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(54) LED driver circuit for an automobile hand brake warning light with open- and short-circuit fault detection

(57) A driver circuit (1) for at least one electronic component (3) driven by an electrical current generated by a corresponding main current source (6) of the driver circuit (1), said driver circuit (1) comprising a diagnostic circuit adapted to detect fault conditions of said current driven electronic component (3) in an on state of said main current source (6) and in an off state of said main current source. Specifically the at least one electronic component (3) is an LED and indicates the status of a vehicle hand brake.

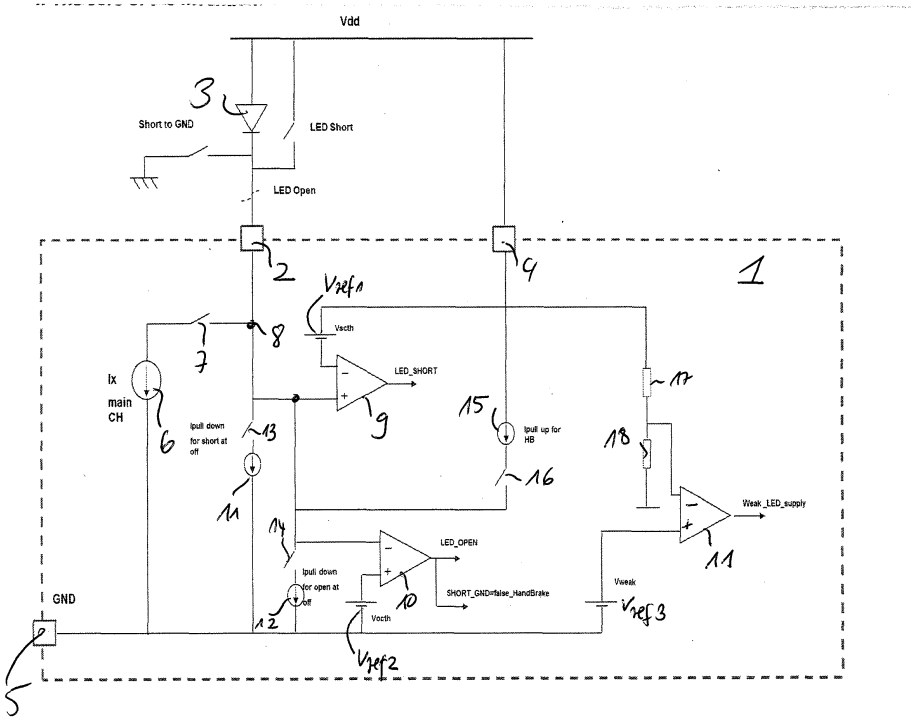

Fig 2

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Description

[0001] The invention relates to a driver circuit for at least one electronic component and in particular to a driver circuit for a light-emitting diode used in automotive applications.

[0002] Electronic components are widely used in many technical devices. Electronic components driven by an electrical current comprise for instance optical components which emit light in response to an electrical current flowing through the respective electric component. These current driven electronic components can be formed by light emitting diodes LEDs. Nowadays, light emitting diodes LEDs become more and more attractive because they occupy less space and are more efficient than usual lamps. Light emitting diodes have a longer operation life time than conventional optical devices such as lamps. Although light emitting diodes LEDs are versatile components they can be used in many applications that require advanced diagnostics to detect a malfunction of the light emitting diode LED. For instance, if the light emitting diode LED is used in an automotive application such as a vehicle to give a warning signal to a driver of the car a malfunction of the light emitting diode LED can be critical. Accordingly, it is necessary to monitor the light emitting diode LED to detect a malfunction. In an automotive environment, a light emitting diode may be provided to indicate a critical state in a car, however if there is a short-cut the light emitting diode LED can no longer indicate this critical situation. There can be different kinds of fault conditions of a light emitting diode LED such as LED short cut, LED open condition and an always-on condition. This kind of fault conditions of the light emitting diode or the current driven electronic component in general has to be detected and communicated to an appropriate control unit of the respective system. If the fault conditions of the light emitting diode LED are detected and communicated to the control unit, the control unit can perform corrective actions. In order that the control unit can take corrective actions the correct diagnostics need to be done both in an on state as well as in an off state of the monitored light emitting diode. A worst case scenario can happen if, for example, one of the terminals of the light emitting diode LED is shortened to one of the power supply lines so that the light emitting diode LED is always on. If the light emitting diode is provided to indicate that a car component such as a hand brake has been activated and if the corresponding light emitting diode LED is always on, the driver of the car may assume erroneously that the car components, i.e. the handbrake of the car, has been activated. In this situation the driver may park his car unsecured, for instance on a parking ramp. This may cause a severe accident because the driver might leave his car in the parking ramp in the believe that he has activated the hand brake since the corresponding light emitting diode LED in the control panel of the car has erroneously indicated this activation because of its fault condition.

[0003] Fig. 1 shows a block diagram of a conventional light emitting diode driver circuit. As can be seen, a light emitting diode LED receiving a supply voltage V_{DD} is connected to a connection pin of the corresponding LED driver circuit. The conventional LED driver circuit comprises a first comparator and a second comparator as illustrated in fig. 1. Fig. 1 shows a conventional low side driver where the LED driver voltage is monitored and compared by comparator circuits with two internal reference voltages. The LED driver circuit shown in fig. 1 comprises a DC current source connected between the connection pin and a ground potential. The first comparator of the conventional LED driver circuit shown in fig. 1 indicates an LED open condition if the monitored voltage is low. In contrast, if the monitored voltage is too high, the LED short condition is signalled by the second comparator of the LED driver circuit shown in fig. 1.

[0004] The conventional driver circuit as illustrated in fig. 1 has several disadvantages. There is no way that the performed diagnostic is valid if the LED current source is switched off. Moreover, the open diagnostic can be false if the supply voltage applied to the monitored LED is lower than normal. Moreover, the short diagnostic can be false if the supply voltage supplied to the LED is higher than normal. A further disadvantage is that that the diagnostic circuit of the LED driver circuit cannot detect an always-on condition, for instance if the respective LED is shorted to ground potential.

[0005] Accordingly it is an object of the present invention to provide a driver circuit for at least one electronic component that overcomes the above mentioned disadvantages and which provides a reliable detection of fault conditions of the driven electronic component.

[0006] This object is achieved by a driver circuit comprising the features of claim 1.

[0007] The invention provides according to first aspect a driver circuit for at least one electronic component driven by an electrical current, generated by a corresponding main current source of the driver circuit, said driver circuit comprising a diagnostic circuit adapted to detect fault conditions of the current driven electronic component in an on state of said main current source and in an off state of said main current source.

[0008] An advantage of the driver circuit according to the present invention results in that it can protect all possible fault conditions of the current driven electronic component, such as a light-emitting diode, in particular also an always-on condition of the current driven electronic component.

[0009] In a further embodiment of the driver circuit according to the present invention the main current source of the driver circuit is adapted to generate an electrical current modulated according to a pulse width modulated signal.

[0010] In a further possible embodiment of the driver circuit according to the present invention in the on state of the main current source a switch of the driver circuit provided between said main current source and the cur-

rent driven electronic component is closed in response to a channel control signal applied to the driver circuit and the PWM modulated electrical current generated by the main current source is applied to the current driven electronic component.

[0011] In a further possible embodiment of the driver circuit according to the first aspect of the present invention, in the off state of a main current source the switch of the driver circuit provided between the main current source and the current driven electronic component is opened in response to the channel control signal applied to the driver circuit and the PWM electrical current generated by the main current source is not applied to said current driven electronic component. In a further possible embodiment of the driver circuit according to the first aspect of the present invention, the current driven electronic component is provided between a supply voltage and a first connection pin of the driver circuit.

[0012] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention the driver circuit has a first comparator adapted to compare a voltage at the first connection pin of the driver circuit with a first reference voltage in the on state of the main current source during an on-time of the PWM modulated electrical current to detect a short-cut fault condition of the current driven electronic component, if the voltage at the first connection pin of the driver circuit is higher than a predetermined first threshold voltage.

[0013] In a still further possible embodiment of the driver circuit according to the present aspect of the present invention, a second comparator within the driver circuit is adapted to compare the voltage at the first connection pin of the driver circuit with a second reference voltage in the on state of the main current source during an on-time of the PWM modulated electrical current to detect a wire-cut fault condition of the current driven electronic component if the voltage at the first connection pin of said driver circuit is lower than a predetermined second threshold voltage.

[0014] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, in the on state of the main current source, the first comparator and the second comparator within the driver circuit are both activated during the on-time of the PWM modulated current and deactivated during the off-time of the PWM modulated current.

[0015] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, in the off state of the main current source, the first comparator and the second comparator within the driver circuit are both deactivated during the on-time of the PWM modulated current.

[0016] In a further possible embodiment of the driver circuit according to the first aspect of the present invention, in response to a falling edge of the PWM signal a timer circuit starts to measure a time until a predetermined time period at the beginning of the off-time of the PWM modulated current has expired.

[0017] In a further possible embodiment of the driver circuit according to the first aspect of the present invention, during the time period both comparators within the driver circuit are activated and switched to associated pull-down current sources within the driver circuit to detect a short-cut fault condition or a wire-cut fault condition of the current driven electronic component.

[0018] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, if the timer circuit indicates that the predetermined time period at the beginning of the off-time of the PWM modulated current has expired, the first comparator and the second comparator are separated from their respective associated pull-down current sources and connected to a pull-up current source of the driver circuit to detect a short-to-ground fault condition of the current driven electronic component during the remaining off-time of the PWM modulated current.

[0019] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, the pull-up current source is connected to a second connection pin of the driver circuit to which the supply voltage of the current driven electronic component is applied.

[0020] In a further possible embodiment of the driver circuit according to the first aspect of the present invention, the pull-down current sources associated with the first and second comparator of the driver circuit are connected to a third connection pin of the driver circuit having ground potential.

[0021] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, a third comparator within the driver circuit is adapted to compare the supply voltage supplied to the second connection pin of the driver circuit with a third reference voltage to detect a weak supply voltage, if the supply voltage is lower than a predetermined third threshold voltage.

[0022] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, a voltage dividing circuit is provided adapted to scale down the supply voltage applied to the second connection pin of the driver circuit for comparison by said third comparator.

[0023] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, the applied channel control signal indicates a state of an actuator.

[0024] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, the current driven electronic component is a light-emitting component being adapted to emit visible light to a user, if the PWM electrical current generated by the current source is applied via the closed switch and the first connection pin to the current driven electronic component in the on state of the main current source in response to the channel control signal, and if the current driven electronic component is in a non-fault condition.

[0025] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, the amplitudes of the electrical currents provided by the pull-up current sources and/or by the pull-down current sources to detect fault conditions of the current driven electronic component in the off state of the main current source are significantly smaller than the amplitude of the electrical current generated by the main current source so that no visible light is emitted by the current driven electronic component to a user during the detection of fault conditions of the current driven electrical component in the off state of the main current source.

[0026] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, the driver circuit is formed by an integrated circuit.

[0027] In a still further possible embodiment of the driver circuit according to the first aspect of the present invention, the actuator is an actuator within a vehicle.

[0028] In a further possible embodiment of the driver circuit according to the first aspect of the present invention, the actuator whose state is indicated by the applied channel control signal is a break handle actuator.

[0029] In a still further possible embodiment of the driver circuit according to the present invention, the current driven electronic component is a light-emitting diode.

[0030] According to a further possible aspect of the present invention, a light-emitting diode is provided which is driven by a driver circuit according to the first aspect of the present invention wherein the light-emitting diode is driven by an electric current generated by a corresponding main current source of the driver circuit, wherein the driver circuit comprises a diagnostic circuit adapted to detect fault conditions of the light emitting diode in an on state of the main current source and in an off state of the main current source.

[0031] The invention further provides according to a further aspect an actuator within a vehicle adapted to apply a channel control signal indicating a state of the actuator to an associated driver circuit of at least one light-emitting electronic component driven by an electrical current generated by a corresponding main current source of said driver circuit, wherein said driver circuit comprises a diagnostic circuit adapted to detect fault conditions of said current driven light-emitting electronic component in an on state of said main current source and in an off state of said main current source,
wherein in an on state of the main current source a switch of the driver circuit provided by the main current source and the current driven light-emitting electronic component is closed in response to the channel control signal received by said driver circuit and a PWM modulated electrical current generated by said main current source is applied to the current driven light-emitting electronic component.

[0032] In the following possible embodiments of different aspects of the present invention are described with reference to the enclosed figures in more detail.

Fig. 1 shows a conventional light-emitting diode driver circuit;

Fig. 2 shows a circuit diagram of a possible embodiment of a driver circuit according to an aspect of the present invention;

Fig. 3 shows a signal diagram for illustrating the operation of a driver circuit according to the present invention as illustrated in fig. 2.

[0033] As can be seen in fig. 2 the driver circuit 1 according to the first aspect of the present invention does in the shown exemplary embodiment comprise a first connection pin 2 to which at least one current driven electronic component can be connected. In the example shown in fig. 2, the current driven electronic component is a light-emitting component, in particular light-emitting diode 3. The light-emitting diode 3 receives a supply voltage V_{DD}, e.g. 5 volts.

[0034] Possible fault conditions of the current driven electronic component 3 are also illustrated in fig. 2. In the first possible fault condition the current driven electronic component 3 might be short-cutted as symbolised by a corresponding switch connected in parallel to the current driven electronic component 3. In a further possible fault condition the current driven component 3 can be shorted to a predetermined potential such as ground potential GND as also symbolised by a switch connecting the current driven component 3 to ground. In a still further possible fault condition a wire between the current driven electronic component 3 and the connection pin 2 of the associated driver circuit 1 might be interrupted as symbolised by dashed lines in fig. 2.

[0035] As can be seen in fig. 2 the driver circuit 1 comprises the first connection pin 2 and a second connection pin 4 which connects the driver circuit 1 directly to the supply voltage V_{DD}. Moreover, the driver circuit 1 comprises a third connection pin connecting the driver circuit 1 to a reference potential, in particular ground potential GND, as shown in fig. 2.

[0036] In a possible embodiment the driver circuit 1 can be built by discrete components such as operation amplifiers, current sources, etc. In a further possible embodiment the driver circuit 1 as shown in fig. 2 can be formed by an integrated circuit. In a further possible implementation the driver circuit 1 can also be integrated in the associated current driven electronic component 3. In a still further possible embodiment the driver circuit 1 can be integrated in a light-emitting electronic component such as light-emitting diode.

[0037] As shown in fig. 2 the driver circuit 1 comprises a main current source 6 which is adapted to generate an electrical current. This electrical current can be modulated in a possible embodiment according to a pulse width modulated signal PWM. The main current source 6 can be connected via a controllable switch 7 to an internal node 8 which is connected to the connection pin 2 of the

driver circuit 1. The driver circuit 1 comprises in the shown embodiment of fig. 2 a first comparator circuit 9, a second comparator circuit 10 and a third comparator circuit 11.

[0038] In the on state of the main current source 6 the switch 7 of the driver circuit 1 provided between the main current source 6 and the current driven electronic component 3 is closed in response to a channel control signal CH applied to the driver circuit 1 and the PWM modulated electrical current generated by the main current source 6 is applied to the current driven electronic component.

[0039] The channel control signal CH applied to the driver circuit 1 can be supplied in a possible embodiment by an actuator unit. The applied channel control signal CH can indicate a current state of the respective actuator unit. In a possible embodiment the actuator unit can be an actuator unit of an automotive application, in particular an actuator of a car. In a specific implementation the actuator can be a hand brake of a car.

[0040] In the off state of the main current source 6 the switch 7 of the driver circuit 1, provided between the main current source 6 and the current driven electronic component 3, is opened in response to the received channel control signal CH, applied to the driver circuit 1 by the actuator unit and the PWM electrical current generated by the main current source 6, is not applied to the current driven electronic component 3.

[0041] The first comparator 9 of the driver circuit 1 is adapted to compare a voltage at the first connection 2 of the driver circuit 1 with a first reference voltage V_{Ref1} in the on state of the main current source 6 during an on-time of the PWM modulated electrical current to detect a short-cut fault condition of the current driven electronic component 3, if the voltage U at the first connection pin of the driver circuit 1 is higher than a predetermined first threshold voltage V_{TH1}. In case of a short-cut the supply voltage V_{DD} is directly applied to the first connection pin 2 and can exceed the first threshold voltage V_{TH1} so that the first comparator 9 generates a corresponding signal, indicating a short-cut fault condition of the current driven electronic component 3.

[0042] The second comparator 10 in the driver circuit 1 is adapted to compare the voltage U at the first connection pin 2 of the driver circuit 1 with a second reference voltage V_{Ref2} in the on state of the main current source 6 during an on-time of the PWM modulated electric current to detect a wire-cut fault condition of the current driven electronic component 3 if the voltage U at the first connection pin 2 of the driver circuit 1 is lower than a predetermined second threshold voltage V_{TH2}. The fault condition is output by the second comparator 10 as an LED open signal.

[0043] In the on state of the main current source 6 the first comparator 9 and the second comparator 10 within the driver circuit 1 are both activated during an on-time t_{ON} of the PWM modulated current and deactivated during the off-time t_{OFF} of the PWM modulated current.

[0044] In the off state of the main current source 6 the first comparator 9 and the second comparator 10 both are deactivated during the on-time of the PWM modulated current, wherein in response to a falling edge of the PWM signal a timer circuit (not shown) starts to measure a time until a predetermined time period at the beginning of the off-time t_{OFF} of the PWM modulated current has expired. During this time period both comparators 9, 10 within the driver circuit 1 are activated and switched to associated pull-down current sources 11, 12 by means of switches 13, 14 as illustrated in fig. 2 to detect the short-cut fault condition or the wire-cut fault condition of the current driven electronic component 3.

[0045] If the timer circuit indicates that the predetermined time period at the beginning of the off-time of the PWM modulated current has expired the first comparator 9 and the second comparator 10 are both separated from their respective associated pull-down current sources 11, 12 and connected to a pull-up current source 15 to detect a short-to-ground fault condition of said current driven electronic component 3 during the remaining off-time of the PWM modulated current.

[0046] As can be seen in fig. 2 the pull-up current source 15 is connected to the second connection pin 4 of the driver circuit 1 to which the supply voltage V_{DD} of the monitored current driven electronic component 3 is applied. The pull-down current sources 11, 12 of the first comparator 9 and the second comparator 10 within the driver circuit 1 are connected to the third connection pin 5 of the driver circuit 1 having for instance ground potential (GND). Switching of the pull-up current source 15 is performed by means of a further switch 16 shown also in fig. 2.

[0047] The driver circuit 1 further comprises a third comparator 11 which is adapted to compare the supply voltage V_{DD} supplied to the second connection pin 4 of the driver circuit 1 with a third reference voltage V_{Ref3} to detect a weak supply voltage if the supply voltage V_{DD} supplied to the second connection pin 4 is lower than a predetermined third threshold voltage V_{TH3}.

[0048] In the shown embodiment of fig. 2 a voltage dividing circuit is provided comprising two voltage dividing resistors 17, 18 to scale down the supply voltage V_{DD} supplied to the second connection pin 4 of the driver circuit 1 for performing the comparison by the third comparator 11.

[0049] In the exemplary embodiment shown in fig. 2 the current driven electronic component 3 is a light-emitting component adapted to emit visible light to a user particular to a driver of a car. The visible light 15 emitted by the light-emitting component only, if the PMW electrical current generated by the main current source 6 is supplied via the closed switch 7 and the first connection pin 1 to the current driven electronic component 3.

[0050] The amplitudes of the electric currents I provided by the pull-up current source 15 and by the pull-down current sources 11, 12 to detect fault conditions of the current driven electronic component 3 in the off state of the main current source 6 are in a preferred embodiment significantly smaller than the amplitude of the electrical

current I generated by the main current source 6 so that no visible light is emitted by the current driven electronic component 3 to the user during the detection of fault conditions of the current driven electrical component 3 in the off state of the main current source 6.

[0051] As can be seen in fig. 2 the driver circuit 1 comprises in the shown embodiment a diagnostic circuit adapted to detect fault conditions of the current driven electronic component 3 in an on state of the main current source 6 and in the off state of the main current source 6. The diagnostic circuit comprises comparators 9, 10, 11 as well as the current sources, in particular the pull-down current sources 11, 12 and the pull-up current source 15, as well as the corresponding switches 13, 14, 16. Further, the diagnostic circuit of the driver circuit 1 includes circuits adapted to generate the reference voltages V_{Ref1}, V_{Ref2}, V_{Ref3}. In a possible embodiment the threshold voltages measured of these reference voltage generators are adjustable. The output signals of the comparators 9, 10, 11 form flag signals indicating each a fault condition of the monitored current driven electronic component 3. The output signals of the comparators 9, 10, 11 can be supplied to a controller (not shown) performing a fault handling operation in response to the received flag signals.

[0052] By adding the additional pull-up and pull-down currents which are internally controlled, the diagnostics can be validated both in on and off conditions. Monitoring at the same time the voltage at the first connection pin 2 and the V_{DD} supply voltage applied to the second connection pin 4 true LED shorts can be detected independent of the variations of the supply voltage V_{DD}. At the same time by monitoring the V_{DD} supply voltage a LED open fault condition can be validated. In many applications the LED driver circuit 1 is required to be able to turn off the light-emitting diode 3 and to drive the current in a PWM mode.

[0053] Fig. 3 shows a signal diagram for illustrating the operation of the driver circuit 1 according to the present invention. If the applied channel control signal received for instance from an actuator unit is on (CH_{ON}) and the PWM signal is also on during the on-time t_{ON} of the PWM modulated electrical current diagnostics are available to detect a LED short and an LED open fault condition. During this time period operators 9, 10 of the diagnostic circuit are both activated. At the same time the respective associated pull-down current sources 11, 12 are deactivated by opening the switches 13, 14. At the same time the pull-up current source 15 is also deactivated by switching off the switch 16. The light-emitting diode 3 is connected to the main current source 6 so that an LED short fault condition can be detected by comparator 9 and an LED open fault condition (e.g. a wire cut) can be detected by the second comparator 10 of the diagnostic circuit.

[0054] Between times t0 and t1 a LED short fault condition detection and an LED open fault condition can be detected by the diagnostic circuit within the driver circuit 1.

[0055] As also shown in fig. 3 after the PWM signal has been switched off and the channel control signal CH is still on, the pull down current sources 11, 12 are off during the time t_{OFF} as illustrated in fig. 3. During this time period diagnostics are disabled in order to be able to reach for instance a 0,1 % PWM dimming. The pull-up current source 15 is activated in order to assure that the LED voltage is well defined. During this time period no measurements are provided. This time period serves to reach a predefined state as a preparation for the following measurements. Accordingly between times t1 and t2 the diagnostics, in particular comparators 9, 10, are disabled and no measurements take place. The switching between an enabled diagnostic circuit and a disabled diagnostic circuit can be repeated once or several times as long as the channel control signal CH is on (CH_{ON}) as illustrated in fig. 3.

[0056] In the example shown in fig. 3 the channel control signal CH is switched off at time t4 and the PWM signal goes high. The comparators 9, 10 are both deactivated. The pull-down current sources 11, 12 are deactivated whereas the pull-up current source 15 is activated. The time period between t4 and t5 is similar to the time period between t1 and t2 and no measurements take place. When the channel control signal CH is switched off and the PWM signal goes low at time t5 the internal timer circuit of the driver circuit 1 starts to run. In response to the falling edge of the PWM signal, the timer circuit starts to measure a time until a predetermined time period at the beginning of the off-time t_{OFF} of the PWM signal has expired. During this time period between t5 and t6 both comparators 9, 10 of the diagnostic circuit within the driver circuit 1 are activated and switched to the associated pull-down current sources 11, 12 by means of the switches 13, 14 to detect a short-cut fault condition and/or a wire-cut fault condition of the current driven electronic component 3. These detections are performed in the off state of the light-emitting diode 3 when it is not connected to the main current source 6. During the off state of the main current source 6 of the light-emitting diode 3 does not get any electrical current from the main current source 6.

[0057] To measure the fault conditions a pull-down current is provided by the activated pull-down current sources 11, 12. The electrical current I generated by the pull-down current sources 11, 12 is significantly smaller than the electrical current provided by the main current source 6. For example, the main current source may generate a current range from 40 to 60 mA. The pull-down current sources 11, 12 may generate a much smaller current, for instance 20 μA. The current provided by the pull-up current source 15 can be twice the current generated by one of the pull-down current sources 11, 12, e.g. 2 x 20 μA = 40 μA. The current driven electronic component 3 is adapted to emit visible light to the user if the PWM electrical current generated by the main current source 6 is applied via the closed switch and the first connection pin

2 to the current driven electronic component 3 in the on state of the main current source 6 in response to the applied channel control signal (CH_{ON}) and if the current driven electronic component 3 is in a non-fault condition.

[0058] The amplitudes of the electrical currents provided by the pull-down current sources 11, 12 to detect the fault conditions of the current driven electronic component 3 in the off state of the main current source 6 (CH_{OFF}) are significantly smaller than the amplitude of the electrical current generated by the main current source 6 so that no visible light is emitted by the current driven electronic component 3 to the user during the detection of fault conditions of the current driven electrical component 3 in the off state (channel off) of the main current source 6. Accordingly, the diagnostic circuit provided within the driver circuit 1 according to the present invention can operate in the background when the light-emitting diode 3 is practically switched off and does not cause any emission of light to the user. Only small currents are flowing through the light-emitting diode 3 to perform the necessary fault condition measurements which do not generate any light visible to the user. Because of the small detection currents the fault condition detection consumes little electrical power.

[0059] After the predetermined time, measured by the timer circuit, elapses, for instance after 20 μsec. In the signal diagram of fig. 3 the predetermined time period ends at time t6. At this time the PWM signal is still off as well as the channel control signal CH_{OFF}. At time t6 the pull-down current sources 11, 12 are deactivated and the pull-up current source 15 is activated. Between times t6 and t7 a short-to-ground fault condition at the light-emitting diode 3 can be detected. Using the same comparator as used for detecting the LED open fault condition, i.e. the second comparator 10, a false handbrake indication HB can be detected. If the light-emitting diode 3 which may be used to indicate the state of the handbrake is shorted to ground GND, an electrical current generated by the active pull-up current source 15 flows via the internal node 8 and the first connection pin 2 to ground GND. This can be detected by the second comparator 10.

[0060] At time t6 when the PWM signal switches back to the high state the channel control signal CH is still off. At this time the pull-up current source 15 is enabled to make sure that the light-emitting diode 3 has no flickering.

[0061] The third comparator 11 of the diagnostic circuit within the driver circuit 1 is connected to a voltage V_{DD} applied to the driver circuit 1 at its second connection pin 4. Accordingly it is possible to monitor the LED supply voltage. A weak supply voltage is detected when the supply voltage V_{DD} is lower than a predetermined third threshold voltage V_{TH3} generated by the reference voltage V_{Ref3}. The weak LED supply voltage flag output by the third comparator 11 can filter out wrong open LED detections.

[0062] The threshold voltages V_{TH1}, V_{TH2}, V_{TH3} can in a possible embodiment be adjusted by a controller. This controller can also comprise the timer circuit defining the time period between times t5, t6. In an alternative embodiment the timer circuit can also be integrated in the driver circuit 1. In a still further possible embodiment the controller can also be integrated in the driver circuit 1. The switches 7, 13, 14, 16 shown in the embodiment of fig. 2 can be implemented by transistors in particular by MOSFET transistors.

Claims

1. A driver circuit (1) for at least one electronic component (3) driven by an electrical current generated by a corresponding main current source (6) of the driver circuit (1),
said driver circuit (1) comprising a diagnostic circuit adapted to detect fault conditions of said current driven electronic component (3) in an on state of said main current source (6) and in an off state of said main current source (6).

2. The driver circuit according to claim 1, wherein the main current source (6) of said driver circuit (1) is adapted to generate an electrical current modulated according to a pulse width modulated (PWM) signal.

3. The driver circuit according to claim 1 or 2, wherein in the on state of said main current source (6) a switch (7) of the driver circuit (1) provided between said main current source and the current driven electronic component (3) is closed in response to a channel control signal (CH) applied to said driver circuit (1) and the PWM modulated electrical current generated by said main current source (6) is applied to said current driven electronic component (3).

4. The driver circuit according to one of the preceding claims 1 to 3, wherein in the off state of said main current source (6) the switch (7) of said driver circuit (1) provided between said main current source (6) and the current driven electronic component (3) is opened in response to the channel control signal (CH) applied to said driver circuit (1) and the PWM electrical current generated by said main current source (6) is not applied to said current driven electronic component (3).

5. The driver circuit according to one of the preceding claims 1 to 4, wherein the current driven electronic component (3) is provided between a supply voltage (V_{DD}) and a first connection pin (2) of said driver circuit (1).

6. The driver circuit according to claim 5, wherein a first comparator (9) within said driver circuit (1) is adapted to compare a voltage at the first connection pin (2) of said driver circuit (1) with a first reference voltage in the on state of the main current source (6) during

an on-time (t_{ON}) of the PWM modulated electrical current to detect a short-cut fault condition of said current driven electronic component (3), if the voltage at the first connection pin (2) of the driver circuit (1) is higher than a predetermined first threshold voltage.

7. The driver circuit according to claim 5 or 6, wherein a second comparator (10) within said driver circuit (1) is adapted to compare the voltage at the first connection pin (2) of the driver circuit (1) with a second reference voltage in the on state of the main current source (6) during an on-time (t_{ON}) of the PWM modulated electrical current to detect a wire-cut fault condition of said current driven electronic component (3) if the voltage at the first connection pin (2) of said driver circuit (1) is lower than a predetermined second threshold voltage.

8. The driver circuit according to claim 6 or 7, wherein in the on state of said main current source (6), the first comparator (9) and the second comparator (10) within the driver circuit (1) are both activated during the on-time (t_{ON}) of the PWM modulated current and deactivated during the off-time (t_{OFF}) of the PWM modulated current.

9. The driver circuit according to one of the preceding claims 6 to 8,
wherein in the off state of the main current source (6), the first comparator (9) and the second comparator (10) within said driver circuit (1) are both deactivated during the on-time (t_{ON}) of the PWM modulated current, wherein in response to a falling edge of the PWM signal a timer circuit starts to measure a time until a predetermined time period at the beginning of the off-time (t_{OFF}) of the PWM modulated current has expired,
wherein during the time period both comparators (9, 10) within the driver circuit (1) are activated and switched to associated pull-down current sources (11, 12) within the driver circuit (1) to detect a short-cut fault condition or a wire-cut fault condition of the current driven electronic component (3).

10. The driver circuit according to claim 9, wherein, if the timer circuit indicates that the predetermined time period at the beginning of the off-time (t_{OFF}) of the PWM modulated current has expired, the first comparator (9) and the second comparator (10) are separated from their respective associated pull-down current sources (11, 12) and connected to a pull-up current source (15) of the driver circuit (1) to detect a short-to-ground fault condition of said current driven electronic component (3) during the remaining off-time (t_{OFF}) of the PWM modulated current.

11. The driver circuit according to claim 10, wherein the pull-up current source (15) is connected to a second connection pin (4) of said driver circuit (1) to which the supply voltage of said current driven electronic component is applied.

12. The driver circuit according to claim 9 or 10, wherein the pull-down current sources (11, 12) associated with the first and second comparator (9, 10) of said driver circuit (1) are connected to a third connection pin (5) of said driver circuit having ground potential (GND).

13. The driver circuit according to one of the preceding claims 6 to 12, wherein a third comparator (11) within said driver circuit (1) is adapted to compare the supply voltage (V_{DD}) supplied to the second connection pin (4) of said driver circuit (1) with a third reference voltage to detect a weak supply voltage, if the supply voltage is lower than a predetermined third threshold voltage.

14. The driver circuit according to claim 13, wherein a voltage dividing circuit (17, 18) is provided adapted to scale down the supply voltage applied to the second connection pin (4) of the driver circuit (1) for comparison by said third comparator (11).

15. The driver circuit according to one of the preceding claims 1 to 14, wherein the applied channel control signal (CH) indicates a state of an actuator.

16. The driver circuit according to one of the preceding claims 1 to 15, wherein the current driven electronic component (3) is a light-emitting component being adapted to emit visible light to a user, if the PWM electrical current generated by the main current source (6) is applied via the closed switch (7) and the first connection pin (2) to the current driven electronic component (3) in the on state of said main current source (6) in response to the channel control signal (CH), and if the current driven electronic component (3) is in a non-fault condition.

17. The driver circuit according to one of the preceding claims 1 to 16, wherein the amplitudes of the electrical currents provided by the pull-up current source (15) and/or by the pull-down current sources (11, 12) to detect fault conditions of the current driven electronic component (3) in the off state of the main current source (6) are significantly smaller than the amplitude of the electrical current generated by the main current source (6) so that no visible light is emitted by said current driven electronic component (3) to a user during the detection of fault conditions of the current driven electrical component (3) in the off state of said main current source (6).

18. The driver circuit according to one of the preceding

claims 1 to 17, wherein the driver circuit (1) is an integrated circuit.

19. The driver circuit according to claim 15, wherein the actuator is an actuator within a vehicle, in particular a break handle.

20. The driver circuit according to claim 16, wherein the current driven electronic component (3) is a light-emitting diode.

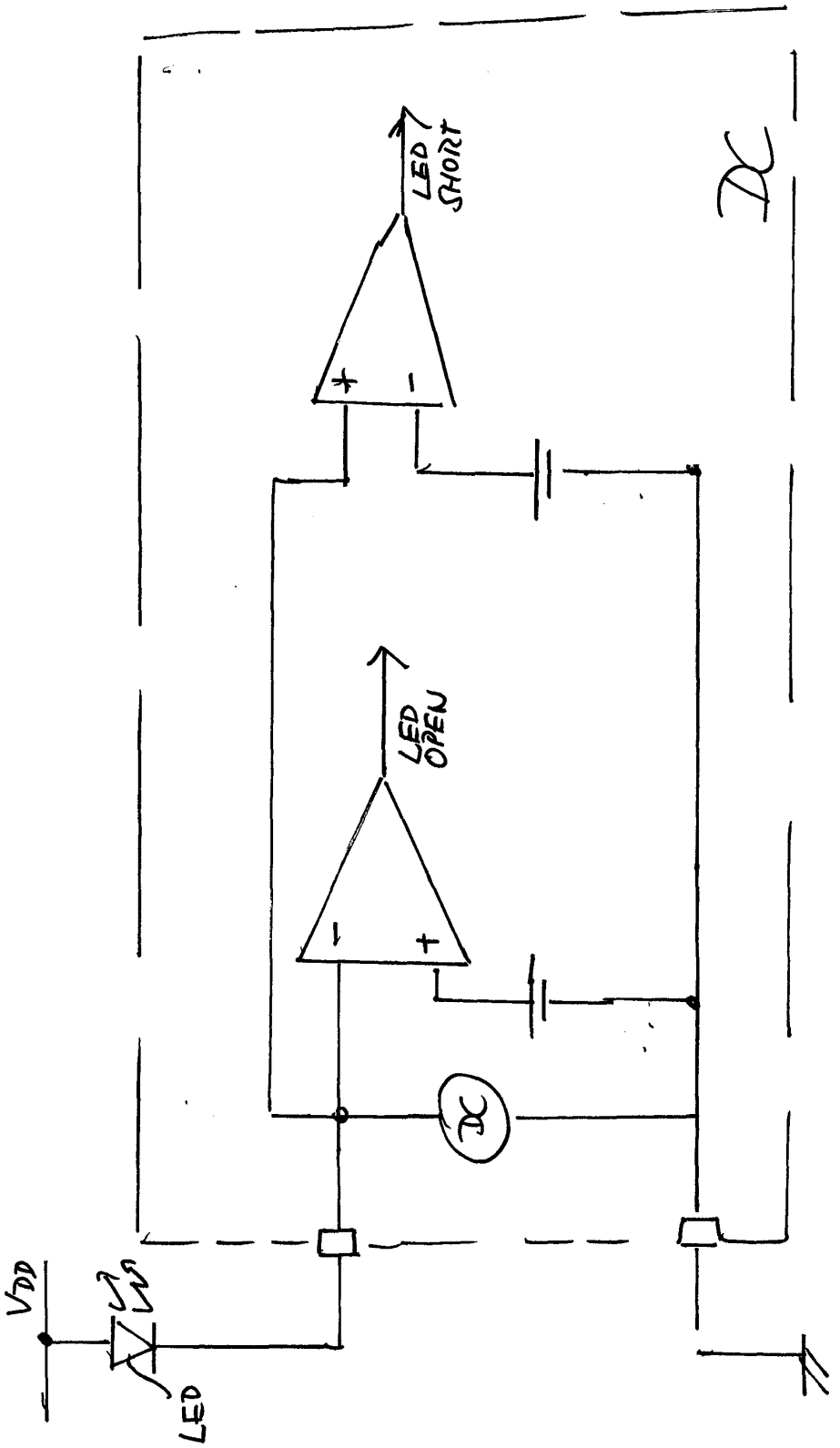
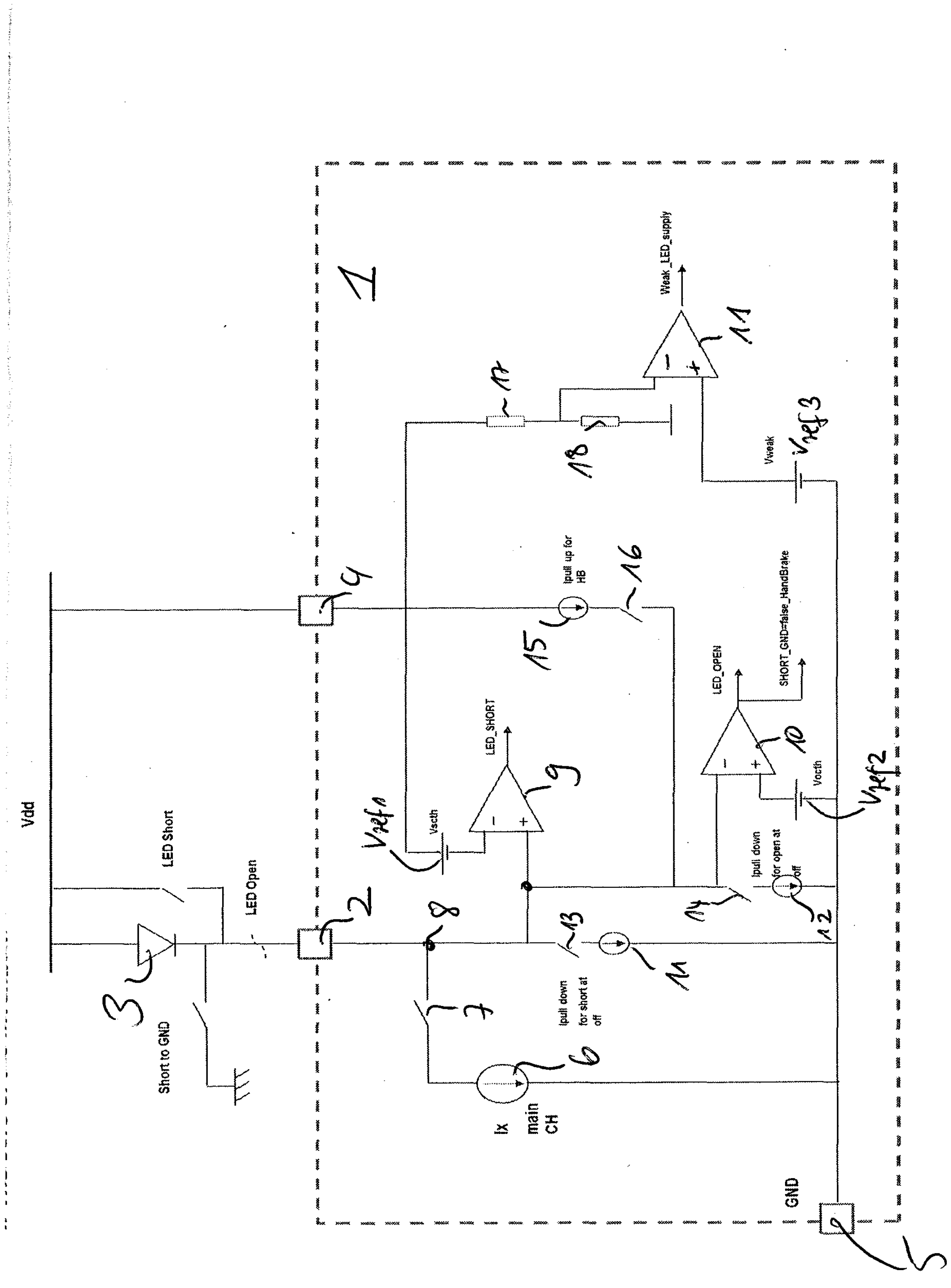


Fig 1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LED Open
Short to GND
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Vscth
Vref1
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SHORT_GND=false_HandBrake
Ipull down for open at off
Vocth
Vref2
Vweak
Vref3
Weak_LED_supply
GND
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Fig 2

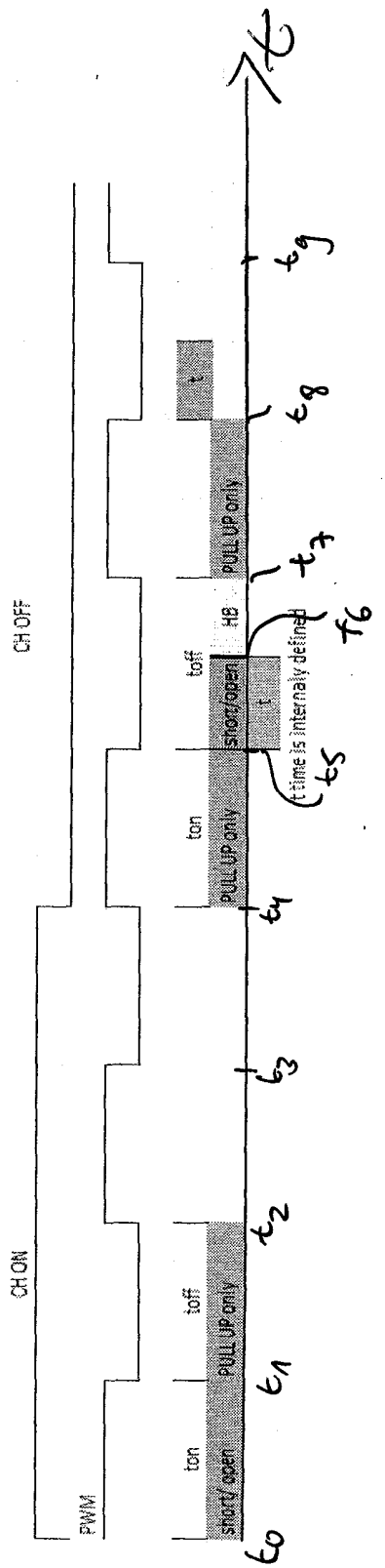
CH OFF
CH ON
PWM
ton
toff
short/open
PULL UP only
t
HB
t (time is internaly defined)
t0
t1
t2
t3
t4
t5
t6
t7
t8
t9

Fig 3

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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 3274

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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