(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 February 2006 (23.02.2006)

PCT

(10) International Publication Number
WO 2006/020268 A2

(51) International Patent Classification:
G21C 17/00 (2006.01)

(21) International Application Number:
PCT/US2005/025490

(22) International Filing Date: 19 July 2005 (19.07.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/589,301 19 July 2004 (19.07.2004) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

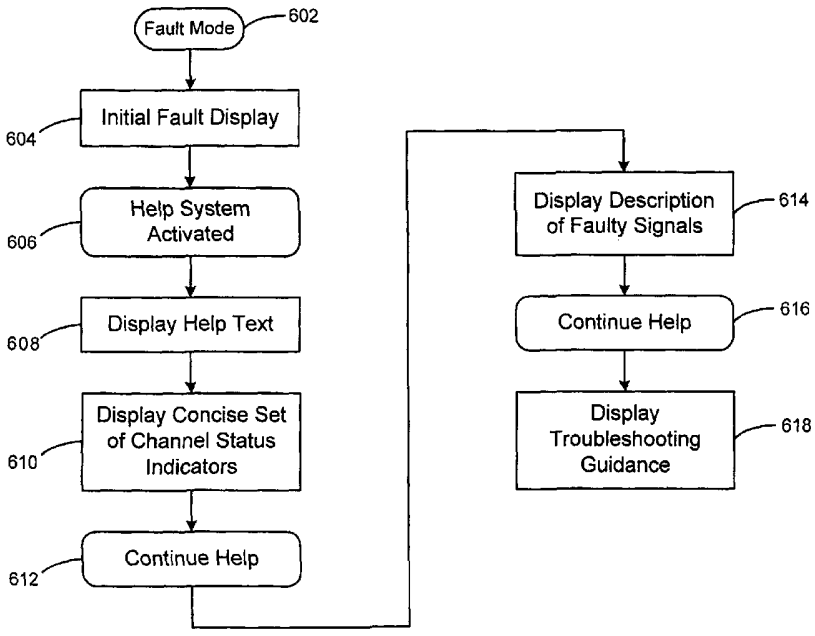
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG,*

[Continued on next page]

(54) **Title:** METHODS AND APPARATUS FOR AN IMPROVED SIGNAL MONITOR



(57) **Abstract:** A malfunction management unit (MMU) includes advanced diagnostic and set-up capabilities accessed through a display-based user interface. In general, the MMU is capable of displaying (1) monitor status information, wherein the monitor status information includes information relating to the status of at least a portion of the input signals; and (2) diagnostic information, wherein the diagnostic information includes an indication of fault type, an indication of faulty signals, and troubleshooting information associated with said fault type and relevant faulty signals. The diagnostic information includes a textual interpretation of the results of a field check analysis.

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SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHODS AND APPARATUS FOR AN IMPROVED SIGNAL MONITOR

FIELD OF THE INVENTION

The present invention generally relates to traffic control devices and, more particularly, to a signal monitor -- sometimes referred to as a "malfunction management unit" (MMU) or "conflict monitor unit" (CMU) -- incorporating advanced diagnostic and set-up capabilities accessed through an interactive, display-based user interface.

BACKGROUND

A signal monitor is a device used in traffic control assemblies to detect and respond to conflicting or otherwise improper signals. Such improper signals may arise, for example, due to field signal conflicts, a malfunctioning controller, faulty load switches, component mis-wiring, improper supply voltages, and the like.

Given the complexity of modern traffic control equipment, it is often difficult for field operators to diagnose and repair cabinet malfunctions. More particularly, while conventional signal monitor units typically display information related to the fault condition itself (i.e., conflicting traffic signals, etc.), the information presented to the operator is not in a form that allows rapid diagnosis. For example, known systems typically present so much information to the operator that it is difficult to pinpoint the particular cause of failure. Furthermore, known systems do not include effective troubleshooting aids that can assist the operator in diagnosing and resolving the underlying malfunction.

SUMMARY OF THE INVENTION

The present invention relates to a signal monitor (often referred to herein as a "malfunction management unit," or simply "MMU") with advanced diagnostic capabilities which incorporates diagnostic and set-up capabilities accessed through a display-based user interface. In general, the MMU is capable of displaying (1) monitor status information, wherein the monitor status information includes information relating to the status of at least a portion of the input signals; and (2) diagnostic information, wherein the diagnostic information includes an indication of

fault type, an indication of faulty signals, and troubleshooting information associated with said fault type and relevant faulty signals. The diagnostic information itself includes a textual interpretation of the results of a field check analysis. In this way, even inexperienced technicians are capable of accurately and quickly diagnosing cabinet malfunctions.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be derived by referring to the detailed description when considered in connection with the Figures, where like reference numbers refer to similar elements throughout the Figures, and:

FIG. 1 is a schematic overview depicting the components of a typical traffic control cabinet in which the present invention may be deployed;

FIG. 2 is a schematic overview of a MMU in accordance with the present invention;

FIG. 3 is an illustration of a front-panel display configuration in accordance with one embodiment of the present invention;

FIG. 4 is an illustration of exemplary intersection status displays;

FIGS. 5A-5B show the progression of an example intersection status display under normal operating conditions;

FIG. 6 is a flowchart showing an exemplary diagnostic procedure;

FIGS. 7A-7D show an example of the progression of diagnostic displays in fault mode; and

FIG. 8 is a flowchart showing an exemplary high-level diagnostic procedure.

DETAILED DESCRIPTION

In general, the present invention relates to a signal monitor of the type used in connection with traffic control systems, and which incorporates diagnostic and set-up capabilities accessed through a display-based user interface. In general, the signal monitor is capable of displaying (1) monitor status information, wherein the monitor status information includes information relating to the status of at least a portion of the input signals; and (2) diagnostic information, wherein the diagnostic information includes an indication of fault type, an indication of faulty signals, and troubleshooting information associated with said fault type and relevant faulty

signals. To further aid the operator, the diagnostic information includes a textual interpretation of the results of a field check analysis. That is, one or more segments or pages of diagnostic information are presented to the operator in textual form, and a portion of that information relates to an analysis of whether the field signals (e.g., signal outputs from the load switches) match the corresponding instructions from the controller.

In this regard, the description that follows is of exemplary embodiments of the invention only, and is not intended to limit the scope, applicability or configuration of the invention in any way. Rather, the following description is intended to provide a convenient illustration for implementing various embodiments of the invention. As will become apparent, various changes may be made in the function and arrangement of the elements described in these embodiments without departing from the scope of the invention.

While different industry specifications use different terms and acronyms when referring to signal monitors, the present invention is not so limited. Thus, the specific term "malfunction management unit" as used herein refers to any type of signal monitor now known or later developed.

Referring to Fig. 1, a typical intersection cabinet (or simply "cabinet") 102 generally contains an input assembly 108, and output assembly 112, a controller 110, and a malfunction management unit (MMU) 120. Those skilled in the art will appreciate that such cabinets vary greatly with respect to both design and components.

As described above, a malfunction management unit (MMU) is a device used in traffic controller assemblies and other applications to detect and respond to conflicting or otherwise improper signals caused by a malfunctioning controller, faulty load switches, cabinet mis-wiring, improper supply voltages, or other such failure mechanisms. MMU units are typically configured as a 16-channel monitor, but may also have 32 channels, 12 channels, 6 channels, or any other number of channels.

The general functional requirements of conventional MMU units are well-known, and are in fact covered by a variety of standards, including, for example, National Electrical Manufacturers Association (NEMA) TS2-2003, Traffic Controller Assemblies with NTCIP Requirements, v02.06, NEMA TS1-1989 (rev. 2000), Traffic

Control Systems, AASHTO/ITE/NEMA Intelligent Transportation Systems (ITS) Standard Specification for Roadside Cabinets, v 01.02.15, Caltrans Transportation Electrical Equipment Specifications (TEES), August 2002. All of these standards are hereby incorporated by reference.

With continued reference to Fig. 1, input assembly 108 typically includes an array 116 of input devices (such as vehicle detectors 117) which receive input signals (104) from the intersection environment through imbedded inductive loops and other such sensors. Similarly, output assembly 112 typically includes a set 114 of output devices (such as load switches 118) which communicate with the environment (via output 106) to effect traffic control via activation of the appropriate traffic signals. To do so, controller 110 communicates with and controls the various assemblies within cabinet 102. The present invention is not limited, however, to specific controller units or communication protocols.

In the illustrated embodiment, and in accordance with the present invention, MMU 120 can be configured such that it receives and processes signals not only from output assembly 112, but also controller 110. In this way, MMU 120 provides "field checking." That is, MMU 120 is capable of determining the output of load switches 118 while at the same time monitoring what controller 110 has instructed those outputs to be. When field check is enabled for a particular channel or input, MMU 120 can check whether the actual device signals for that channel or input match the desired signal specified by controller 110.

As shown in Fig. 2, an MMU 120 in accordance with the present invention generally includes a display 214, a memory 210 (e.g., RAM, ROM, EEPROM, or combination thereof), a microprocessor or microcontroller 212, and input output (I/O) circuitry (or simply "I/O") 208. I/O 208 receives signals 202 from the controller as well as signals 204 from the various load switches in the output assembly (i.e., the "field"). I/O 208 also produces output 206, which may be used, for example, to place the traffic intersection into emergency mode (e.g., via flashing red intersection signals) in the event of a fault.

Display 214 of MMU 120 comprises one or more display components capable of displaying information pertinent to the operation of MMU 120 as discussed below. In this regard, display 214 may include one or more displays of any type now known or developed in the future, including without limitation liquid

crystal displays (LCDs), light emitting diode (LED) displays, electroluminescent displays, and the like. Similarly, such displays might be general-purpose, pixel-based displays or custom displays with dedicated display components ("icon-based"), or a combination thereof. Display 214 is preferably interactive (or "navigable") in that its displayed content is responsive to some form of user input – e.g., the use of buttons, touch screen signals, or any form of direct or indirect input.

Referring now to Fig. 3, an MMU 120 in accordance with the illustrated embodiment comprises a front panel 301 having an integral display region 214 comprising an alphanumeric display 306 and two intersection status displays 308 and 309. Front panel 301 also includes, among other things, a button or other such actuation device 302, and suitable I/O connectors 304. The present invention is not limited to any particular size, shape, geometry, or configuration of inputs and outputs.

Figure 4 shows an example of suitable intersection status displays 308 and 309. As shown, displays 308 and 309 include a total of 16 columns, each corresponding to a different channel or approach lane associated with the intersection. Each column includes five indicators: a channel indicator 402, a red indicator 404, a yellow indicator 406, a green indicator 408, and a walk indicator 410. It will be appreciated that only a subset of these indicators may be used, depending on how the intersection is mapped to the channels, how the MMU is configured, and whether certain standards (TS2, TS1, etc., previously referenced) are applicable.

During normal operation, displays 308 and 309 show the status of the various intersection channels (i.e., "monitor status information"). As shown in Figs. 5A-5C, for example, channel 1 might initially display a red indicator 502 while channel 2 displays a green indicator 504 (Fig. 5A). At the appropriate time, channel 2 would switch to a yellow indicator 504(b) (Fig. 5B), and eventually a red indicator 504(c), at which time channel 1 would change to a green indicator 502(a). The term "indicator" as used herein is not limited to a dedicated display element, but encompasses pixel-based displays and the like.

In the event some form of malfunction occurs at the intersection, the MMU enters into a fault mode to assist the operator in diagnosing and troubleshooting the

problem. Fault mode may be entered automatically when a fault condition has been detected.

In general, referring to Fig. 6, the diagnostic process involves a number of successive displays. Initially, when the system enters fault mode (602), a description of the initial fault is displayed (604). In step 606, the help system is then activated (e.g., by the user pressing button 302 shown in Fig. 3). Alphanumeric display 306 then presents the appropriate help text while displays 308 and 309 present a concise set of channel status indicators (steps 608 and 610); that is, only a relevant subset of channel status indicators remain displayed.

After reviewing the presented information, the operator may further continue the help process (again, by pressing button 302) (step 612). At this point, the system displays a description of the known faulty signals (step 614). Further continuing the help process (step 616), results in a display of troubleshooting guidance (step 618). It will be appreciated that this invention contemplates that this process may be carried out in fewer or more steps.

Figures 7A-7D depict one example of the successive displays occurring during a fault -- specifically, a conflict-type fault. This example corresponds to a TS2 type fault with field check enabled where the channel 1 green signal is "on", but should be "off".

As shown in Fig. 7A, the initial fault display includes a basic description of the fault (display 306), and a display of which signals were active at the time of fault (display 308). After the help system is activated (Fig. 7B), display 306 presents a first level of help text, and display 308 is modified to present a concise set of channel status indicators. That is, display 308 focuses on channels 1 and 2, and the remaining indicators are extinguished so as not to confuse the operator.

Next, as shown in Fig. 7C, the help processes continues with a description of the known faulty signals (display 306) referencing a further simplified display 308, which indicates that the channel 1 green signal is "on" when it should not be. The system therefore displays diagnostic information that includes a textual interpretation of the results of the field check analysis. Finally, as shown in Fig. 7D, display 306 presents troubleshooting guidance designed to assist the operator or field technician in determining the root cause of the fault.

As a further example, figure 8 shows a high-level fault mode decision tree applicable to the present invention. Those skilled in the art will recognize the nature of this flowchart and the content of the various boxes. In general, the decision tree progresses from initiation of fault mode (802), to a determination of the general fault categories (boxes 816, 818, 820, 830, and 832). A computer program listing is included herewith that sets forth a particular embodiment for providing the relevant troubleshooting information.

In the illustrated embodiment, there are five categories, depending generally upon (a) whether and to what extent field checking is enabled, (b) whether the inputs to fault channels match their respective control unit outputs, and (c) the faulty signals themselves. Once the individual category of fault is determined, the system continues with the context-specific help/diagnostic system. The initial fault display is generated in step 804, and the fault definition text and concise signal display are generated in step 806 after the operator presses the "help" key (or provides any suitable input) 805. For example, the help screens shown in Fig. 7 correspond to a category 4 fault (steps 804, 806, 808, 812, 818, 836).

If all inputs of the faulty channels have field check enabled (as determined from data 810), the system continues at step 812. Otherwise, the system continues with step 814. Under step 812, if all inputs of the faulty channels match the control unit, processing continues with successive steps 816 and 834, which present the operator with an "all signals match" message and troubleshooting advice. Alternatively, if any inputs of the faulty channels do not match the control unit, the known faulty signals are pinpointed (818), and further troubleshooting advice is presented to the operator (836).

With respect to step 814, corresponding to the case where not all inputs of the faulty channels have field check enabled, the system then determines whether *any* inputs are so enabled, then branches to steps 820 and 822 accordingly. In step 820, the system displays the potential (suspected) faulty signals as well as a setup warning regarding field check disable limitations. In step 838 the system generates further troubleshooting advice.

In step 822, however, the system further checks whether all inputs of the faulty channels with field check enabled match. If so, processing continues with steps 830, wherein matching signals are pinpointed. In step 844, the system then

displays the remaining potential (suspected) faulty signals as well as a setup warning regarding field check disable limitations. In step 852 the system generates further troubleshooting advice.

If the result of step 822 is "No," then the known faulty signals are pinpointed (832), the system then displays the remaining potential (suspected) faulty signals as well as a setup warning regarding field check disable limitations (846). In step 854 the system generates further troubleshooting advice.

In accordance with another aspect of the present invention, the MMU incorporates an advanced setup algorithm that assists the technician in accomplishing initial setup of the system at an intersection. More particularly, the setup algorithm asks a series of questions regarding the intersection geometry and operation. It then uses these responses to formulate the detailed monitor configuration parameters automatically. This eliminates the need for the technician to understand the individual monitor settings and the criteria used to determine these settings.

In general, the setup algorithm converts the highly-technical signal monitor language to a system that can be easily understood by non-experts. For example, in accordance with one embodiment, these questions (or prompts), include: "Select unused channels"; "Are pedestrian 'Don't Walk' signals monitored?"; "Select pedestrian channels"; and "Select protected-permissive turn channels.

The answers received in response to these prompts (through a suitable front-panel interface) are then used to configure, for example, the parameters for dual-indication monitoring, red fail monitoring, minimum yellow+red clearance monitoring, and field check monitoring. These parameters, in conjunction with other parameters and the jumpers placed on the standard program card, are used to configure the monitor.

The following listing depicts exemplary help message source code in accordance with one embodiment of the present invention:

```
.TITLE 'LCDpage: Database for lcd pages'
;*******************************************************************************
.comment *
        (C) COPYRIGHT 2004 EBERLE DESIGN INC.
        TS2: MMU16LE RMS
```

```
        MODULE NAME: LCDpage

        FUNCTION:
                This module describes the lcd pages and how to format and execute
5   them.
                Bank switching is used to store the Help text data.
    *
    ********************************************************************************
    . . .

10  ; Help Messages
    *
        .DEFSEG    help_text1,OVERLAY
        .SEG  help_text1
    help_1              db     "FIELD CHECK STATUS: "
15                      db     "Inputs shown are the"
                        db     "signals that did not"
                        db     "match the CU output."
    help_1_size  equ    $-help_1
    help_2a             db     "RECURRENT PULSE (RP)"
20                      db     "Inputs shown were   "
                        db     "PULSING On or Off   "
                        db     "during the fault.  ~"
    help_2a_size equ    $-help_2a
    help_2b             db     "Inputs PULSED ON for"
25                      db     "Conflict or Dual Ind"
                        db     "and PULSED OFF for  "
                        db     "Red Fail."
    help_2b_size equ    $-help_2b
    help_3              db     "CABINET VOLTAGES:   "
30                      db     "Values shown are at "
                        db     "the time of the     "
                        db     "current fault."
    help_3_size  equ    $-help_3
```

```
help_4          db    "RMS FIELD VOLTAGES: "
                db    "Use NEXT button to  "
                db    "view field terminal "
                db    "input voltages."
help_4_size equ $-help_4
help_5          db    "CABINET VOLTAGES:   "
                db    "Current values are  "
                db    "shown."
help_5_size equ $-help_5
help_6          db    "NEXT button moves   "
                db    "cursor. SELECT butt-"
                db    "on picks more Status"
                db    "or the Menu list."
help_6_size equ $-help_6
help_7          db    "NEXT button moves   "
                db    "the cursor.         "
                db    "SELECT button picks "
                db    "an item."
help_7_size equ $-help_7
help_8          db    "Button Functions:   "
                db    "NEXT- inc field     "
                db    "SELECT- next field  "
                db    "EXIT- exit Clock Set"
help_8_size equ $-help_8
help_8a         db    "The clock can be set"
                db    "in Type12 mode, or  "
                db    "in Type 16 mode with"
                db    "Port1 Disable =True."
help_8a_size equ $-help_8a
help_9          db    "Consult the factory "
                db    "for current revision"
                db    "level of firmware   "
                db    "sets."
```

```
help_9_size  equ   $-help_9
help_10      db    "If the Check Value  "
             db    "differs from a prev "
             db    "value, then monitor "
             db    "setup is different."
help_10_size equ   $-help_10
help_13      db    "Select a type of    "
             db    "Event Log to View."
help_13_size equ   $-help_13
help_14a     db    "Field Check should  "
             db    "be Enabled on all   "
             db    "inputs that have    "
             db    "actual signal loads~"
help_14a_size      equ   $-help_14a
help_14b     db    "The Channel Status  "
             db    "display shows inputs"
             db    "that are enabled for"
             db    "Field Checking."
help_14b_size      equ   $-help_14b
help_15      db    "Dual monitoring is  "
             db    "enabled by input    "
             db    "color pairs:        "
             db    "R-G, R-Y, and G-Y."
help_15_size equ   $-help_15
help_16      db    "ID and Name are set "
             db    "with ECcom software."
             db    "These params are    "
             db    "stored in the unit."
help_16_size equ   $-help_16
help_17a     db    "Min Y+R Clearance is"
             db    "ENABLED for channels"
             db    "with Y & R displayed"
             db    "below:          ~"
```

```
help_17a_size    equ   $-help_17a
;help_17a   db    "The Channel Status  "
;                 db    "display shows chann-"
;                 db    "els ENABLED for Min "
;                 db    "Y+R Clearance:    ~"
;help_17a_size    equu  $-help_17a
help_17b    db    "Min Y+R Clearance   "
                  db    "can be Disabled when"
                  db    "MUTCD 4D.10 is not  "
                  db    "complied with. This~"
help_17b_size    equ   $-help_17b
help_17c    db    "mainly occurs with  "
                  db    "legacy overlaps     "
                  db    "without a yellow    "
                  db    "arrow signal."
help_17c_size    equ   $-help_17c
help_19          db    "pgm card memory...  "
                  db    "                    "
                  db    "                    "
                  db    "                    "
help_19_size equ   $-help_19
help_20          db    "PF Log shows status "
                  db    "at the time of the  "
                  db    "fault. PF#1 is the  "
                  db    "most recent event."
help_20_size equ   $-help_20
help_21          db    "MR Log shows time & "
                  db    "date & input source "
                  db    "when a fault was    "
                  db    "reset (flash exit)."
help_21_size equ   $-help_21
```

```
help_22         db      "AC Log shows time & "
                db      "date, type, & Mains "
                db      "voltage. Event means"
                db      "relays transferred."
help_22_size    equ     $-help_22
help_23a        db      "Select one of four  "
                db      "event logs to clear."
                db      "ALL LOGS will clear "
                db      "all four at once.  ~"
help_23a_size   equ     $-help_23a
help_23b        db      "CLEAR item clears   "
                db      "the log type shown. "
                db      "CANCEL quits with no"
                db      "effect."
help_23b_size   equ     $-help_23b
help_24         db      "This Wizard changes "
                db      "Field Check, Dual   "
                db      "Indication & RedFail"
                db      "Enable settings."
help_24_size    equ     $-help_24
help_25         db      "<Next>choice accepts"
                db      "data, moves to next "
                db      "page.<Edit> choice  "
                db      "returns to data page"
help_25_size    equ     $-help_25
help_25a        db      "Select channels that"
                db      "have NO load switch."
                db      "Use SELECT to toggle"
                db      "the channel state."
help_25a_size   equ     $-help_25a
```

```
help_25b    db    "The NO selection   "
                  db    "prevents the monitor"
                  db    "from responding to a"
                  db    "failure of Dont Walk"
help_25b_size     equ   $-help_25b
help_25c    db    "Select channels that"
                  db    "are monitoring the  "
                  db    "Walk (and Dont Walk)"
                  db    "PED signals."
help_25c_size     equ   $-help_25c
help_25d    db    "Select Turn channels"
                  db    "that DO NOT have a  "
                  db    "Red arrow (protected"
                  db    "-permissive)."
help_25d_size     equ   $-help_25d
help_25e    db    "Next button shows   "
                  db    "3-section, Unused,  "
                  db    "Ped, & Prot-Perm    "
                  db    "Turn channels."
help_25e_size     equ   $-help_25e
help_25f    db    "<Set> choice accepts"
                  db    "data, stores to mem."
                  db    "<Edit>choice returns"
                  db    "to start of wizard."
help_25f_size     equ   $-help_25f
help_26           db    "<Set> choice accepts"
                  db    "data, stores to mem."
                  db    "<Edit>choice returns"
                  db    "to data entry page."
help_26_size equ  $-help_26
```

```
help_27a    db    "Red Fail should be "
                  db    "enabled for channels"
                  db    "that have 3 section "
                  db    "heads: R, Y, & G.  ~"
help_27a_size     equ   $-help_27a
help_27b    db    "The Channel Status "
                  db    "display shows the  "
                  db    "channels enabled for"
                  db    "Red Fail monitoring."
help_27b_size     equ   $-help_27b
help_28a    db    "Red-Green Dual Ind "
                  db    "should be enabled on"
                  db    "channels with a true"
                  db    "R AND G signal load~"
help_28a_size     equ   $-help_28a
help_28b    db    "The Channel Status "
                  db    "display shows the  "
                  db    "channels enabled for"
                  db    "RG-Dual Indication."
help_28b_size     equ   $-help_28b
help_29a    db    "Red-Yellow Dual Ind "
                  db    "should be enabled on"
                  db    "channels with a true"
                  db    "R AND Y signal load~"
help_29a_size     equ   $-help_29a
help_29b    db    "The Channel Status "
                  db    "display shows the  "
                  db    "channels enabled for"
                  db    "RY-Dual Indication."
help_29b_size     equ   $-help_29b
```

```
help_30a    db    "Green-Yellow DualInd"
                  db    "should be enabled on"
                  db    "channels with a true"
                  db    "G AND Y signal load~"
help_30a_size     equ   $-help_30a
help_30b    db    "The Channel Status  "
                  db    "display shows the   "
                  db    "channels enabled for"
                  db    "GY-Dual Indication."
help_30b_size     equ   $-help_30b
help_31a    db    "Primary CH:G,Y,W is "
                  db    "allowed to be active"
                  db    "concurrently with   "
                  db    "channels below:   ~"
help_31a_size     equ   $-help_31a
help_31b    db    "Permissive program  "
                  db    "is READ ONLY of the "
                  db    "jumpers on the Nema "
                  db    "Program Card."
help_31b_size     equ   $-help_31b
help_32a    db    "Min Yellow Change is"
                  db    "ENABLED for channels"
                  db    "with Y displayed    "
                  db    "below:          ~"
help_32a_size     equ   $-help_32a
help_32b    db    "Program Card params "
                  db    "are READ ONLY of the"
                  db    "jumpers on the Nema "
                  db    "Program Card."
help_32b_size     equ   $-help_32b
```

```
help_33a    db    "The RECURRENT PULSE "
                  db    "monitor is ENABLED  "
                  db    'when "ON".          '
                  db    "RYG ONLY REDFAIL,  ~"
help_33a_size     equ   $-help_33a
help_33b    db    "is used in Type 12  "
                  db    'mode only. When "ON"'
                  db    "it prevents a active"
                  db    "Walk input from    ~"
help_33b_size     equ   $-help_33b
help_33c    db    "preventing a vehicle"
                  db    "RYG Red Fail.       "
                  db    "LOG CVM FAULT should"
                  db    'be "OFF" if CVM    ~'
help_33c_size     equ   $-help_33c
help_33d    db    "is used for nonfault"
                  db    "flash such as time- "
                  db    "of-day flash."
help_33d_size     equ   $-help_33d
help_34a    db    "Pin MSA-S monitored "
                  db    "for transitions when"
                  db    "EXTERN WATCHDOG is  "
                  db    '"ON".              ~'
help_34a_size     equ   $-help_34a
help_34b    db    "When 24V-2=12VDC is "
                  db    '"ON", the 24V-2     '
                  db    "input (MSB-R) can be"
                  db    "used to monitor a  ~"
help_34b_size     equ   $-help_34b
help_34c    db    "12Vdc power supply. "
                  db    "When PGMCARD MEMORY "
                  db    'is "ON", the nonvol '
                  db    "memory on the EDI  ~"
```

```
help_34c_size   equ   $-help_34c
help_34d   db   "PGM CARD will load &"
                db    "store the monitor   "
                db    "enhanced programming"
                db    "parameters."
help_34d_size   equ   $-help_34d
help_35a   db   "Modified signal volt"
                db    "thresholds are used "
                db    "for LED signals when"
                db    'LEDguard is "ON".'
help_35a_size   equ   $-help_35a
*
help_37a   db   "Noncompatible Green,"   ;ts1 conflict definition
                db    "Yellow, or Walk    "
                db    "signals are active.~"
help_37a_size   equ   $-help_37a
;help_37b   db   "Check: Load Switch, "
;               db    "bad CU output, short"
;               db    "circuit, open load, "
;               db    "or CU/MMU pgm error."
;help_37b_size   equ   $-help_37b
help_37b   db   "Check: Load Switch, "
                db    "short ckt,open load,"
                db    "bad CU output, or   "
                db    "CU or MMU pgm error."
help_37b_size   equ   $-help_37b
help_38a   db   "Noncompatible Green "   ;ts2 conflict definition
                db    "or Yellow signals   "
                db    "are active.      ~"
help_38a_size   equ   $-help_38a
help_38b   db   "Signals below with  "
                db    "Field Check enabled "
                db    "DO match CU Outputs~"
```

```
help_38b_size    equ   $-help_38b
help_38d    db    "'Faulty' status is  "
                  db    "not known for these "
                  db    "signals since Field "
                  db    "Check is disabled. ~"
help_38d_size    equ   $-help_38d
help_39b    db    "Signals below are   "
                  db    "known to be faulty. "
                  db    "Signals are ON but  "
                  db    "should be OFF.    ~"
help_39b_size    equ   $-help_39b
help_40b    db    "Signals DO match the"
                  db    "Controller outputs. "
                  db    "The CU has driven   "
                  db    "the fault state.  ~"
help_40b_size    equ   $-help_40b
help_40c    db    "Check: CU config    "
                  db    "error or MMU Program"
                  db    "Card error."
help_40c_size    equ   $-help_40c
;help_41c    db    "Check: Load Switch, "
;                 db    "bad CU / BIU output,"
;                 db    "field short circuit,"
;                 db    "or field open load."
;help_41c_size    equ   $-help_41c
help_41c    db    "Check: Load Switch, "
                  db    "field short circuit,"
                  db    "field open load, or "
                  db    "bad CU / BIU output"
help_41c_size    equ   $-help_41c
;dual indication
```

```
;help_42b     db    "Check: LoadSwitch,  "
;                   db    "bad CU / BIU output,"
;                   db    "short ckt,open load,"
;                   db    "or CU/MMU pgm error."
;help_42b_size      equ   $-help_42b
help_42b     db    "Check: LoadSwitch,  "
                    db    "short ckt,open load,"
                    db    "bad CU / BIU output,"
                    db    "or CU/MMU pgm error."
help_42b_size      equ   $-help_42b
help_43a     db    "More than one signal"     ;dual indication definition
                    db    "color (RY,RG,YG,RYG)"
                    db    "is active together  "
                    db    "on a channel.     ~"
help_43a_size      equ   $-help_43a
help_47c     db    "Check: MMU Dual Ind "
                    db    "config error, or    "
                    db    "Controller config   "
                    db    "error."
help_47c_size      equ   $-help_47c
;red fail
help_44a     db    "No signal color is  ";red fail definition
                    db    "active for these    "
                    db    "channels:         ~"
help_44a_size      equ   $-help_44a
help_45b     db    "Check:Bad LoadSwitch"
                    db    "or CU output. Note: "
                    db    "Bad field load/wires"
                    db    "dont cause Red Fail."
help_45b_size      equ   $-help_45b
```

```
help_46b    db    "Signals below are  "
                  db    "known to be faulty. "
                  db    "Signals are OFF but "
                  db    "should be ON.    ~"
help_46b_size     equ   $-help_46b
help_48c    db    "Check:Bad LoadSwitch"
                  db    "or CU / BIU output. "
                  db    "Bad field load/wires"
                  db    "dont cause Red Fail."
help_48c_size     equ   $-help_48c
help_55a    db    "The Controller Unit "      ;cvm
                  db    "(CU) has detected a "
                  db    "problem. Check the  "
                  db    "CU for the cause."
help_55a_size     equ   $-help_55a
help_55b    db    "The Cabinet Power  "       ;24v-1,24v-2
                  db    "Supply is below the "
                  db    "18Vdc minimum."
help_55b_size     equ   $-help_55b
help_55c    db    "The Cabinet Power  "       ;24v-2 in 12 Vdc mode
                  db    "Supply is below the "
                  db    "9Vdc minimum. 24V-2="
                  db    "12Vdc option is On."
help_55c_size     equ   $-help_55c
help_56           db    "MMU Local Flash is "       ;local flash
                  db    "driven by AUTO/FLASH"
                  db    "switches in cabinet "
                  db    "and Police panel."
help_56_size equ  $-help_56
help_57           db    "The Program Card   "       ;local flash
                  db    "must be inserted at "
                  db    "all times."
help_57_size equ  $-help_57
```

```
help_58a    db    "The MMU was TS1-Type";type 16->12 error
                  db    "12 but now is TS2- "
                  db    "Type-16. Check the "
                  db    "Type Select input."
help_58a_size     equ   $-help_58a
help_58b    db    "The MMU was TS2-Type";type 12->16 error
                  db    "16 but now is TS1- "
                  db    "Type-12. Check the "
                  db    "Type Select input."
help_58b_size     equ   $-help_58b
help_59           db    "EXT WD input at pin "     ;ext watchdog
                  db    "'"MSB-S" has stopped '
                  db    "toggling. The EXTERN"
                  db    "WATCHDOG option = On"
help_59_size equ  $-help_59
help_60           db    "An unknown fault  "       ;unknown
                  db    "code has been set. "
                  db    "Event memory may be "
                  db    "corrupted."
help_60_size equ  $-help_60
help_61           db    "An internal hardware"     ;diagnostic
                  db    "problem is detected."
                  db    "Remove MMU from ser-"
                  db    "vice to test/repair."
help_61_size equ  $-help_61
help_62           db    "SDLC frames are not "     ;port 1
                  db    "being received from "
                  db    "the CU. Check cables"
                  db    "and CU Tx outputs."
help_62_size equ  $-help_62
```

```
help_63a    db    "The Yellow Clearance"    ;short clearance
                  db    "time was less than  "
                  db    "2.7 sec minimum, on "
                  db    "these channels:"
help_63a_size     equ   $-help_63a
help_64a    db    "The Yellow Clearance"    ;skipped clearance
                  db    "time was 0 seconds, "
                  db    "Red followed Green, "
                  db    "on these channels:"
help_64a_size     equ   $-help_64a
help_65a    db    "Yellow+Red Clearance"    ;gg clearance
                  db    "time was less than  "
                  db    "2.7 sec minimum on  "
                  db    "these channels:   ~"
help_65a_size     equ   $-help_65a
help_65b    db    "These active Green  "    ;gg clearance
                  db    "channels caused the "
                  db    "Y+R Clearance:"
help_65b_size     equ   $-help_65b
help_66a    db    "These MMU inputs do "    ;field check
                  db    "not match CU outputs"
                  db    "Check: wiring error,"
                  db    "CU/MMU pgm error.  ~"
help_66a_size     equ   $-help_66a
help_67           db    "RECURRENT PULSE (RP)"    ;recurrent    pulse
conflict/dual
                  db    " Inputs shown were  "
                  db    " PULSING ON during  "
                  db    " the fault.      ~"
help_67_size equ  $-help_67
```

```
help_68         db   "RECURRENT PULSE (RP)"    ;recurrent pulse red
fail
                db   " Inputs shown were  "
                db   " PULSING OFF during "
                db   " the fault.      ~"
help_68_size equ $-help_68
help_79a    db  "Program Card Memory "  ;program card memory gone
                db   "is Enabled, but can-"
                db   "not be found on the "
                db   "Program Card.    ~"
help_79a_size   equ  $-help_79a
help_79b    db  "Use an EDI card with"     ;program card memory gone
                db   "memory, or disable  "
                db   "PGM CARD MEMORY in  "
                db   "UNIT OPTIONS."
help_79b_size   equ  $-help_79b
;help_79b    db  "Either Disable the  "     ;program card memory gone
;               db   "PGM CARD MEMORY in  "
;               db   "UNIT OPTIONS or use "
;               db   "a card with memory."
;help_79b_size   equ  $-help_79b
help_80a    db  "Program Card Memory "  ;program card memory bad
                db   "is Enabled, but data"
                db   "read is corrupt.  ~"
help_80a_size   equ  $-help_80a
help_80b    db  "Modify any config   "     ;program card memory bad
                db   "parameter to rewrite"
                db   "the PGM CARD MEMORY."
help_80b_size   equ  $-help_80b
help_81         db   "Default turns OFF  "     ;set factory default
                db   "enhanced functions; "
                db   "unit is set to basic"
                db   "Nema minimums."
```

```
help_81_size equ  $-help_81
help_82           db    "Check: MMU Red Fail "
                  db    "config error, or    "
                  db    "Controller config   "
                  db    "error."
help_82_size equ  $-help_82
*
```

Other advantages and structural details of the invention will be apparent from the attached figures, which will be well understood by those skilled in the art. The present invention has been described above with respect to a particular exemplary embodiment. However, many changes, combinations and modifications may be made to the exemplary embodiments without departing from the scope of the present invention.

CLAIMS

1. A signal monitor of the type configured to accept a plurality of input signals associated with traffic control at an intersection, said signal monitor comprising:

an interactive display capable of providing a visual representation of:

a) monitor status information, wherein said monitor status information includes information relating to the status of at least a portion of said plurality of input signals;

b) diagnostic information, wherein said diagnostic information includes an indication of fault type, an indication of faulty input signals, and troubleshooting information associated with said fault type and faulty input signals, wherein said diagnostic information includes a textual interpretation of the results of a field check analysis performed on said input signals.

2. The signal monitor of claim 1, wherein said indication of faulty signals comprises a concise display of relevant fault signals.

3. The signal monitor of claim 1, wherein said troubleshooting information includes a list of probable causes associated with said fault type and indication of faulty signals.

4. The signal monitor of claim 1, wherein said interactive display is further capable of displaying historical fault information.

5. The signal monitor of claim 1, wherein said diagnostic information is provided to the operator in the form of a set of successive display pages.

6. A method of processing faults sensed by a malfunction management unit (MMU) coupled to a plurality of inputs, comprising the steps of:

a) sensing a fault condition associated with said plurality of inputs;

b) displaying diagnostic information related to said fault condition via an interactive display, wherein said diagnostic information includes an indication

of a fault type associated with said fault condition, an indication of faulty signals attending said fault condition, and troubleshooting information associated with said fault condition, wherein said diagnostic information includes a textual interpretation of the results of a field check analysis performed on said input signals.

7. The method of claim 6, wherein said step of providing an indication of faulty signals includes the step of providing a concise display of relevant fault signals.

8. The method of claim 6, wherein said step of providing troubleshooting information includes the step of listing probable causes associated with said fault condition.

9. The method of claim 6, wherein said step of displaying diagnostic information includes the step of providing diagnostic information in a set of successive pages navigable by an operator.

10. A computer-readable medium having program code embodied therein for causing a malfunction management unit (MMU) to perform the steps of:

a) sensing a fault condition associated with a plurality of inputs to the MMU;

b) performing a field check analysis on said inputs;

c) displaying diagnostic information related to said fault condition via an interactive display, wherein said diagnostic information includes an indication of a fault type associated with said fault condition, an indication of faulty signals attending said fault condition, and troubleshooting information associated with said fault condition, wherein said diagnostic information includes a textual interpretation of the results of said field check analysis.

11. The computer-readable medium of claim 10, wherein said step of providing an indication of faulty signals includes the step of providing a concise display of relevant fault signals.

12. The computer-readable medium of claim 10, wherein said step of providing troubleshooting information includes the step of listing probable causes associated with said fault condition.

13. The computer-readable medium of claim 10, wherein said step of displaying diagnostic information includes the step of providing diagnostic information in a set of successive pages navigable by an operator.

14. An interactive display for use in a memory management unit (MMU), said display configured to produce a visual representation of (a) monitor status information, wherein said monitor status information includes information relating to the status of at least a portion of said plurality of input signals; and (b) diagnostic information, wherein said diagnostic information includes an indication of fault type, an indication of faulty signals, and troubleshooting information associated with said fault type and relevant faulty signals, wherein said diagnostic information includes a textual interpretation of the results of a field check analysis.

15. A signal monitor of the type configured to monitor a first signal corresponding to a controller instruction to a load switch and a second signal corresponding to the actual state of the load switch, said signal monitor comprising an interactive display for providing textual diagnostic information responsive to whether said first signal matches said second signal.

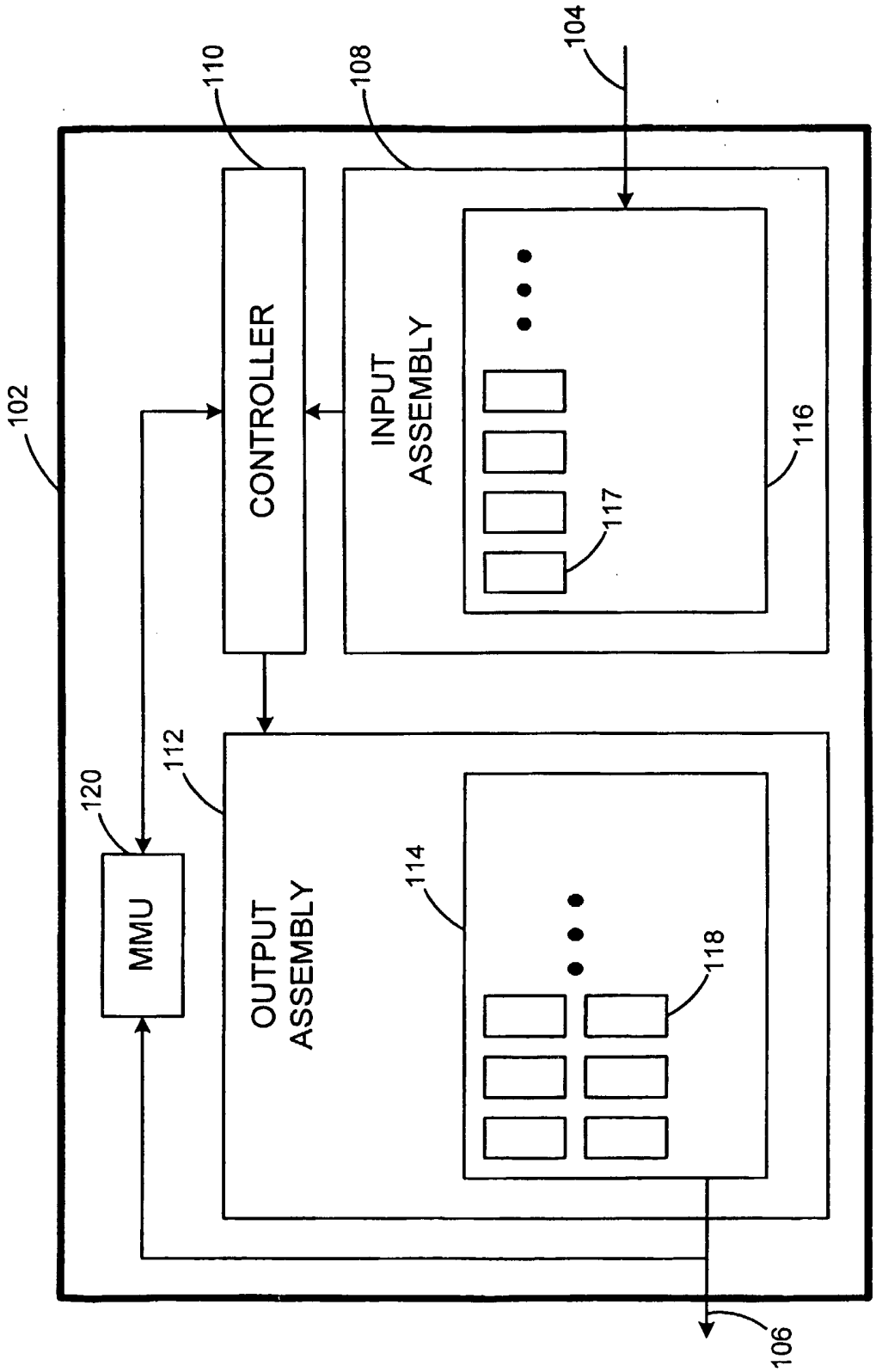
102
104
106
108
110
112
114
116
117
118
120
CONTROLLER
INPUT ASSEMBLY
OUTPUT ASSEMBLY
MMU

FIG. 1

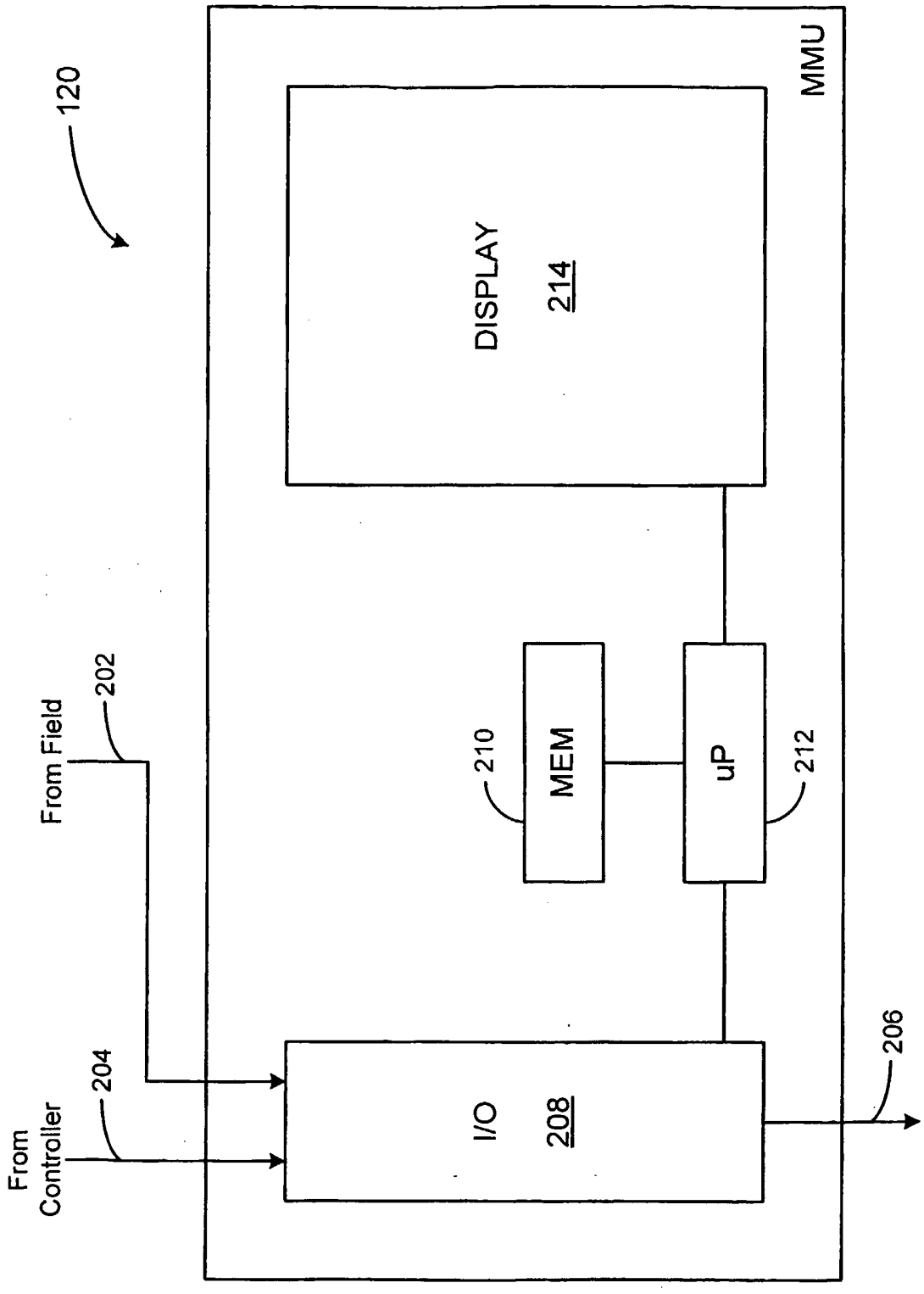
120
MMU
DISPLAY
214
From Field
202
210
MEM
uP
212
From Controller
204
I/O
208
206

FIG. 2

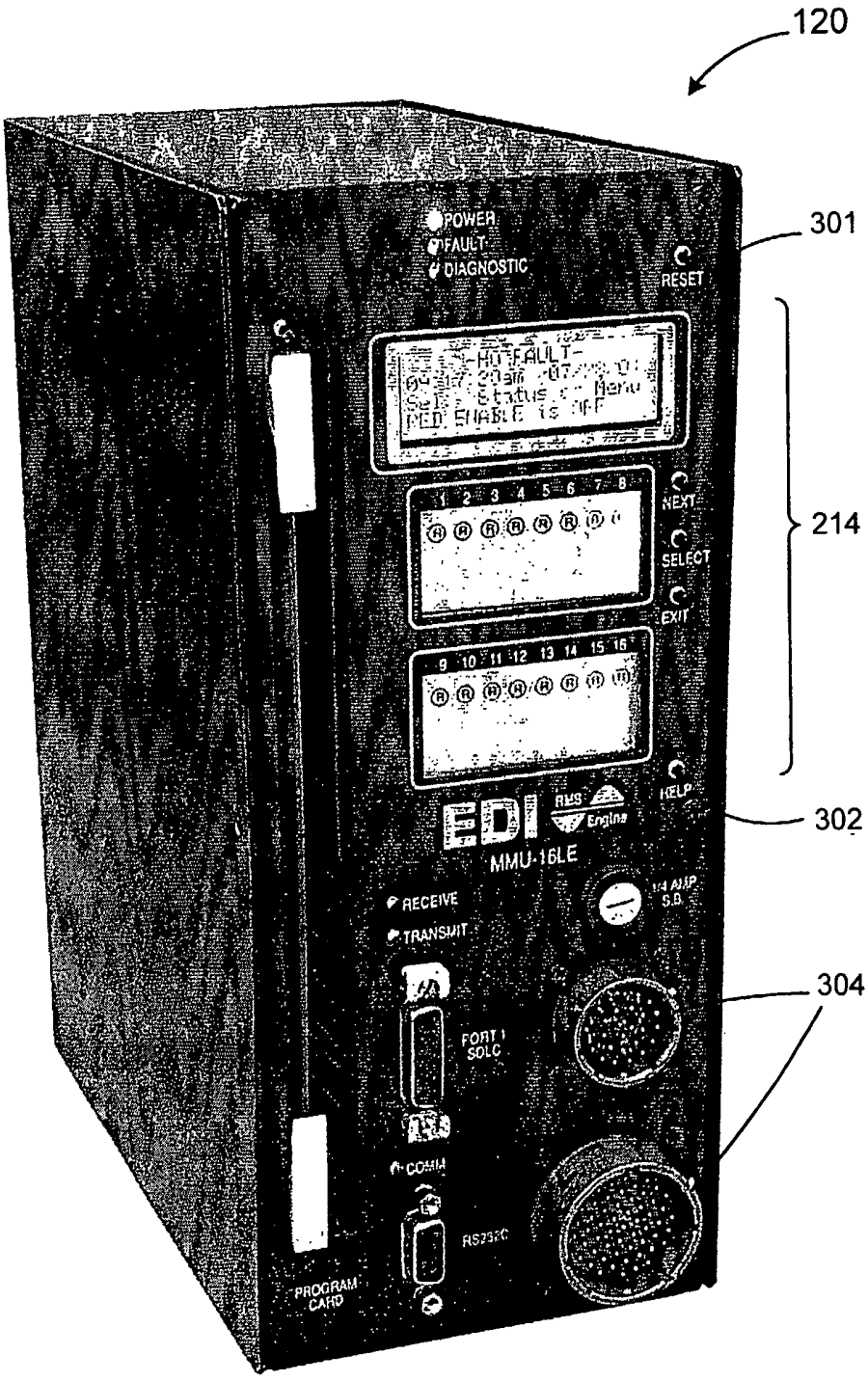
120
301
214
302
304
POWER
FAULT
DIAGNOSTIC
RESET
NEXT
SELECT
EXIT
HELP
EDI
RMS
Engine
MMU-16LE
RECEIVE
TRANSMIT
PORT 1
SCLC
COMM
RS232C
PROGRAM
CARD

FIG. 3

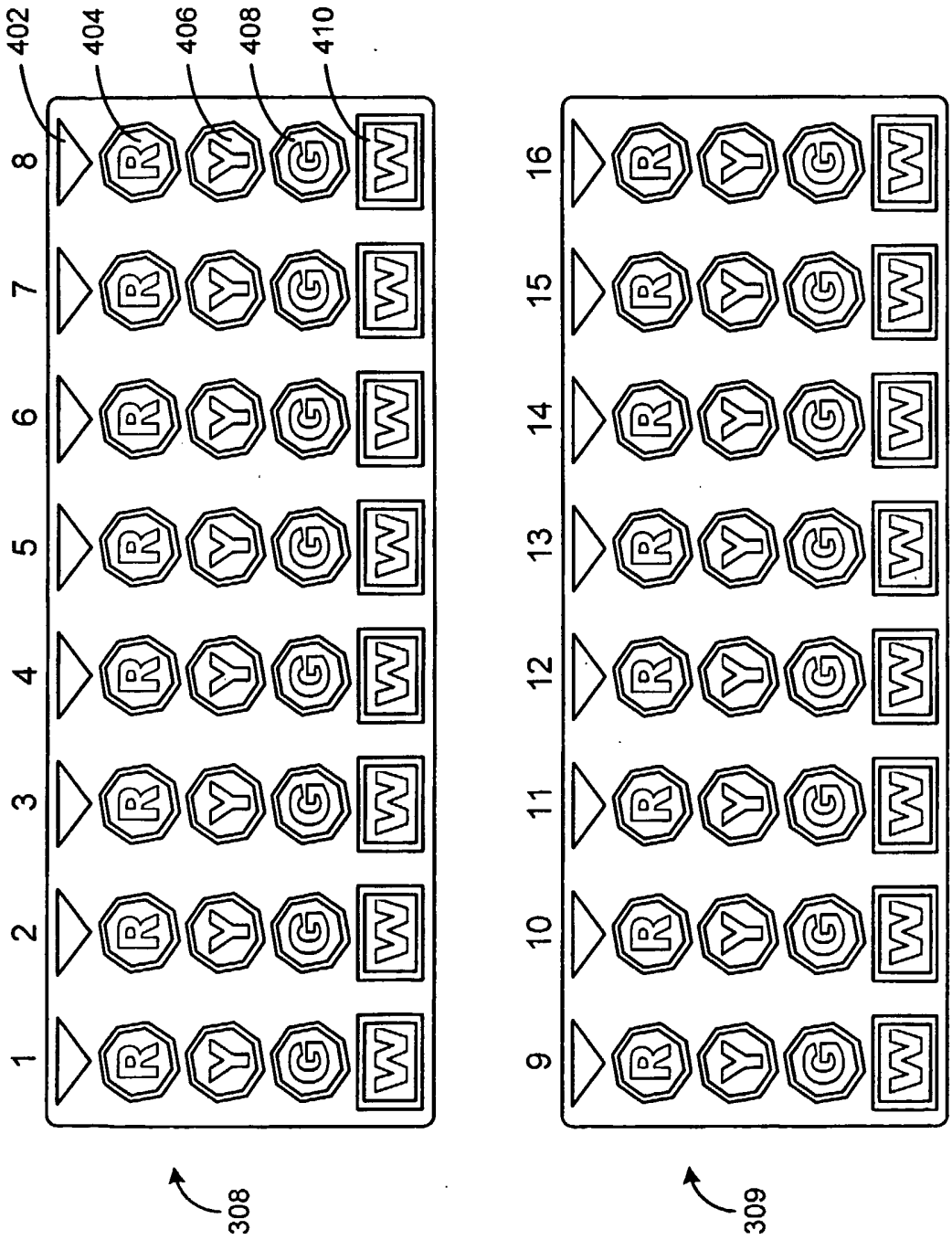

FIG. 4

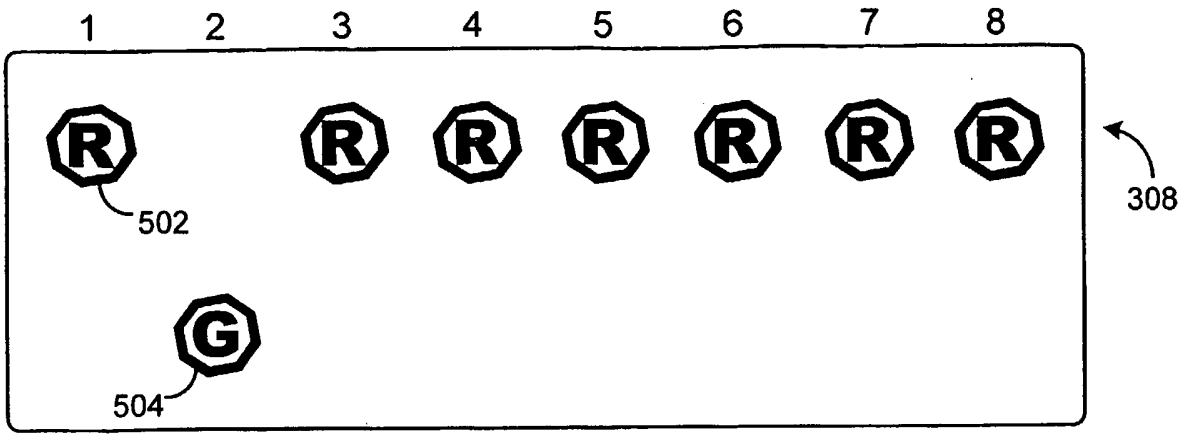

FIG. 5A

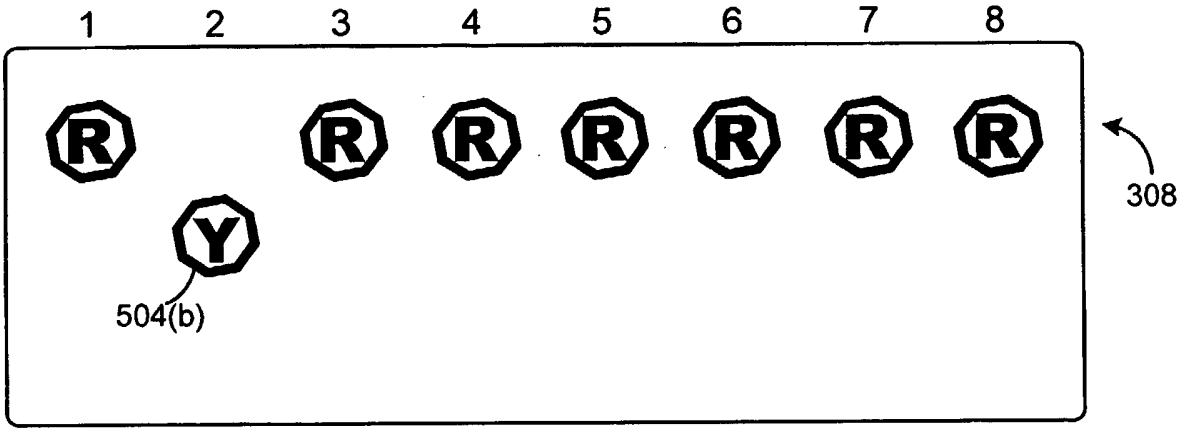

FIG. 5B

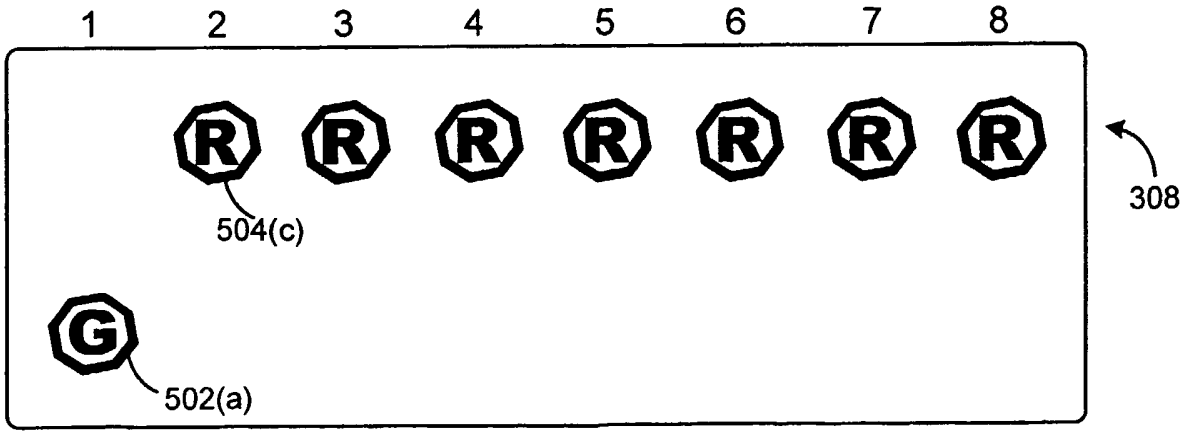

FIG. 5C

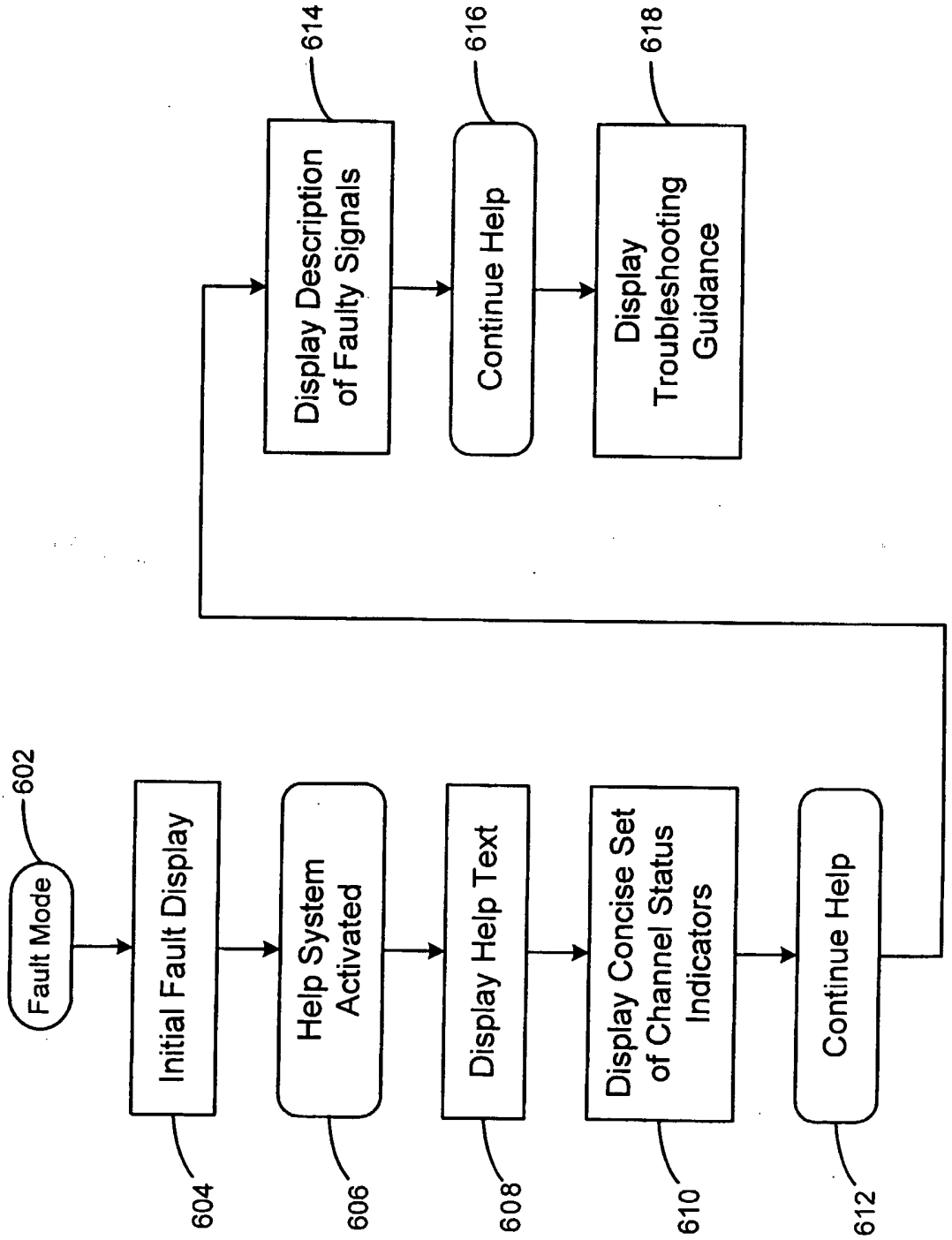
Fault Mode
602
Initial Fault Display
604
Help System Activated
606
Display Help Text
608
Display Concise Set of Channel Status Indicators
610
Continue Help
612
Display Description of Faulty Signals
614
Continue Help
616
Display Troubleshooting Guidance
618

FIG. 6

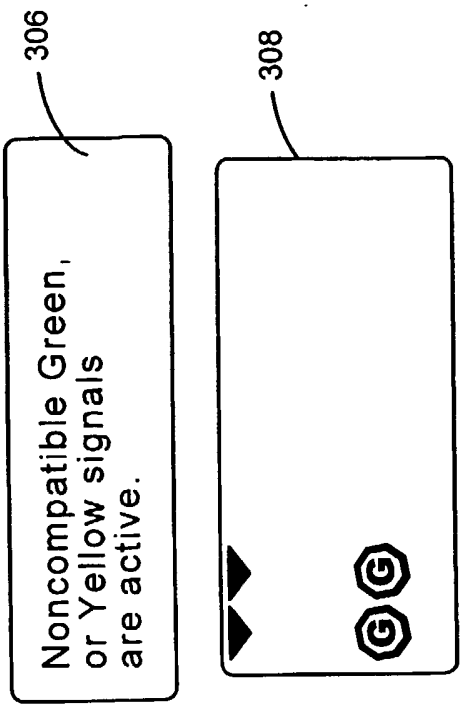

FIG. 7B

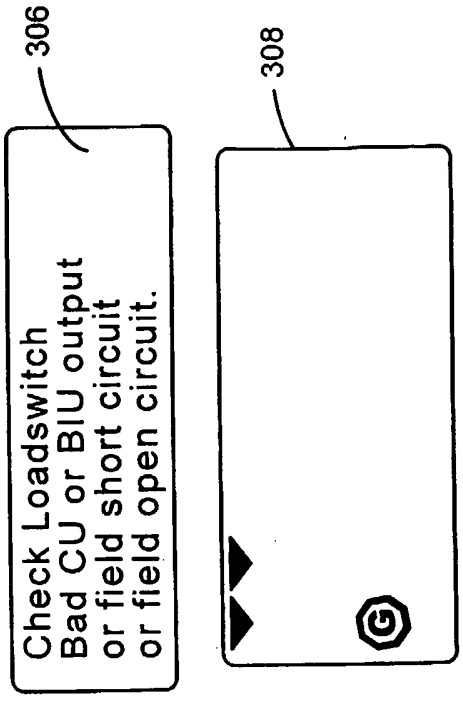

FIG. 7D

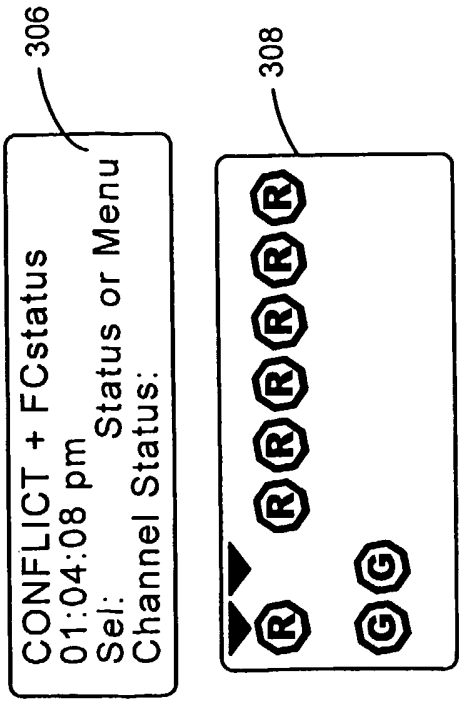

FIG. 7A

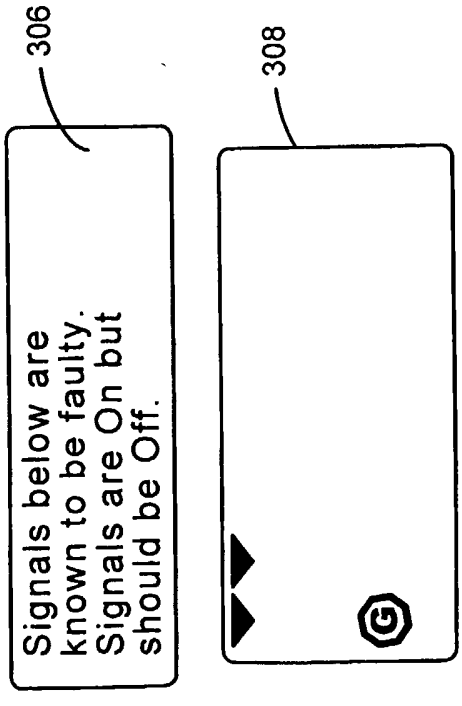

FIG. 7C

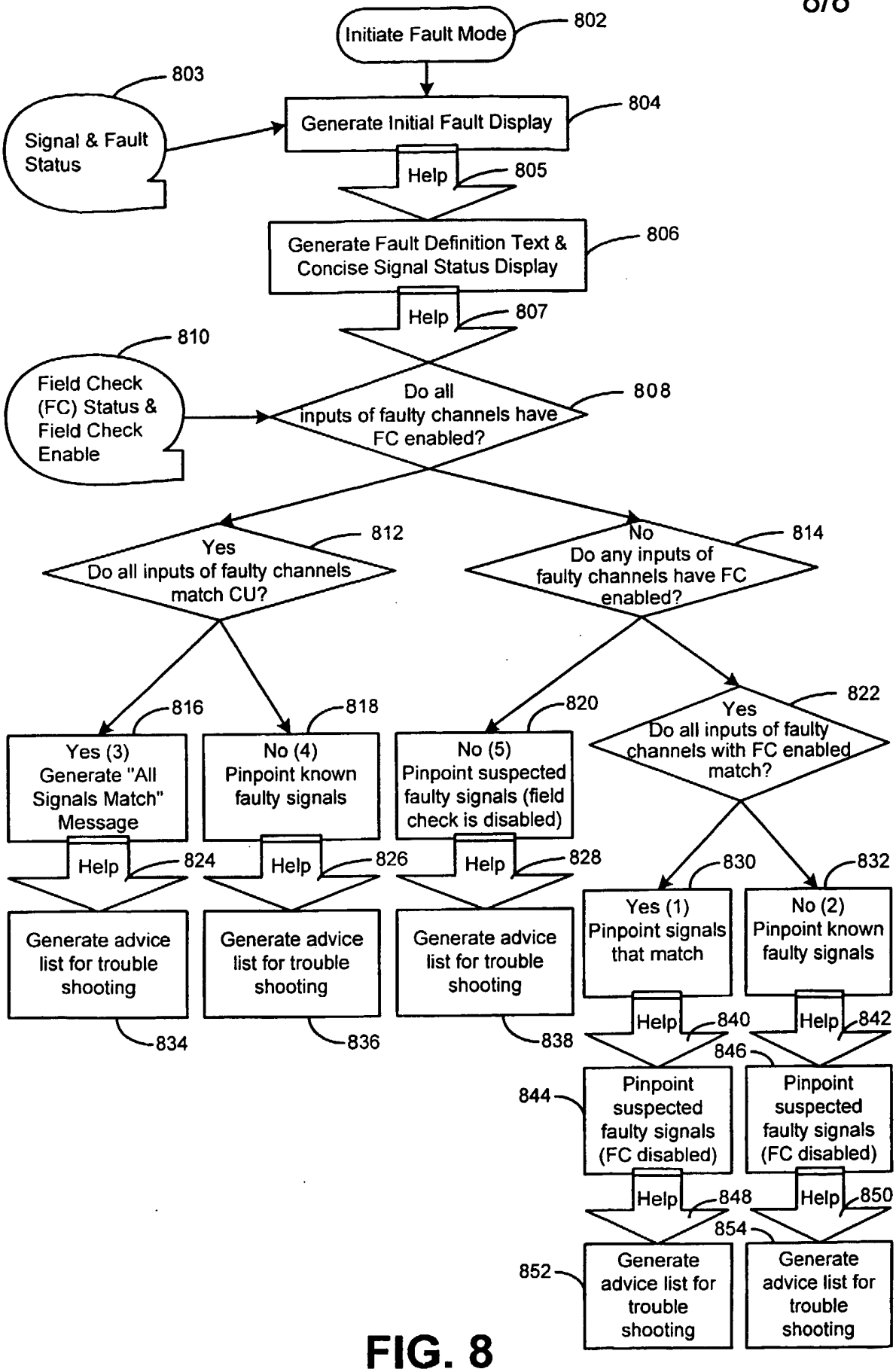
Initiate Fault Mode
802
803
Signal & Fault Status
Generate Initial Fault Display
804
Help
805
Generate Fault Definition Text & Concise Signal Status Display
806
Help
807
810
Field Check (FC) Status & Field Check Enable
Do all inputs of faulty channels have FC enabled?
808
Yes
Do all inputs of faulty channels match CU?
812
No
Do any inputs of faulty channels have FC enabled?
814
816
Yes (3) Generate "All Signals Match" Message
818
No (4) Pinpoint known faulty signals
820
No (5) Pinpoint suspected faulty signals (field check is disabled)
822
Yes
Do all inputs of faulty channels with FC enabled match?
Help
824
Help
826
Help
828
830
Yes (1) Pinpoint signals that match
832
No (2) Pinpoint known faulty signals
Generate advice list for trouble shooting
Generate advice list for trouble shooting
Generate advice list for trouble shooting
834
836
838
Help
840
Help
842
846
844
Pinpoint suspected faulty signals (FC disabled)
Pinpoint suspected faulty signals (FC disabled)
Help
848
Help
850
854
852
Generate advice list for trouble shooting
Generate advice list for trouble shooting

FIG. 8