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Liu et al.

(10) **Patent No.: US 9,971,330 B2**
(45) **Date of Patent: *May 15, 2018**

(54) **SAFETY RELAY CONFIGURATION EDITOR**

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(73) Assignee: **Rockwell Automation Technologies, Inc.**, Mayfield Heights, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 551 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/640,564**

(22) Filed: **Mar. 6, 2015**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
G05B 19/042 (2006.01)
G05B 23/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G05B 19/0428*** (2013.01); ***G05B 23/0216*** (2013.01); ***G06F 3/0484*** (2013.01); ***G06F 8/34*** (2013.01); *G05B 2219/24024* (2013.01)

(58) **Field of Classification Search**
CPC G05B 19/0428; G05B 2219/24024; G05B 23/0216; G06F 3/0484; G06F 8/34
See application file for complete search history.

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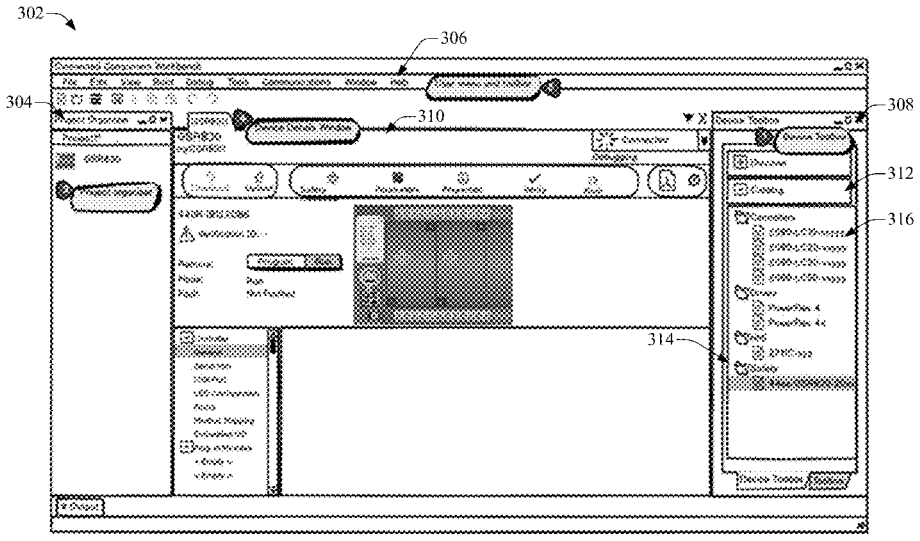
Primary Examiner — Abdelmoniem Elamin
(74) *Attorney, Agent, or Firm* — Amin, Turocy & Watson, LLP

(57) **ABSTRACT**

A safety relay configuration system for configuring safety functions to be carried out by a safety relay is provided. The configuration system comprises a number of features that facilitate intuitive and simplified configuration of an industrial safety relay, including but not limited to features that guide the user through the configuration process using an intuitive sequential procedure, enforce design consistency throughout the configuration project by intelligently limiting user selections, and visually organize configuration and status information in a manner that efficiently utilizes display space and allows the user to quickly evaluate available configuration options. The configuration system organizes function blocks into columns according to function block type and uses pass-through blocks and signal flow line drawing rules to yield an organized program visualization that can be easily followed and interpreted.

20 Claims, 24 Drawing Sheets



(51) **Int. Cl.**
G06F 3/0484 (2013.01)
G06F 9/44 (2018.01)

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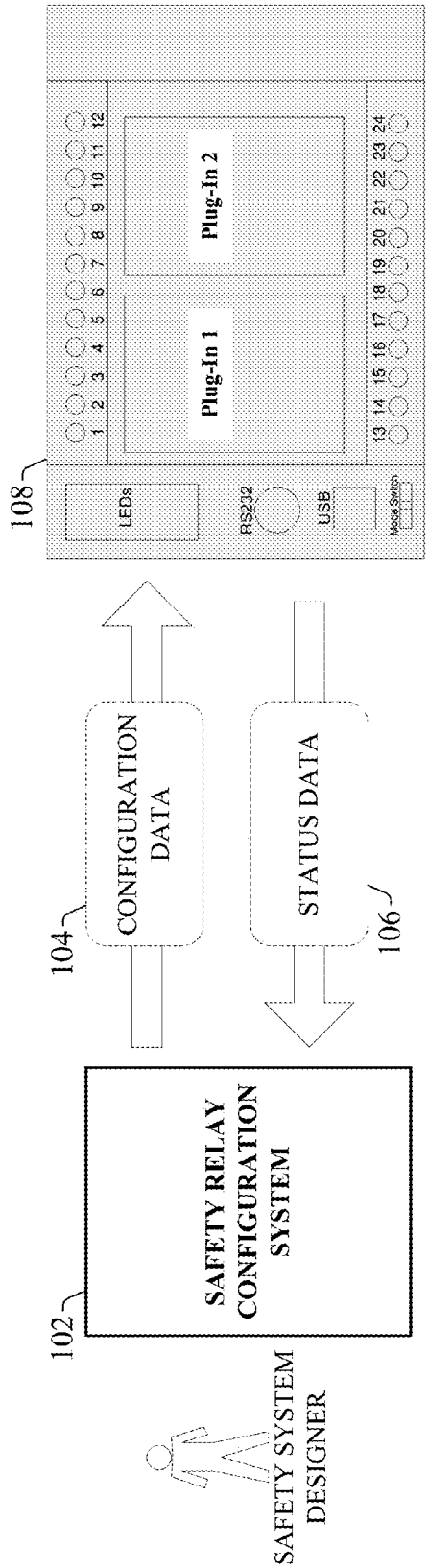
SAFETY SYSTEM DESIGNER
102
SAFETY RELAY CONFIGURATION SYSTEM
104
CONFIGURATION DATA
106
STATUS DATA
108
LEDs
RS232
USB
Mode Switch
Plug-In 1
Plug-In 2
1 2 3 4 5 6 7 8 9 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24

FIG. 1

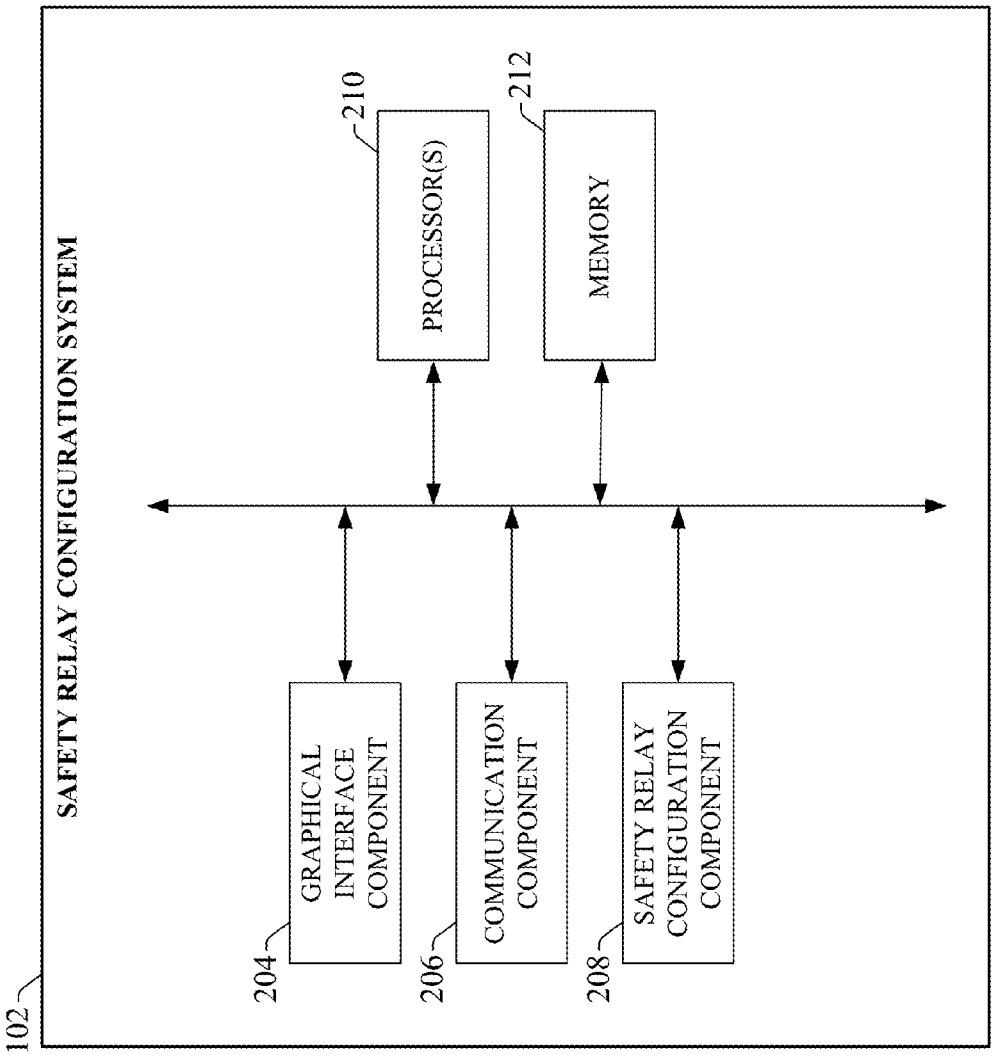
SAFETY RELAY CONFIGURATION SYSTEM
102
210
PROCESSOR(S)
212
MEMORY
204
GRAPHICAL INTERFACE COMPONENT
206
COMMUNICATION COMPONENT
208
SAFETY RELAY CONFIGURATION COMPONENT

FIG. 2

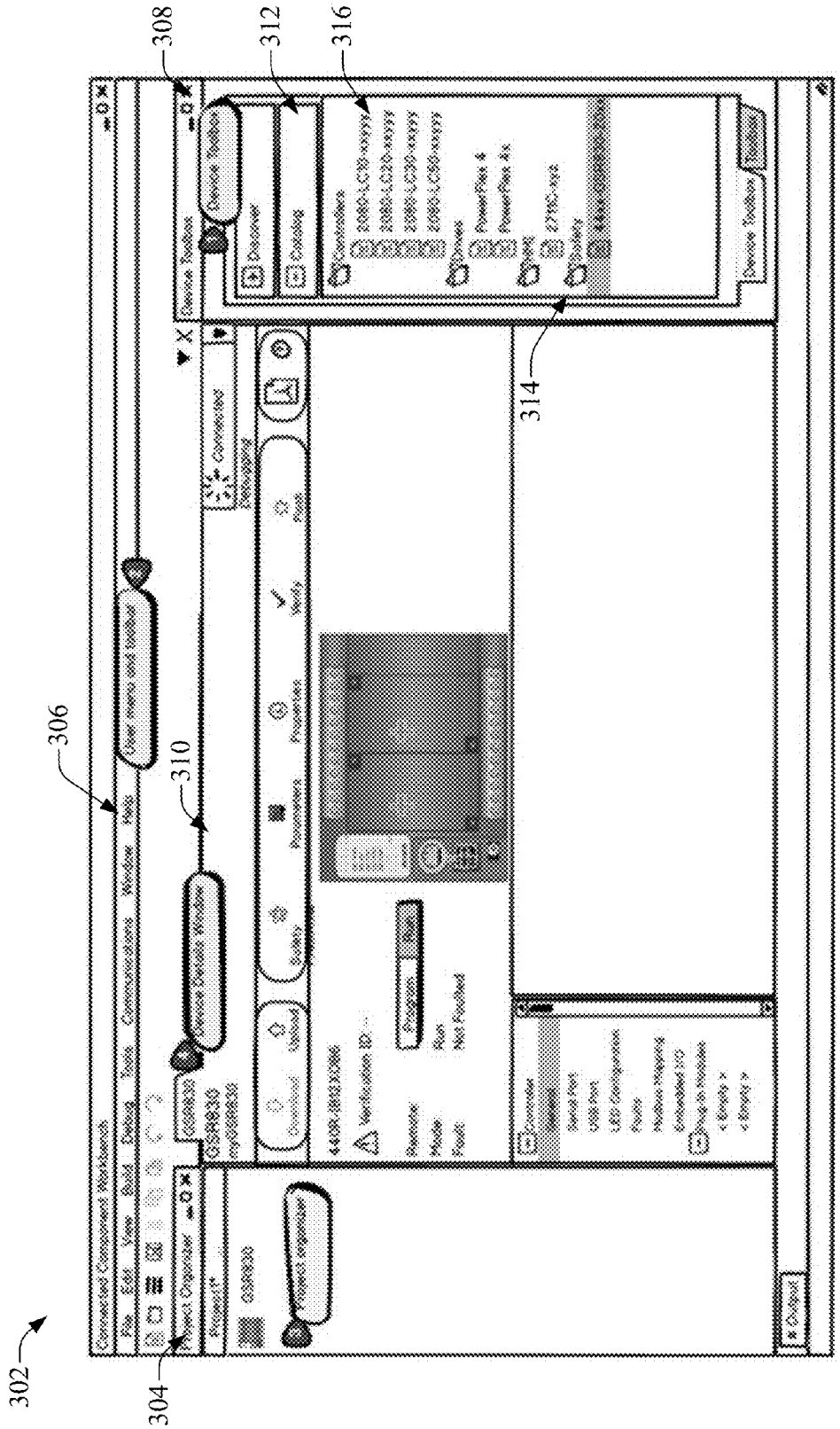

FIG. 3

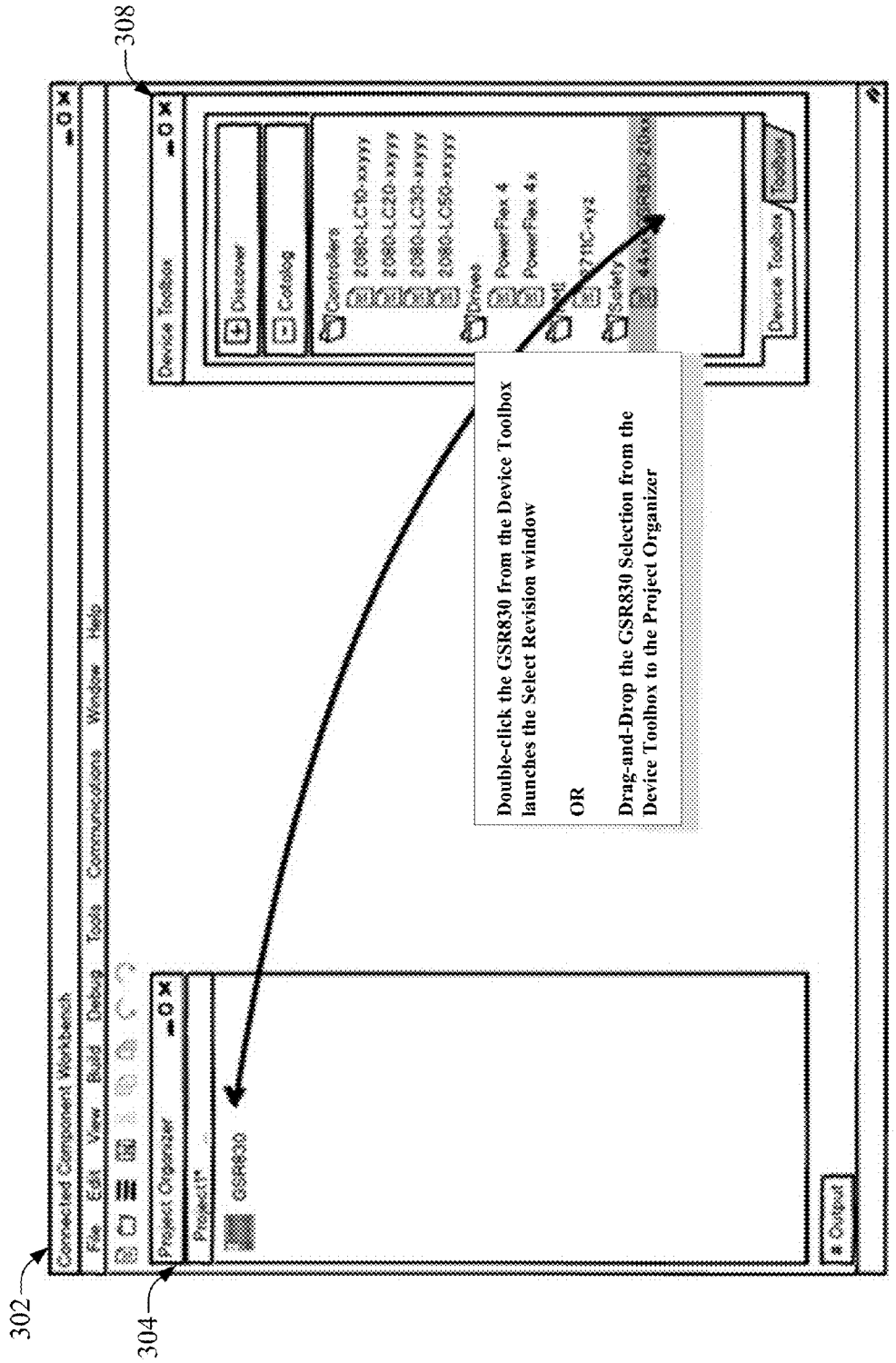
308
302
304
Connected Component Workbench
File Edit View Build Debug Tools Communications Window Help
Project Organizer
Project1*
controller
Device Toolbox
Discover
Catalog
Controllers
2080-LC50-xxxyy
2080-LC30-xxxyy
2080-LC20-xxxyy
2080-LC50-xxxyy
Drives
PowerFlex 4
PowerFlex 4x
Safety
Double-click the GSR830 from the Device Toolbox launches the Select Revision window
OR
Drag-and-Drop the GSR830 Selection from the Device Toolbox to the Project Organizer
Output

FIG. 4

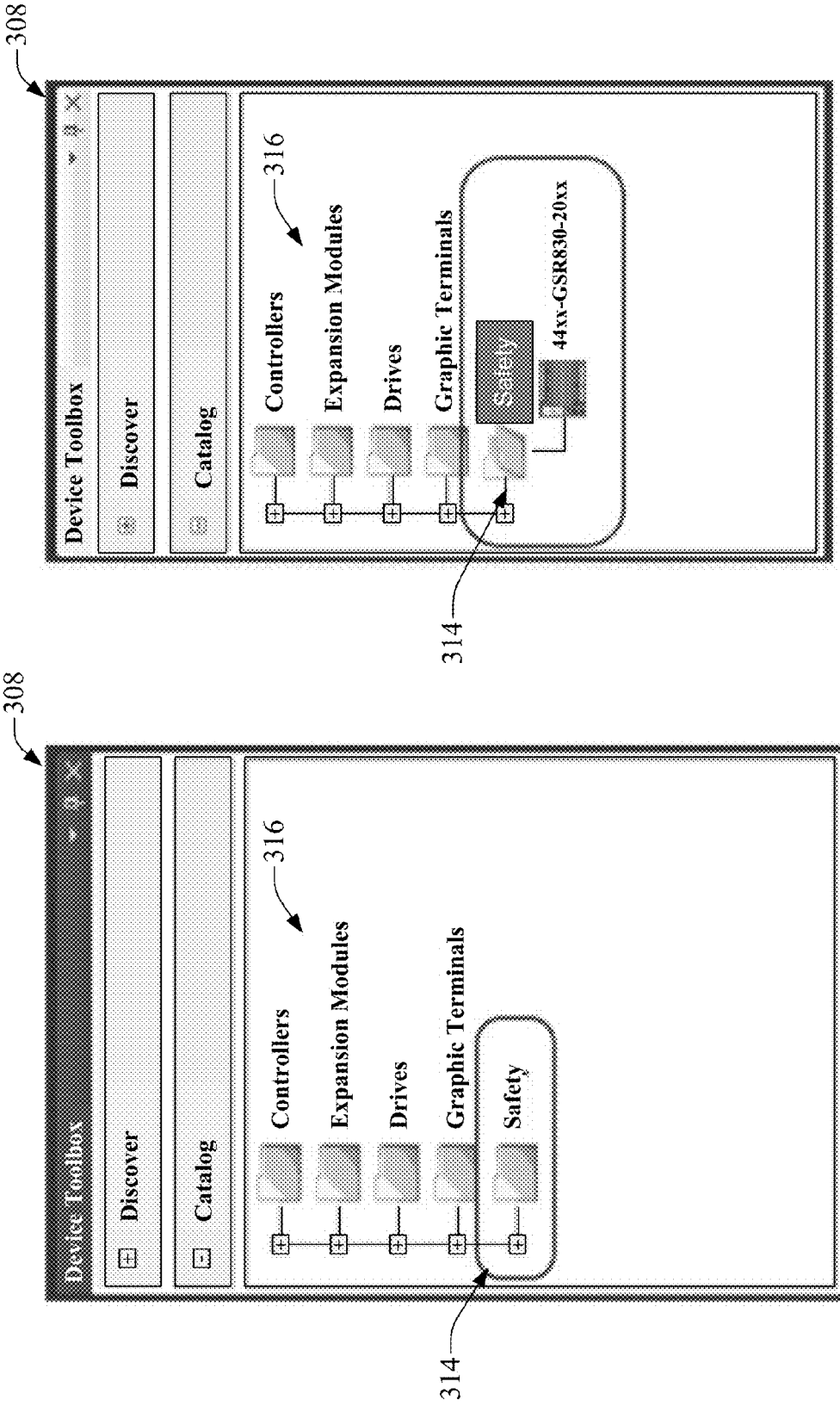
308
Device Toolbox
Discover
Catalog
316
Controllers
Expansion Modules
Drives
Graphic Terminals
Safety
314
308
Device Toolbox
Discover
Catalog
316
Controllers
Expansion Modules
Drives
Graphic Terminals
Safety
44xx-GSR830-20xx
314

FIG. 5a

FIG. 5b

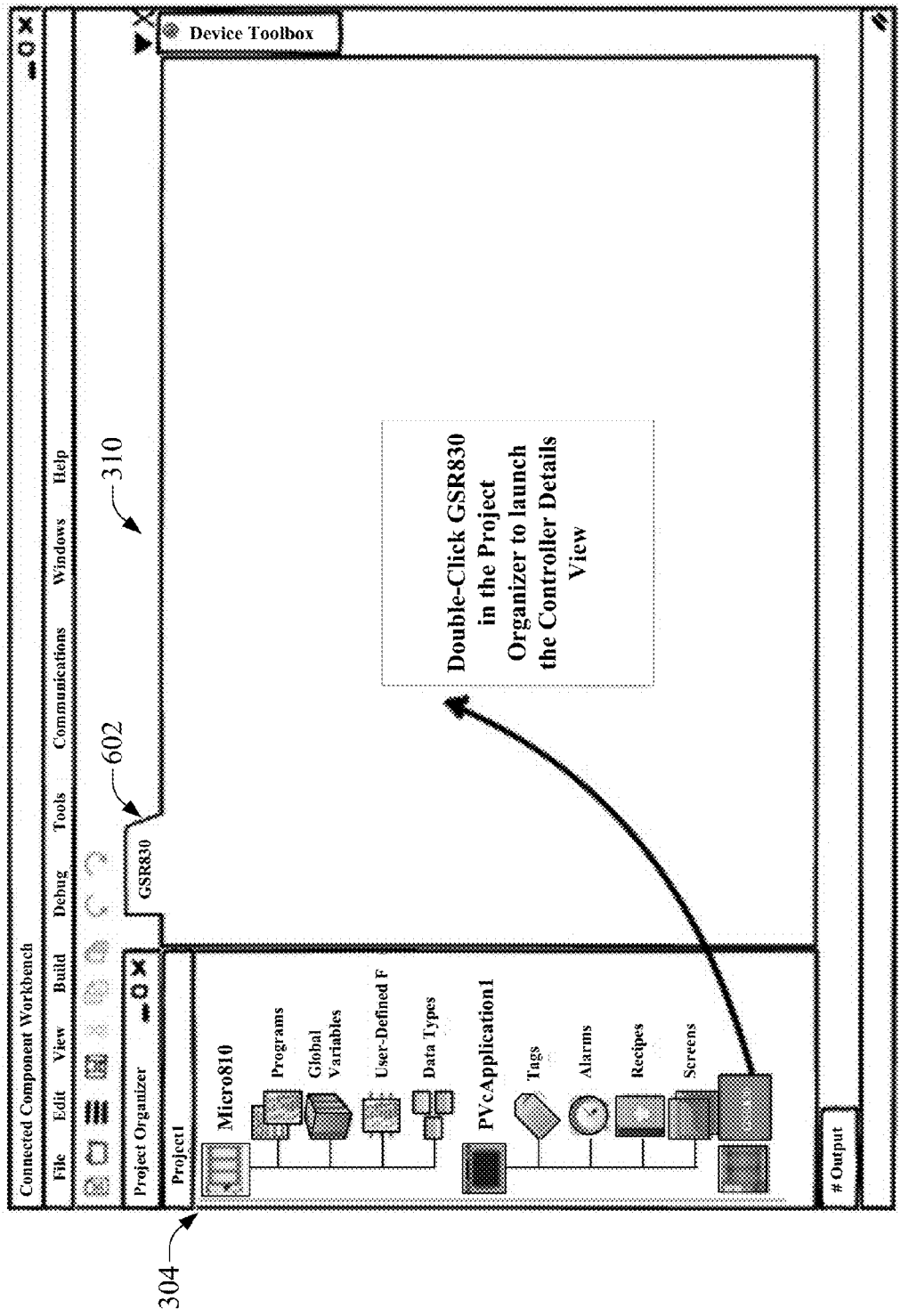
Connected Component Workbench
File Edit View Build Debug Tools Communications Windows Help
Project Organizer
Project1
Micro810
Programs
Global Variables
User-Defined F
Data Types
PVcApplication1
Tags
Alarms
Recipes
Screens
GSR830
Device Toolbox
Output
Double-Click GSR830 in the Project Organizer to launch the Controller Details View
304
310
602

FIG. 6

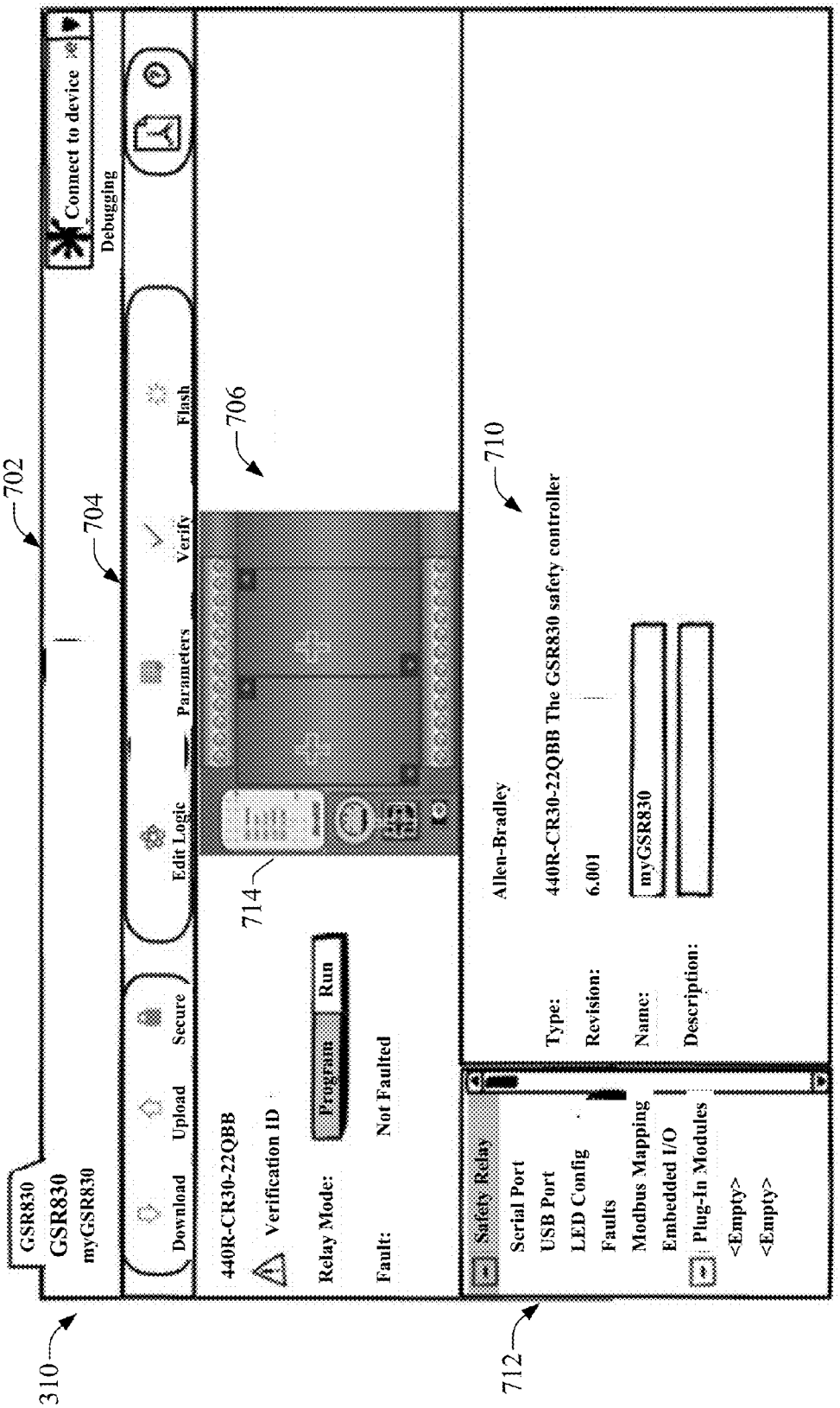
GSR830
GSR830
myGSR830
Connect to device
Debugging
Download
Upload
Secure
Edit Logic
Parameters
Verify
Flash
440R-CR30-22QBB
Verification ID
Relay Mode:
Program
Run
Fault:
Not Faulted
Safety Relay
Serial Port
USB Port
LED Config
Faults
Modbus Mapping
Embedded I/O
Plug-In Modules
<Empty>
<Empty>
Allen-Bradley
Type:
440R-CR30-22QBB The GSR830 safety controller
Revision:
6.001
Name:
myGSR830
Description:
310
702
704
706
710
712
714

FIG. 7

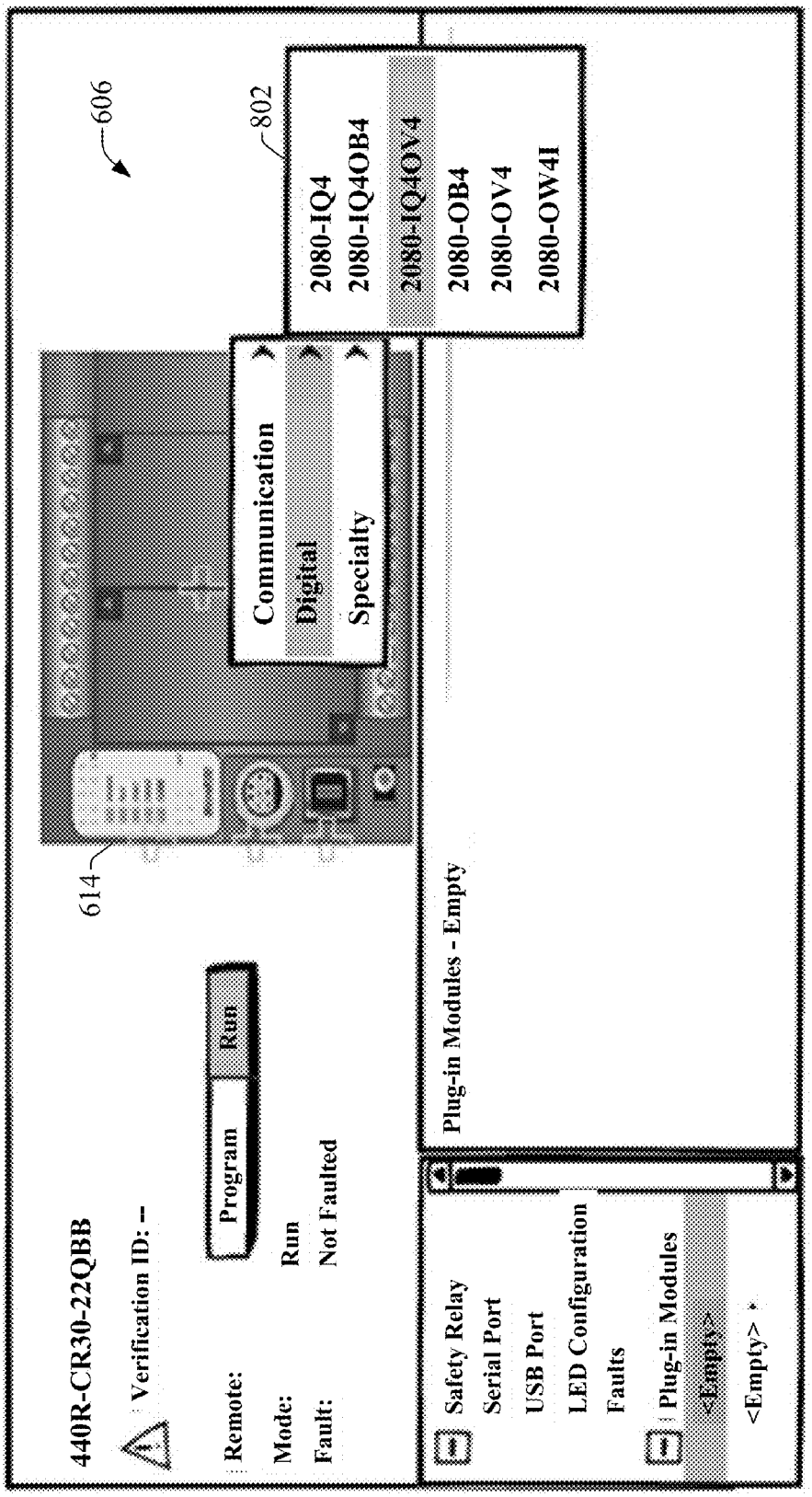
606
802
614
440R-CR30-22QBB
Verification ID: --
Remote:
Mode: Run
Fault: Not Faulted
Program
Run
Communication
Digital
Specialty
2080-IQ4
2080-IQ4OB4
2080-IQ4OV4
2080-OB4
2080-OV4
2080-OW4I
Plug-in Modules - Empty
Safety Relay
Serial Port
USB Port
LED Configuration
Faults
Plug-in Modules
<Empty>
<Empty>

FIG. 8

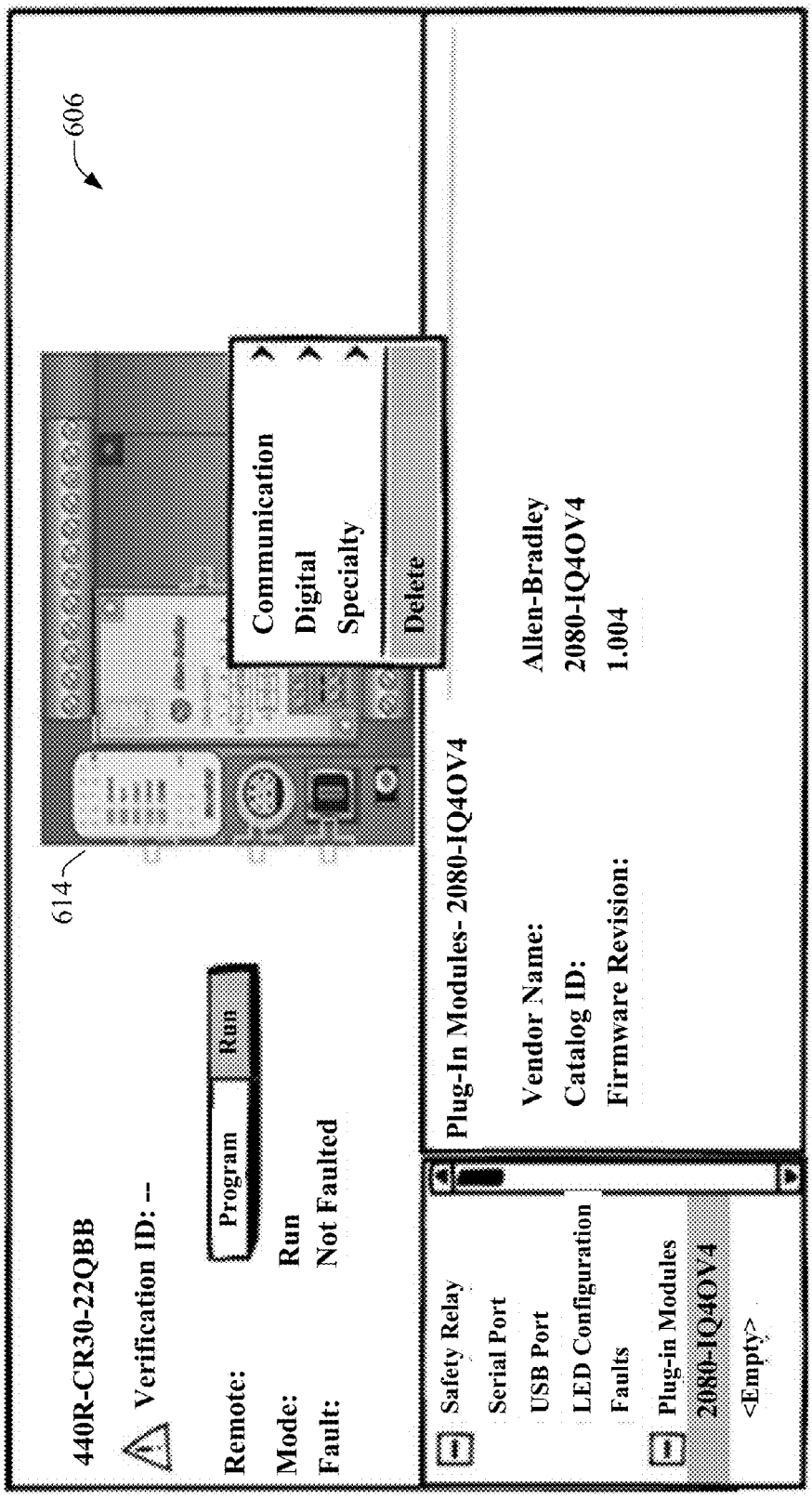
606
614
440R-CR30-22QBB
Verification ID: --
Remote:
Mode: Run
Fault: Not Faulted
Program
Run
Communication
Digital
Specialty
Delete
Plug-In Modules- 2080-IQ4OV4
Vendor Name: Allen-Bradley
Catalog ID: 2080-IQ4OV4
Firmware Revision: 1.004
Safety Relay
Serial Port
USB Port
LED Configuration
Faults
Plug-in Modules
2080-IQ4OV4
<Empty>

FIG. 9

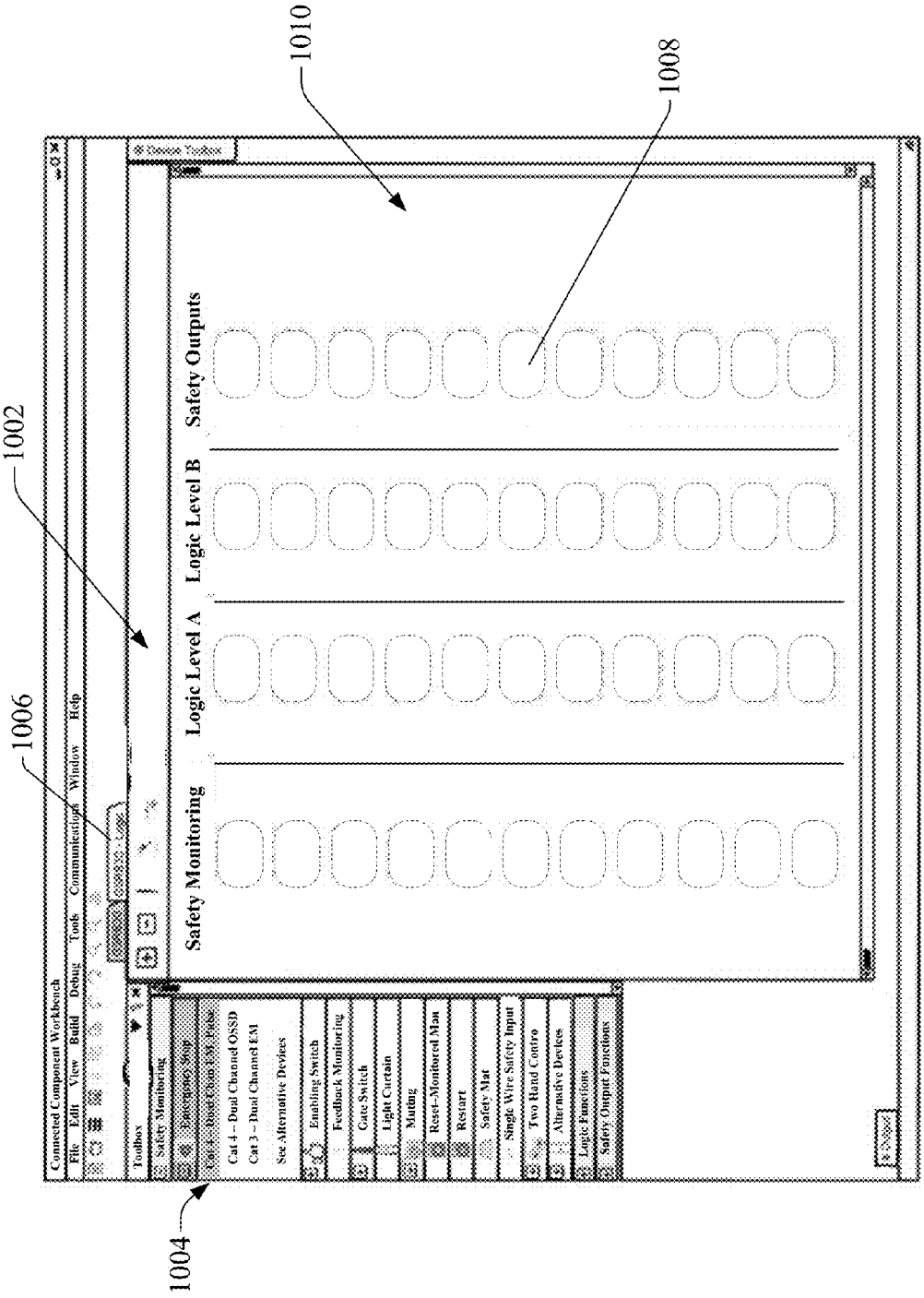
1010
1008
1002
1006
1004
Safety Outputs
Logic Level B
Logic Level A
Safety Monitoring
Connected Component Workbench
File Edit View Build Debug Tools Communication Window Help
Toolbox
Safety Monitoring
Emergency Stop
Cat 4 – Dual Channel OSSD
Cat 3 – Dual Channel EM
See Alternative Devices
Enabling Switch
Feedback Monitoring
Gate Switch
Light Curtain
Muting
Reset–Monitored Man
Restart
Safety Mat
Single Wire Safety Input
Two Hand Contro
Alternative Devices
Logic Functions
Safety Output Functions

FIG. 10

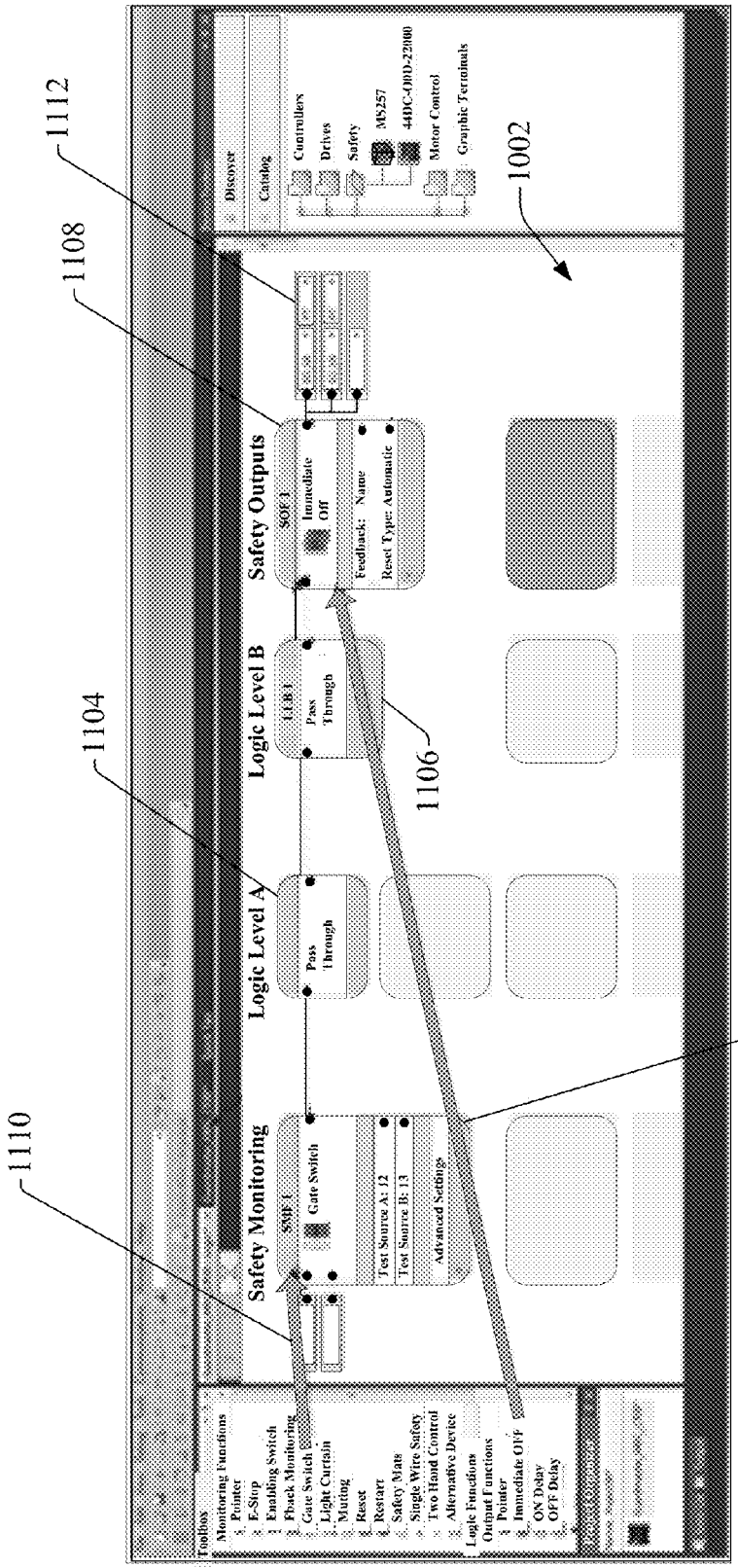
1112
1108
1104
1110
1106
1102
1002
Safety Monitoring
Logic Level A
Logic Level B
Safety Outputs
Toolbox
Discover
Catalog
Controllers
Drives
Safety
Motor Control
Graphic Terminals
Gate Switch
Pass Through
Immediate Off
Feedback: None
Reset Type: Automatic
Test Source A: 12
Test Source B: 13
Advanced Settings

FIG. 11

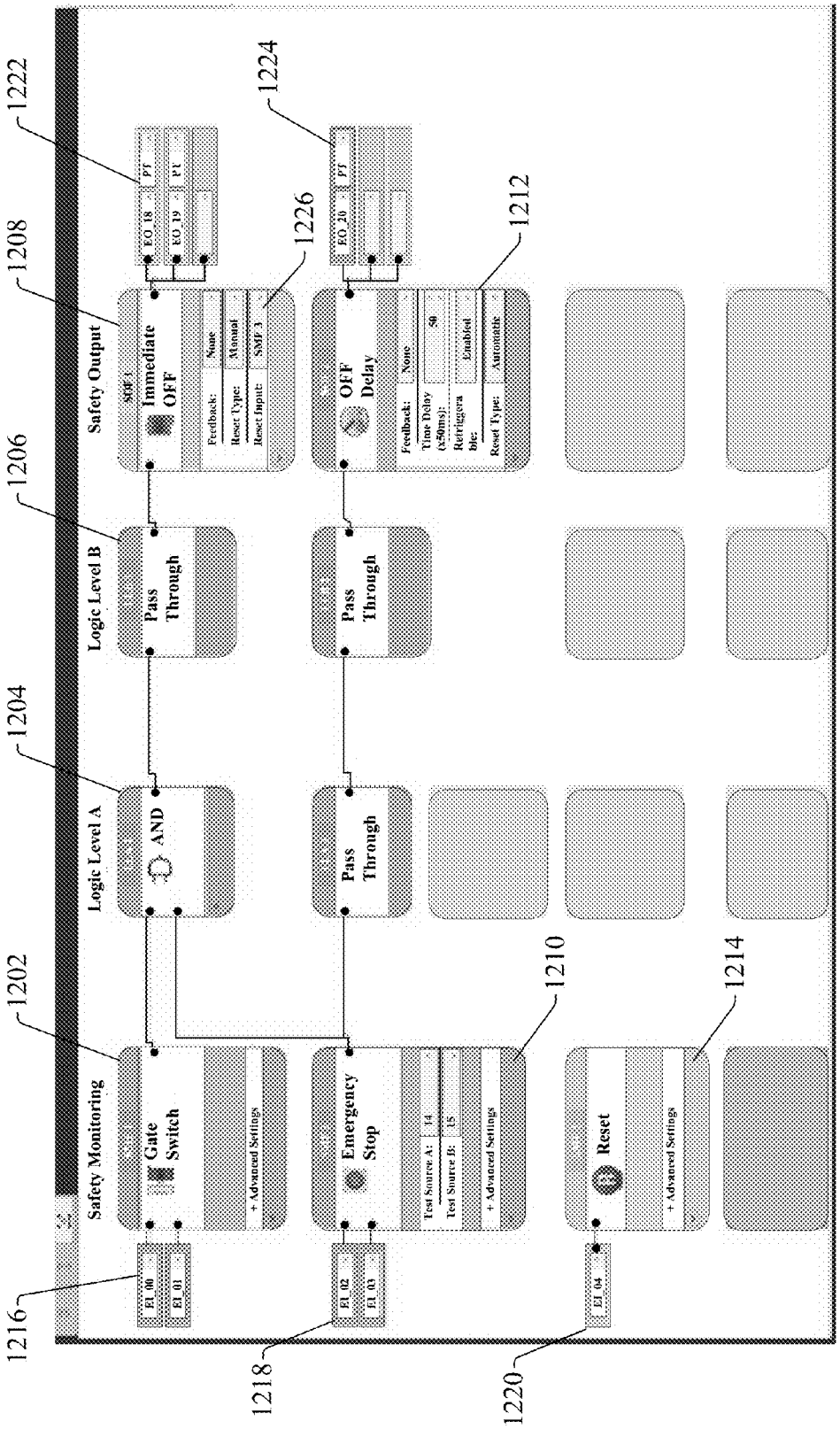
1222
1224
1208
1226
1212
1206
1204
1202
1210
1214
1216
1218
1220
Safety Output
Immediate OFF
Feedback:
None
Reset Type:
Manual
Reset Input:
SMF 3
OFF Delay
Feedback:
None
Time Delay (x50ms):
50
Retriggerable:
Enabled
Reset Type:
Automatic
Logic Level B
Pass Through
Pass Through
Logic Level A
AND
Pass Through
Safety Monitoring
Gate Switch
+ Advanced Settings
Emergency Stop
Test Source A:
14
Test Source B:
15
+ Advanced Settings
Reset
+ Advanced Settings
EI_00
EI_01
EI_02
EI_03
EI_04
EO_18
EO_19
EO_20
PT
PT
PT

FIG. 12

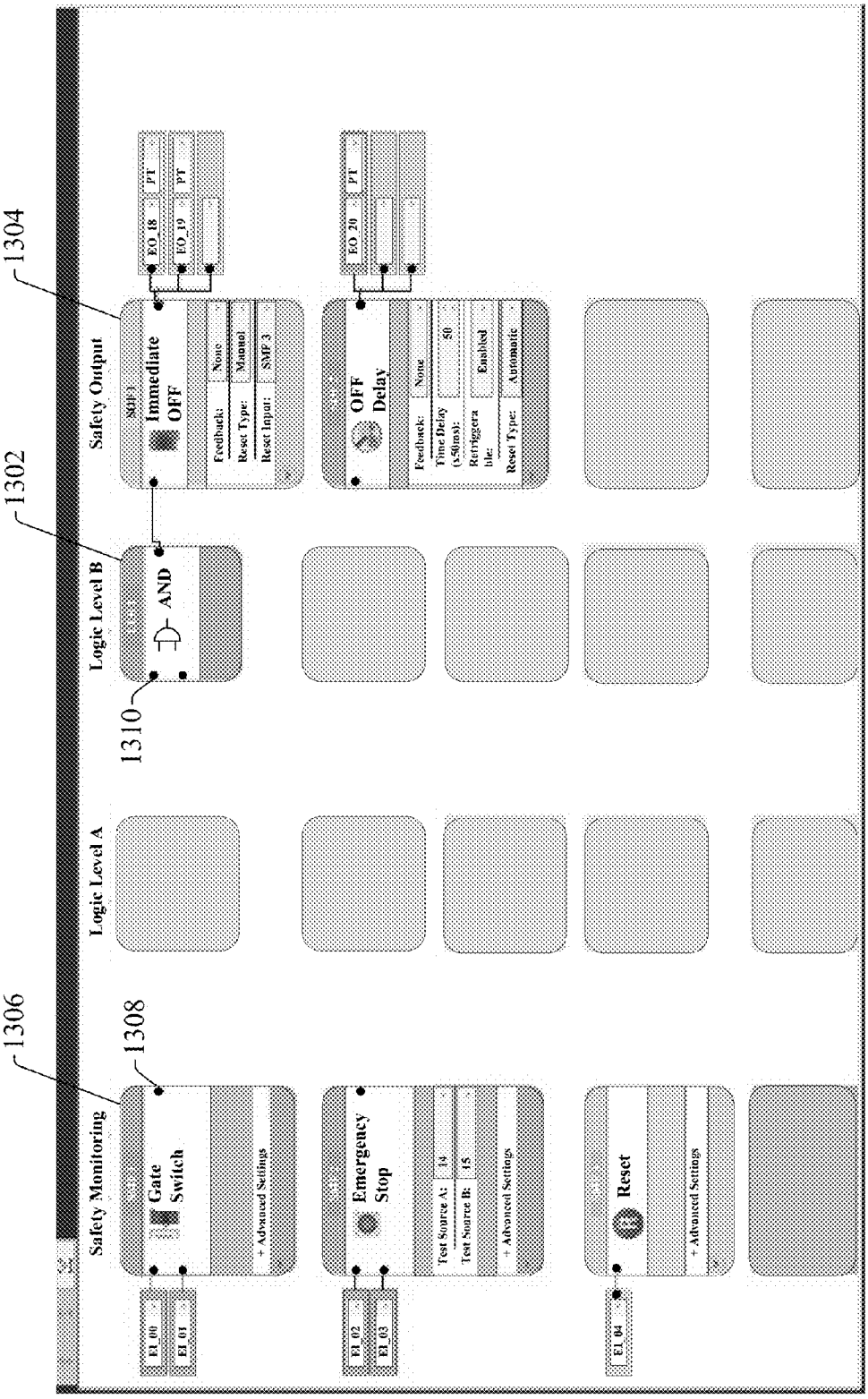
1304
1302
1306
1308
1310
Safety Monitoring
Logic Level A
Logic Level B
Safety Output
Gate Switch
Emergency Stop
Reset
AND
Immediate OFF
OFF Delay
+ Advanced Settings
EO_18
EO_19
EO_20
PT

FIG. 13

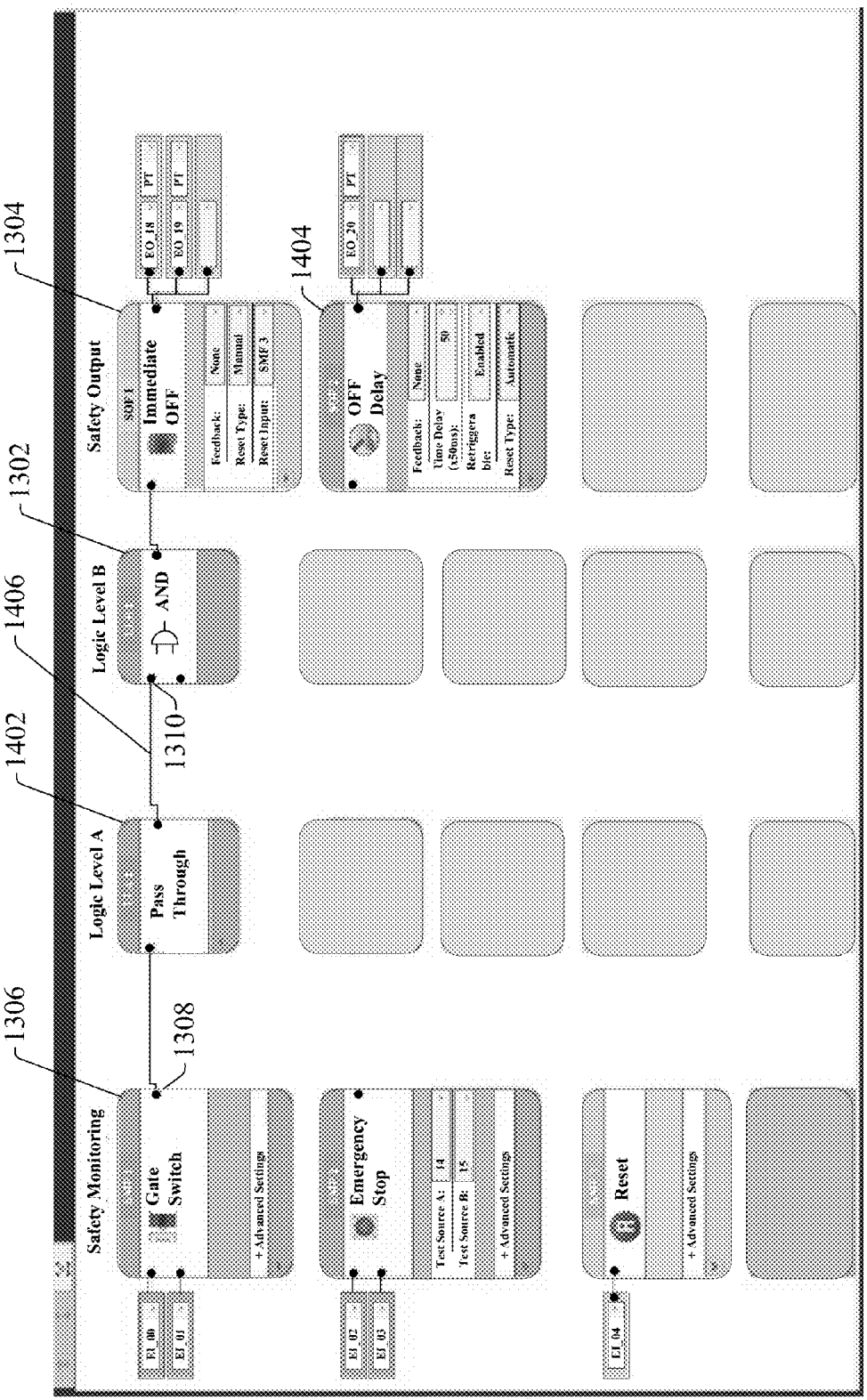
1304
1404
1302
1406
1402
1310
1306
1308
Safety Output
SDI 1
Immediate OFF
Feedback: None
Reset Type: Manual
Reset Input: SMF 3
EO_18 PT
EO_19 PT
EO_20 PT
OFF Delay
Feedback: None
Time Delay (x50ms): 50
Retriggerable: Enabled
Reset Type: Automatic
Logic Level B
AND
Logic Level A
Pass Through
Safety Monitoring
Gate Switch
+ Advanced Settings
EI_00
EI_01
Emergency Stop
Test Source A: I4
Test Source B: I5
+ Advanced Settings
EI_02
EI_03
Reset
+ Advanced Settings
EI_04

FIG. 14

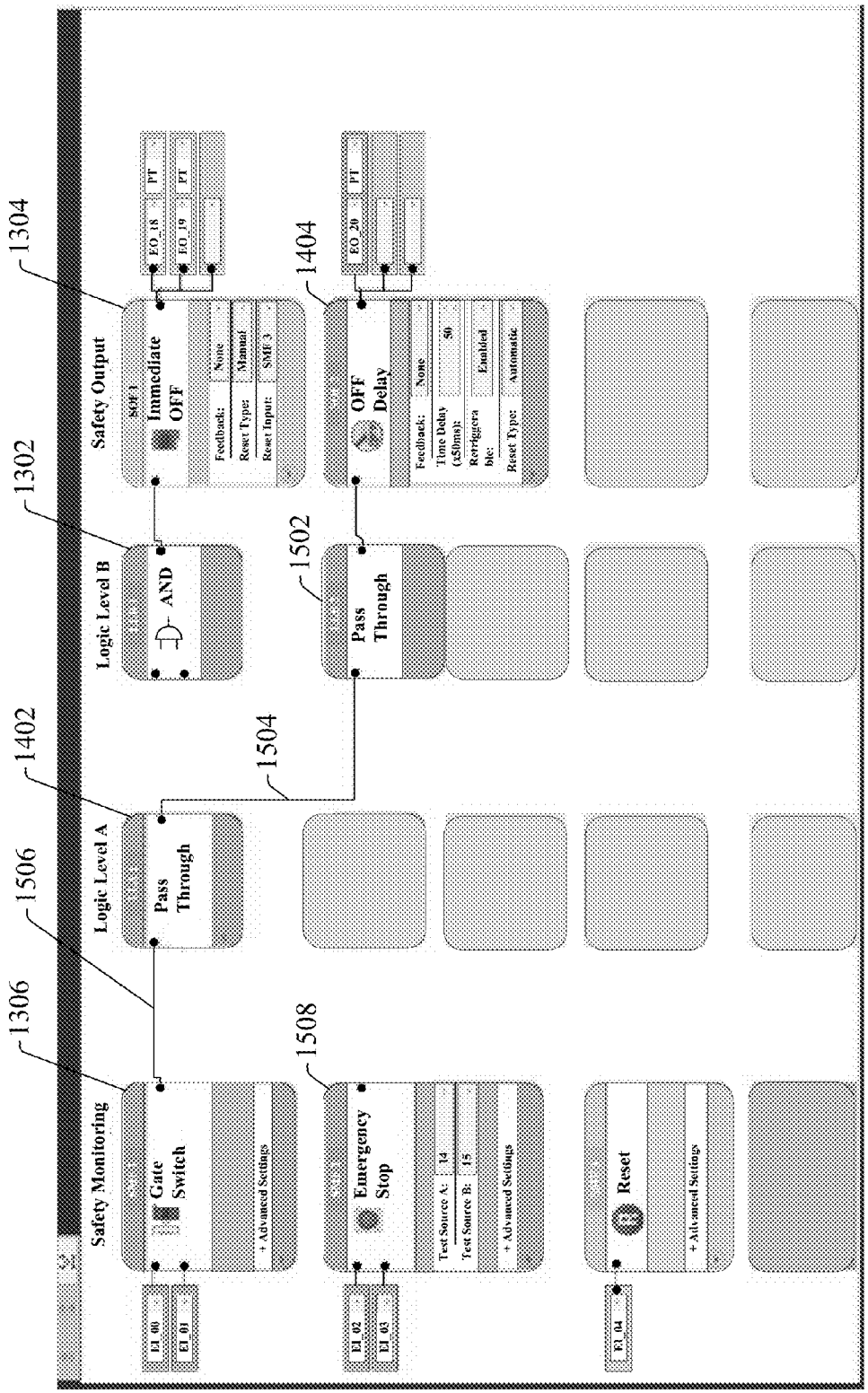
1304
1302
1402
1506
1306
1508
1504
1502
1404
Safety Monitoring
Gate Switch
+ Advanced Settings
Logic Level A
Pass Through
Logic Level B
AND
Safety Output
SOF1
Immediate OFF
Feedback:
None
Reset Type:
Manual
Reset Input:
SMF3
EO_18
EO_19
PT
Pass Through
OFF Delay
Feedback:
None
Time Delay (x50ms):
50
Retriggerable:
Enabled
Reset Type:
Automatic
EO_20
Emergency Stop
Test Source A:
14
Test Source B:
15
+ Advanced Settings
Reset
+ Advanced Settings
EI_00
EI_01
EI_02
EI_03
EI_04

FIG. 15

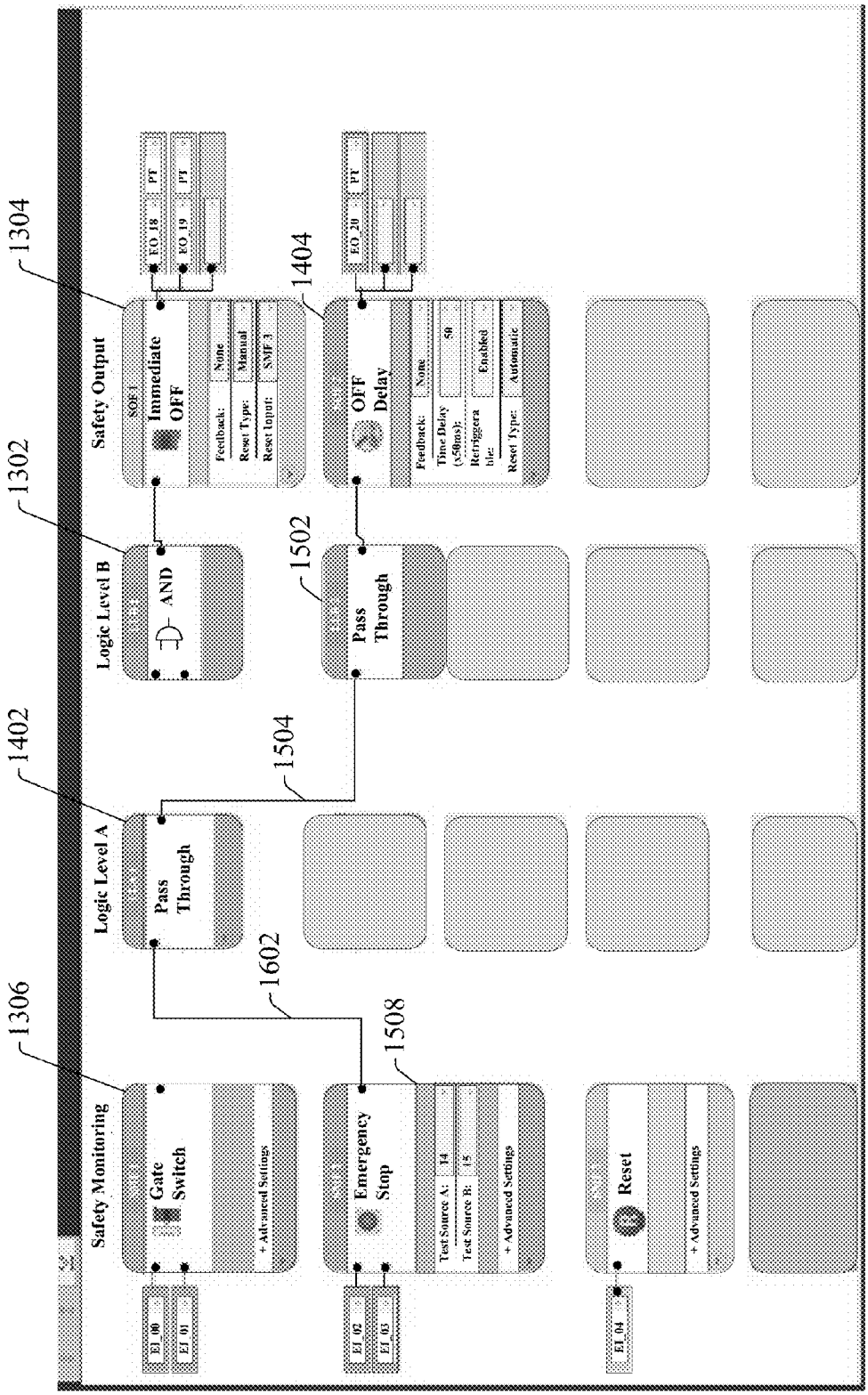
1304
1302
1402
1306
1602
1504
1502
1404
1508
Safety Output
Logic Level B
Logic Level A
Safety Monitoring
Immediate OFF
AND
Pass Through
OFF Delay
Gate Switch
Emergency Stop
Reset
+ Advanced Settings

FIG. 16

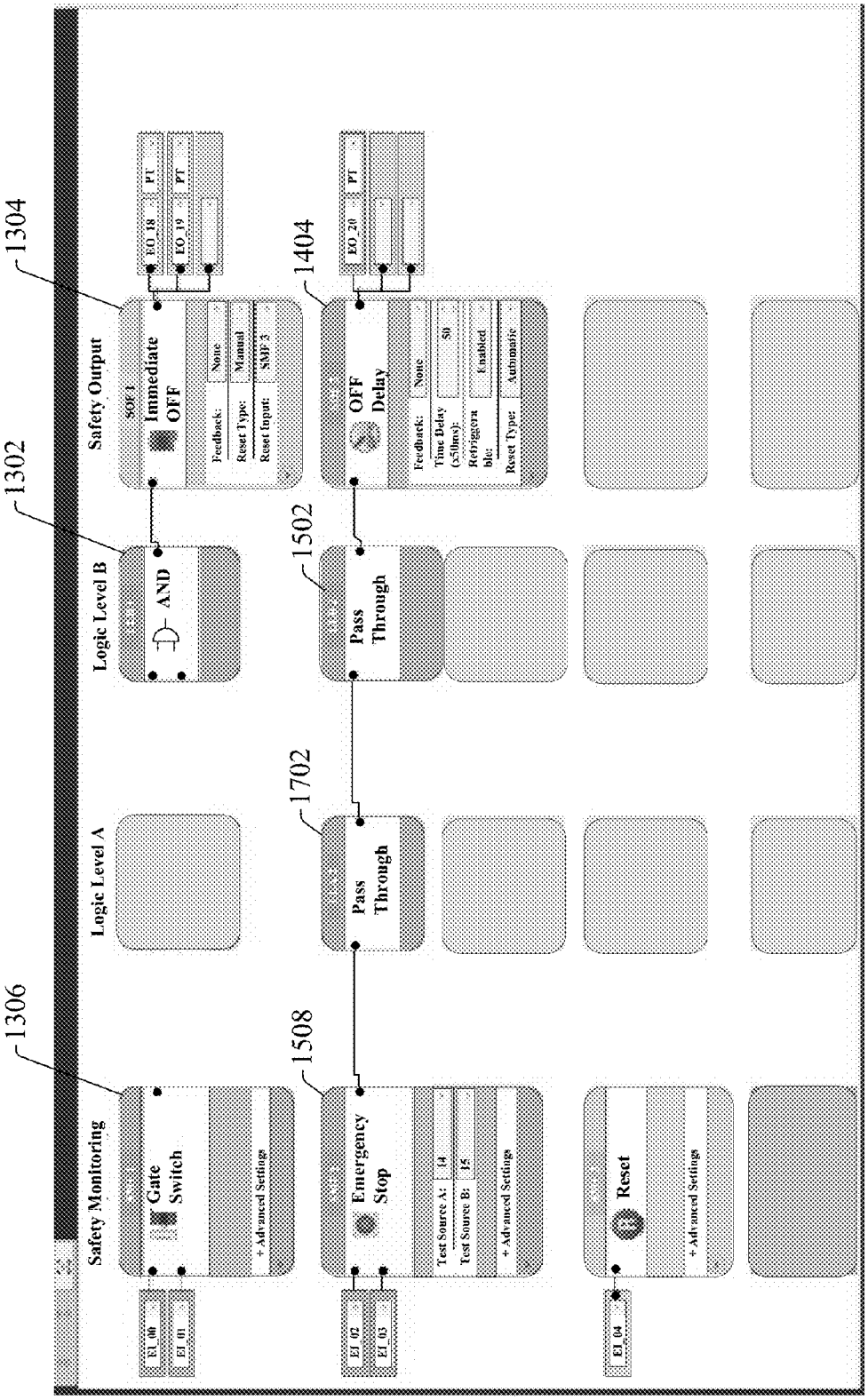
1304
1302
1306
1404
1502
1702
1508
Safety Monitoring
Logic Level A
Logic Level B
Safety Output
Gate Switch
Emergency Stop
Reset
AND
Pass Through
Pass Through
Immediate OFF
OFF Delay
+ Advanced Settings
+ Advanced Settings
+ Advanced Settings
EO_18
EO_19
EO_20
PT
PT
PT
None
Manual
SMF 3
None
50
Enabled
Automatic
Test Source A: 14
Test Source B: 15

FIG. 17

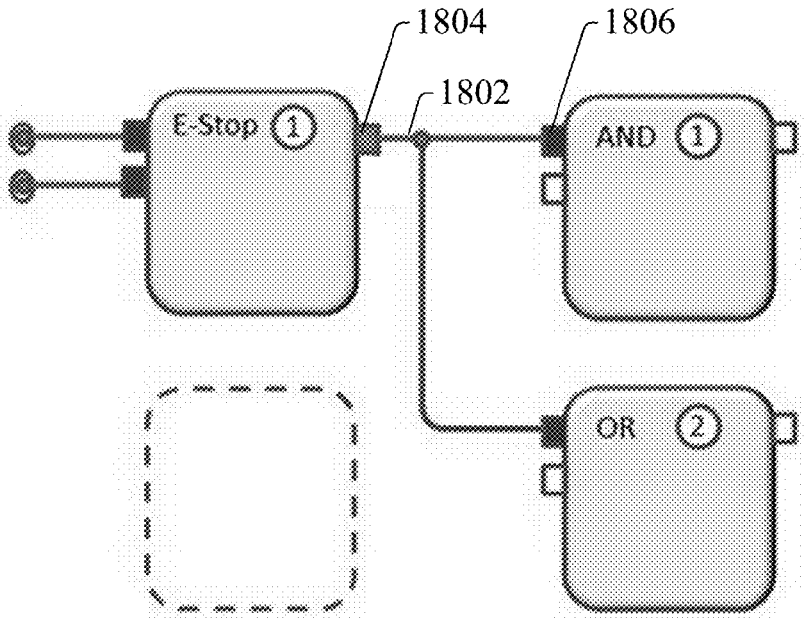
1804
1806
1802
E-Stop 1
AND 1
OR 2

FIG. 18

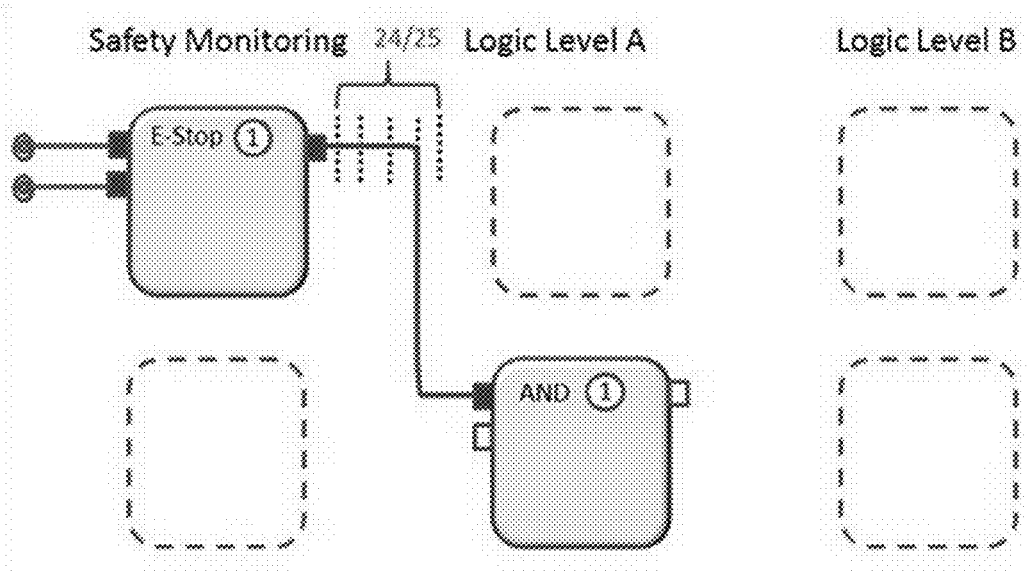
Safety Monitoring 24/25
Logic Level A
Logic Level B
E-Stop 1
AND 1

FIG. 19

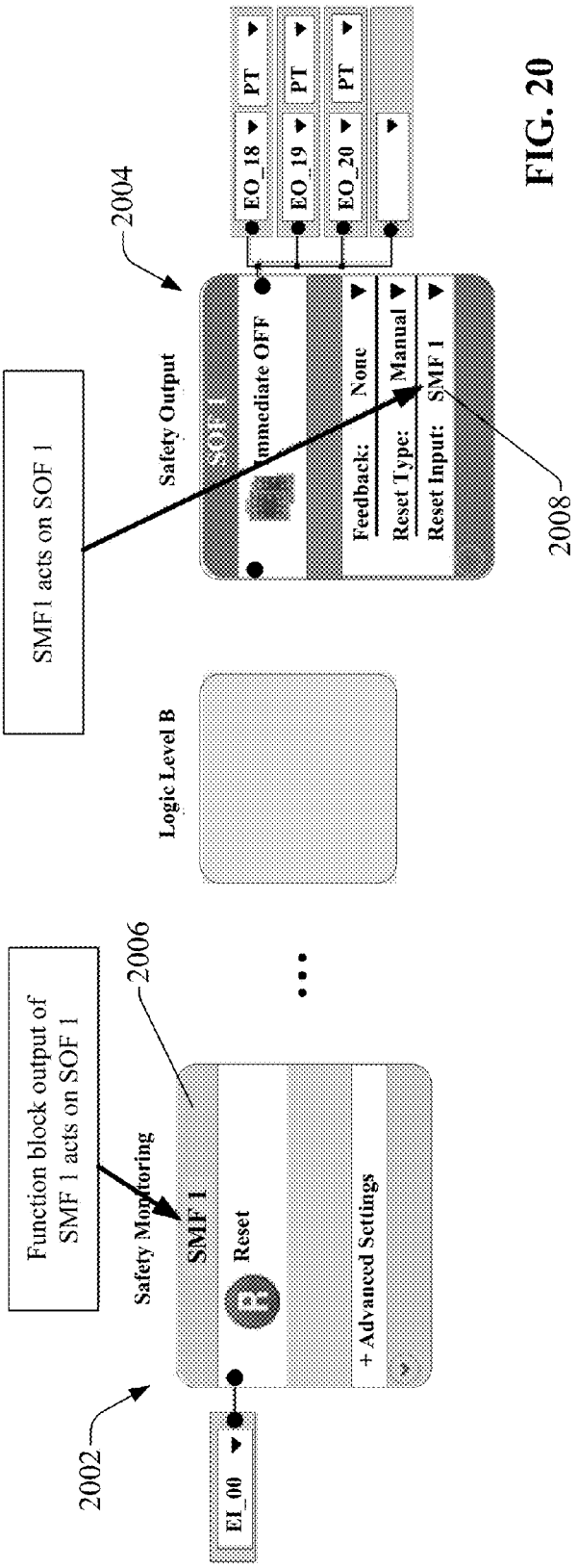
2004
EO_18
PT
EO_19
PT
EO_20
PT
SMF1 acts on SOF 1
Safety Output
SOF 1
Immediate OFF
Feedback: None
Reset Type: Manual
Reset Input: SMF 1
2008
Logic Level B
Function block output of SMF 1 acts on SOF 1
2006
Safety Monitoring
SMF 1
Reset
+ Advanced Settings
2002
EI_00

FIG. 20

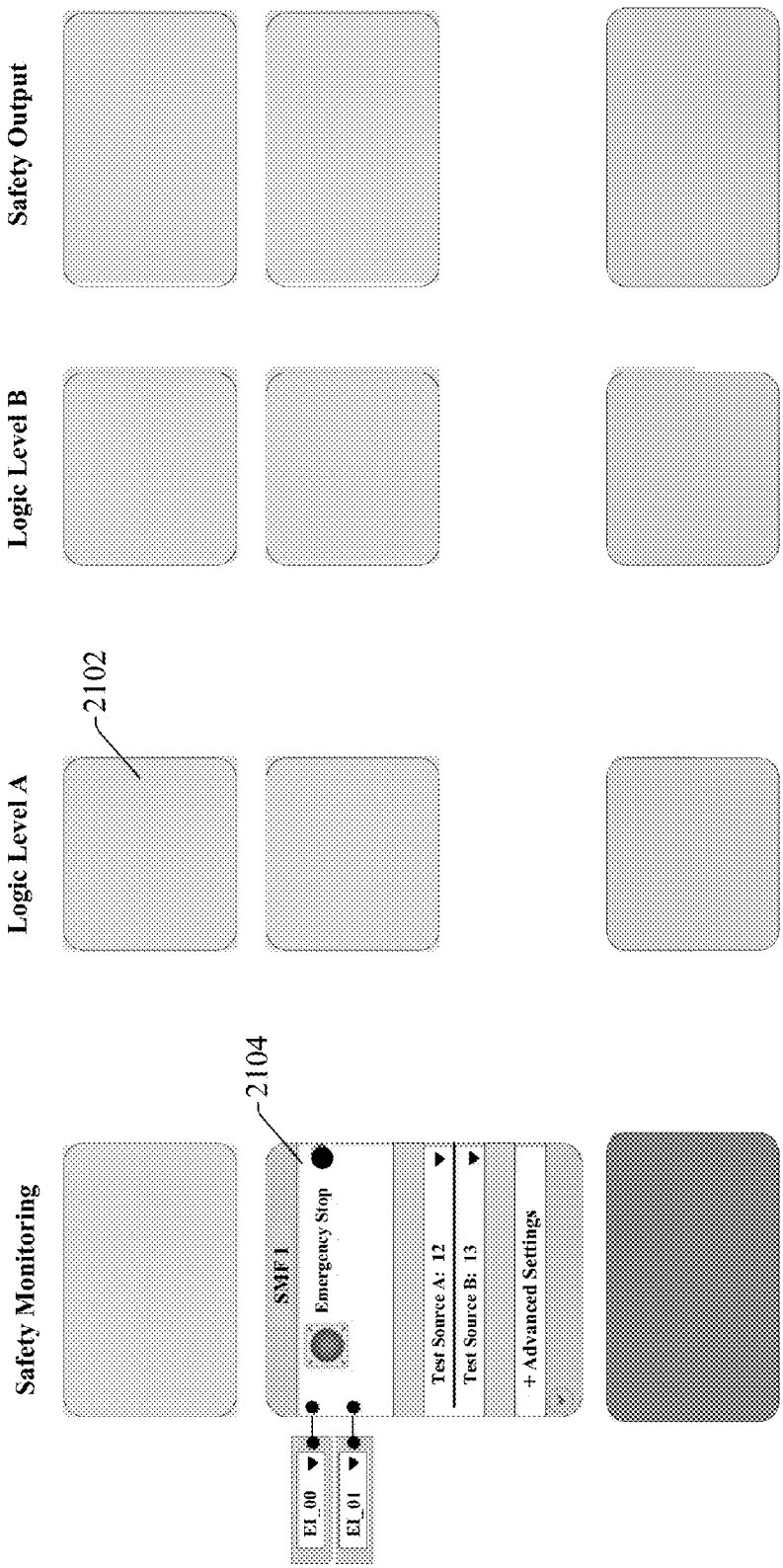
Safety Output
Logic Level B
Logic Level A
2102
Safety Monitoring
2104
SMF 1
Emergency Stop
Test Source A: 12
Test Source B: 13
+ Advanced Settings
EI_00
EI_01

FIG. 21

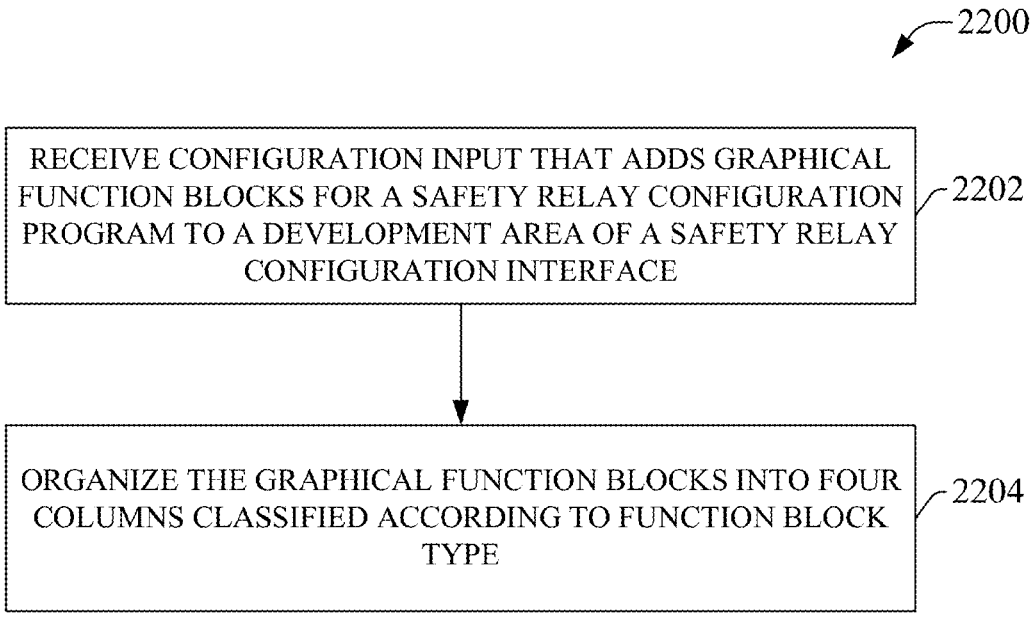
2200
RECEIVE CONFIGURATION INPUT THAT ADDS GRAPHICAL FUNCTION BLOCKS FOR A SAFETY RELAY CONFIGURATION PROGRAM TO A DEVELOPMENT AREA OF A SAFETY RELAY CONFIGURATION INTERFACE
2202
ORGANIZE THE GRAPHICAL FUNCTION BLOCKS INTO FOUR COLUMNS CLASSIFIED ACCORDING TO FUNCTION BLOCK TYPE
2204

FIG. 22

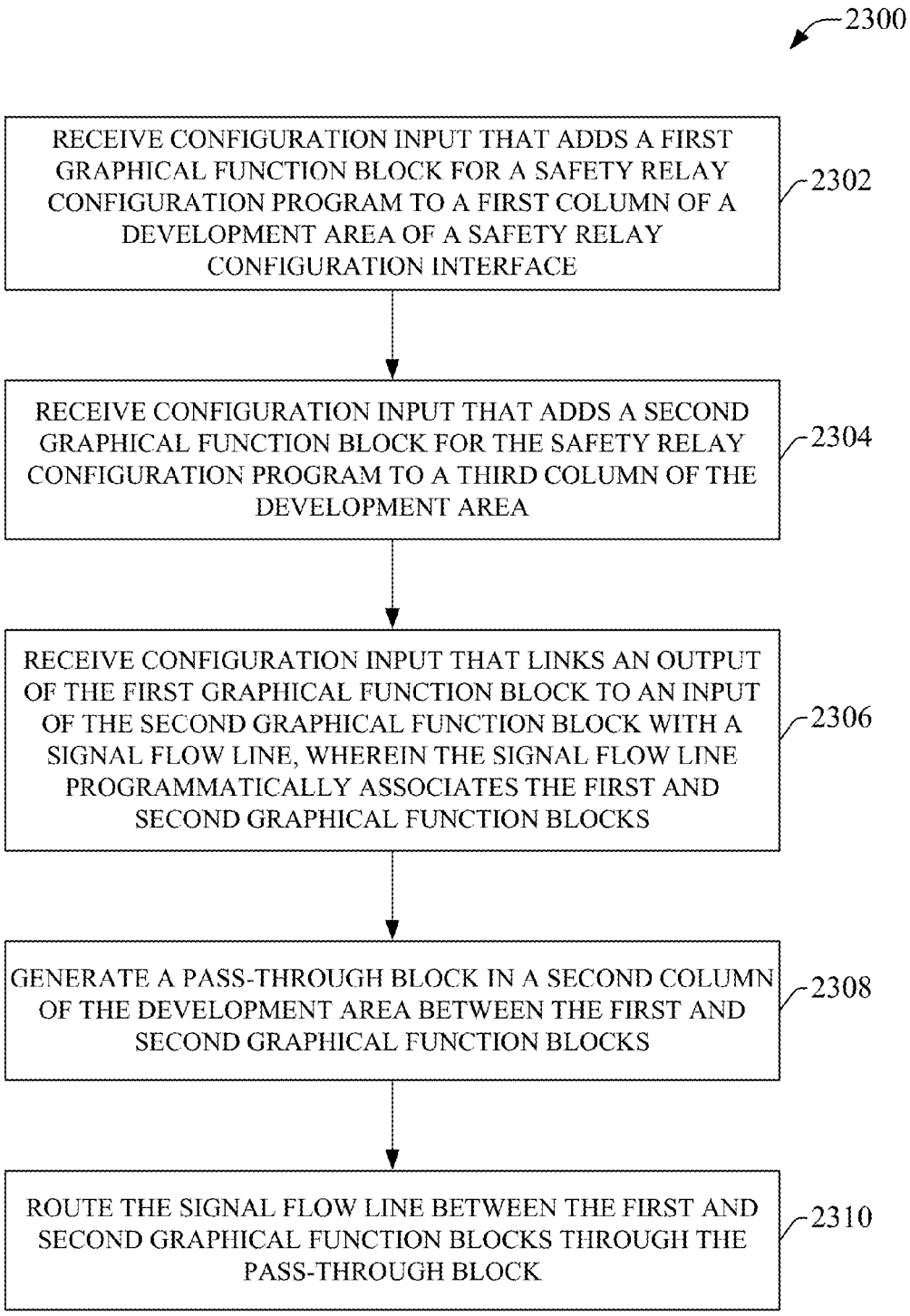
2300
RECEIVE CONFIGURATION INPUT THAT ADDS A FIRST GRAPHICAL FUNCTION BLOCK FOR A SAFETY RELAY CONFIGURATION PROGRAM TO A FIRST COLUMN OF A DEVELOPMENT AREA OF A SAFETY RELAY CONFIGURATION INTERFACE
2302
RECEIVE CONFIGURATION INPUT THAT ADDS A SECOND GRAPHICAL FUNCTION BLOCK FOR THE SAFETY RELAY CONFIGURATION PROGRAM TO A THIRD COLUMN OF THE DEVELOPMENT AREA
2304
RECEIVE CONFIGURATION INPUT THAT LINKS AN OUTPUT OF THE FIRST GRAPHICAL FUNCTION BLOCK TO AN INPUT OF THE SECOND GRAPHICAL FUNCTION BLOCK WITH A SIGNAL FLOW LINE, WHEREIN THE SIGNAL FLOW LINE PROGRAMMATICALLY ASSOCIATES THE FIRST AND SECOND GRAPHICAL FUNCTION BLOCKS
2306
GENERATE A PASS-THROUGH BLOCK IN A SECOND COLUMN OF THE DEVELOPMENT AREA BETWEEN THE FIRST AND SECOND GRAPHICAL FUNCTION BLOCKS
2308
ROUTE THE SIGNAL FLOW LINE BETWEEN THE FIRST AND SECOND GRAPHICAL FUNCTION BLOCKS THROUGH THE PASS-THROUGH BLOCK
2310

FIG. 23

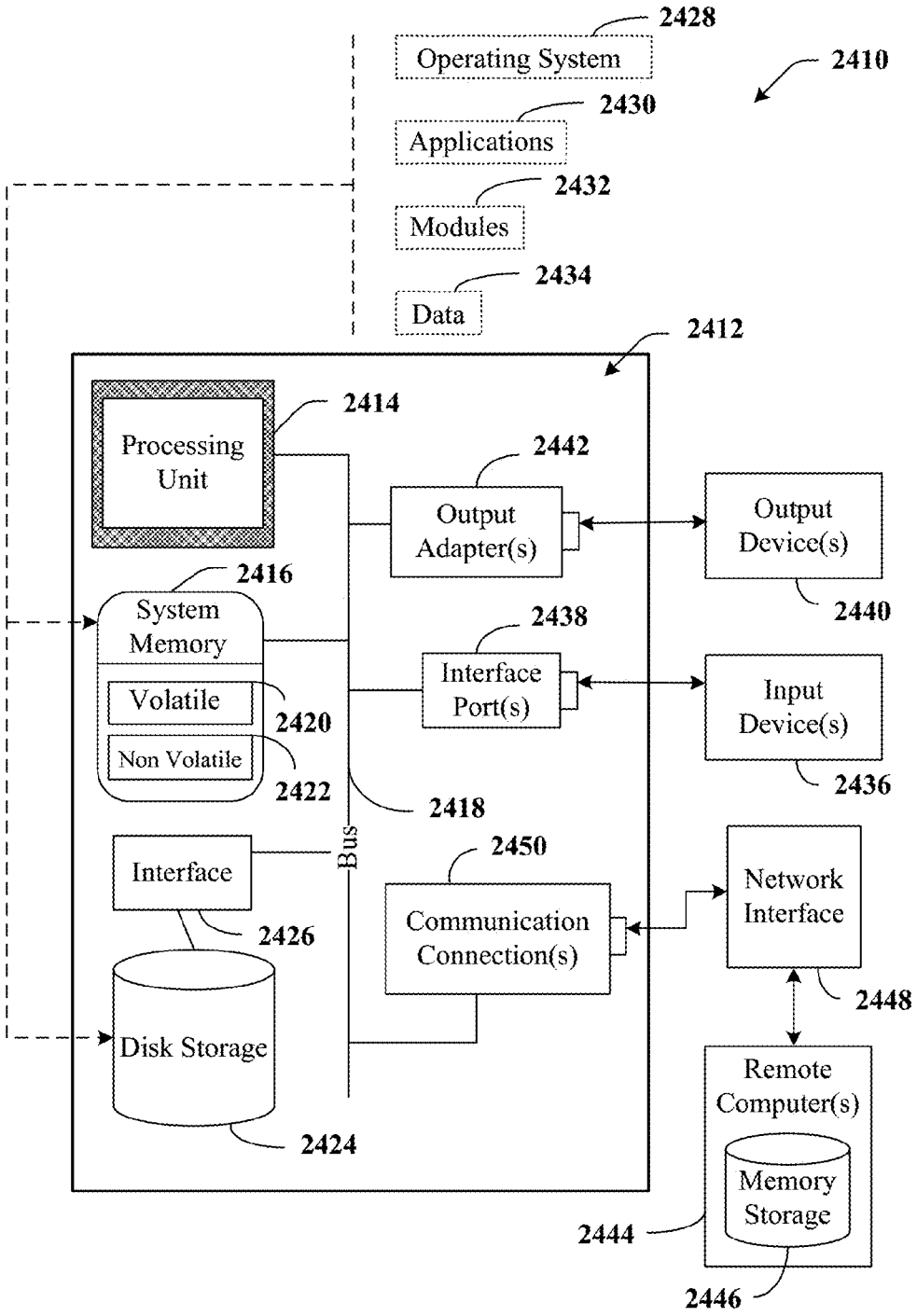
2428
Operating System
2410
2430
Applications
2432
Modules
2434
Data
2412
2414
Processing Unit
2442
Output Adapter(s)
Output Device(s)
2440
2416
System Memory
2438
Interface Port(s)
Input Device(s)
2436
Volatile
2420
Non Volatile
2422
2418
Bus
Interface
2426
2450
Communication Connection(s)
Network Interface
2448
Disk Storage
2424
Remote Computer(s)
Memory Storage
2444
2446

FIG. 24

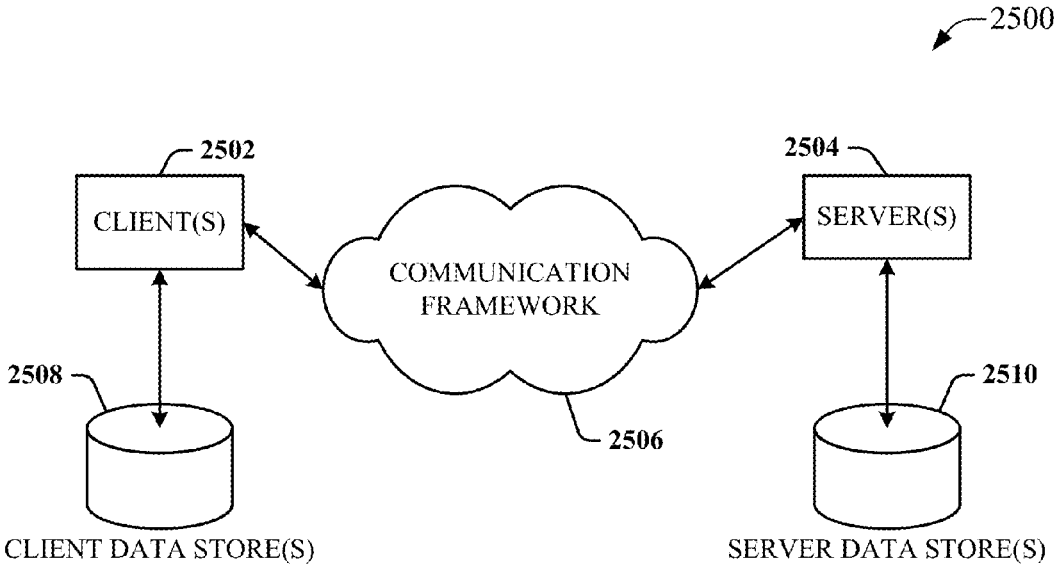
2500
2502
CLIENT(S)
2504
SERVER(S)
COMMUNICATION FRAMEWORK
2506
2508
2510
CLIENT DATA STORE(S)
SERVER DATA STORE(S)

FIG. 25

SAFETY RELAY CONFIGURATION EDITOR

BACKGROUND

The subject matter disclosed herein relates generally to configuration systems and graphical interfaces for configuration and monitoring of an industrial safety relay

BRIEF DESCRIPTION

The following presents a simplified summary in order to provide a basic understanding of some aspects described herein. This summary is not an extensive overview nor is intended to identify key/critical elements or to delineate the scope of the various aspects described herein. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

In one or more embodiments, a system for programming an industrial safety relay is provided, comprising a configuration component configured to create a configuration program for a safety relay based on configuration input that manipulates graphical function blocks and signal flow lines between the graphical function blocks; and a graphical interface component configured to receive the configuration input and to display the graphical function blocks on an editing area of a configuration interface, wherein the graphical interface component is configured to organize the graphical function blocks into four columns of the editing area, and wherein the four columns are classified according to function block type.

Also, according to one or more embodiments, a non-transitory computer-readable medium is provided having stored thereon instructions that, in response to execution, cause a system to perform operations, the operations comprising displaying graphical function blocks on an editing area of a configuration interface, wherein the displaying comprises arranging the graphical function blocks into four columns according to function block type; receiving configuration input via manipulation of one or more of the graphical function blocks and signal flow lines between the graphical function blocks; and generating a configuration program for a safety relay based on the configuration input.

Also, one or more embodiments provide a method for constructing a program for an industrial safety relay, comprising adding, by a system comprising at least one processor, graphical function blocks to an editing area of a configuration interface in response to first configuration input, wherein the adding comprises aligning the graphical function blocks into four columns classified according to function block type; adding, by the system, signal flow lines between at least a subset of the graphical function blocks in response to receipt of second configuration input, wherein the signal flow lines programmatically associate the subset of the graphical function blocks; and creating, by the system, a configuration program for a safety relay based on the graphical function blocks and the signal flow lines.

To the accomplishment of the foregoing and related ends, certain illustrative aspects are described herein in connection with the following description and the annexed drawings. These aspects are indicative of various ways which can be practiced, all of which are intended to be covered herein. Other advantages and novel features may become apparent from the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a general overview of the relationship between a safety relay configuration system and an industrial safety relay.

FIG. **2** is a block diagram of an example safety relay configuration system that facilitates configuration, programming, and monitoring of an industrial safety relay.

FIG. **3** is an example screen layout for a device configuration screen of a safety relay configuration system.

FIG. **4** is an example screen layout illustrating selection of a device from a list of available devices for inclusion in a project organizer area of the safety relay configuration system.

FIG. **5***a* is an example screen layout for the device toolbox area of the safety relay configuration system.

FIG. **5***b* is an example screen layout for the device toolbox area of the safety relay configuration system illustrating expansion of a device folder.

FIG. **6** is an example screen layout illustrating creation of a new project for a selected device on the project organizer area.

FIG. **7** is an example screen layout depicting sections of a device details area when a project for a selected safety device is open.

FIG. **8** is an example screen layout illustrating configuration of a plug-in module for a safety relay configuration project.

FIG. **9** is an example screen layout of a project window of the safety relay configuration system including a graphical representation of a plug-in module.

FIG. **10** is an example screen layout of a safety logic editor screen of the safety relay configuration system.

FIG. **11** is an example screen layout illustrating creation of an example safety relay logic program.

FIG. **12** is an example screen layout illustrating an example safety relay logic program.

FIG. **13** is a layout view of a safety logic program in the process of development.

FIG. **14** is a layout view of a safety logic program illustrating automatic insertion of a pass-through block.

FIG. **15** is a layout view of a safety logic program in which an output of a pass-through block has been re-routed to a different safety output function block.

FIG. **16** is a layout view of a safety logic program in which an input of a pass-through block has been re-routed to a different safety monitoring function block.

FIG. **17** is a layout view of a safety logic program in which a pass-through function block has been automatically moved to a different row in response to a signal flow line modification.

FIG. **18** is a diagram illustrating connection of function block inputs and outputs using signal flow lines.

FIG. **19** is a diagram illustrating an editing environment that maintains a fixed horizontal distance between function blocks.

FIG. **20** is a function block diagram illustrating function block referencing.

FIG. **21** is an example development environment in which available memory is represented by function block targets.

FIG. **22** is a flowchart of an example methodology for organizing graphical function blocks of a safety relay program on a development area of a safety relay configuration system interface.

FIG. **23** is a flowchart of an example methodology for organizing signal flow lines between graphical function

blocks of a safety relay configuration program on a development area of a safety relay configuration system interface.

FIG. **24** is an example computing environment.

FIG. **25** is an example networking environment.

DETAILED DESCRIPTION

Various aspects of this disclosure are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It should be understood, however, that certain aspects of this disclosure may be practiced without these specific details, or with other methods, components, materials, etc. In other instances, well-known structures and devices are shown in block diagram form to facilitate describing one or more aspects.

As used in this application, the terms "component," "system," "platform," "layer," "controller," "terminal," "station," "node," "interface" are intended to refer to a computer-related entity or an entity related to, or that is part of, an operational apparatus with one or more specific functionalities, wherein such entities can be either hardware, a combination of hardware and software, software, or software in execution. For example, a component can be, but is not limited to being, a process running on a processor, a hard disk drive, multiple storage drives (of optical or magnetic storage medium) including affixed (e.g., screwed or bolted) or removably affixed solid-state storage drives; an object; an executable; a thread of execution; a computer-executable program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components can reside within a process and/or thread of execution, and a component can be localized on one computer and/or distributed between two or more computers. Also, components as described herein can execute from various computer readable storage media having various data structures stored thereon. The components may communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems via the signal). As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry which is operated by a software or a firmware application executed by a processor, wherein the processor can be internal or external to the apparatus and executes at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts, the electronic components can include a processor therein to execute software or firmware that provides at least in part the functionality of the electronic components. As further yet another example, interface(s) can include input/output (I/O) components as well as associated processor, application, or Application Programming Interface (API) components. While the foregoing examples are directed to aspects of a component, the exemplified aspects or features also apply to a system, platform, interface, layer, controller, terminal, and the like.

As used herein, the terms "to infer" and "inference" refer generally to the process of reasoning about or inferring states of the system, environment, and/or user from a set of observations as captured via events and/or data. Inference can be employed to identify a specific context or action, or can generate a probability distribution over states, for example. The inference can be probabilistic—that is, the computation of a probability distribution over states of interest based on a consideration of data and events. Inference can also refer to techniques employed for composing higher-level events from a set of events and/or data. Such inference results in the construction of new events or actions from a set of observed events and/or stored event data, whether or not the events are correlated in close temporal proximity, and whether the events and data come from one or several event and data sources.

In addition, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from the context, the phrase "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, the phrase "X employs A or B" is satisfied by any of the following instances: X employs A; X employs B; or X employs both A and B. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more" unless specified otherwise or clear from the context to be directed to a singular form.

Furthermore, the term "set" as employed herein excludes the empty set; e.g., the set with no elements therein. Thus, a "set" in the subject disclosure includes one or more elements or entities. As an illustration, a set of controllers includes one or more controllers; a set of data resources includes one or more data resources; etc. Likewise, the term "group" as utilized herein refers to a collection of one or more entities; e.g., a group of nodes refers to one or more nodes.

Various aspects or features will be presented in terms of systems that may include a number of devices, components, modules, and the like. It is to be understood and appreciated that the various systems may include additional devices, components, modules, etc. and/or may not include all of the devices, components, modules etc. discussed in connection with the figures. A combination of these approaches also can be used.

Industrial system designers typically program the safety functions to be carried out by an industrial safety relay using a software development platform that is proprietary to the safety relay. The workflow for developing a safety relay program using these development platforms is often complicated, particularly as the number of safety relay terminals to be used for safety monitoring and output signaling grows larger. Moreover, the development interface layout of many safety relay programming platforms often yields a program visualization that is difficult to interpret and troubleshoot.

The safety relay configuration systems, software, and graphical interfaces described herein comprise a number of features that facilitate intuitive and simplified configuration of an industrial safety relay. These features include, for example, a programming environment that enforces an organized layout of function blocks that simplifies program building and yields an uncluttered program view that is easy to read and troubleshoot.

FIG. **1** is a general overview of the relationship between the safety relay configuration system **102** and an industrial safety relay **108**. Safety relay **108** can comprise any suitable industrial safety relay or similar device configured to monitor an industrial safety system and control the ability of an industrial system or machine to start or run based on the monitored statuses of one or more safety devices (e.g., emergency stop buttons, safety mats, light curtains, emergency pull cords, etc.). The safety relay can comprise a

number of input terminals for monitoring the status of one or more safety devices, and output terminals that control certain machine states based on the statuses of the safety devices. In an example configuration, power to selected control components of the industrial system or machine can be connected to the machine via the safety relay outputs, and the safety relay **108** can be programmed to close the outputs only when the relevant safety devices are in their respective safe states. To ensure control reliability, the safety relay **108** typically includes a number of integrated self-monitoring features to reduce the possibility of a relay failure and to ensure that the industrial system remains safe in the event of such a relay failure. These integrated safety features can include, for example, redundant circuits, internal monitoring to detect short-circuits between contacts, and other such features.

Safety relay **108** is programmable, allowing the user to configure the function of each input and output terminal and to develop logic that controls the behavior of each relay output based on the states of the safety device inputs. Accordingly, safety relay configuration system **102** is designed to communicate with safety relay **108** and to execute a configuration application that allows the user to configure and program safety relay **108**. Safety relay configuration system **102** can communicate with safety relay **108** using any suitable communication means, including communication via a local connection between the configuration system and the safety relay **108** (e.g., universal serial bus, RS232, etc.), or over a networked connection (e.g., Ethernet, Modbus, Common Industrial Protocol, Controlnet, Devicenet, etc.). In one or more embodiments, safety relay configuration system **102** can also communicate with safety relay **108** remotely via the Internet.

Once communication between the safety relay configuration system **102** and safety relay **108** is established, the configuration system can download configuration data **104** to the safety relay based on configuration and programming input provided to the configuration system by the user. For example, the user can develop safety relay logic within the development environment of the configuration application executed by the configuration system **102**, and download the developed program to safety relay **108**. Additionally, safety relay configuration system **102** can read and display status data **106** from the safety relay **108**. The configuration system can render status data **106** on a graphical environment having a similar structure to the development environment used to create the safety relay logic, allowing the user to monitor the statuses of the input devices and relay outputs within the logic environment.

FIG. **2** is a block diagram of an example safety relay configuration system that can facilitate configuration, programming, and monitoring of an industrial safety relay. Aspects of the systems, apparatuses, or processes explained in this disclosure can constitute machine-executable components embodied within machine(s), e.g., embodied in one or more computer-readable mediums (or media) associated with one or more machines. Such components, when executed by one or more machines, e.g., computer(s), computing device(s), automation device(s), virtual machine(s), etc., can cause the machine(s) to perform the operations described.

One or more embodiments of safety relay configuration system **102** can include a graphical interface component **204**, a communication component **206**, a safety relay configuration component **208**, one or more processors **210**, and memory **212**. In various embodiments, one or more of the components **204-208**, the one or more processors **210**, and memory **212** can be electrically and/or communicatively coupled to one another to perform one or more of the functions of the safety relay configuration system **102**. In some embodiments, components **204-208** can comprise software instructions stored on memory **212** and executed by processor(s) **210**. The safety relay configuration system **102** may also interact with other hardware and/or software components not depicted in FIG. **2**. For example, processor(s) **210** may interact with one or more external user interface devices, such as a keyboard, a mouse, a display monitor, a touchscreen, or other such interface devices.

Graphical interface component **204** can be configured to receive user input and to render output to the user in any suitable format (e.g., visual, audio, tactile, etc.). User input can be, for example, safety relay terminal configuration input, safety device selection input, function block selection and configuration input, user responses to prompts provided by the graphical interface component **204**, or other such data. Communication component **206** can be configured to communicatively interface with the safety relay and exchange data between the relay and the configuration system. Communication between the configuration system and the safety relay can be via a local communication link such as USB, RS232, or the like, or via a remote connection over a network or the Internet.

Safety relay configuration component **208** can be configured to execute a safety relay configuration application having features and graphical interface characteristics to be described in more detail herein. The one or more processors **210** can perform one or more of the functions described herein with reference to the systems and/or methods disclosed. Memory **212** can be a computer-readable storage medium storing computer-executable instructions and/or information for performing the functions described herein with reference to the systems and/or methods disclosed.

FIG. **3** is an example, non-limiting screen layout **302** for a device configuration screen of the safety relay configuration system. The example layout **302** includes a device toolbox area **308**, a user menu and toolbar area **306**, a project organizer area **304**, and a device details area **310**.

The device toolbox area **308** can include a catalog drop-down window **312**. When expanded, catalog drop-down window **312** can display a list of available devices **316** for selection by the user for inclusion in the current project. The list of available devices **316** can be organized according to device type, with each device type displayed as an expandable node. For example, selecting the "Safety" node **314** can reveal a list of available safety relays. In some embodiments, hovering a cursor over one of the devices in the list invokes a pop-up window containing additional information about the selected device. A device from the list of available devices **316** can be added to the project organizer area **304** by double-clicking on the selected device in the list, or by dragging the selected device to the project organizer area **304**. In either case, selection of a device from the list of available devices **316** causes the selected device to appear in the project organizer area **304**, as shown in FIG. **4**. Adding a device to the project organizer area **304** makes that device available for creation of a new project.

FIGS. **5***a* and **5***b* illustrate the device toolbox area **308** in more detail. FIG. **5***a* depicts the list of available devices with each device category node collapsed. When one of the category nodes is selected, the available devices under the selected category are expanded and displayed, as shown in FIG. **5***b*.

Turning now to FIG. **6**, selection of a safety relay or other device within the project organizer area **304** (e.g., a safety

relay or other device previously selected from the device toolbox area **308** for inclusion in the project organizer area **304**) creates a new project for the selected device. In the illustrated example, a GSR830 safety relay is to be configured and programmed. Accordingly, a device icon corresponding to this type of safety relay is selected from the project organizer area **304**, which launches a "controller details" view within the device details area **310**. In the present example, a project tab **602** is displayed at the top of the device details area **310**, which corresponds to the new project.

FIG. **7** illustrates the areas of the device details area **310** when a project for a selected safety device is open. Device details area **310** includes a device header **702** containing relevant information about the selected device, including the safety device's identity and connection information. Device toolbar area **704** lists a number of selectable operations and commands. These can include both common operations that pertain to all device types (e.g., upload, download, etc.) and device-specific operations that depend on the type of selected safety device (e.g., safety configure, validate, debug, secure, variables). Device toolbar area **704** can also include flash information, such as a manual for the safety device or on-line help information.

Device graphic view area **706** displays the name of the project and a graphical representation **714** of the selected safety device. If the safety relay configuration system is currently connected to the safety device, the device graphic view area **706** can also display operational status information for the device, such as the current mode of the device (program mode, running, etc.), whether the device is currently faulted, identification of the fault, etc. The user can also switch the mode of the safety relay between program mode and running mode from this area. This area also indicates whether the current project has been verified (e.g., the program has been checked for errors or inconsistencies prior to download), and displays a verification identifier for verified projects.

The user can also add configurations for any plug-in modules installed on the safety relay from the device graphic view area **706**. In some embodiments, this can be performed by right-clicking or otherwise selecting an empty slot on the graphical representation of the safety relay, as illustrated in FIG. **8**. This invokes a pop-up configuration window **802** that allows the user to select a category of the plug-in module (e.g., communication module, digital I/O module, or specialty module), and to select a particular model of the plug-in module within the selected category. Once selected, a graphical representation of the plug-in module appears on the graphical representation of the safety relay, as illustrated in FIG. **9**.

Returning now to FIG. **7**, device tree area **612** provides navigation to various configurable aspects of the selected safety device, including but not limited to the communication ports of the safety relay, the devices visual indicators (e.g., LEDs or other indicators), embedded inputs and outputs, and any plug-in modules that are attached to the safety relay (e.g., expansion I/O modules).

Device configuration property pane **610** allows the user to view and edit the current configuration of the selected safety relay. When the user selects an item from the device tree area **612**, the device configuration property pane displays detailed configuration information for the selected item.

Selection of a logic editor button on the device toolbar area **604** launches a safety logic editor, as illustrated in FIG. **10**. In some embodiments, the safety logic editor will be opened in a new tab **1006**. In the illustrated example, a toolbox area **1004** containing selectable safety functions is located on the left-hand side of the screen, and a safety logic editor toolbar **1002** is located across the top of the window. The safety logic editor pane **1010** allows the user to create, view, and edit safety logic and configuration data for the safety relay associated with the current project. In FIG. **10**, the safety logic editor pane **1010** is depicted in its blank state, which is presented to the user when a new project is created. As will be described in more detail herein, the safety relay configuration system allows the used to build safety logic programs for the safety relay by adding function blocks to available memory spaces **1008** on the safety logic editor pane **1010**.

As illustrated in FIG. **10**, the safety logic editor pane **1010** comprises a grid of four columns—Safety Monitoring, Logic Level A, Logic Level B, and Safety Outputs—with each column comprising a number of available memory spaces **1008**. Memory spaces **1008** represent pre-defined positions on which function blocks can be added, and are arranged in a grid-like manner to enforce an organized arrangement of function blocks. Function blocks can be added to the respective memory spaces **1008** by selecting the function blocks from the toolbox area **1004**. Function blocks can be organized within the toolbox area **1004** according to device type, logic function, safety monitoring function, or other suitable categories. The categories can be displayed as nodes within toolbox area **1004**, such that selection of a node expands the selections available within the selected category.

The Safety Monitoring column of the safety logic editor pane **1010** will typically contain function blocks corresponding to safety input devices to be monitored by the safety relay (e.g., gate switches, light curtains, safety mats, emergency stop buttons, pull cords, etc.). The Logic Level A and B columns are used to contain logical operations that act on the safety inputs in a manner determined by the user in order to control how the safety inputs control the states of the safety outputs. The Safety Output column will typically contain function blocks corresponding to safety outputs of the safety relay. The safety relay configuration system allows each function block to be configured directly on the function block graphic, and allows the user to link function block inputs and outputs with connection lines (also referred to as signal flow lines) in order to build a complete safety relay program that can be downloaded to and executed on the safety relay. The column-wise classification of function block types yields an organized program visualization that is easy to interpret and troubleshoot. Moreover, as will be described in more detail herein, the use of pass-through function blocks can allow the user to modify interconnections between function blocks while minimizing necessary changes to related interconnections to accommodate the modified interconnections, thereby reducing development time and maintaining a readable program view.

An example workflow is now described with reference to FIG. **11** in order to provide a general overview of the process for building safety relay programs according to one or more embodiments. In this example, a gate switch is to be monitored by the safety relay, and the user is to develop logic for controlling a safety relay output based on the monitored status of the gate switch. Accordingly, a Gate Switch function block **1102** selected from the Safety Monitoring Functions tree of the toolbox area and dragged to an available memory space of the safety monitoring column of the safety logic editor pane **1010**. As will be described in more detail herein, the safety relay configuration system automatically assigns to available (unused) input terminal

addresses **1110** to the Gate Switch function block **1102** when the function block is added to the program. If desired, these input terminal addresses can be changed if the user wishes to assign different input terminals to the Gate Switch function block **1102**. Other configuration settings for the Gate Switch function block **1102** can be set through interaction with the Gate Switch function block **1102**.

Next, the user selects a Safety Output function block **1108** from the Safety Output Functions tree of the toolbox area and drags this function block to an available memory space of the Safety Outputs column of the safety logic editor pane **1010**. Similar to the Gate Switch function block **1102**, the safety relay configuration system will automatically assign two available (unused) safety relay output terminal addresses **1112** to the Safety Output function block **1108**. These output addresses can be changed by the user if desired through interaction with the function block on the editor pane. Other configuration settings for the Safety Output function block **1108** can be set through interaction with the function block. For example, the Reset Type for the Safety Output function block **1108** can be changed from Manual to Automatic by selecting the appropriate setting from a drop-down box on the function block.

In this example, no logical operators are to be performed on the gate switch status, but instead the safety output is to be directly controlled by the status of the gate switch. Accordingly, the user can directly connect the output of the Gate Switch function block **1102** to the input of the Safety Output function block **1108**. This can be performed, for example, by clicking on the input of the Safety Output function block **1108** (which is colored blue to indicate that no connection has yet been made), then clicking on the output of the Gate Switch function block **1102** (similarly colored blue when no connection is yet made). In response to these selections, the safety relay configuration system automatically creates two pass-through blocks between the Gate Switch and Safety Output function blocks in the Logic Level A and B columns, respectively, and draws a connection line between the two function blocks through the two pass-through blocks. The pass-through blocks perform no logical functions, but merely pass status information, unchanged, from their inputs to their outputs.

Once the logic program is completed, the user can compile and download the program to the safety relay by selecting appropriate controls on the device toolbar area **604**.

FIG. **12** illustrates another example logic program according to one or more embodiments. In this example, the safety monitoring column contains three safety monitoring blocks corresponding to three safety input devices—a Gate Switch function block **1202**, an Emergency Stop function block **1210**, and a Reset function block **1214**. Each of the safety monitoring function blocks have been assigned to selected input terminals of the safety relay using address windows **1216**, **1218**, and **1220**. The outputs of Gate Switch function block **1202** and Emergency Stop function block **1210** have been connected to respective two inputs of an AND function block **1204** in the Logic Level A column. The AND function block generates a high signal on its output when the outputs of the Gate Switch function block **1202** and the Emergency Stop function block **1210** are both ON. The output of the AND function block **1204** is connected to the input of an Immediate OFF function block **1208** in the Safety Output column, via a pass-through function block **1206**. The Safety Output column controls two output terminals of the safety relay—designated in address window **1222**—based on the output of the AND function block and the configuration settings specified by the user on the function block **1208**.

The output of the Emergency Stop function block **1210** is also connected to an OFF Delay function block **1212** in the Safety Output column (via two pass-through function blocks). By this configuration, the OFF Delay function block **1212** controls the output terminal designated in the address window **1224** based on the output of the Emergency Stop function block **1210**.

Reset function block **1214** has been designated an available input terminal address in address window **1220**, and has been linked to the Immediate OFF function block **1208** by reference using the Reset Input window **1226** on the Immediate OFF function block **1208**. In this way, the Reset function block **1214**, controlled by input address specified in **1220**, is configured to reset the Immediate OFF function block **1208**.

In addition to development, the safety logic layout depicted in FIG. **12** can also be used to monitor the safety relay logic during runtime after the logic has been downloaded to the relay. During runtime monitoring, live status information corresponding to the respective safety monitoring devices and outputs can be overlaid over their respective function blocks. Additionally, the function blocks can include color animation that changes the color of the function blocks based on their respective current statuses.

The use of pass-through function blocks to organize the program view is now described with reference to FIGS. **13-17**. FIG. **13** is a layout view of a safety logic program in the process of development. In this example, a first safety output function block **1304** (Immediate OFF) has been placed in the Safety Output column of the development environment, and an AND function block **1302** has been placed in the Logic Level B column in the same row as the safety output function block **1304**. The output of the AND function block **1302** has been linked to the input of safety output function block **1304**. A safety monitoring function block **1306** (corresponding to a gate switch) has been placed in the Safety Monitoring column. The user wishes to connect the output **1308** of the safety monitoring function block **1306** to an input **1310** of the AND function block **1302**, so that the Immediate OFF function of safety output function block **1304** will be jointly controlled by the state of safety monitoring function block **1306** (the gate switch state) and that of another function block to be determined

Since the output **1308** of safety monitoring function block **1306** will be connected directly to the **1310** input of the AND function block **1302**, there is no need for an operator function block to be placed in the Logic Level A column between safety monitoring function block **1306** and AND function block **1302**. However, as illustrated in FIG. **14**, when the user connects the output **1308** of safety monitoring function block **1306** to the input **1310** of AND function block **1302** (e.g., by clicking output **1308** and input **1310** in succession or by another interaction with the function blocks), the configuration interface inserts a pass-through block **1402** in the Logic Level A column between safety monitoring function block **1306** and AND function block **1302** in the same row as those function blocks. The system then links output **1308** to input **1310** via pass-through block **1402**.

Although performing no operation on the output of safety monitoring function block **1306** before passing the output to AND function block **1302**, the pass-through block **1402** assists in organizing and managing the connecting lines between function blocks to create an orderly arrangement of function blocks and interconnections. In addition to rendering a readable program visualization that can be followed and understood easily, the use of pass-through blocks to

minimize the number of interconnection lines that must be reconfigured when the user modifies a connection. For example, the user may decide to disconnect the output of safety monitoring function block **1306** from AND function block **1302** and reconnect the safety monitoring function block output to the input of a second safety output function block **1404** (an OFF Delay function block). The user can perform this reconnection either by deleting connection line **1406** and creating a new connection line between the output of the pass-through block **1402** and the input of safety output function block **1404**, or by dragging the end of connection line **1406** connected to the input **1310** of AND function block **1302** to the input of safety output function block **1404**. As shown in FIG. **15**, when this reconnection is implemented by the user, the system creates another pass-through block **1502** in the Logic Level B column, through which pass-through block **1402** connects to safety output function block **1404**. All connecting lines to the left of pass-through block **1402** (e.g., connection line **1506**) remain unchanged.

If the user subsequently wishes to change the input of safety output function block **1404** from safety monitoring function block **1306** to safety monitoring function block **1508**, connection line **1506** can be deleted and—as illustrated in FIG. **16**—a new connection line **1602** can be created between safety monitoring function block **1508** and pass-through block **1402**. This changes the controlling safety device for the OFF delay from the gate switch of function block **1306** to the emergency stop button of function block **1508**. Since connecting pass-through block **1402** to safety monitoring function block **1508** causes the connecting lines between function blocks **1508** and **1404** to unnecessarily jump from the second row to the first row, the configuration system can automatically create a new pass-through block **1702** in the second row of the Logic Level A column in response to the user's command reconnection, as shown in FIG. **17**. The system then connects safety monitoring function block **1508** to pass-through block **1502** via pass-through block **1702**, yielding a more linear connection between function blocks **1508** and **1404**.

Using pass-through blocks to organize connecting lines, the safety relay configuration interface prevents overlap between connecting lines, reducing possible confusion and allowing the program to be read and understood more easily. The configuration system's editing environment also supports signal flow line drawing rules that control routing of signal flow lines to prevent overlap of signal flow lines between the function blocks. As illustrated in FIG. **18**, a signal flow line **1802** is typically used to logically tie the output **1804** of one function block to an input **1806** of another function block. In one or more embodiments, the function block columns of the safety relay configuration system's editing environment can enforce a fixed horizontal distance between function blocks, as illustrated in FIG. **19**. When the X,Y coordinate locations of function blocks are restricted in this fashion, a line drawing rule set can be designed that results in aesthetically consistent, easily followed signal flow lines throughout the project. For example, the system can enforce a line drawing rule specifying that a first instance of a line break (that is, a 90 degree bend in order to connect to an input on a different horizontal level) within a column must break 90 degrees from horizontal 24/25ths of the horizontal distance between two columns, while a second instance of a line break in the column must break 90 degrees from the horizontal 23/25ths of the horizontal distance between the two columns. Such rules will ensure that no wiring connection from two separate output pins will share the same vertical line location on the graphical interface.

In a related aspect, the various organization elements and their spacing on the function block editing environment can have respective fixed widths, allowing a full, completed safety relay configuration to be printable without compression.

One or more embodiments of the safety relay configuration system can also reduce the number of signal flow lines on a project by supporting function block references between function blocks. This aspect allows a first function block whose output is acting on another function block located multiple columns adjacent to the first function block to make an association by a combo box selection rather than by creating a signal flow wire that spans multiple columns. FIG. **20** illustrates an example of this type of function block referencing. In this example, safety output function block **2004** is linked to the Reset function block **2002** by selecting the name of function block **2002** ("SMF 1," found in the name bar **2006** of Reset function block **2002**) in the Reset Input window **2008** of safety output function block **2004**. This name-based referencing mitigates the need to create a signal flow line between the Reset function block **2002** and the safety output function block **2004**.

One or more embodiments of the safety monitoring configuration system can also provide a real-time graphical representation of an amount of memory consumed in the function block editor against a total available memory. As illustrated in FIG. **21**, this can be achieved using a memory map in which available memory is represented as individual blank function block targets **2102**. When a function block (e.g., function block **2104**) is assigned to a blank function target, either by dragging-and-dropping the function block **2104** to the target or through other assignment means, the blank target disappears and the selected function block is displayed in its place. The label in the name bar of the function block (SMF 2) corresponds to the memory location of the function block. The number of available blank function block targets **2102** is analogous to the amount of remaining memory space available for addition of more function blocks. When all blank function block targets **2102** have received a function block assignments, no more function blocks can be added to the project. The function block targets **2102** intuitively convey an amount of available memory remaining for addition of function blocks to a project.

FIGS. **22-23** illustrate various methodologies in accordance with one or more embodiments of the subject application. While, for purposes of simplicity of explanation, the one or more methodologies shown herein are shown and described as a series of acts, it is to be understood and appreciated that the subject innovation is not limited by the order of acts, as some acts may, in accordance therewith, occur in a different order and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with the innovation. Furthermore, interaction diagram(s) may represent methodologies, or methods, in accordance with the subject disclosure when disparate entities enact disparate portions of the methodologies. Further yet, two or more of the disclosed

example methods can be implemented in combination with each other, to accomplish one or more features or advantages described herein.

FIG. **22** illustrates an example methodology **2200** for organizing graphical function blocks of a safety relay program on a development area of a safety relay configuration system interface. Initially, at **2202**, configuration input is received that adds graphical function blocks to a development area of a safety relay configuration interface. These can include, for example, safety monitoring function blocks, safety output function blocks, and logical operator function blocks. At **2204**, the graphical function blocks are organized in the development area into four columns classified according to function block type. For example, the four columns can include a first column for safety monitoring function blocks, second and third columns for logical operator function blocks and pass-through function blocks, and a fourth column for safety output function blocks.

FIG. **23** illustrates an example methodology **2300** for organizing signal flow lines between graphical function blocks of a safety relay configuration program on a development area of a safety relay configuration system interface. Initially, at **2302**, configuration input is received that adds a first graphical function block for a safety relay configuration program to a first column of a development area of a safety relay configuration interface (e.g., a safety monitoring column). At **2304**, configuration input is received that adds a second graphical function block for the safety relay configuration program to a third column of the development area (e.g., a logic level column). At **2306**, configuration input is received that links an output of the first graphical function block to an input of the second graphical function block with a signal flow line, wherein the signal flow line programmatically associates the first and second graphical function blocks.

At **2308**, a pass-through block is generated in a second column of the development area between the first and second graphical function blocks. This pass-through block is added automatically by the configuration system when the configuration input instructing the signal flow line to be created between the first and second graphical function blocks is received at step **2306**. At **2310**, the signal flow line is routed between the first and second graphical function blocks through the pass-through block. The pass-through block performs no logical operation on the output of the first graphical function block prior to passing the output to the input of the second graphical function block, but instead is used only to organize signal flow lines between function blocks.

Embodiments, systems, and components described herein, as well as industrial control systems and industrial automation environments in which various aspects set forth in the subject specification can be carried out, can include computer or network components such as servers, clients, programmable logic controllers (PLCs), communications modules, mobile computers, wireless components, control components and so forth which are capable of interacting across a network. Computers and servers include one or more processors—electronic integrated circuits that perform logic operations employing electric signals—configured to execute instructions stored in media such as random access memory (RAM), read only memory (ROM), a hard drives, as well as removable memory devices, which can include memory sticks, memory cards, flash drives, external hard drives, and so on.

Similarly, the term PLC as used herein can include functionality that can be shared across multiple components, systems, and/or networks. As an example, one or more PLCs can communicate and cooperate with various network devices across the network. This can include substantially any type of control, communications module, computer, Input/Output (I/O) device, sensor, actuator, and human machine interface (HMI) that communicate via the network, which includes control, automation, and/or public networks. The PLC can also communicate to and control various other devices such as I/O modules including analog, digital, programmed/intelligent I/O modules, other programmable controllers, communications modules, sensors, actuators, output devices, and the like.

The network can include public networks such as the internet, intranets, and automation networks such as control and information protocol (CIP) networks including DeviceNet, ControlNet, and Ethernet/IP. Other networks include Ethernet, DH/DH+, Remote I/O, Fieldbus, Modbus, Profibus, CAN, wireless networks, serial protocols, and so forth. In addition, the network devices can include various possibilities (hardware and/or software components). These include components such as switches with virtual local area network (VLAN) capability, LANs, WANs, proxies, gateways, routers, firewalls, virtual private network (VPN) devices, servers, clients, computers, configuration tools, monitoring tools, and/or other devices.

In order to provide a context for the various aspects of the disclosed subject matter, FIGS. **24** and **25** as well as the following discussion are intended to provide a brief, general description of a suitable environment in which the various aspects of the disclosed subject matter may be implemented.

With reference to FIG. **25**, an example environment **2410** for implementing various aspects of the aforementioned subject matter includes a computer **2412**. The computer **2412** includes a processing unit **2414**, a system memory **2416**, and a system bus **2418**. The system bus **2418** couples system components including, but not limited to, the system memory **2416** to the processing unit **2414**. The processing unit **2414** can be any of various available processors. Dual microprocessors and other multiprocessor architectures also can be employed as the processing unit **2414**.

The system bus **2418** can be any of several types of bus structure(s) including the memory bus or memory controller, a peripheral bus or external bus, and/or a local bus using any variety of available bus architectures including, but not limited to, 8-bit bus, Industrial Standard Architecture (ISA), Micro-Channel Architecture (MSA), Extended ISA (EISA), Intelligent Drive Electronics (IDE), VESA Local Bus (VLB), Peripheral Component Interconnect (PCI), Universal Serial Bus (USB), Advanced Graphics Port (AGP), Personal Computer Memory Card International Association bus (PCMCIA), and Small Computer Systems Interface (SCSI).

The system memory **2416** includes volatile memory **2420** and nonvolatile memory **2422**. The basic input/output system (BIOS), containing the basic routines to transfer information between elements within the computer **2412**, such as during start-up, is stored in nonvolatile memory **2422**. By way of illustration, and not limitation, nonvolatile memory **2422** can include read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable PROM (EEPROM), or flash memory. Volatile memory **2420** includes random access memory (RAM), which acts as external cache memory. By way of illustration and not limitation, RAM is available in many forms such as synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate

SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), and direct Rambus RAM (DRRAM).

Computer **2412** also includes removable/non-removable, volatile/nonvolatile computer storage media. FIG. **22** illustrates, for example a disk storage **2424**. Disk storage **2424** includes, but is not limited to, devices like a magnetic disk drive, floppy disk drive, tape drive, Jaz drive, Zip drive, LS-100 drive, flash memory card, or memory stick. In addition, disk storage **2424** can include storage media separately or in combination with other storage media including, but not limited to, an optical disk drive such as a compact disk ROM device (CD-ROM), CD recordable drive (CD-R Drive), CD rewritable drive (CD-RW Drive) or a digital versatile disk ROM drive (DVD-ROM). To facilitate connection of the disk storage **2424** to the system bus **2418**, a removable or non-removable interface is typically used such as interface **2426**.

It is to be appreciated that FIG. **24** describes software that acts as an intermediary between users and the basic computer resources described in suitable operating environment **2410**. Such software includes an operating system **2428**. Operating system **2428**, which can be stored on disk storage **2424**, acts to control and allocate resources of the computer **2412**. System applications **2430** take advantage of the management of resources by operating system **2428** through program modules **2432** and program data **2434** stored either in system memory **2416** or on disk storage **2424**. It is to be appreciated that one or more embodiments of the subject disclosure can be implemented with various operating systems or combinations of operating systems.

A user enters commands or information into the computer **2412** through input device(s) **2436**. Input devices **2436** include, but are not limited to, a pointing device such as a mouse, trackball, stylus, touch pad, keyboard, microphone, joystick, game pad, satellite dish, scanner, TV tuner card, digital camera, digital video camera, web camera, and the like. These and other input devices connect to the processing unit **2414** through the system bus **2418** via interface port(s) **2438**. Interface port(s) **2438** include, for example, a serial port, a parallel port, a game port, and a universal serial bus (USB). Output device(s) **2440** use some of the same type of ports as input device(s) **2436**. Thus, for example, a USB port may be used to provide input to computer **2412**, and to output information from computer **2412** to an output device **2440**. Output adapters **2442** are provided to illustrate that there are some output devices **2440** like monitors, speakers, and printers, among other output devices **2440**, which require special adapters. The output adapters **2442** include, by way of illustration and not limitation, video and sound cards that provide a means of connection between the output device **2440** and the system bus **2418**. It should be noted that other devices and/or systems of devices provide both input and output capabilities such as remote computer(s) **2444**.

Computer **2412** can operate in a networked environment using logical connections to one or more remote computers, such as remote computer(s) **2444**. The remote computer(s) **2444** can be a personal computer, a server, a router, a network PC, a workstation, a microprocessor based appliance, a peer device or other common network node and the like, and typically includes many or all of the elements described relative to computer **2412**. For purposes of brevity, only a memory storage device **2446** is illustrated with remote computer(s) **2444**. Remote computer(s) **2444** is logically connected to computer **2412** through a network interface **2448** and then physically connected via communication connection **2450**. Network interface **2448** encompasses communication networks such as local-area networks (LAN) and wide-area networks (WAN). LAN technologies include Fiber Distributed Data Interface (FDDI), Copper Distributed Data Interface (CDDI), Ethernet/IEEE 802.3, Token Ring/IEEE 802.5 and the like. WAN technologies include, but are not limited to, point-to-point links, circuit switching networks like Integrated Services Digital Networks (ISDN) and variations thereon, packet switching networks, and Digital Subscriber Lines (DSL).

Communication connection(s) **2450** refers to the hardware/software employed to connect the network interface **2448** to the system bus **2418**. While communication connection **2450** is shown for illustrative clarity inside computer **2412**, it can also be external to computer **2412**. The hardware/software necessary for connection to the network interface **2448** includes, for exemplary purposes only, internal and external technologies such as, modems including regular telephone grade modems, cable modems and DSL modems, ISDN adapters, and Ethernet cards.

FIG. **25** is a schematic block diagram of a sample-computing environment **2500** with which the disclosed subject matter can interact. The sample-computing environment **2500** includes one or more client(s) **2502**. The client(s) **2502** can be hardware and/or software (e.g., threads, processes, computing devices). The sample-computing environment **2500** also includes one or more server(s) **2504**. The server(s) **2504** can also be hardware and/or software (e.g., threads, processes, computing devices). The servers **2504** can house threads to perform transformations by employing one or more embodiments as described herein, for example. One possible communication between a client **2502** and servers **2504** can be in the form of a data packet adapted to be transmitted between two or more computer processes. The sample-computing environment **2500** includes a communication framework **2506** that can be employed to facilitate communications between the client(s) **2502** and the server(s) **2504**. The client(s) **2502** are operably connected to one or more client data store(s) **2508** that can be employed to store information local to the client(s) **2502**. Similarly, the server(s) **2504** are operably connected to one or more server data store(s) **2510** that can be employed to store information local to the servers **2504**.

What has been described above includes examples of the subject innovation. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the disclosed subject matter, but one of ordinary skill in the art may recognize that many further combinations and permutations of the subject innovation are possible. Accordingly, the disclosed subject matter is intended to embrace all such alterations, modifications, and variations that fall within the spirit and scope of the appended claims.

In particular and in regard to the various functions performed by the above described components, devices, circuits, systems and the like, the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., a functional equivalent), even though not structurally equivalent to the disclosed structure, which performs the function in the herein illustrated exemplary aspects of the disclosed subject matter. In this regard, it will also be recognized that the disclosed subject matter includes a system as well as a computer-readable medium having computer-executable instructions for performing the acts and/or events of the various methods of the disclosed subject matter.

In addition, while a particular feature of the disclosed subject matter may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "includes," and "including" and variants thereof are used in either the detailed description or the claims, these terms are intended to be inclusive in a manner similar to the term "comprising."

In this application, the word "exemplary" is used to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion.

Various aspects or features described herein may be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques. The term "article of manufacture" as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer readable media can include but are not limited to magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips . . .), optical disks [e.g., compact disk (CD), digital versatile disk (DVD) . . .], smart cards, and flash memory devices (e.g., card, stick, key drive . . .).

What is claimed is:

1. A system for programming an industrial safety relay, comprising:

a memory that stores executable components; and

a processor, operatively coupled to the memory, that executes the executable components, the executable components comprising:

a configuration component configured to create a configuration program for a safety relay based on configuration input that manipulates graphical function blocks and signal flow lines between the graphical function blocks; and

a graphical interface component configured to receive the configuration input and to display the graphical function blocks organized into columns of an editing area of a configuration interface, the columns comprising at least a safety monitoring column, a first logic column, a second logic column, and a safety output column

wherein the graphical interface component is further configured to:

in response to the configuration input instructing creation of a signal flow line between an output of a first graphical function block in the safety monitoring column and an input of a second graphical function block in one of the second logic column or the safety output column:

insert a pass-through function block in the first logic column,

connect the output of the first graphical function block to an input of the pass-through function block using a first signal flow line, and

connect an output of the pass-through function block to the input of the second graphical function block using a second signal flow line, and

in response to the configuration input instructing deletion of the first signal flow line, delete the first signal flow line and leave the second signal flow line connecting the output of the pass-through function block to the input of the second graphical function block unchanged.

2. The system of claim **1**, wherein the safety monitoring column contains a first subset of the graphical function blocks corresponding to safety input devices, the first logic column contains a second subset of the graphical function blocks that define first logical operations, the second logic column contains a third subset of the graphical function blocks that define second logical operations, and the safety output column contains a fourth subset of the graphical function blocks corresponding to safety outputs of the safety relay.

3. The system of claim **1**, wherein a spacing between adjacent columns of the columns is a fixed distance.

4. The system of claim **1**, wherein the pass-through function block performs no logical operation on an output signal from the first graphical function block.

5. The system of claim **1**, wherein the graphical interface component is further configured to organize the signal flow lines on the editing area according to defined line drawing rules.

6. The system of claim **5**, wherein the defined line drawing rules include a rule specifying that vertical portions of two signal flow lines from respective two different function block outputs will not share a same vertical line location.

7. The system of claim **1**, wherein the graphical interface component is further configured to programmatically associate an output of a first function block of the graphical function blocks with an input of a second function block of the graphical function blocks in response to a reference parameter located on the second function block being set to an identifier of the first function block.

8. The system of claim **1**, wherein a width of the graphical function blocks within one of the columns is fixed for all rows of the graphical function blocks.

9. A non-transitory computer-readable medium having stored thereon instructions that, in response to execution, cause a system comprising a processor to perform operations, the operations comprising:

displaying graphical function blocks on an editing area of a configuration interface, wherein the displaying comprises arranging the graphical function blocks into columns according to function block type, and wherein the columns comprise at least a safety monitoring column, a first logic column, a second logic column, and a safety output column;

receiving configuration input via manipulation of one or more of the graphical function blocks and signal flow lines between the graphical function blocks;

in response to receiving, as a first portion of the configuration input, an instruction to create a signal flow line between an output of a first graphical function block in the safety monitoring column and an input of a second graphical function block in one of the second logic column or the safety output column:

creating a pass-through function block in the first logic column,

connecting the output of the first graphical function block to an input of the pass-through function block using a first signal flow line, and

connecting an output of the pass-through function block to the input of the second graphical function block using a second signal flow line;

in response to receiving, as a second portion of the configuration input, an instruction to delete the first

signal flow line, deleting the first signal flow line and leaving the second signal flow line connecting the output of the pass-through function block to the input of the second graphical function block intact; and

generating a configuration program for a safety relay based on the configuration input.

10. The non-transitory computer-readable medium of claim **9**, wherein the arranging comprises:

placing a first subset of the graphical function blocks corresponding to safety input devices in the safety monitoring column;

placing a second subset of the graphical function blocks that define first logical operations in the first logic column;

placing a third subset of the graphical function blocks that define second logical operations in the second logic column; and

placing a fourth subset of the graphical function blocks corresponding to safety outputs of the safety relay in the safety output column.

11. The non-transitory computer-readable medium of claim **9**, wherein the arranging comprises spacing the columns according to a fixed distance.

12. The non-transitory computer-readable medium of claim **9**, wherein the pass-through function block performs no operation on an output value of the first graphical function block.

13. The non-transitory computer-readable medium of claim **9**, wherein the operations further comprise organizing the signal flow lines according to one or more defined line drawing rules, and wherein the defined line drawing rules comprise at least a rule specifying that vertical portions of two signal flow lines from respective two different function block outputs will not occupy a same vertical line location.

14. The non-transitory computer-readable medium of claim **9**, wherein the operations further comprise programmatically linking an output of a first function block of the graphical function blocks with an input of a second function block of the graphical function blocks in response to setting a reference parameter located on the second function block to an identifier of the first function block.

15. The non-transitory computer-readable medium of claim **10**, wherein the displaying comprises displaying the graphical function blocks to have a same width for all rows within one of the columns.

16. A method for constructing a program for an industrial safety relay, comprising:

adding, by a system comprising at least one processor, graphical function blocks to an editing area of a configuration interface in response to first configuration input, wherein the adding comprises aligning the graphical function blocks into columns classified according to function block type, and the columns comprise at least a safety monitoring column, a first logic column, a second logic column, and a safety output column;

adding, by the system, signal flow lines between at least a subset of the graphical function blocks in response to receipt of second configuration input, wherein the signal flow lines programmatically associate the subset of the graphical function blocks, wherein the adding comprises, in response to receiving, as a portion of the second configuration input, an instruction to create a signal flow line between an output of a first graphical function block in the safety monitoring column and an input of a second graphical function block in one of the second logic column or the safety output column:

creating a pass-through function block in the first logic column,

connecting the output of the first graphical function block to an input of the pass-through function block using a first signal flow line, and

connecting an output of the pass-through function block to the input of the second graphical function block using a second signal flow line;

in response to receiving, as another portion of the second configuration input, an instruction to delete the first signal flow line, deleting the first signal flow line and leaving the second signal flow line connecting the output of the pass-through function block to the input of the second graphical function block unchanged; and

creating, by the system, a configuration program for a safety relay based on the graphical function blocks and the signal flow lines.

17. The method of claim **16**, wherein the aligning comprises:

locating a first subset of the graphical function blocks corresponding to safety input devices in the safety monitoring column;

locating a second subset of the graphical function blocks that define first logical operations in the first logic column;

locating a third subset of the graphical function blocks that define second logical operations in the second logic column; and

placing a fourth subset of the graphical function blocks corresponding to safety outputs of the safety relay in the safety output column.

18. The method of claim **16**, wherein the pass-through function block performs no operation on an output signal from the first graphical function block.

19. The system of claim **5**, wherein the defined line drawing rules include a rule specifying that a first 90 degree break in a first signal flow line within a space between two of the columns is to occur at a first fraction of a distance between the two of the columns, and a second 90 degree break in a second signal flow line in the space between the two of the columns is to occur at a second fraction of the distance between the two of the columns.

20. The non-transitory computer-readable medium of claim **13**, wherein the line drawing rules specify that a first 90 degree break in a first signal flow line within a space between two of the columns is to occur at a first fraction of a distance between the two of the columns, and a second 90 degree break in a second signal flow line in the space between the two of the columns is to occur at a second fraction of the distance between the two of the columns.

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