(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 220 405 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
01.05.2024 Bulletin 2024/18

(21) Application number: **17156272.1**

(22) Date of filing: **15.02.2017**

(51) International Patent Classification (IPC):
H01H 71/12 (2006.01) ***H01H 47/00*** (2006.01)
G01R 31/327 (2006.01) ***H02H 3/04*** (2006.01)
H01H 83/20 (2006.01) *H01H 1/60* (2006.01)

(52) Cooperative Patent Classification (CPC):
G01R 31/3278; H01H 47/002; H01H 71/125; H02H 3/04; H01H 1/605; H01H 2083/201

(54) A SIGNAL CONDITIONING CIRCUIT AND A RELAY/CIRCUIT BREAKER CONTROL APPARATUS INCLUDING SUCH A SIGNAL CONDITIONING CIRCUIT

SIGNALAUFBEREITUNGSSCHALTUNG UND RELAIS-/SCHUTZSCHALTERSTEUERUNGSVORRICHTUNG MIT SOLCH EINER SIGNALAUFBEREITUNGSSCHALTUNG

CIRCUIT DE CONDITIONNEMENT DE SIGNAL ET RELAIS/APPAREIL DE COMMANDE DE DISJONCTEUR DE CIRCUIT COMPRENANT UN TEL CIRCUIT DE CONDITIONNEMENT DE SIGNAL

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **26.02.2016 GB 201603385**

(43) Date of publication of application:
20.09.2017 Bulletin 2017/38

(73) Proprietor: **Analog Devices International Unlimited Company**
Limerick (IE)

(72) Inventors:
- **HURWITZ, Jonathan Ephraim David**
  Edinburth, Lothian EH6 7JP (GB)
- **DANESH, Seyed Amir Ali**
  Edinburgh, Lothian EH9 1ES (GB)
- **BARNETT, Iain**
  Lasswade, EH18 1JT (GB)

(74) Representative: **Wallin, Nicholas James**
Withers & Rogers LLP
2 London Bridge
London SE1 9RA (GB)

(56) References cited:
EP-A1- 0 559 580
EP-A2- 1 763 137
WO-A1-99/43065
WO-A1-2013/137971
US-A- 5 499 155
US-A1- 2005 231 858
US-A1- 2006 185 429
US-A1- 2014 055 151
US-A1- 2014 312 871

EP 3 220 405 B1

Description

FIELD

[0001] The present disclosure relates to a signal conditioning circuit suitable for use in relay control systems, as typically found in power distribution systems.

BACKGROUND

[0002] It is known to provide electromechanical switches, for example in the form of relays and circuit breakers within electricity distribution systems. The purpose of relays is to control the flow of energy from one place to another, whereas the primary purpose of a circuit breaker is more protective, in that it seeks to prevent damage from occurring in over voltage or over current conditions by becoming open circuit.

[0003] In order to reliably detect the status of a relay or a circuit breaker, such relays or circuit breakers often have additional sensing contacts formed on the armature which moves to open or close the primary current flow path associated with the armature. Thus the sensing contacts enable a sensing signal to be applied to the relay to confirm whether the relay is open or closed. This stops unexpected fault modes, which may result from failure of a relay coil or sensing circuitry associated with a relay or circuit breaker from remaining hidden to the power distribution system or to a control system associated with the power distribution system.

[0004] Manufacturers and installers of relay and circuit breaker monitoring equipment have applied monitoring signals to the sensing contacts. However, the magnitude of the signals chosen has not benefitted from the provision of international standards and varies by manufacturer, application and country. Thus some manufacturers and installers have chosen to use relatively low sensing voltages, for example in the 5 to 10 volt range, whereas other manufacturers and installers have used sensing voltages at the prevailing mains distribution voltage, and therefore such voltages may be in the 115 volt range, 230-240 volt range or even higher. This inhibits the provision of equipment which is interoperable with the various relay control and monitoring systems installed around the world.

[0005] EP 0559580, cited by the European Patent Office, discloses a current measuring apparatus where a connector block contains three toroidal cores, each acting as transformer having a primary winding connected to a current sensor (a current transformer) and a secondary winding. The secondary windings are linked to a connected integral with the connector block, and arranged to engage a complementary connector of a relay. The arrangement allows the relay to be disconnected whilst the current carrying conductors being monitored by the current sensors are live. The secondary windings are loaded by a resistance that is switchable between two discrete values.

[0006] WO 2013/137971 relates to a relay including a first terminal, a second terminal, a third terminal, a fourth terminal, separable contacts electrically connected between the first and second terminals, an actuator coil comprising a first winding and a second winding electrically connected between the third and fourth terminals, a processor, an output, a first voltage sensing circuit cooperating with the processor to determine a first voltage between the first and second terminals, and a second voltage sensing circuit cooperating with the processor to determine a second voltage between the third and fourth terminals. The processor determines that the separable contacts are closed when the first voltage does not exceed a first predetermined value and the second voltage exceeds a second predetermined value and responsively outputs a corresponding status to the output.

[0007] US2005/0231858 A1 discloses a method for preventing corrosion of a contact, including comparing a potential of a signal line connected to the contact with a predetermined potential corresponding to the corrosion of the contact; flowing a corrosion-prevention current into the contact when a result of the comparing shows that the contact is corroded; inputting into the signal line a signal used for judging a logical value of a connection state of the contact; and in the magnitude relation, setting the predetermined potential on another side of a threshold level used in the judging of the logical value of the connection state of the contact.

[0008] US2014/0312871 A1 discloses an apparatus and method for wetting current measurement and control. A voltage signal and a wetting current are received from a switching device. A first pulse train is created from the voltage signal and the first pulse train has a first duty cycle that is proportional to the voltage at the switching device. The first pulse train is transmitted across an isolation barrier. The first pulse train that is received across the isolation barrier is digitized and at least one operating condition of the switching device is determined based upon the digitized pulse train. A second pulse train having a second duty cycle is received and the wetting current from the switching device is controlled based upon the second duty cycle.

SUMMARY

[0009] According to a first aspect of this disclosure there is provided a signal conditioning circuit defined by claim 1.

[0010] Preferably the input stage is programmable.

[0011] By providing a programmable input stage, it becomes possible to programmatically control an amount of attenuation provided to an input signal in order that various magnitudes of input signal may be converted to a similar signal voltage range for subsequent processing.

[0012] Alternatively the input signal could be attenuated by a set value that suits any expected input voltage. It may then be subjected to gain and/or scaling in the analog or digital domain.

[0013] Within the context of a relay or circuit breaker control system, which may handle high voltages and large currents, there is potential for the electrical environment to be electrically noisy. The provision of an adjustable load connected to the input node and thereby to the relay or circuit breaker sensing contacts associated with that node gives the signal conditioning circuit some robustness against electrical noise.

[0014] Advantageously the adjustable load is controllable to vary its impedance, or at least the current drawn by the load, to provide robustness in the presence of noise whilst not needlessly consuming current.

[0015] Advantageously the programmable input stage further comprises a programmable thresholding circuit or comparator and/or a programmable attenuator such that the noisy input signals can be converted into a well-defined binary signal for use by relay control logic.

[0016] Advantageously the adjustable load is responsive to relay or circuit breaker control signals to open or close the relay in order that the load can provide a wetting current in order to break any surface film that is formed on the contacts of the relay which might otherwise form and break the electrical circuit.

[0017] According to a second aspect of the present disclosure there is provided a method defined by claim 15.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Embodiments of the present disclosure will be described, by way of non-limiting example only, with reference to the accompanying Figures, in which:

Figure 1 schematically illustrates a circuit breaker and its controller within part of a power distribution system;

Figure 2 schematically illustrates the components that may be provided within a controller for a plurality of relays or circuit breakers within a distribution system;

Figure 3 schematically illustrates the circuit components within a signal conditioning circuit constituting an embodiment of the present disclosure;

Figure 4 schematically illustrates the effect of contact bounce during operation of a relay or contact breaker;

Figure 5a diagrammatically indicates how the voltage at the input node may evolve depending on whether the signal applied thereto is real or spurious, and Figure 5b schematically illustrates the demand current demanding by the intelligent load in response to a change of voltage at the input node;

Figure 6 schematically represents a single channel of an embodiment of an input stage in accordance with the present disclosure;

Figure 7 shows sub-systems within the current configuration system in greater detail;

Figure 8 illustrates a circuit diagram for an embodiment of the variable load; and

Figure 9 is a flow chart showing steps performed as part of a data exchange across the isolation barrier in an embodiment of this disclosure.

DESCRIPTION OF SOME EMBODIMENTS OF THE DISCLOSURE

[0019] Figure 1 schematically illustrates a part of a power distribution system. A first power line 10 may be connected to a power distribution network, for example to a generator facility or to distribution nodes within an industrial or residential area. The power line 10 may provide electrical power to a plurality of users (be that individuals, houses, factories, offices, or items of plant or machinery) by way of various distribution spurs of which one, designated 12, is indicated in Figure 1. The power distribution company is under an obligation to provide electrical power to all of its users and hence it does not want the activities of one user, be those malicious or inadvertent, to cause failure of the power distribution network. For this reason the electrical power passes through protective devices, in the form of relays or, as shown here, a circuit breaker 14 which can serve to interrupt the flow of current through distribution line 12 in the event that the current therein becomes too large. The provision of relays and circuit breakers allows reconfiguration of the power distribution system.

[0020] In the past such circuit breakers 14 used to be able to act autonomously to interrupt current flow when it was excessive without knowledge of or consideration of the impact of such an action. This can be detrimental to the power distribution system as a whole and can contribute to cascading power failures, and as a result of that the industry has moved towards management and control systems where the status of a plurality of relays or contact breakers are monitored and controlled by a local relay controller, which may be one control node in a distributed control system or may be responsive to a centralized control node within the local area. The local relay controller is indicated as item 20 in Figure 1.

[0021] For the purposes of the following discussion the term "relay" or circuit breaker should be regarded as referring to an electrically controllable switch. The switch may be mechanical or solid state.

[0022] The term relay controller refers to a device which provides a control signal to the relay to control whether it is conducting between first and second nodes or not conducting between first and second nodes.

[0023] The relay controller 20 can control the status of relays and circuit breakers for a plurality of load lines L1, L2 and so on of which line 12 represents a first line L1. In order to monitor the status of the distribution system the relay controller 20 is responsive to a current measurement device which indicates the current flow in line L1 and provides an indication of that current to input I1 of the relay controller 20. The measurement device can conveniently be a current transformer 22. Similarly, the relay controller 20 may be responsive to a measurement circuit 24 which measures the voltage V of line L1 or on distribution line 10 and provides this to input V1. These two inputs give the controller 20 direct knowledge of the current and voltage pertaining at that time on the distribution line L1 (12). The controller 20 is operable to provide a control signal C1 to control the status of the circuit breaker 14. Thus when C1 is energized an armature within the circuit breaker 14 may be moved to interrupt current flow along line L1. Because component failure may make it difficult to determine the state of the circuit breaker, for example the connection to the current transformer 22 may fail, the controller may monitor a sensing voltage or a sensing current flow through some sensing or measurement contacts 16 provided within the circuit breaker 14, where the status of the sensing or measurement contacts is indicative of the status of the main current flow path through the circuit breaker 14. The sensing/measurement contacts 16 can be assessed by one or two terminals, designated M1, which confirm that the status of the circuit breaker 14 associated with line L1. Similar components, namely circuit breakers or relays, current transformers and if desired volt meters, can be associated with further lines L2, L3, L4 and so on, none of which have been shown, each controlled by the controller 20.

[0024] The controller 20 may have one or more further inputs by which it can receive data relating to the status of other relays or other system parameters such as line current, line voltage or line frequency, which are either directly connected to it or where that data is transferred to the controller 20 by way of other controllers within a distributed control network. These other inputs are designated D1 to DN. Being able to exchange data with other controllers is beneficial in enabling a controller to decide how to respond to an event within the power supply system. For example if line L1 were to become short circuited then the current in line 12/L1 would rise and the voltage on line 10 would drop, giving a good indication of a short circuit event. However a rise in current could arise from a large (and legitimate) load being connected to L1. If, however, the loading on the distribution as a whole was also large and the generating capacity had not, as yet, managed to respond to the load then the voltage on line 10 may fall from its nominal voltage. Under these circumstances a controller acting in isolation might conclude that a short circuit condition exists and act to operate the circuit breaker 14 even though the line 12/L1 was not shorted. However if the controller 20 could receive information from other controllers and be aware of the large currents and lower voltages prevailing in other sections of the distribution network it would be better able to correctly decide not to operate the circuit breaker 14. This is advantageous, both in terms of avoiding unnecessary interruption of supply to a consumer and also avoiding prompting the network to enter a potentially unstable or hazarded state where cascade disconnections may occur.

[0025] Various manufacturers may install circuit breakers within a single installation (or area, factory or distribution station). Each manufacturer may have specified a respective voltage to be supplied to the sensing contacts within their respective circuit breaker or relay. Indeed, that voltage may be supplied by a different (further) component, such as one provided in close association with the respective relay or circuit breaker such that the connection to the controller 20 is only by way of a single line and controller has no influence over the sensing voltage that is provided to it. The use of differing sensing voltages by different equipment manufactures has hindered users from adopting equipment from differing suppliers, thereby allowing equipment suppliers to lock customers in. To allow interoperability between competing systems the controller may need to cope with a wide range of sensing voltages. Additionally, when faced with the chance to supply equipment to an existing installation, a manufacturer may be compelled to install equipment operating at the site sensing voltage. This may require the manufacturer to change the attenuation level within their equipment, with the need to provide adjustable or controllable attenuators on a circuit board. This gives an increased cost to the manufacturer, and an increased risk that board may be installed incorrectly. All of these costs are eventually borne by the customer.

[0026] Figure 2 schematically illustrates the components provided within an embodiment of a controller 20 shown in Figure 1 and constituting an embodiment of the present disclosure. The controller 20 may include several sub-systems. In the arrangement shown in Figure 2 the controller comprises a data processor 32 in association with a memory 34 such that the processor 32 can execute various relay control algorithms. The data processor is responsive to input signals by way of a binary input module 36 and can control the relays that it is responsible for by way of a binary output module 38 having outputs OUT1 to OUTN for driving relay coils or circuit breaker coils. The data processor may further be associated with a display and/or other user interface 40 and a machine to machine communication interface 42. The controller 20 may further include an analogue interface 44 for receiving the outputs of the current transformers and/or voltage sensing circuits.

[0027] The binary input module 36 performs a signal conditioning function, in that it may receive a variety of notionally binary (switched) signals which may be in any one of a plurality of input voltage ranges. Thus, some of the sensing contacts may be connected to a relatively low voltage supply, such as a 10 volt supply, and may provide a digital signal that spans between zero and 10 volts. However other ones of the sensing contacts may be connected to a rectified version of the line voltage on the power line 10, and hence the input voltage may be in the range of several hundred volts, and possibly around 300 to 320 volts. These voltage ranges are only provided as examples.

[0028] In order to provide a versatile binary input module which is widely applicable within a number of different relay and circuit breaker control environments, the binary input module 36 advantageously comprises a programmable input circuit designated 50 in Figure 3 which comprises a programmable attenuator, for example in the form of a resistor string and associated switches, which enables the input range to be transformed from the potentially large input range to a more tightly controlled one. The programmable resistor string may be associated with protection circuits, such as clamping diodes, in order to ensure that mis-programming of the attenuator range does not damage the components within the binary input module 36. Resistor string attenuators are not the only input circuit that might be provided, and as an example other input circuits might simply comprise clamping components to clamp the input signals to a prescribed range or the input circuits might monitor the current flow rather than the voltage through the sensing contacts and might include current to voltage converters, for example by measuring the voltage drop across a resistor in the current flow path, in order to transform the input signals into a predefined voltage domain for subsequent processing by other circuits within the binary input module. The input circuit may also include programmable level shifters and threshold generators for generating comparison thresholds for comparators used to clean the input signals into a more reliable digitized form. As a further alternative the programmable input circuit may include one or more analog to digital convertors which serve to digitize the various input signals and to provide digital words to further sub-systems within the binary input module 36. The use of analog to digital convertors allows more information to be gathered concerning the evolution of currents or voltages at or around a circuit trip event which may facilitate diagnostic activities of the distribution system operator at a later date. In a further option the attenuators may be fixed to cope with the largest input voltage that the manufacturer would expect to see across all installations. The attenuated signal may then be subjected to variable gain and/or variable thresholding.

[0029] The programmable input circuit 50 is responsive to a plurality of input nodes in the range 1 to N of which only one input node I_1 has been shown in Figure 3 for diagrammatic simplicity.

[0030] An output of the programmable input circuitry 50 can be sent to various sub-systems within the binary input module 36. Thus a first output can be provided to a programmable filter and hysteresis unit 52 which can be used to provide a low pass or a delaying function to the signals received from the programmable input circuitry 50 in order to implement a switch de-bounce function. Signals from the input circuitry can also be logged in an event viewer which may keep a snapshot of the status of the signals on the inputs IN1 to INn within a period of time determined by the size of the memory allocated to the event viewer 54. An output of the input circuitry 50 may also be supplied to a health check module 56 whose function is to monitor the power supply to the sensing contacts and/or to infer the physical and electrical goodness of the contacts from the electrical response of the contacts both in a switched state and during the switching event. Thus in an embodiment the health check module 56 may monitor the impedance of the monitoring contacts. It may also check the voltage supplied to the monitoring contacts such that wiring faults cannot remain hidden. Additionally the health check circuitry may also be arranged to monitor other things such as the integrity of the supply to the input circuit, the electrical noise that the circuit is exposed to or parameters of the substation supply, such as mains line voltage, frequency, harmonic content and so on, or these tasks may be performed by one or more functional blocks within the relay controller.

[0031] The input circuitry 50, filter 52 , event viewer 54 and health check system 56 have the potential to be exposed to high voltages, either during normal operation or in the event of a perturbation of the power supply, for example as a result of a lightning strike to a distribution line. It is therefore desirable to protect components of the controller 20 from exposure to such high voltages which might damage those components, such as the data processor 32.

[0032] The binary input module 36 can be configured to address the problem of overvoltage damage occurring within the controller 20 by separating the components of the binary input module into components within a first domain 60 which connects to the at least one input node, components within a second domain 62 which are in direct (galvanic) connection with other components within the controller 20, and an isolation domain 64 between the first domain 60 and the second domain 62.

[0033] The circuits in the first domain 60 require electrical power to operate. This could be derived from the lines that are being monitored (for example by way of the current transformer). However a preferred approach is to use power from a known voltage supply V_{sup} in a low power (second) domain, which is transformed across a power isolator, such as a magnetic transformer, to form an isolated power supply V_{IS} which is provided to the input circuit 50, the filter 52, the event viewer 54 and the health checking component 56. In this embodiment the binary input module 36 also includes a controllable load 70 which may be responsive to signals transferred to it from other components within the controller 20 and/or may act autonomously in response to the voltage received at one of the input nodes to which it has been associated, either programmatically or by the use of physical switches or jumpers. In other variations the controllable load may be provided outside of the binary input circuit.

[0034] Mechanical relays and circuit breakers show a couple of undesirable characteristics. One of these is that the metal contacts act like springs during switching and when closing a relay the contacts initially touch then bounce apart then touch again and then bounce apart and so on before finally closing properly. This rapid series of switching events can look very much like external noise and can also be the source of electrical noise. Therefore rapid switching signals might be real because they are related to contact bounce or they might be spurious because they stem from electrical noise. It is desirable to be able to clean up the input signals resulting from both of these actions and to differentiate between them.

[0035] We will firstly consider the case of contact bounce, i.e. a real signal, but where the switching transient is dirty because of the bouncing contacts and the parasitic capacitance and inductance associated with the various connections to the monitoring contacts within the relay or circuit breaker.

[0036] Figure 4 schematically illustrates the evolution of voltage with respect to time at the monitoring node of the binary input module associated with the sensing contacts of relay in response to a switching event occurring at time Ts causing the contacts to close. Initially there is a delay whilst the contacts are moved from their open position to their closed position. At time T_a the contacts touch and the voltage starts to rise. However a little while later the contacts bounce apart again at time T_b and the voltage starts to fall. Then some time later, at time T_c, the contacts touch again and the voltage starts to rise. This time the magnitude of the bounce is smaller and hence the voltage rises much further towards its final point until at time Ta the contacts separate and the voltage starts to fall, until time T_e when the contacts make for the final time and the voltage rises towards its final steady state value, this value being obtained around time T_f.

[0037] Combinational logic systems would be sufficiently fast in order to be affected by the spurious making and breaking of contact, and hence it is desirable to filter the signal in the filtering and hysteresis unit 52 in order to clean the signal up so that an output signal only transitions one time from the zero value to the asserted value (or vice versa, as appropriate) thereby confirming the operation of the relay. The programmable filtering provided by the unit 52, which may for example by implemented by a finite impulse response low pass filter introduces some delay in confirming that the contact breaker or relay has operated, and hence the filter characteristics need to be chosen with some degree of care in order to achieve the right compromise between responsiveness and excess delay.

[0038] When the sensing contact 16 (Figure 1) is open, the associated input node of the programmable input circuitry 50 may be allowed to float. It therefore becomes responsive to spurious signals which may look like the relay has closed. It is therefore desirable to provide some loading at the input path to pull the signals to ground or some other defined value. In an electrically noisy environment as might occur when switching hundreds of amps at mains voltage or at distribution voltages then electrical noise may be significant. Under such circumstances it would be desirable for the loading at the binary input module inputs to be quite low impedance in order to be robust against the influence of interference. However a downside with this approach is sinking a significant amount of current generates heat, especially when the binary input module is implemented in a small space such as that of an integrated circuit or a module on a circuit board. Therefore it is desirable to use an adjustable or intelligent load 70 which can be controlled to vary the amount of current that it sinks in response to the voltage at the input node.

[0039] Figure 5A shows the voltage V at the input node IN1 and its evolution with respect to time. At time T1 the voltage starts to rise. However at this point in time it is unclear whether the rise is a result of a real switching event or is a result of a spurious signal. However the binary input module can determine which one of these conditions is occurring as a result of controlling the current sunk by the adjustable load 70. As noted before, it is undesirable to pass large amounts of current all the time, and hence as shown in Figure 5B the adjustable load largely passes little or potentially no current. However the adjustable load is responsive to the programmable input circuitry to monitor the rate of change of the voltage at the input node. The voltage rises at a relatively steep rate between periods T_1 and T_2, and this continuing rate of change is sufficient to indicate to processing circuitry within the input circuit, within the adjustable load 70 or to the data processor that a switching event may be occurring and that the system needs to be able to determine whether the switching event is actually happening or whether the signal is spurious. In order to do this, the adjustable load starts to increase the current (autonomously or under instruction from the data processor or a suitable control circuit) that it sinks from time T_2 where the current rises from a minimal value to a load value. If the relay is switching states, and hence the change in voltage is real, then the current flow path through the monitoring relay contacts, whether they bounce or not, will be sufficient to provide current flow in excess of that maximum current I load drawn from the adjustable load 70, and hence the voltage will continue to rise as indicated by the path of the chain line in Figure 5. However, if the voltage change observed in Figure 5A results from electrically induced noise, then once the adjustable load starts to draw current the voltage will collapse towards zero as indicated by the chain-dot line in Figure 5A. Thus operation of the load can be used to determine whether a switching event is real or spurious without having to continuously and needlessly drawn current. The load current can be returned to its notional low value a short time after the potential switching event was detected.

[0040] Another feature of relays and contacts is their need to have a wetting current. In the absence of a wetting current the electrodes tend to oxidize and hence when the relay is operated the oxide may prevent an electrical circuit being made. If a wetting current is provided then this can prevent oxidation from occurring, and also the switching spark can break through any oxidation that has occurred. However, continuously providing a wetting current is wasteful of energy and is not necessary. It is advantageous to be able to periodically provide a wetting current in order to ensure correct operation of the relay without having to sink/supply current needlessly hour after hour. Thus, once again, the adjustable load 70 can be caused to pass a current, the load 70 acting either autonomously or in response to a wetting current control signal which has been passed to it from the data processor across a communications bus that links the various components within the controller 20.

[0041] Figure 6 schematically illustrates an interface 76 comprising an input processing sub-system 78 and an adjustable load 70. The adjustable load comprises a current configuration section 80 and a current source/current sink 82.

[0042] The input processing sub-system 78 in this example comprises a signal conditioning section which may provide programmable gain/attenuation to input signals to bring them into a harmonized voltage range. The signal conditioning section may be the programmable input circuit 50 described with respect to Figure 3. The conditioned signal from one or more input nodes Inx is, in this example, then digitized by an analog to digital converter 82. The analog to digital converter may be of any suitable implementing technology, with successive approximation or sigma-delta converters being likely choices. The digital output representing the input signal is provided to a programmable threshold and hysteresis unit 52a and then to a programmable glitch filter 52b, both of which may be provided in block 52 of Figure 3, so as to yield a cleaned signal indicating the status of the monitoring signal provided by the sensing contacts 16.

[0043] Figure 7 shows the current configuration system 80 in greater detail. The current configuration system 80 may comprise several sub-systems. Examples of such sub-systems include a current supply 91 where the current varies as a function of the input voltage. A simple function would be to make the current proportional to the voltage, thereby simulating current flow through a resistor. As a further alternative a capacitor may be used such that the current flow is proportional to the rate of change of voltage. This gives a wetting current as the input is switched. Both of these approaches may be used singularly or in combination. However other functions can be implemented. The functions may be continuous or they may be discontinuous (stepped).

[0044] A second module or sub-system 92 may provide a piece-wise linear current of a controllable magnitude and duration. The second sub-system 92 may be responsive to changes in the input voltage as shown and/or may be responsive to an external trigger.

[0045] A third sub-system 93 may supply a fixed current. However that current may be switched on or off in response to the input voltage and/or an external trigger. Alternatively the value of the "fixed" current may be a value which has a first value if the input voltage lies in a first voltage range and a second value if the input voltage lies in a second voltage range (not overlapping with the first) but hysteresis may be applied to the transition between voltages.

[0046] An impedance monitor 94 provided, for example, as part of the health check system may also be provided and be able to command a change in the current so as to be able to determine the contact impedance of the sensing contacts.

[0047] The various current demands are summed by a summer 95, and a current demand signal used to cause the current source 82 to cause a current to flow at the input node, and hence through the sensing contact.

[0048] The current drawn by the adjustable load 70 can be controlled/set by various circuits, including a bank of resistors that can be switched into and out of a current flow path. However an approach with more resolution and control is to control the current with a current mirror circuit in operation with a voltage to current convertor, such as that shown in Figure 8. Thus, a digital to analog convertor 96 may receive a digital word indicating the amount of current that should be drawn by the programmable and hence adjustable current load. The digital word may be provided either to set a wetting current or it may be used in the determination as to whether an input signal is real or is spurious as described hereinbefore. If the rate of change of voltage is monitored by an analog to digital converter (ADC) operating within the programmable input circuit 50, then a output of the ADC can be processed to provide a signal to the digital to analogue convertor 96 within the adjustable load. However, it would also be possible to monitor the evolution of voltage by way of, for example, a capacitor and resistor high pass filter combination which might be connected directly to the drain of a master transistor 110 within the current mirror or which might trigger a monostable 112 to provide a fixed duration pulse to the drain of the transistor 110. Thus the load 70 could be triggered both from control signals within the digital domain and control signals emanating from within an analog domain. The voltage from the monostable 112 or the analogue to digital convertor 90 (optionally by way of a buffer 114) can be converted into current via series resistors 116 and/or 118. The current then flows through the diode connected transistor 110, which has its gate connected to a slave transistor 120 to form a current mirror, as is well known to the person skilled in the art, to draw a current via the node 72.

[0049] As noted before each of the programmable filter 52, event viewer 54, health checking component 56 and programmable load 70 may need to communicate its information with other components within the controller 20. However in the event of device failure the input circuitry, filter 52, event viewer 54 and health check system 56 as well as load 70 might become exposed to high voltages which would damage the rest of the control system. Therefore digital information from these systems is exchanged with the rest of the controller by way of a communications interface, such as a two wire communications interface 130 shown in Figure 3 and a data isolator 132 which provides galvanic isolation between the communications interface and the input circuit 50, filter 52, event viewer 54 and health checker 56.

[0050] Digital data could simply be transmitted by way of DC blocking capacitors. However other isolation devices, such as optical isolators and magnetic couplers also exist and which may provide more robust isolation, especially in terms of common mode rejection. Preferably data transmitters and receivers in association with the isolation barrier may be used in a handshaking mode rather than an open loop mode. Such an arrangement will be discussed with respect to Figure 9. For the purpose of this discussion it will be assumed that the programmable filter 52 has been selected by way of instructions sent over the communication interface 130 and isolator 132 to transmit the status of a selected input node. The node data may be prefaced by an identifier indicating the number of the node and then contain one of more bits of data representing the status of that node.

[0051] The isolator may be provided in association with a suitable data conditioning circuit that receives incoming data, for example as a word and formats it in a form suitable for transmission across the isolation barrier. We may assume for simplicity that the word is placed in a word buffer at step 150. From here assume that a parallel to serial conversion is performed by a data transmitter such that each bit of the data is sequentially received at step 160 from the word buffer, encoded at step 170 (for example by pulse encoding the rising and falling edges of a bit in different ways or representing a "1" with a tone of a first frequency and a "0" with a tone of a second frequency or no tone at all), and passing the data across the isolation barrier. A receiver circuit associated with, for example provided as part of, the isolator 132 decodes the received data at step 190 to regenerate the transmitted bit. The received data, either on a bit-by-bit basis or a word-by-word basis can be re-encoded at step 200 and transmitted back across the isolation barrier to the data transmitter. The data transmitter can then compare the word that it received at step 150 with the word returned to it from the receiver at step 210 and 215. The comparison of the word that was originally sent and the word which has been received across the isolation barrier can be performed by storing the received data in a correspondingly sized register and a bit by bit exclusive or (XOR) can be performed in order to check if all of the bits are identical.

[0052] If there is a discrepancy, the data can be flagged as being in error at step 220. This may cause the data processor 32 to implement some recovery procedure, for example instructing the data to be resent and/or modifying the procedure it used to control the circuit breaker. Furthermore, the data transmitter may also be arranged to confirm that the data provided by the receiver was indeed correct, and it can send a "data valid" signal at step 230 to the receiver to tell the receiver that the data that it has received is valid, and then can be output at step 240 to other devices over the communication interface 130. It will be appreciated that other data channels may be provided to speed data throughput and/or to provide bidirectional communication across the isolator.

[0053] The data link incorporating the isolator may be used to transmit empty data packets or link checking data when no useful data is transmitted so as to monitor the link to avoid any failure thereof going undetected.

[0054] It may be desirable to make the monitoring system more robust and enhance its ability to detect faults within the supply network that it is monitoring. For example, multiple sensing contacts may be provided within a relay and/or a single sensing contact may be connected to multiple input nodes via suitable impedances such that redundancy and additional signal processing robustness is provided by the binary input module. When multiple inputs relate to the same armature, then majority voting may be applied to combine the several inputs into a single output. The multiple inputs may come from a single contact or from multiple armature contacts. Although not illustrated in Figure 3, the binary input module may also include one or more majority vote or other combinational logic circuits which are programmable to allow for simple signal combinations to be tested and acted on. However a disadvantage with this approach is the use of additional inputs requires additional channels and additional pins. Furthermore if the additional inputs provide redundant measurements of the same point in a system, then the reason for a fault being reported may be hidden.

[0055] Consider the operation of a single impedance monitor on a single channel that is monitoring the status of a normally closed contact. The impendence monitor can look at the impedance that exists in a path from the impedance monitor through wiring to the contact, and then from the contact through more wiring to a voltage source (such as a battery providing the sensing voltage). If the impedance goes unexpectedly high, indicating a fault, the location of the fault is unknown. One cannot tell the difference between a fault at the voltage source, oxide build up on the contacts or problems with the connecting cables or cable terminals.

[0056] However by aggregating data from different points in the system the nature of the failure can be resolved, or at least the number of possible causes reduced. Thus, a pair of inputs could be configured with one connected to a sensing contact and one connected to the voltage source to determine whether the problem is caused by a supply fault or is specific to the sensing contact.

[0057] Alternatively, where some circuit components are shared, such as the voltage source, the presence or absence of a shared failure can be used to infer where the failure occurs.

[0058] Additionally providing a sensing path that replicates part or all on an input signal path may provide redundancy against failure of that replicated path but only require one pin. This could provide protection against failure of an attenuator within the input module.

[0059] The input signal conditioning circuit may provide multiple different paths for at least part of the signal path through the conditioning circuit. For example implementing paths within different levels of attenuation and/or different filtering techniques in conjunction with majority voting gives redundancy (for example if some filters fail to reject a signal others may correctly reject it) and the option to enhance resilience for example by changing the majority needed to pass a vote.

[0060] The event monitor may, depending on the size of memory allocated to it, repeatedly record various voltage, current and relay position and performance measurements or a rolling basis such that if a noteworthy event occurs that data can be made available for fault mode analysis.

[0061] The provision of controllable gain, filtering and current stages facilitates the integration of the input module into an integrated circuit to replace the plurality of individual printed circuit boards that are commonplace at the time of writing this disclosure.

[0062] The binary input module and/or the processor 32 in communication with it may adjust the filter responses. The binary input module 36 may be arranged such that the filter responses vary as a function of the impedance of the contacts as determined by the contact health check (impedance monitor) as, for example, a higher impedance may imply a greater susceptibility to noise. Thus the filter response may be adapted dynamically to provide higher resilience to noise when needed, and provide faster response times when the improved resilience is not needed.

[0063] Another approach is to provide multiple filters with different characteristics acting on the same input signal and to weight or mask their outputs as appropriate. Thus outputs may be masked in response to measurement of output impedance. The number of filters operating may be adjusted depending on estimates of noise or interference in the system. Thus all the filters could be masked in the event of an EMC event (such as a lightening strike) based on rate of charge of voltage input and overvoltage conditions. Filters may also be masked or have a lower weight assigned to them if they are judged to be faulty by the processor 32.

[0064] It is thus possible to provide an integrated circuit having the necessary functionality to be used in a wide variety of binary input systems, such as those found within the relay and circuit breaker control environment.

[0065] Some channels of the binary input may be arranged to monitor the relay/circuit breaker contacts directly instead of or as well as monitoring the sensing contacts, for example by operating in a current mode to monitor the contact impedance.

Claims

1. A signal conditioning circuit (36) for monitoring the status of a mechanical relay or a mechanical circuit breaker (14), the signal conditioning circuit (36) comprising:

   at least one input node;
   an input stage (78) connected to the at least one input node, wherein the input stage (78) is for processing an input signal received at the at least one input node and for monitoring the voltage at the at least one input node; and
   an adjustable load (70) to apply a load at the at least one input node,
   characterised in that the adjustable load (70) is configured to temporarily increase the current drawn by the load in response to a voltage rise at the at least one input signal node, or to a rate of voltage rise at the at least one input signal node, in order to remove spurious signals at the input node that would be present if the voltage rise resulted from electrically induced noise.

2. A signal conditioning circuit as claimed in claim 1, in which the signal conditioning circuit (36) converts the input signal received at the at least one input node to a binary signal.

3. A signal conditioning circuit as claimed in claim 1 or 2, in which the input stage (78) includes at least one programmable attenuator, or at least one fixed attenuator and a programmable amplifier to enable the input range to be transformed.

4. A signal conditioning circuit as claimed in any preceding claim, in which the input stage (78) includes a programmable threshold circuit (52a) and/or comparator to clean the input signals into a more reliable digitized form.

5. A signal conditioning circuit as claimed in any preceding claim, in which the adjustable load (70) passes a current, and where the current is controlled by a current source (82).

6. A signal conditioning circuit as claimed in any preceding claim, in which the input stage (78) further comprises a programmable filter (52) to provide a low pass or a delaying function to the input signal.

7. A signal conditioning circuit as claimed in any preceding claim, further including an event viewer (54) to keep a snapshot of the status of the input signals.

8. A signal conditioning circuit as claimed in any preceding claim, further including:

an at least one isolation barrier (132) with provides galvanic isolation, and
data processing circuits on either side of the isolation barrier for transmitting data between a first side of the isolation barrier and a second side of the isolation barrier.

9. A signal conditioning circuit as claimed in claim 8, in which the data processing circuits are configured to confirm to each other what data has been transmitted.

10. A signal conditioning circuit as claimed in any preceding claim, in which the signal conditioning circuit (36) comprises a plurality of signal processing paths connected to at least one input node, and the outputs of the signal processing paths are provided to a majority vote circuit.

11. An integrated circuit scale package comprising a signal conditioning circuit as claimed in any preceding claim.

12. An integrated circuit and preferably a monolithically integrated circuit, comprising a signal conditioning circuit (36) as claimed in any of claims 1 to 10.

13. A relay or circuit breaker controller (20) comprising a signal conditioning circuit (36) as claimed in any of claims 1 to 10.

14. A relay or circuit breaker as claimed in claim 13, when, in use, the adjustable load is connected to the sensing contacts of a relay or circuit breaker to provide a load current and/or a wetting current.

15. A method of monitoring a mechanical relay or a mechanical circuit breaker (14), the relay or circuit breaker including sensing contacts (16) to which a sensing signal is applied to confirm whether the relay or circuit breaker is open or closed, the method comprising:

monitoring a voltage at a sensing signal input node associated with the sensing contacts (16) or a rate of change of voltage at the sensing signal input node associated with the sensing contacts (16) to identify a possible switching event;
temporarily increasing a current at the input node through an adjustable load (70) applying a load at the input node in response to sensing a voltage rise at the input signal node, or to the rate of voltage rise at the at least one input signal node; and; and
determining if the voltage rise resulted from electrically induced noise, or is indicative of the closing of the mechanical relay or mechanical circuit breaker (14).

Patentansprüche

1. Signalkonditionierungsschaltung (36) zum Überwachen des Status eines mechanischen Relais oder eines mechanischen Schaltungsunterbrechers (14), wobei die Signalkonditionierungsschaltung (36) Folgendes umfasst:

wenigstens einen Eingangsknoten;
eine Eingangsstufe (78), die mit dem wenigstens einen Eingangsknoten verbunden ist, wobei die Eingangsstufe der Verarbeitung eines Eingangssignals, das an dem wenigstens einen Eingangsknoten empfangen wird, und der Überwachung der Spannung an dem wenigstens einen Eingangsknoten dient; und
eine einstellbare Last (70), um an den wenigstens einen Eingangsknoten eine Last anzulegen,
dadurch gekennzeichnet, dass
die einstellbare Last (70) konfiguriert ist, den durch die Last gezogenen Strom in Reaktion auf einen Spannungsanstieg an dem wenigstens einen Eingangssignalknoten oder eine Spannungsanstiegsrate an dem wenigstens einen Eingangssignalknoten vorübergehend zu erhöhen, um Störsignale an dem Eingangsknoten, die vorhanden wären, wenn der Spannungsanstieg eine Folge von elektrisch induziertem Rauschen wäre, zu entfernen.

2. Signalkonditionierungsschaltung nach Anspruch 1, wobei die Signalkonditionierungsschaltung (36) das an dem wenigstens einen Eingangsknoten empfangene Eingangssignal in ein binäres Signal umsetzt.

3. Signalkonditionierungsschaltung nach Anspruch 1 oder 2, wobei die Eingangsstufe (78) wenigstens einen programmierbaren Dämpfer enthält oder wenigstens einen festen Dämpfer und einen programmierbaren Verstärker enthält, um den Eingangsbereich transformieren zu können.

4. Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch, wobei die Eingangsstufe (78) eine Schaltung (52a) mit programmierbaren Schwellenwert und/oder einen Komparator enthält, um die Eingangssignale in eine zuverlässigere digitalisierte Form zu reinigen.

5. Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch, wobei die einstellbare Last (70) einen Strom durchlässt und wobei der Strom durch eine Stromquelle (82) gesteuert wird.

6. Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch, wobei die Eingangsstufe (78) ferner ein programmierbares Filter (52) enthält, um für das Eingangssignal eine Tiefpass- oder eine Verzögerungsfunktion bereitzustellen.

7. Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch, die ferner einen Ereignisbeobachter (54) enthält, um einen Schnappschuss des Status der Eingangssignale zu halten.

8. Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch, die ferner Folgendes umfasst:

wenigstens eine Isolationssperre (132), die eine galvanische Isolation bereitstellt, und
Datenverarbeitungsschaltungen auf jeder Seite der Isolationssperre, um Daten zwischen einer ersten Seite der Isolationssperre und einer zweiten Seite der Isolationssperre zu übertragen.

9. Signalkonditionierungsschaltung nach Anspruch 8, wobei die Datenverarbeitung konfiguriert sind, sich gegenseitig zu bestätigen, welche Daten übertragen worden sind.

10. Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch, wobei die Signalkonditionierungsschaltung (36) mehrere Signalverarbeitungspfade umfasst, die mit wenigstens einem Eingangsknoten verbunden sind, und wobei die Ausgänge der Signalverarbeitungspfade für eine Mehrheitsbeschlussschaltung bereitgestellt werden.

11. Baugruppe auf der Skala integrierter Schaltungen, die eine Signalkonditionierungsschaltung nach einem vorhergehenden Anspruch enthält.

12. Integrierte Schaltung und vorzugsweise monolithisch integrierte Schaltung, die eine Signalkonditionierungsschaltung (36) nach einem der Ansprüche 1 bis 10 enthält.

13. Steuereinheit (20) für Relais oder Schaltungsunterbrecher, die eine Signalkonditionierungsschaltung (36) nach einem der Ansprüche 1 bis 10 enthält.

14. Relais oder Schaltungsunterbrecher nach Anspruch 13, wobei im Gebrauch die einstellbare Last mit den Erfassungskontakten eines Relais oder eines Schaltungsunterbrechers verbunden ist, um einen Laststrom und/oder einen Benetzungsstrom bereitzustellen.

15. Verfahren zum Überwachen eines mechanischen Relais oder eines mechanischen Schaltungsunterbrechers (14), wobei das Relais oder der Schaltungsunterbrecher Erfassungskontakte (16) aufweist, an die ein Erfassungssignal angelegt wird, um zu bestätigen, ob das Relais oder der Schaltungsunterbrecher geöffnet oder geschlossen ist, wobei das Verfahren Folgendes umfasst:

Überwachen einer Spannung an einem Erfassungssignal-Eingangsknoten, der den Erfassungskontakten (16) zugeordnet ist, oder einer Spannungsänderungsrate an dem Erfassungssignal-Eingangsknoten, der den Erfassungskontakten 16) zugeordnet ist, um ein mögliches Schaltereignis zu identifizieren;
vorübergehendes Erhöhen eines Stroms an dem Eingangsknoten durch eine einstellbare Last (70), die an den Eingangsknoten eine Last anlegt, in Reaktion auf die Erfassung eines Spannungsanstiegs an dem Eingangssignalknoten oder die Spannungsanstiegsrate an dem wenigstens einen Eingangssignalknoten; und
Bestimmen, ob der Spannungsanstieg die Folge eines elektrisch induzierten Rauschens ist oder das Schließen des mechanischen Relais oder des mechanischen Schaltungsunterbrechers (14) angibt.

Revendications

1. Circuit de conditionnement de signal (36) pour surveiller l'état d'un relais mécanique ou d'un disjoncteur mécanique (14), le circuit de conditionnement de signal (36) comprenant :

au moins un noeud d'entrée ;
un étage d'entrée (78) connecté au au moins un noeud d'entrée, dans lequel l'étage d'entrée (78) est destiné à traiter un signal d'entrée reçu au niveau du au moins un noeud d'entrée et à surveiller la tension au niveau du au moins un noeud d'entrée ; et
une charge ajustable (70) pour appliquer une charge au niveau du au moins un noeud d'entrée,

caractérisé en ce que la charge ajustable (70) est configurée pour augmenter temporairement le courant consommé par la charge en réponse à une augmentation de tension au niveau du au moins un noeud de signal d'entrée, ou à un taux d'augmentation de tension au niveau du au moins un noeud de signal d'entrée, afin d'éliminer des signaux parasites au niveau du noeud d'entrée qui seraient présents si l'augmentation de tension résultait d'un bruit induit électriquement.

2. Circuit de conditionnement de signal selon la revendication 1, dans lequel le circuit de conditionnement

de signal (36) convertit le signal d'entrée reçu au niveau du au moins un noeud d'entrée en un signal binaire.

3. Circuit de conditionnement de signal selon la revendication 1 ou 2, dans lequel l'étage d'entrée (78) inclut au moins un atténuateur programmable, ou au moins un atténuateur fixe et un amplificateur programmable pour permettre à la plage d'entrée d'être transformée.

4. Circuit de conditionnement de signal selon l'une quelconque des revendications précédentes, dans lequel l'étage d'entrée (78) inclut un circuit à seuil programmable (52a) et/ou un comparateur pour nettoyer les signaux d'entrée sous une forme numérisée plus fiable.

5. Circuit de conditionnement de signal selon l'une quelconque des revendications précédentes, dans lequel la charge ajustable (70) fait passer un courant, et dans lequel le courant est commandé par une source de courant (82).

6. Circuit de conditionnement de signal selon l'une quelconque des revendications précédentes, dans lequel l'étage d'entrée (78) comprend en outre un filtre programmable (52) pour fournir une fonction passe-bas ou de retard au signal d'entrée.

7. Circuit de conditionnement de signal selon l'une quelconque des revendications précédentes, incluant en outre un observateurs d'événements (54) pour conserver un instantané de l'état des signaux d'entrée.

8. Circuit de conditionnement de signal selon l'une quelconque des revendications précédentes, incluant en outre :

au moins une barrière d'isolation (132) qui fournit une isolation galvanique, et
des circuits de traitement de données de chaque côté de la barrière d'isolation pour transmettre des données entre un premier côté de la barrière d'isolation et un second côté de la barrière d'isolation.

9. Circuit de conditionnement de signal selon la revendication 8, dans lequel les circuits de traitement de données sont configurés pour confirmer les unes aux autres les données qui ont été transmises.

10. Circuit de conditionnement de signal selon l'une quelconque des revendications précédentes, dans lequel le circuit de conditionnement de signal (36) comprend une pluralité de trajets de traitement de signal connectés à au moins un noeud d'entrée, et les sorties des trajets de traitement de signal sont fournies à un circuit de vote majoritaire.

11. Boîtier à l'échelle de circuit intégré comprenant un circuit de conditionnement de signal selon une quelconque revendication précédente.

12. Circuit intégré et de préférence un circuit intégré de manière monolithique, comprenant un circuit de conditionnement de signal (36) selon l'une quelconque des revendications 1 à 10.

13. Dispositif de commande de relais ou de disjoncteur (20) comprenant un circuit de conditionnement de signal (36) selon l'une quelconque des revendications 1 à 10.

14. Relais ou disjoncteur selon la revendication 13 lorsque, en utilisation, la charge ajustable est connectée aux contacts de détection d'un relais ou d'un disjoncteur pour fournir un courant de charge et/ou un courant de mouillage.

15. Procédé de surveillance d'un relais mécanique ou d'un disjoncteur mécanique (14), le relais ou le disjoncteur incluant des contacts de détection (16) auxquels un signal de détection est appliqué pour confirmer si le relais ou le disjoncteur est ouvert ou fermé, le procédé comprenant les étapes consistant à :

surveiller une tension au niveau d'un noeud d'entrée de signal de détection associé aux contacts de détection (16) ou un taux de changement de tension au niveau du noeud d'entrée de signal de détection associé aux contacts de détection (16) pour identifier un événement de commutation possible ;
augmenter temporairement un courant au niveau du noeud d'entrée par l'intermédiaire d'une charge applicable (70) appliquant une charge au niveau du noeud d'entrée en réponse à la détection d'une augmentation de tension au niveau du noeud de signal d'entrée, ou au taux d'augmentation de tension au niveau du au moins un noeud de signal d'entrée ; et
déterminer si l'augmentation de tension résulte d'un bruit induit électriquement, ou indique la fermeture du relais mécanique ou du disjoncteur mécanique (14).

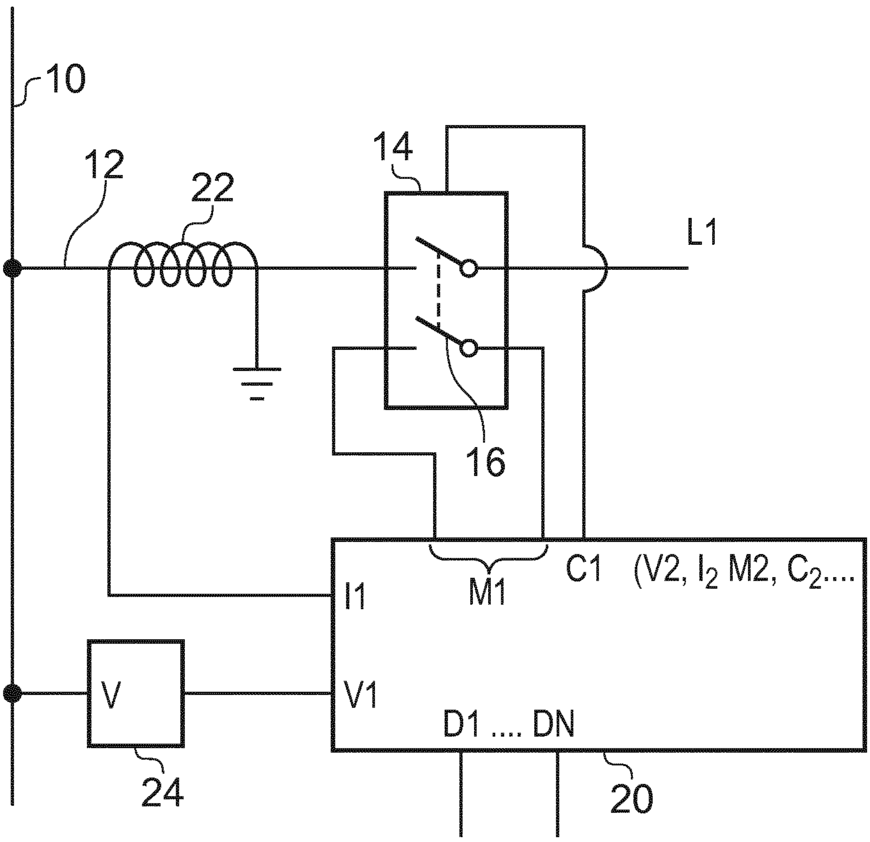


FIG. 1

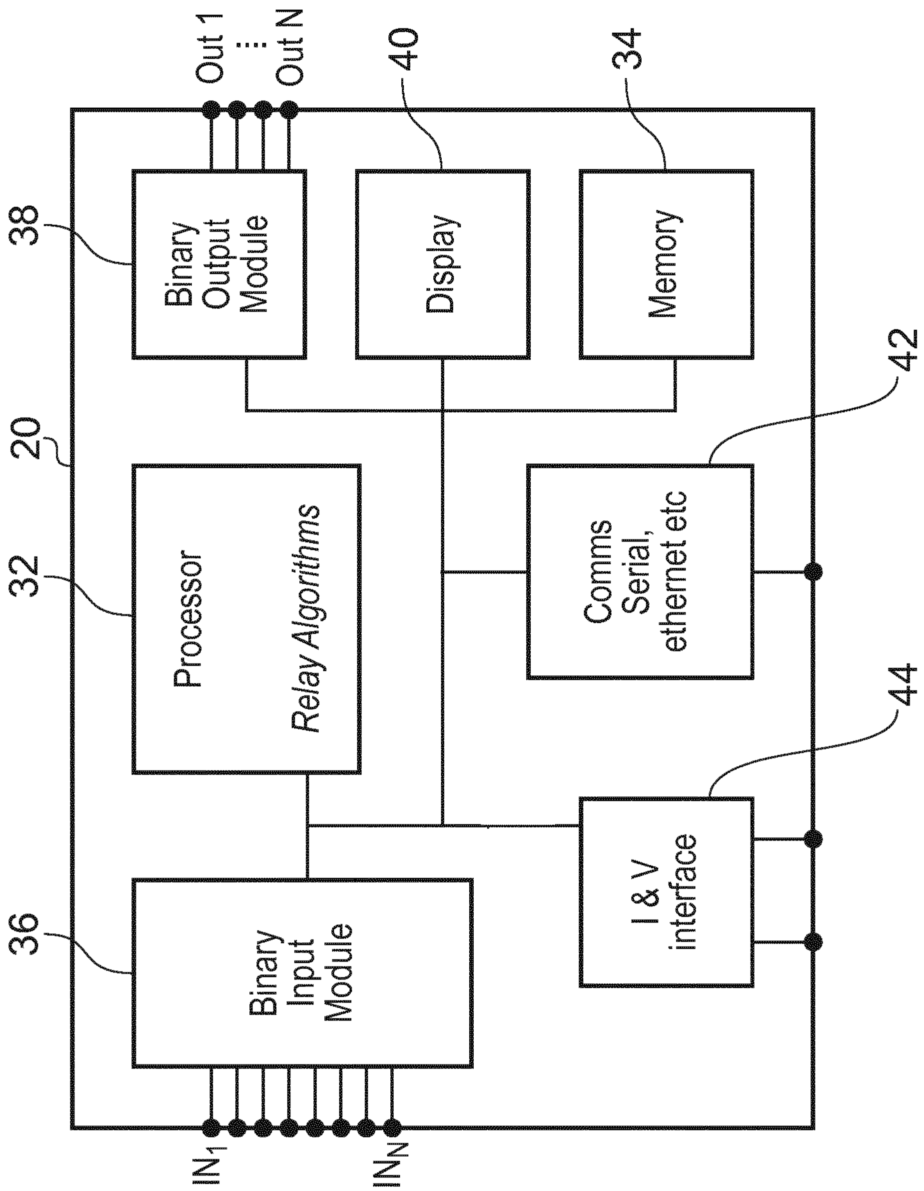
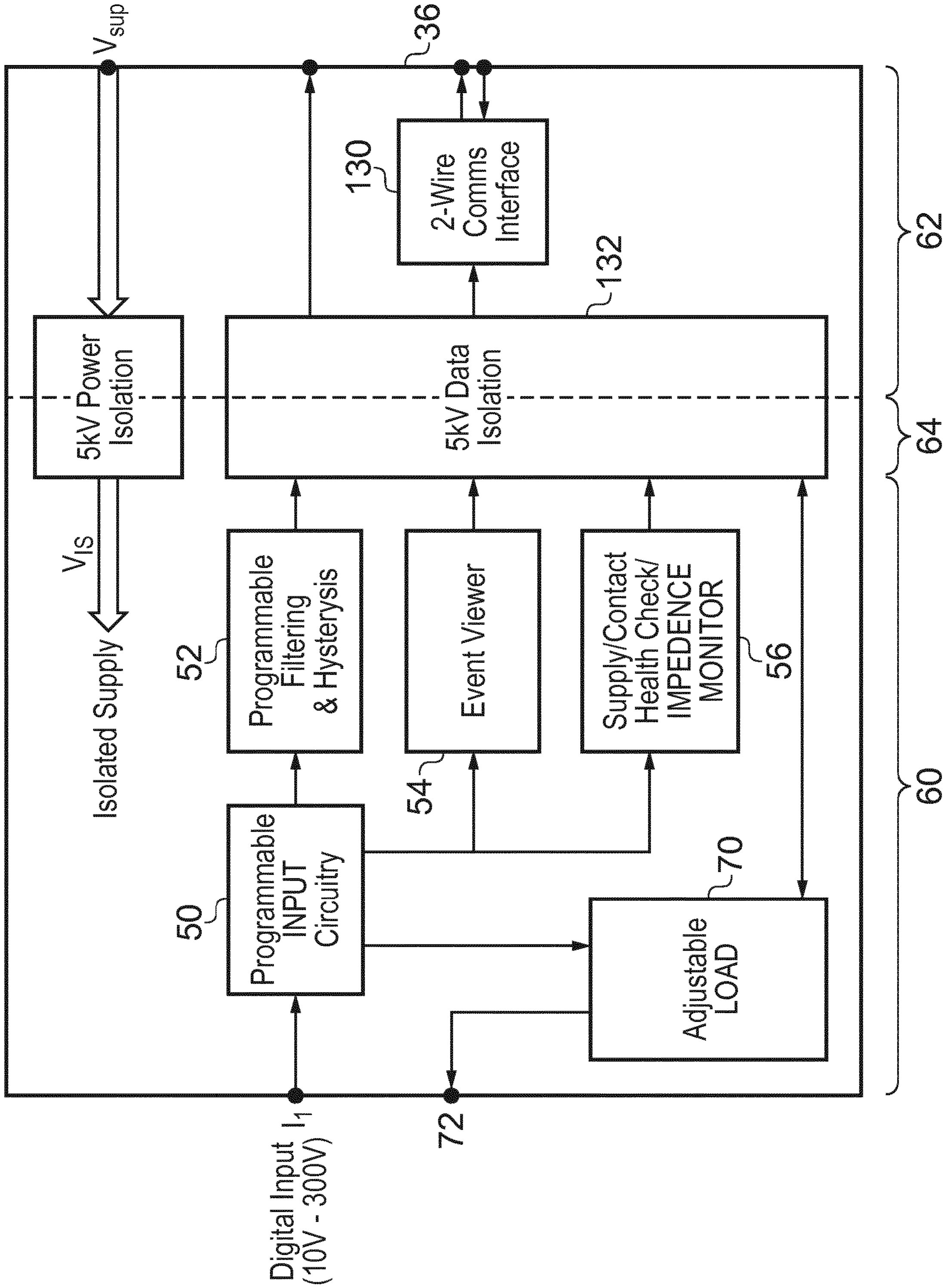

38
Binary Output Module
Out 1
Out N
40
Display
34
Memory
20
32
Processor
Relay Algorithms
42
Comms Serial, ethernet etc
36
Binary Input Module
44
I & V interface
IN_1
IN_N

FIG. 2



Vsup
36
130
2-Wire Comms Interface
132
62
5kV Power Isolation
5kV Data Isolation
64
VIS
Isolated Supply
52
Programmable Filtering & Hysterysis
Event Viewer
Supply/Contact Health Check/ IMPEDENCE MONITOR
56
54
60
50
Programmable INPUT Circuitry
70
Adjustable LOAD
Digital Input (10V - 300V) I1
72

FIG. 3

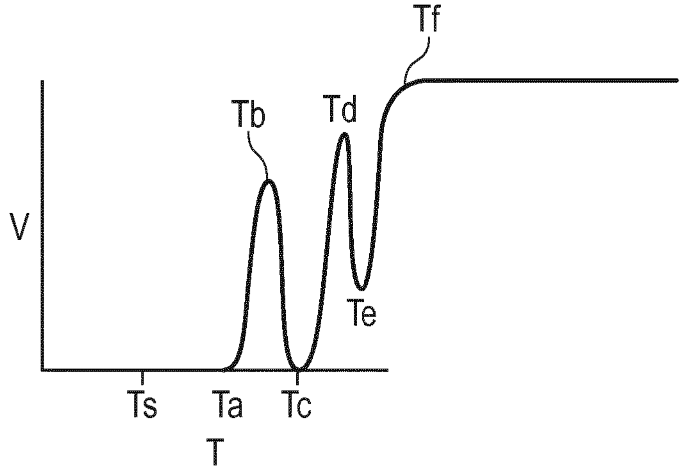


FIG. 4

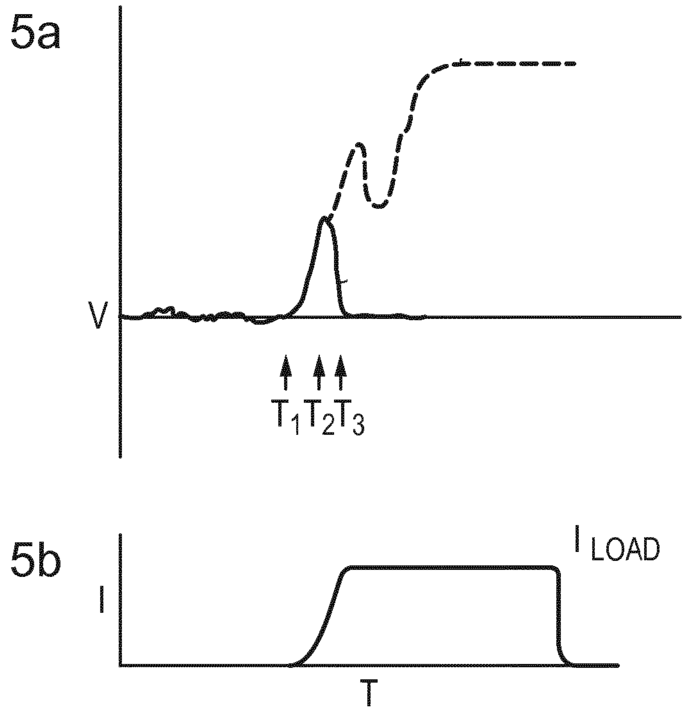


FIG. 5

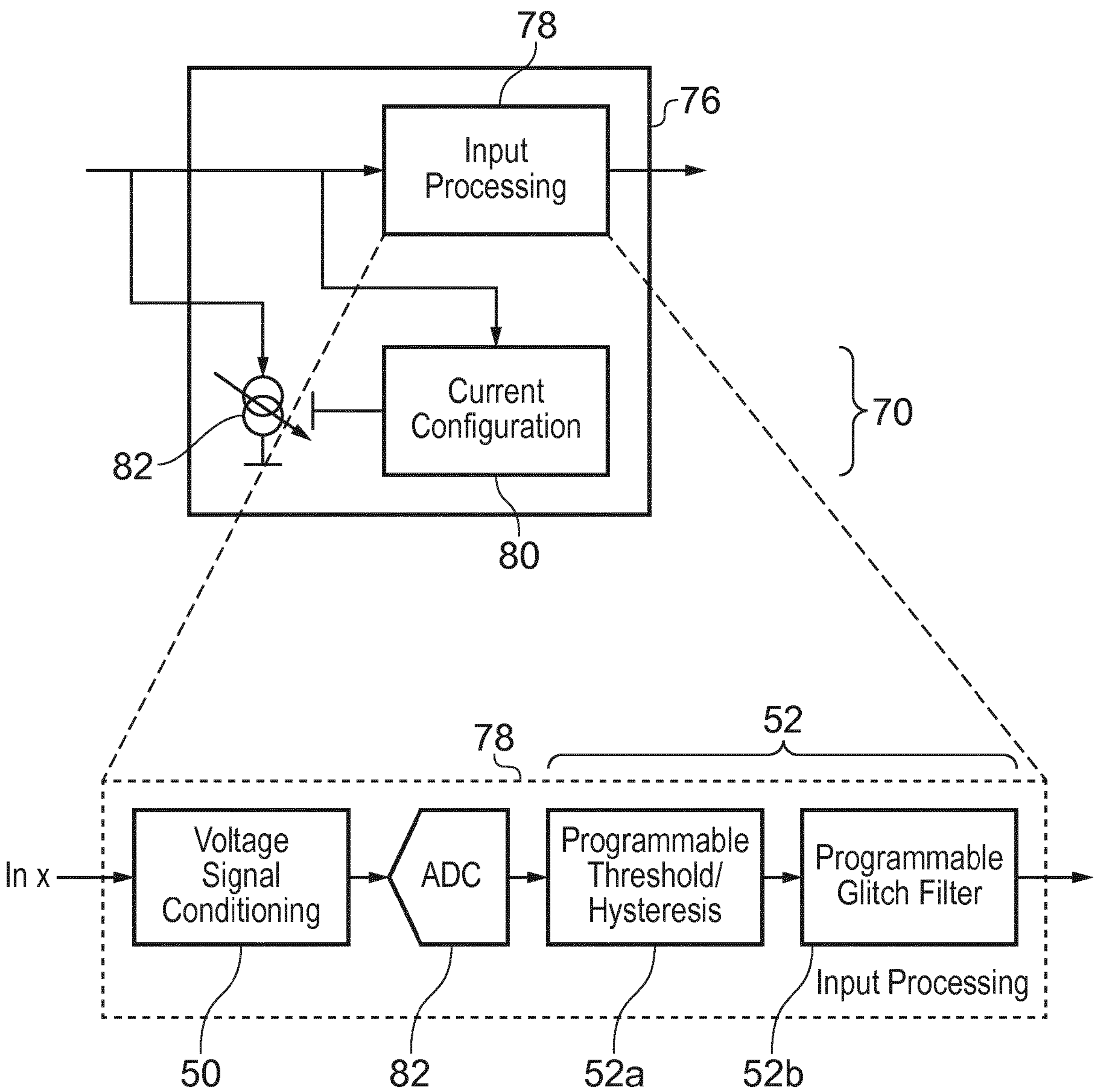

78
76
Input
Processing
Current
Configuration
82
80
70
78
52
In x
Voltage
Signal
Conditioning
ADC
Programmable
Threshold/
Hysteresis
Programmable
Glitch Filter
Input Processing
50
82
52a
52b

FIG. 6

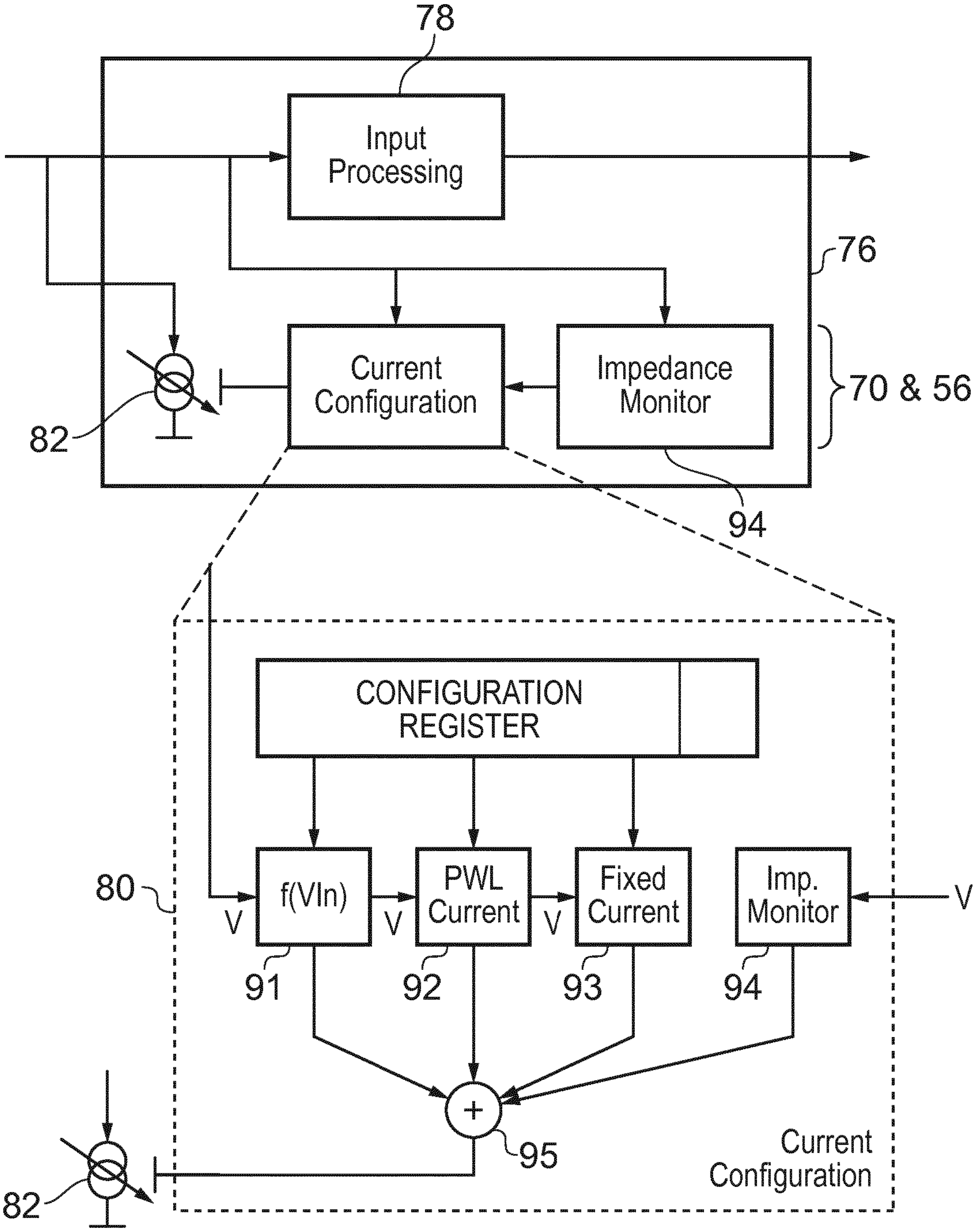

78
Input
Processing
76
Current
Configuration
Impedance
Monitor
70 & 56
82
94
CONFIGURATION
REGISTER
80
V
f(VIn)
V
PWL
Current
V
Fixed
Current
Imp.
Monitor
V
91
92
93
94
+
95
82
Current
Configuration

FIG. 7

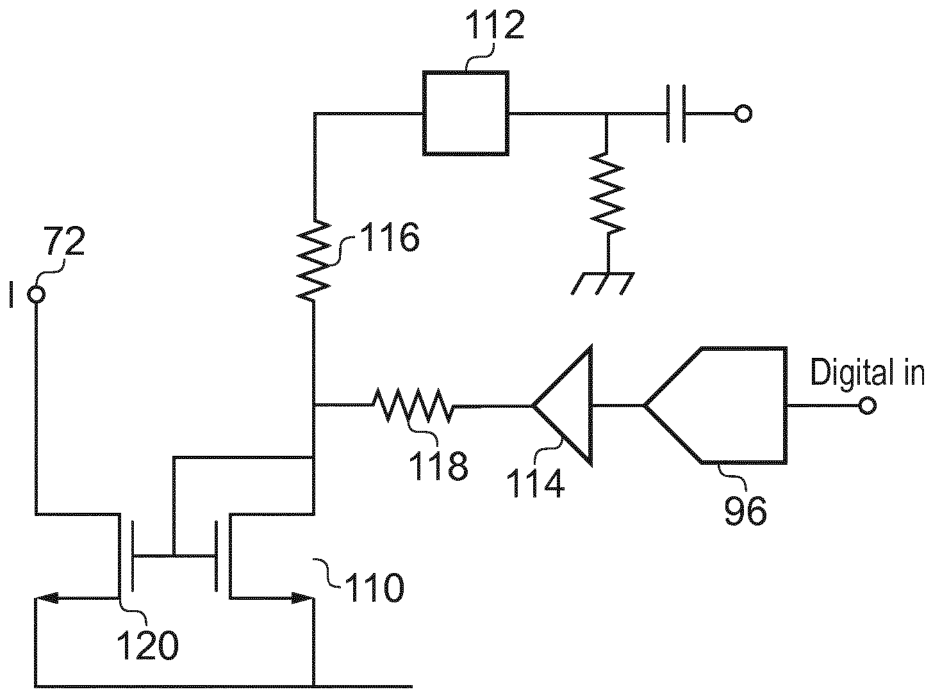


FIG. 8

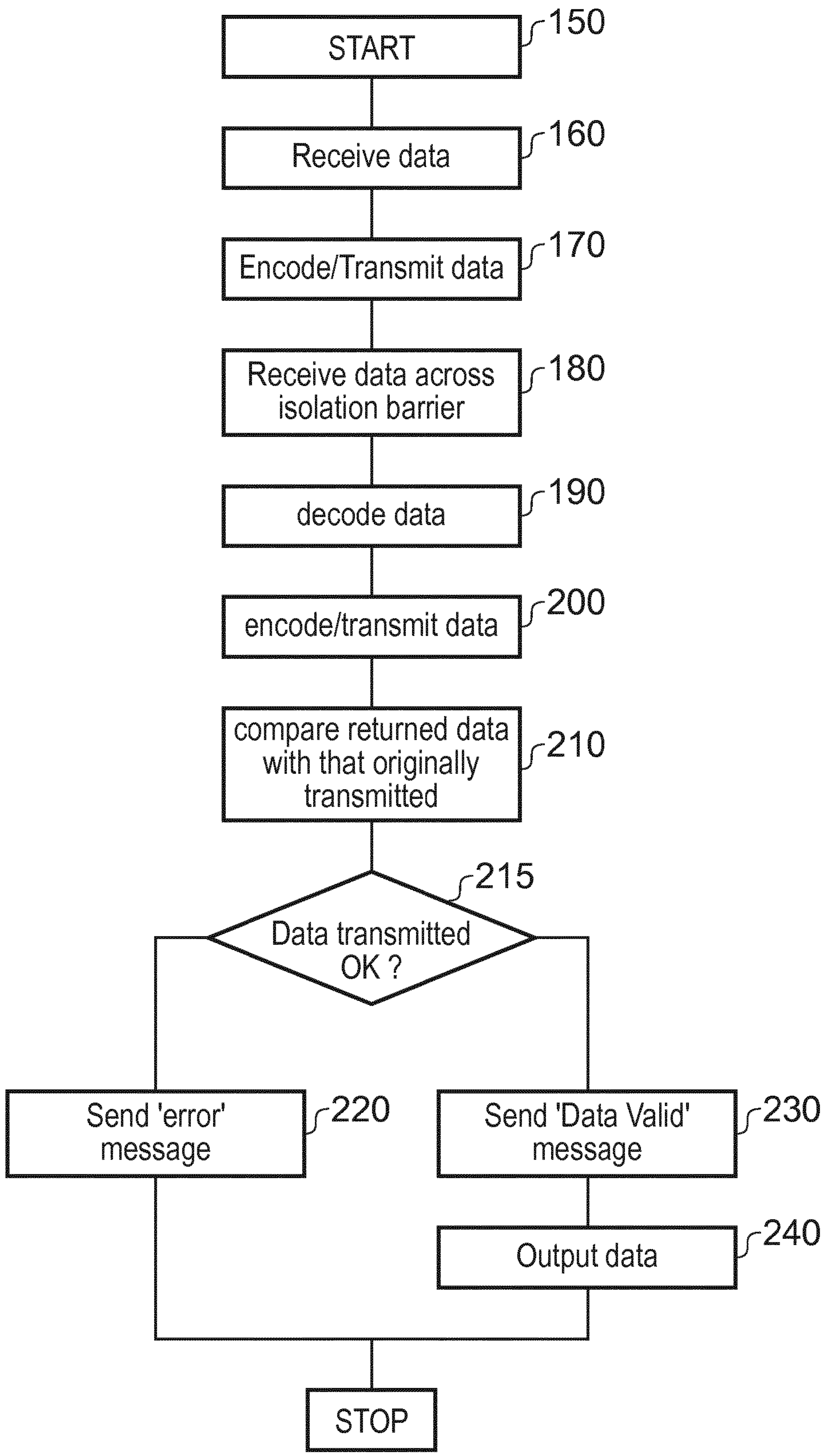

START
150
Receive data
160
Encode/Transmit data
170
Receive data across isolation barrier
180
decode data
190
encode/transmit data
200
compare returned data with that originally transmitted
210
Data transmitted OK ?
215
Send 'error' message
220
Send 'Data Valid' message
230
Output data
240
STOP

FIG. 9

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 0559580 A **[0005]**
- WO 2013137971 A **[0006]**
- US 20050231858 A1 **[0007]**
- US 20140312871 A1 **[0008]**