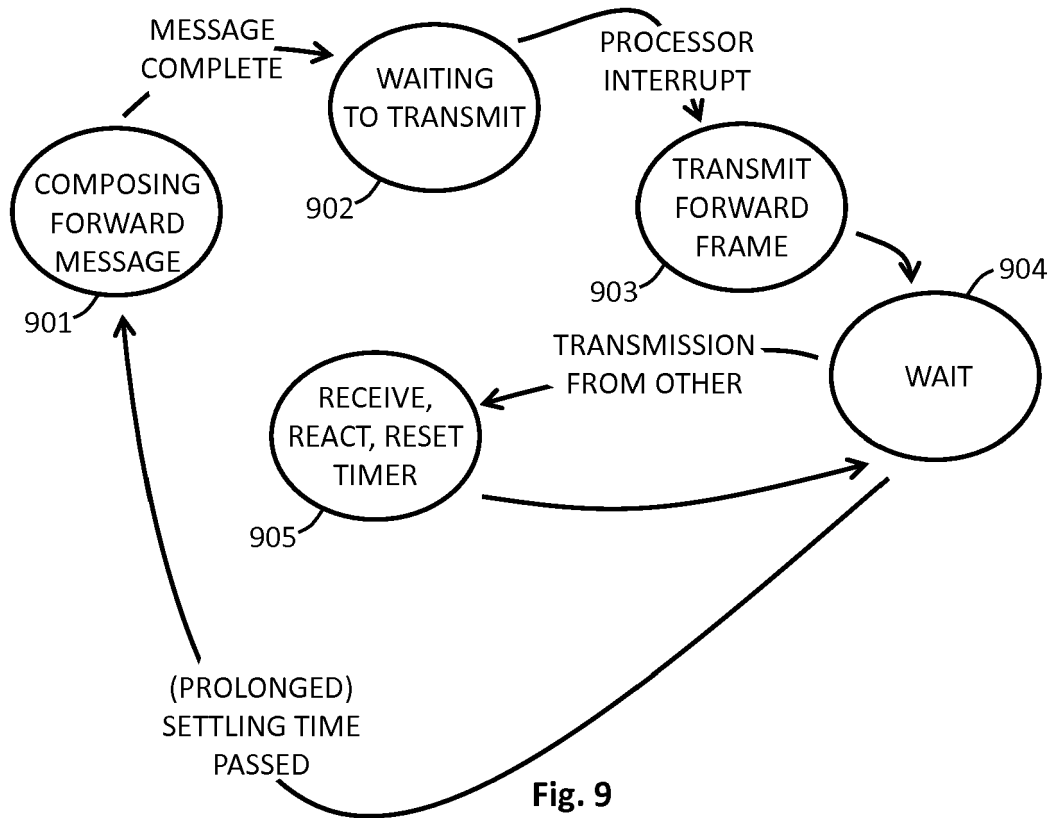


Fig. 9

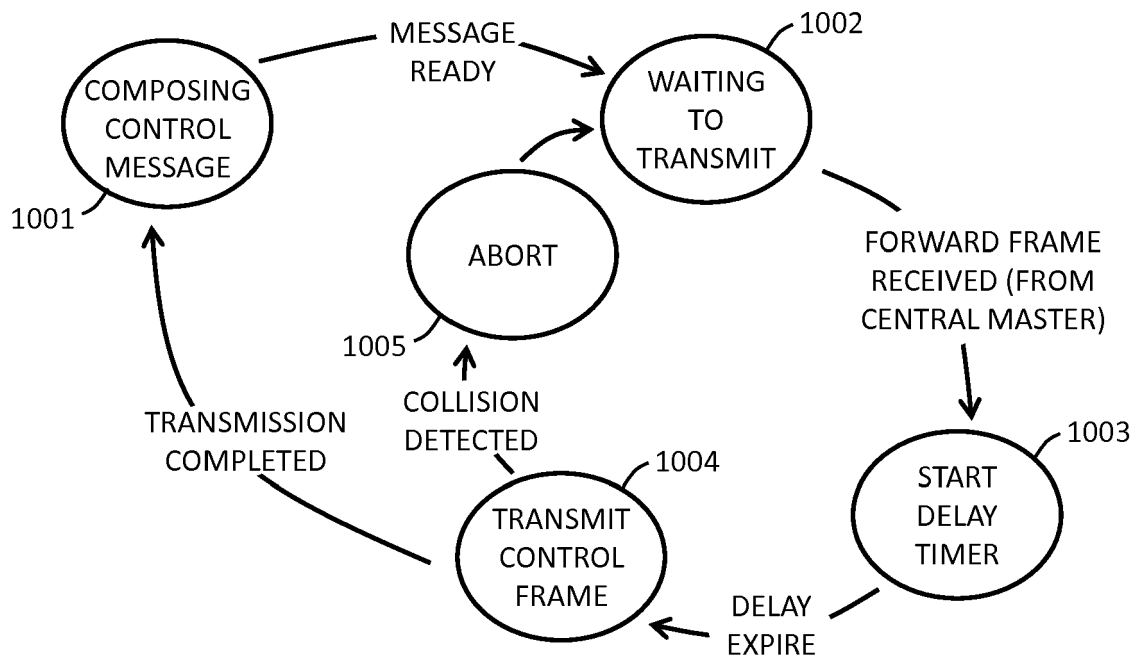


Fig. 10

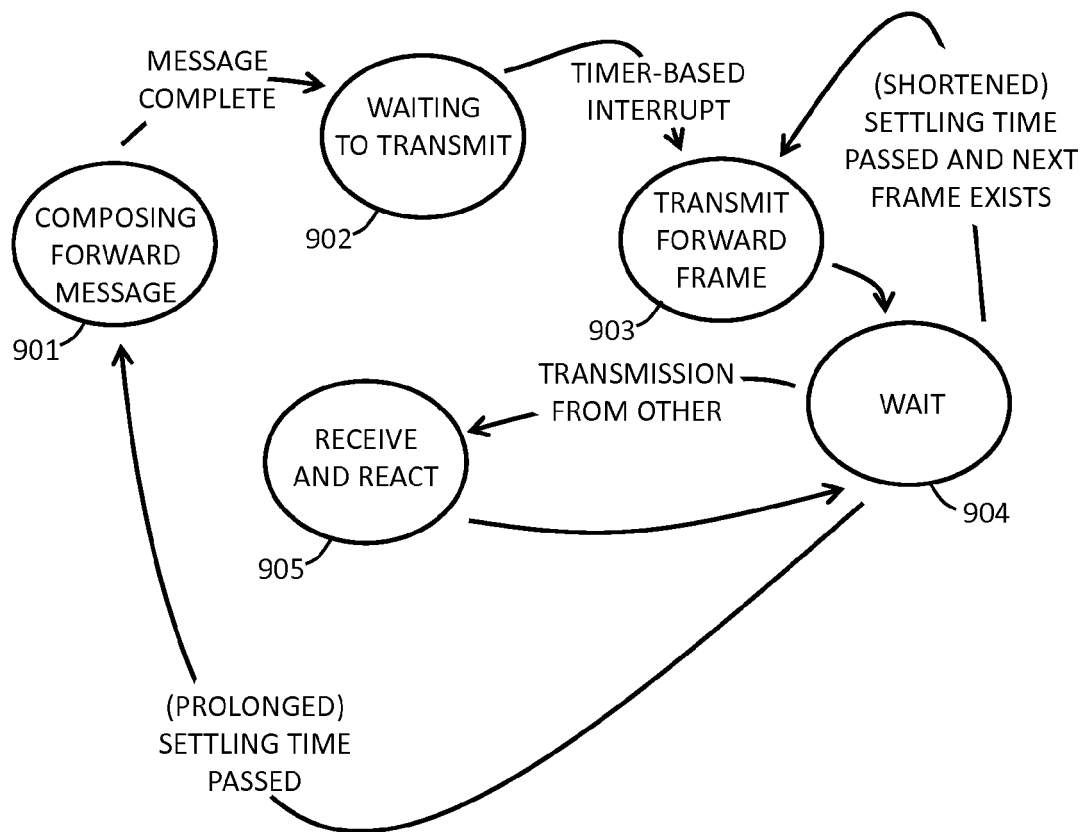


Fig. 11

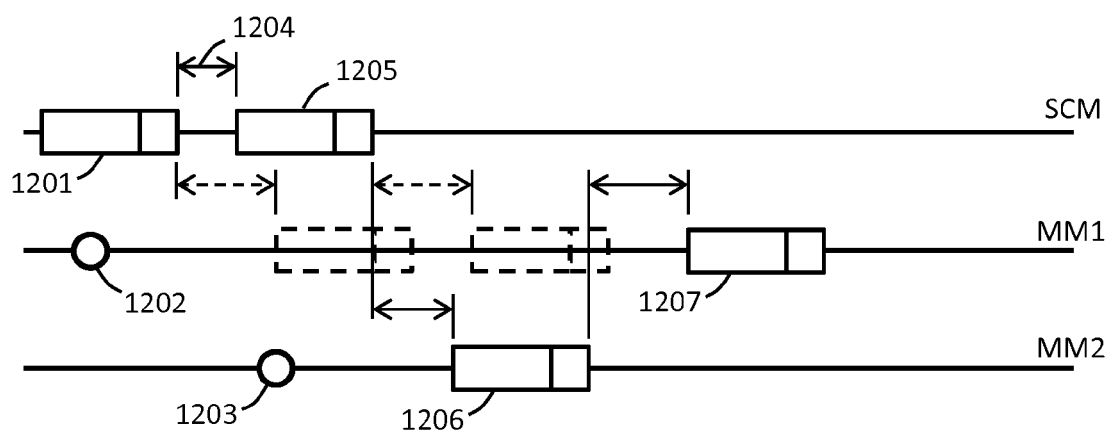


Fig. 12



EUROPEAN SEARCH REPORT

Application Number
EP 14 19 7519

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			H05B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 28 September 2015	Examiner Plamann, Tobias
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

28-09-2015

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