EXTRACT FROM Patent Application

Description of the Prior Art

Since the advent of programmable controllers in the early 1970's (such as that disclosed in U.S. Pat. No. 3,686,639), these devices have been able to replace the hard wire relay logic control systems used in many industrial control applications. In the ensuing years, they have become more powerful, replacing not only relay ladder-type control programs, but also performing non-relay functions such as timing and counting, as well as performing data manipulation and transfer such as that disclosed in U.S. Pat. No. 3,930,233. Indeed, programmable controllers have become so powerful in recent years, controlling virtually thousands of outputs and performing many diverse and complicated data manipulation and transfer operations that they in many circumstances can replace the minicomputer for controlling complex industrial control systems. The Modicon 1084 Programmable Controller disclosed in pending U.S. patent applications Ser. No. 646,412 filed Jan. 2, 1976, now abandoned, and divisional application Ser. No. 873,407 filed Jan. 30, 1978, now U.S. Pat. No. 4,162,536 are characteristic of these large, high-powered controllers/data processors.

It has also been found during the relatively short history of the programmable controller that a need existed for small, low cost programmable controllers to replace control programs that would normally utilize eight or more hard-wired relays. It has further been found that it is at times desirable to allow the control engineer to program not only ladder-type control programs with each rung of the ladder representing an electrical circuit line having one or more nodes or contacts and a coil output which may be referenced to other nodes, but also a network of logic lines with interconnections between nodes of adjacent lines. Some companies such as Texas Instruments and Allen-Bradley have provided programmable controllers with programming panels capable of being programmed with control networks which can have interconnections between adjacent lines within the network. However, it has been found that, due to the type of solution employed by these programmable controllers, constraints had to be placed upon the user in terms of the number of vertical connections that could be placed between adjacent lines as well as the number of nodes that could be encompassed within two vertical lines of the control program. The present invention eliminates these problems in prior art programmable controllers by providing a control network without any limitations on the user in terms of the number of vertical interconnections that can be made within the network nor in the arrangement of nodes between vertical interconnections of the network. This is achieved by the utilization of what is called a "column solver" which for each network solves the vertical power flow in both the up and down directions for each node in a column.

The present invention also provides a programmable controller with improvements not found in prior art programmable controllers, such as the capability of inserting one or more networks between two existing networks so as to effectively re-number the remaining networks and thereby insure correct sequential solution of the networks where such a solution is desired.

The output point in the I/O system to which the coil output of a user line references, is assignable by the user and not dictated by line number. This further reduces the constraints placed on the user in formulating his or her control program.

The present invention also provides a programmable controller that has multiple discrete outputs on some calculate functions. These multiple outputs facilitate use of the result of the calculate function by the control engineer. Furthermore, the present invention not only provides for discrete input/output but also register input/output on the same I/O modules for the transferral of data to and from the programmable controller and interconnected devices such as other programmable controllers in a hierarchical control arrangement. In addition, the present invention provides a cursor display on its CRT which allows the user to have the real-time display of power status at any particular node in any selected line of the ladder-diagram network. Specialized search features are also present to the user.

In addition, the present programmable controller is housed in a unique modular arrangement suitable to a rugged industrial environment. The various features of the mechanical aspects of the present invention are disclosed and claimed in a co-pending patent application filed simultaneously with the present patent

application; namely, U.S. patent application Ser. No. 883,277, filed May 3, 1978, U.S. Pat. No. 4,215,386.

All of the improvements synergistically combine to provide a low cost, flexible, and easily viable programmable controller.

SUMMARY OF THE INVENTION

An improved programmable controller according to the present invention comprises a power supply and central processing unit (CPU) and memory forming a mainframe enclosed in a first housing, and an input/output assembly having an input/output (I/O) bus interconnected to the mainframe at one end and to one or more I/O housings in a daisy chain fashion. Depending on their length, each I/O housing has from one to four or from one to eight I/O modules. Each I/O module has either four discrete input points or four discrete output points. There are separate I/O modules for AC and DC inputs and outputs. The I/O bus is housed in an I/O duct which provides easy installation as well as effective electromagnetic interference (EMI) protection.

Insertion of a user generated control program is performed by an interconnectable programming panel which allows for the generation of electrical ladder diagram networks up to seven rows in length and eleven columns in width, representing up to 77 nodes. The programming panel in conjunction with the mainframe allows the user to move a cursor to any node in the network with an associated light-emitting diode (LED) on the programming panel indicating the real-time power status of that node.

The CPU further comprises a column solver which solves the vertical power status between adjacent nodes in different lines or rows on a column-by-column basis interacting with the solution of the nodes by other portions of the mainframe.

The programming panel allows the user to insert one or more networks between two existing networks in such a manner that the networks below the inserted network are effectively pushed down not only on the CRT display but also in the solution order as performed by the mainframe. This feature coupled with the user assignability of coil outputs to any I/O point allows for more effective user programming, especially where solution order of the program is important.

Finally, the programming panel in conjunction with the memory has a percentage memory feature and an associated check count which is stored during a power-down sequence and compared with the count obtained during a power-up sequence in order to prevent the operation of the controller in solving the user networks if the two check counts do not match. This prevents the use of incorrectly stored data in memory in a power-up sequence.

OBJECTS OF THE INVENTION

Therefore, it is a principal object of the present invention to provide an improved programmable controller which is able to generate and solve multi-node electrical ladder-diagram networks in conjunction with a column solver for the rapid and efficient columnar solving of interconnections between adjacent lines of the ladder-diagram network;

It is a further object of the present invention to provide an improved programmable controller of the above description utilizing a CRT programming panel which displays the user generated ladder-diagram networks and which has a user movable cursor that can be placed at any node within the ladder-diagram network for displaying on an associated LED the real-time power status of that node as it is solved by the CPU;

Another object of the present invention is to provide an improved programmable controller of the above character capable of performing calculate functions with multiple outputs so as to facilitate use of the resultant output in other portions of the control program;

A still further object of the present invention is to provide an improved programmable controller of the above character in which the I/O system incorporates one or more I/O housings, each housing connecting with one or more input or output modules which can communicate with the mainframe not only discrete input/output

data but also register input/output data for data processing purposes;

Another object of the present invention is to provide an improved programmable controller of the above description which has a programming panel and associated mainframe which allows the user to insert networks between existing networks and which provides for the sequential solution of the inserted networks;

An additional object of the present invention is to provide a programmable controller of the above character having coil I/O assignability independent of its line and network location;

Another object of the present invention is to provide a programmable controller of the above character having specialized search techniques to facilitate monitoring and de-bugging of the user program.

A still further object of the present invention is to provide a programmable controller of the above character which generates a check count during a power-down sequence indicative of the contents of memory and to generate a second check count during a power-up sequence representative of the same status of the memory and to prevent operation of the controller if the two check counts are not the same.