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APPLICATION OF PROGRAMMABLE CONTROLLERS TO VACUUM SYSTEM INTERLOCKS

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Abstract

At Doublet III a Texas Instruments 5TI, Programmable Controller System (PCS) performs all interlock logic operations required by the Vacuum Control System. A PCS utilizes solid-state circuitry and techniques to perform machine control functions ordinarily accomplished by relay-logic panels or solid-state card logic systems. In this appliction, the use of a PCS expedited the initial design and reduces machine down-time required for maintenance, revisions and systems expansion.

This paper describes the Doublet III Vacuum Control System in which all input signals and output loads are connected to a programmable controller (PC) for logical interfacing. Input signals derived from CAMAC, control panels, limit switches, etc., are implemented as output signals to CAMAC, vacuum valves, pump motors, etc., according to a logic program stored in the PC memory. The memory can be easily programmed by anyone familar with either Boolean algebra or relay-ladder network diagrams. The program data is entered with the aid of a calculator like, keyboard instrument with LED readout displays. The PC system contains a 1024 word RAM memory with a battery backup system to provide 72 hours protection of contents in case of power failure.

The PC System can be programmed to perform complex logic operations on any combination of inputs, subject to memory capacity limitations. Up/Down counters and delay functions can also be programmed. The ultimate capacity of the PC is limited to 256 inputs and 256 outputs. The present Doublet III System has approximately 137 inputs and 44 outputs and uses 550 words of memory.

The described system has performed reliably since installation in December, 1977 and has successfully demonstrated its "fail-safe" and memory-protection features on several occasions.

Introduction

Doublet III vacuum instrumentation and control system are provided to indicate system pressures, status, and to protect the vacuum system in the event of malfunction. The logic is designed with three major purposes in mind:

1) Make the vacuum system accident proof by requiring enough conditions that unsafe modes of operation cannot be initiated.

2) Build in redundancy such that component failures have an opportunity to be recognized before unsafe operation occurs.

3) Recognize that safety is more important than convenience.

System Description

Doublet III vacuum control interlock logic is implemented through the 5TI programmable controller, which is an all solid state logic control system capable of performing the same functions as relays, static controls or card logic control systems. It detects the change in state of input signals from push buttons, limit switches, and sensors and acts on this information to produce desired output signals to drive loads such as motor controllers, relays, solenoids and pilot lights.

The programmable control system consists of three main components:

1) the programmable sequencer

2) The programmer

3) The I/O (input and output) system

Figure 1 is a block diagram of the system.

Ladder Diagram Symbology

The programmable controller is like a minicomputer, but it does not require the understanding of complex computer software for application. It employes conventional ladder logic diagrams or Boolean equations as shown in Figure 2. Different ladder diagram symbology can be used, depending on the application and personal preference. Doublet III vacuum interlocks use the following conventions to depict logic through the use of symbols:

General Conventions

1) Each individual restraint for an action is represented by a switch contact —| |—

2) A closure of a switch is equivalent to a permit —|/|—

3) Each switch's state is represented by a passive high (open circuit) or low (closed circuit) at the corresponding input buffers.

4) Logic sequences are represented by the series (AND-function) connection, or parallel (OR-function) connection of these switches.

Programming Example

Figure 2 shows a programming example of a series/parallel ladder diagram. The label above the switch denotes the X (input) or Y (output) terminal number which the sequencer utilizes for permits (action). The label below each switch represents the logic state required to produce an "active low" at the input buffer. Outputs are considered to be energized (action taken) whenever a "conduction" path exists from the extreme left to extreme right of the diagram.

Ladder Diagram

Stored Program For The Ladder Diagram of Figure 2

Memory Locations	Program	
0	STR	X1
1	AND	NOT X2
2	OR	X3
3	STR	X4
4	AND	X5
5	STR	X6
6	AND	X7
7	OR STR	
8	AND STR	
9	OUT Y4	

Equivalent Boolean Equation

$$Y4 = \left[(X1 \cdot \overline{X2}) + X3\right] \cdot \left[(X4 \cdot X5) + (X6 \cdot X7)\right]$$

Hence; only 10 words required in memory to perform this function.

General Operating Description Reference Figure 2

Mp2 (Mechanical pump) ON causes an "active low" of input X1, when X2 "remains" "high" (i.e., vessel vent not permitted, and inputs X4 and X5 are also at an active low, then Y4 output, is energized, causing TV2's solenoid to switch the air pressure in a fashion that opens the valve (and holds it open as long as X1, X4 and X5 is "low"). Another way Y4 can remain energized is to have X3, X6 and X7 at an active low. Anytime there is not a complete conductive path from the extreme left to extreme right Y4 is de-energized causing TV2's valve to close.

The programmable controller sequentially scans the stored program causing the logic to compare the programmed (open/closed) status of input devices such as push button switches, limit switch pressure switches and the programmed (energized/de-energized) status of output devices such as motor starters and solenoids to the active status of these devices. Based upon these comparisons, the (PC) energizes or de-energizes the desired output devices.

The stored program of Figure 2 permits the control system designer to implement virtually any control scheme he desires using the standard (PC) programmable controller by simply creating the stored program. A different control scheme would only require changes in the stored program and would not require equipment or wiring changes. Once created, the program is easily loaded into memory by using the 5TI programmer. Once this program is in memory it can be stored by using the STR-110 to accumulate a permanent library of programs on tape cassettes. The STR-110 is a portable program loader for the 5TI programmable controller.

Vacuum Pressure Interlocks

Doublet III vacuum pressure interlock status comes from Hi/Lo setpoints wired into the programmable controller. Set point information comes from three types of instruments used for measuring the pressure in the vacuum system.

1) In the high pressure range from atomospheric to 10^{-1} Torr, a capacitance manometer (CM) is used.

2) From 10^{-1} Torr to 10^{-3} Torr, a thermocouple (TC) is used.

3) From 10^{-3} Torr to 10^{-11} Torr, a ionization gauge (IG) is used.

Figure 3 shows the block diagram of the Doublet III ionization system interlock with the programmable controller and the main computer via CAMAC. CAMAC is a standard modular system particularly adapted to data acquisition, process control and all other systems based on digital handling of the information usually in association with a computer.

General operating Description Reference Figure 3

Analog data is picked up by the ion gauge tube and TC guage tube and is fed to the ion gauge/TC controller where the signals are processed. The setpoint information for both the ion gauge and TC gauge goes to the input modules of the programmable controller. Once this data is in the system, the programmer need only to program in his required logic as shown in Figure 2. The same setpoint information is fed to a graphics control panel for LED display to provide an operator with a visual display of the system status. The setpoint information is also fed to the main computer through a CAMAC interface, the computer monitors and logs the setpoint information, if any changes occur in the setpoint reference.

The block diagram of Figure 3 is a typical reprepresentation of all Doublet III vacuum interlock systems used in conjunction with the programmable controller.

Graphics Control Panel

All information to and from the programmable controller is displayed on a system graphics control panel (Figure 4,) showing a complete diagram of the vacuum interlock system. LED's are used to indicate valve limit switch status for open and closed, ion gauge setpoint Hi/Lo, and TC gauge setpoint Hi/Lo status. The on/off status or turbo-pumbps, mechanical-pumps and cryo-pumps are also indicated.

All monitored information displayed at the graphics interlock control panel is availabe at the control room operator's console where it is monitored and controlled via a CAMAC interface. The computer can ask for a given command; but it cannot override the programmable controller if the program indicates the action should not be permitted.

Conclusion

Employing the programmable controller to operate Vacuum system interlocks, allows the operator to change the program when logic changes are needed. Having this kind of interlock control through a programmable controller makes the Doublet III vacuum interlock control system safe and efficient and has reduced machine down time.

References

Texas Instruments industrial controls publication 643-B

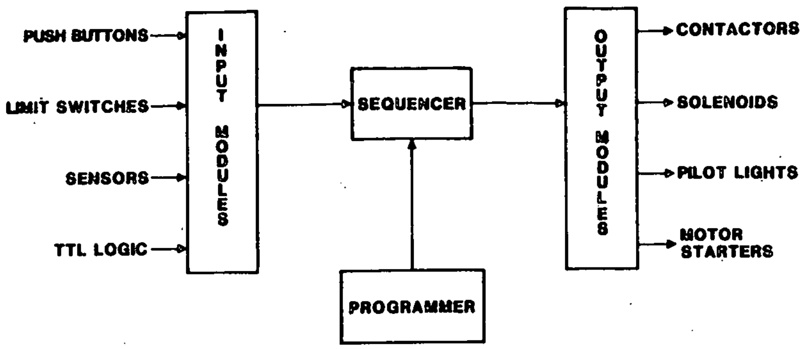

Figure 1
Block Diagram 5TI Programmable Control System

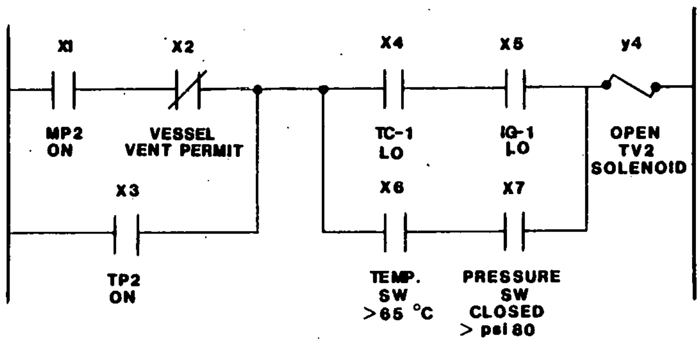

Figure 2
Ladder Diagram Symbology

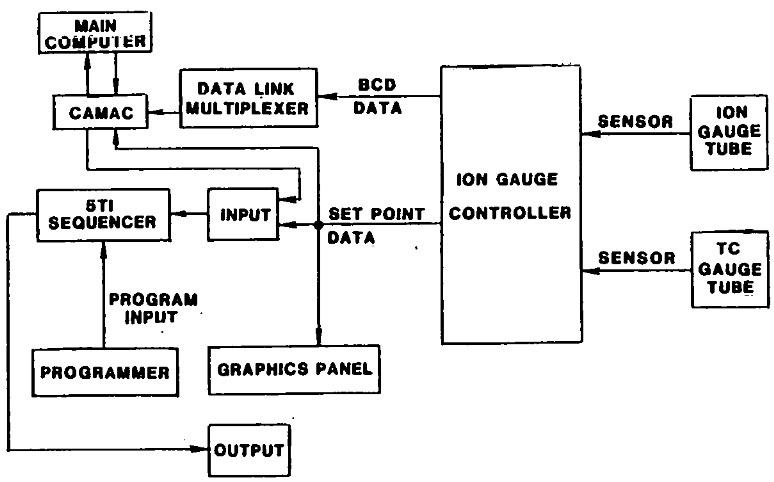

Figure 3
DIII Ionization Interlock System

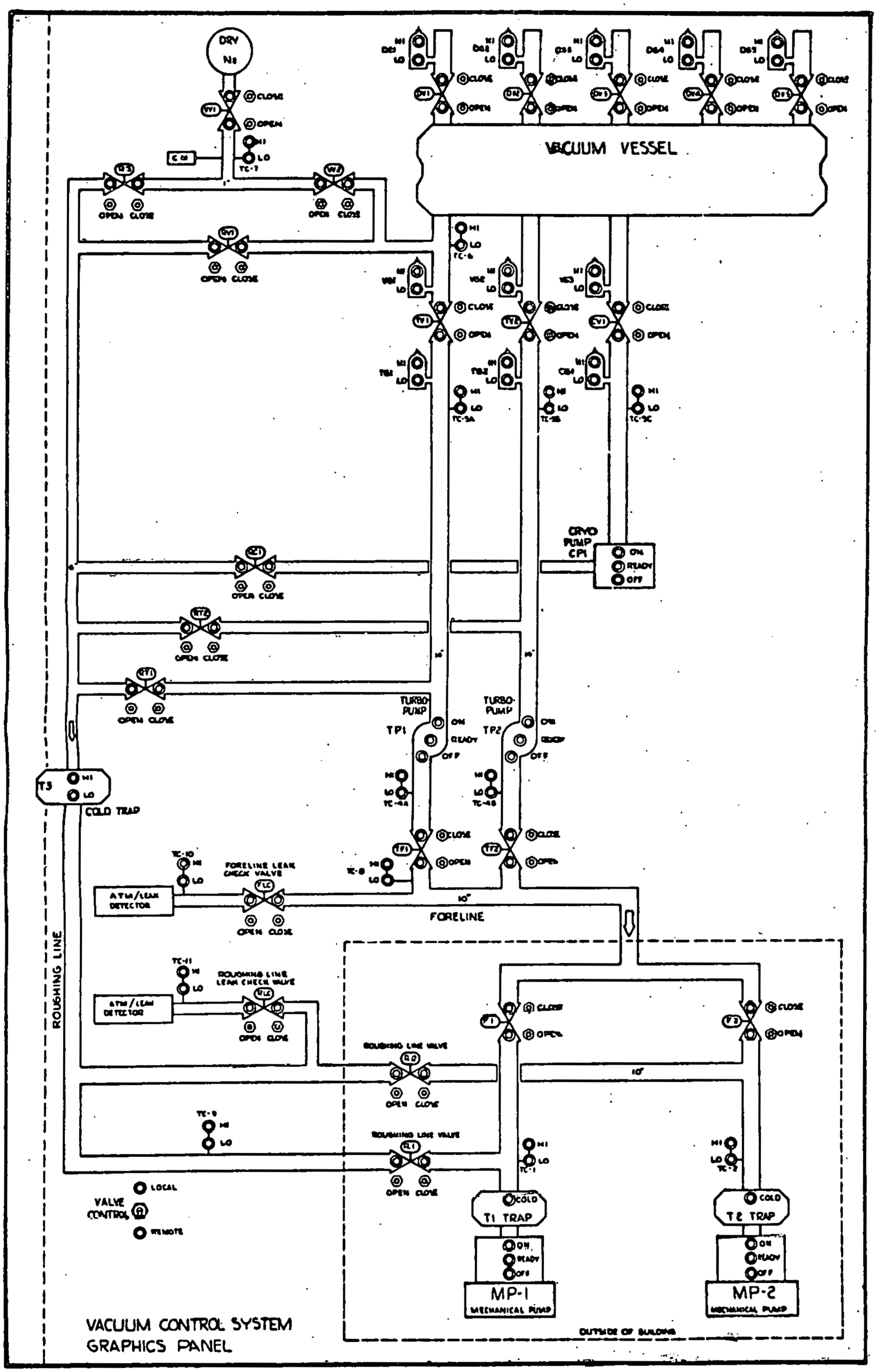

Figure 4
DIII Vacuum Control System

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