MODBUS

Introduction

A MODBUS network is a communication system that links programmable controllers, with intelligent terminals and computers, over common carrier or dedicated, locally installed lines. Consisting of both hardware and software products, this communications system can be used for a variety of data acquisition and supervisory control applications including:

- energy management and environmental control
- security monitoring
- process control
- management information collection and reporting
- production monitoring
- quality control
- pipeline monitoring and control
- transfer line and conveyor control
- machine monitoring

Gould introduced the MODBUS system in November 1978. The first system was installed in March 1979. Within months, systems were being installed for energy management, transfer line control, pipeline monitoring, and data acquisition.

A MODBUS network has a single master device that originates all communications and supports up to 247 slave devices placed throughout a plant or in remote locations. (The total number of devices supported is dependent upon the communications equipment used.) At present, only currently sold models of Gould programmable controllers (PCs) can be used as slave devices on the MODBUS system. By using this system, the PCs can exchange information with the central master device without interfering with the performance of the PCs' control tasks. MODBUS can support a variety of different types of master devices including minicomputers, mainframes, intelligent terminals, and certain Gould PCs. In addition, the system allows the user to select his own transmission medium including locally installed twisted-pair cables, voice-grade telephone lines, radio and satellite communication systems, fiber optics, and baseband or broadband in-plant cable systems. The selection of a transmission medium may be made on the basis of existing communications systems, cost, type of application and geographic factors.

MODBUS supports a variety of networking configurations including bus architectures (device attachment to a common cable) and radial point-to-point configurations. Hierarchical systems employing several networks can also be implemented.

MODBUS system communications operates in a half-duplex mode through a series of asynchronous commands common to all Gould PCs used as slaves. These commands can be sent as either a query-response message (transmitted request to a specified slave, requiring a response) or a broadcast message (request to all units with no response required). In the former case, the master "talks" to one slave, waits for an answer, and then goes on to the next slave. Broadcasting allows for the simultaneous sending of messages to all slave devices where no response is required.

Messages typically consist of commands for reading or modifying registers, coils, or discrete inputs. Other messages are used for handling such functions as testing the communication system and altering the stored program in the controller.

The implementation of these commands is governed by a set of transmission rules known as a protocol. This communication discipline defines the structure and format of the messages that are transmitted on the network. The MODBUS protocol has been specifically developed by Gould to simplify communications with remote PCs on a MODBUS network.

To send or receive information, users need only specify the slave address, the command to be performed and the data required to execute the command. In addition to permitting the implementaton of common command functions for all Gould PCs, the protocol provides for extensive error checking, addressing for bus-type network architectures, and other transmission rules that are totally transparent to the user.

When the MODBUS protocol is selected as the communications discipline, Gould PCs can be easily attached to the network by installing a plug-in MODBUS interface unit, one for each slave PC. Use of this unit eliminates the need to program any changes in the PC. The interface unit has the ability to handle all communications with the master device. By the rearrangement of interface units and cable, PCs can be added to or dropped from a MODBUS network without PC reprogramming. This allows the user to expand networks as needed. The MODBUS-to-PC interface capability is accomplished by a microprocessor located in the interface. This microprocessor is programmed to interpret the MODBUS protocol and convert the information received to a format that the PC understands. In addition, the PC interface unit determines if the message received is intended for its respective PC slave and automatically performs several levels of error checking.

Besides these interface units, other MODBUS products currently include industrial modems, FORTRAN IV-based software which allows computers to be used as master devices, and a mini-cartridge tape used to program a 584 PC to be a master device. These products have been developed specifically to function reliably in industrial environments.

Industrial modems are used in a MODBUS network to convert the transmitted message signal to a format suitable for long distance transmission. For dedicated lines using 4-wire twisted-pair cable, specially designed MODBUS modems can be used to ensure maximum message integrity over the entire network. These modems have 16 selectable transmission rates, ranging from 50 to 19,200 bits-per-second (baud), and have an RS-232C interface. (RS-232C is a widely accepted EIA compatibility standard.)

A single MODBUS modem can handle up to 32 devices at distances up to 15,000 feet from the master. For common carrier systems or dedicated lines not employing twisted-pair cable as the selected medium, commercial modems must be used. The limit of 32 slaves over 15,000 feet of cable does not always apply to system using commercial modems.

FORTRAN IV-based software is available for computers used as MODBUS masters. The software (e.g., Communications Handler) validates the user's requests, formats the messages for transmission on the MODBUS network, and performs any necessary decoding and error checking. In addition, other software products (i.e., Load/Dump/Compare Utilities) allow the memory of the PC slave to be recorded in the computer's mass memory. Once stored, comparisons can be made between the slave's logic and any previously recorded program to determine where logic and configuration changes have been made. This same logic can then be loaded into other PC slaves. When supplemented with a third software product (Ladder Lister), the Load/Dump/Compare software can be used to generate ladder diagram printouts. These printouts contain extensive captions for labeling each element in the ladder diagram, as well as comments, and cross referencing elements.

Features/Benefits

Key features of the MODBUS system include:

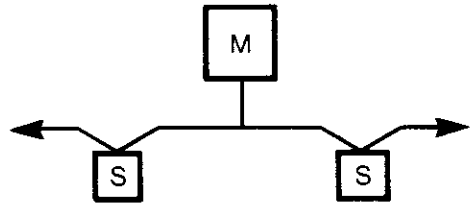
- Communications independent of PC control task — malfunction in one slave PC does not affect the others.
- System modularity — plug-in slave attachment through off-the-shelf interface units.
- System portability — addition or removal of slaves does not interfere with system performance when arranged in a multi-drop configuration. The use of FORTRAN, a high level language, allows programs to be easily transported from one computer to another.

- Ease of installation — one MODBUS network can easily accommodate up to 247 slaves without requiring network redesign. No modifications are made to the PCs used as slaves. Point-to-point cabling requirements are eliminated through support of bus type architecture.
- Extensive error checking — loopback diagnostics for identifying communications faults, system diagnostics through software and status indicator lights in interface units.
- Specially designed protocol — allows access to common carrier networks and simplifies user programming and testing procedures.
- Specially designed modems — operate reliably in harsh industrial environments and are equipped with an RS-232C interface and a voice communication channel.
- Multi-functional — read and modify contents of registers, coils, and discrete inputs plus perform system tests, PC program alterations, and PC status checks.
- Multi-application — supports a variety of data acquisition, supervisory control, and uploading/downloading functions.

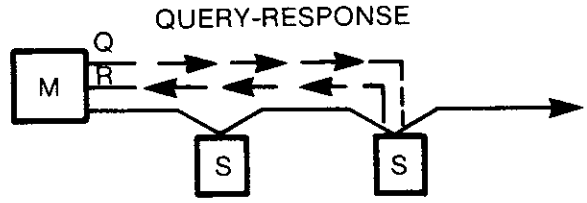
Network Operation

Type of Transaction

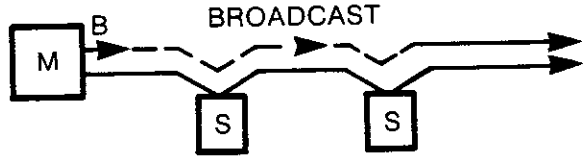
The MODBUS system's operation is based on a fixed master-slave relationship (refer to the following figure). A programmable controller, computer, or an intelligent terminal can act as the MODBUS system master. In all cases, only a master device can initiate transactions. The two types of transactions are query-response and broadcast.



- Query-response — Master sends a query message to a specific slave PC, which then performs the indicated action and sends a response message to the master. The master processes the slave's response (refer to the following figure).



- Broadcast — Master sends a broadcast message to all slaves in the network, which then perform the indicated action. No response message is sent from the slaves to the master (refer to the following figure).



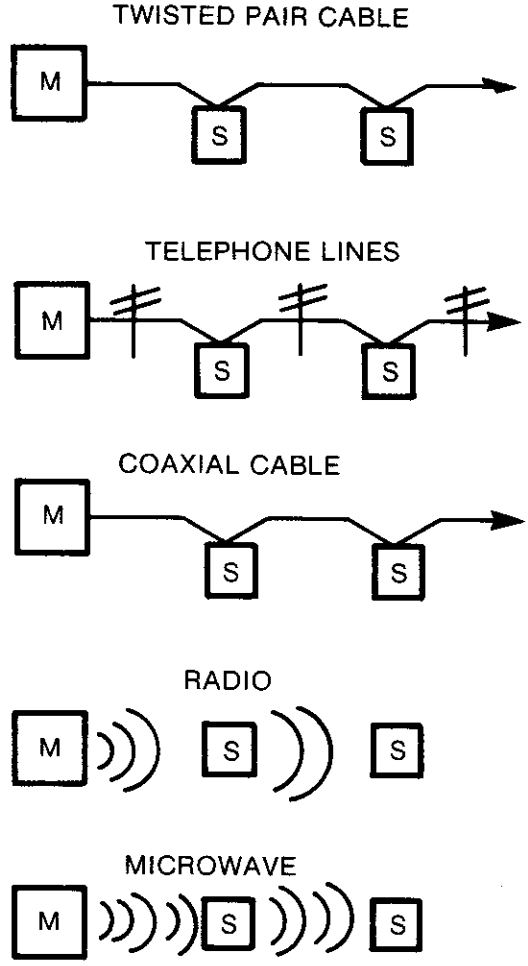
A query-response transaction may only be sent to one slave at a time. Two separate transactions must be initiated to send the same query to two different slaves. A broadcast transaction is sent to all slaves and cannot be sent to a specified group of slaves.

The two types of transactions are distinguished by the slave address that is part of the message. If a specific slave's address is given, the transaction will be a query-response. If a slave address of zero is indicated, the transaction will be a broadcast. These two types of transactions can be used on all MODBUS systems, independent of the type of master (computer, PC, or intelligent terminal), the type of slave PC, the arrangement of the network, and the media used for communication (refer to the following figure).

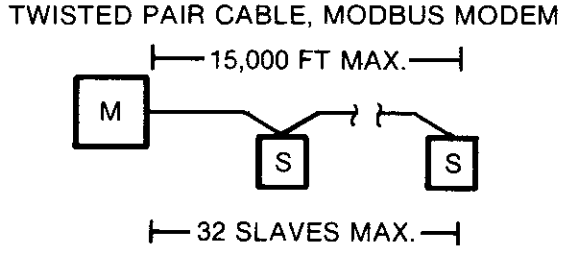
SLAVE ADDRESS		TRANSACTION TYPE
1,2,3 . . . 247	=	QUERY-RESPONSE
0	=	BROADCAST

Type of Transmission Medium

There are many types of media that can be used to transmit a message between the master and slaves: fully shielded twisted-pair cable, baseband or broadband coaxial systems, voice grade telephone lines, radio/microwave signals, satellite transmission and fiber optics. Each has its advantages depending upon application and environment (refer to the following figure).



Twisted-pair dedicated cable is typically used for local communications where cost, availability, and easy installation is the user's primary consideration in selecting a transmission medium. The maximum length of the main transmission cable for a single network is 15,000 feet (4,572 meters) if MODBUS modems are used. A single such network using MODBUS modems and twisted-pair cable will support a maximum of 32 slaves (refer to the next figure).



Some installations are currently using coaxial cable networks. Either baseband (passive) or broadband (cable TV) coaxial systems can be used as the transmission media for a MODBUS system.

Transmission by common carrier facilities (e.g., telephone lines) allows a system to make use of existing media and to communicate with slave PCs at widely separated sites. Radio transmission is particularly useful in applications where solid transmission media are not practical, such as offshore or pipeline operations. Many industrialized areas have established microwave channels for communications.

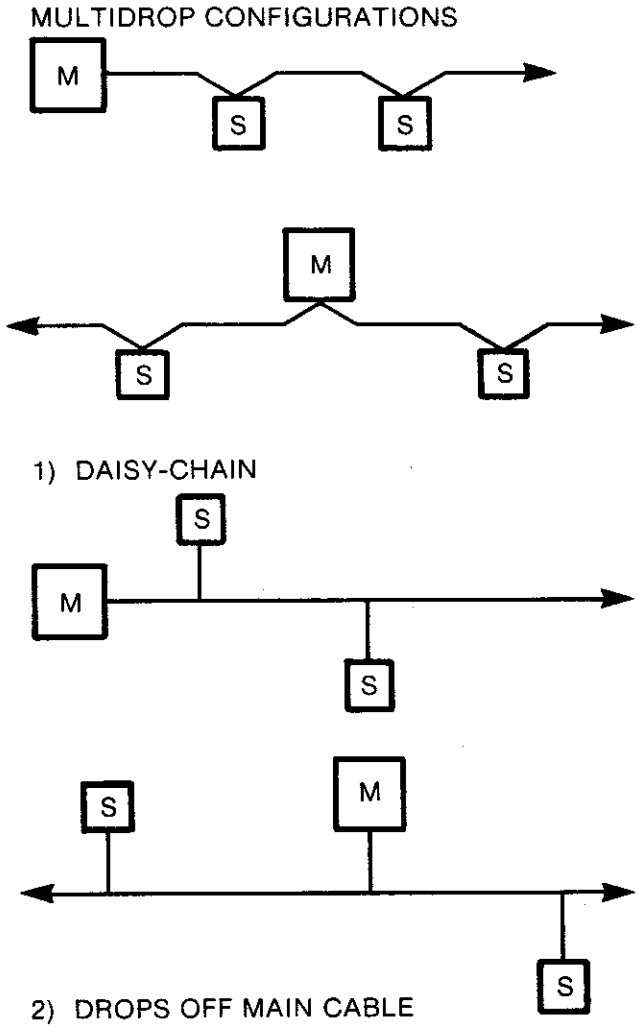
Transmission by coaxial cable systems, telephone lines, microwave, or radio means that a commercial modem or transceiver must be used. A modem is located at the MODBUS master and at each slave PC. The size and arrangement of the system is largely determined by the capabilities of the commercial modems used. The table below describes the system characteristics of commercial and MODBUS modems.

	Gould MODBUS Modem	**Any Commercial Modem**
Media	Shielded twisted-pair cable	Any modem-compatible media
Distance	15,000 ft.*	Unlimited
No. of Slave Devices	32*	247
Operating Speed	Up to 19.2 Kbps	Up to 19.2 Kbps
Industrial Reliability	Maximum ruggedness and noise immunity	Limited ruggedness and noise immunity

*Transmission distance, number of slaves, operating speed, and topology are all inter-related parameters. For instance, distance can be increased if the number or length of drops is reduced.

Network Arrangement

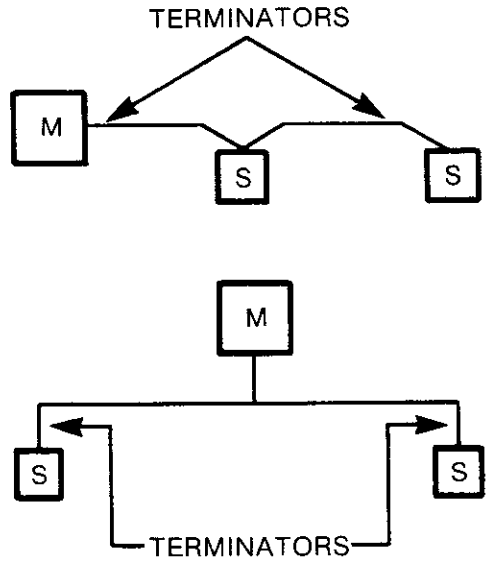
The network arrangement is already partially determined for systems using telephone lines and coaxial cable, and the arrangement of radio and microwave systems is determined by commercial modem capabilities. Systems using twisted-pair cable as the transmission medium are arranged in a multi-drop configuration; two or more slaves are connected to the master by the same main cable. A drop is a cable which connects the slave to the main cable. The slaves may be connected directly to the main cable in a daisy-chain arrangement or by drops of up to 500 feet off the main cable (refer to the following figure).



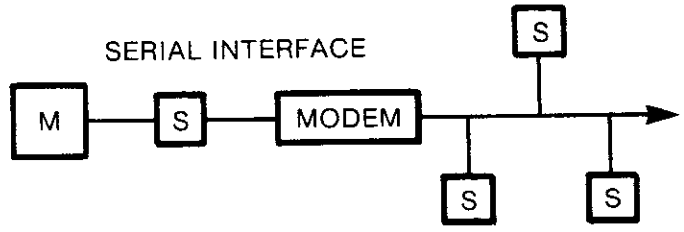
The daisy-chain arrangement is the simpler of the two arrangements. It may be described as a series of "zero-length" drops off the main cable. The cable goes from the master to the closest slave, to the next-closest slave, and so on to the furthest slave. The master may be located at either end, or at any point along the cable. The slaves are connected directly to the main cable.

In the other form of multi-drop configuration the master is connected to the slaves by short (less than 500 feet) lengths of cable (drops) off the main cable. Each slave has its own drop directly off the main cable. The master may be located at either end, or at any point along the cable.

In both arrangements, terminators are located at the ends of the main cable. In a system with the master at one end of the cable, one terminator is located at the master and one at the furthest slave. In a system with the master at some point along the line, terminators are located at the two slaves at the ends of the main cable (refer to the following figure).

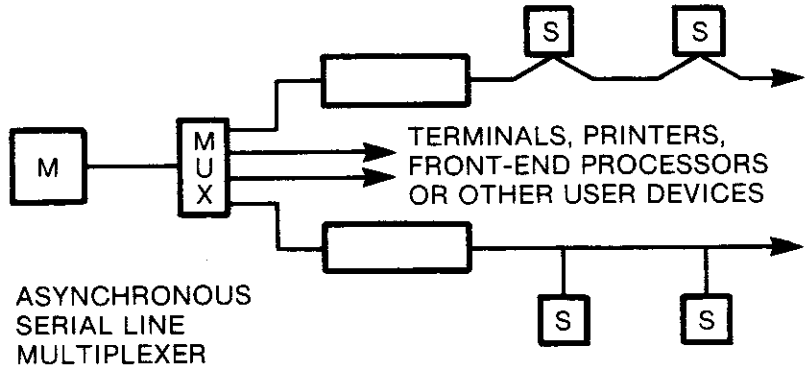


A single MODBUS network can be connected to a computer master using a serial interface and a modem (refer to the following figure).



COMPUTER MASTER, SINGLE LINE

Multiple MODBUS networks can also be connected to a single computer master. The various networks are connected to the computer through a serial line asynchronous multiplexer and a modem. Any combination of acceptable network arrangements can be used; each network is independent in its operation. Multiplexer ports not used by a MODBUS network can be used for other applications, such as connection to terminals. CRTs, printers, secondary memory storage, front-end processors, and other devices (refer to the following figure).



The following network arrangement guidelines are intended only for twisted-pair cable systems using MODBUS modems.

A. Networks using twisted-pair cables for transmission are arranged in a multi-drop configuration; one or more slaves connected to a single master by the same transmission cable. The slaves may be connected by a main cable with zero-length drops, or drops up to 500 feet (150 meters) in length. Both methods may be used in a single network.

B. The maximum main cable length in a single multi-drop network may not exceed 15,000 feet (4,572 meters).

C. A maximum of 32 slaves can be connected on a single network (assuming MODBUS system modems are used).

D. The cable must be fully shielded, with two twisted-pairs, and no less than 22 AWG. (Very tightly wound cable should be avoided.) For detailed specification of cable requirements, refer to the MODBUS *System Planning Guide*.

E. The cable must be terminated at both ends in the characteristic impedance of that cable.

Network Components

The components of the MODBUS system may be divided into two categories, Gould-supplied hardware and software and user-supplied hardware and software. The extent to which one or the other of these categories is used depends upon the type of master and the type of transmission media in the specific system.

MODBUS Masters

Master devices range from certain Gould supplied PCs and man-machine interfaces to user supplied computers and intelligent terminals. The table below summarizes the applications and limitations of a variety of devices used as MODBUS masters.

MODBUS MASTERS

Type	Uses	Limitations
Computer	Data Acquisition Supervisory Control Uploading/Downloading Ladder Lister	Not Designed for Harsh Environments Requires Trained Computer Personnel High Cost
PC Master	Data Acquisition Supervisory Control	Low Speed No Load/Dump/Compare or Ladder Lister Supports Function Codes 1-6 (see Functional Capabilities) Limited Memory for Supported Functions
Intelligent Terminal	Data Acquisition Supervisory Control Graphic Displays Logging and Report Displays	No Load/Dump/Compare or Ladder Lister Limited Memory for Supported Functions Not Designed for Harsh Environments Requires Specially Trained Personnel
Programming Panel	Uploading/Downloading Programming PCs (one PC at a time) Unannotated Ladder Lists	Requires Separate Tape Installation for each Slave Does Not Support Typical MODBUS Functions (See Functional Capabilities)
MODVUE Man-Machine Interface	Data Acquisition Supervisory Control Graphic Display Logging and Report Displays	No Ladder Lister or Load/Dump/Compare (Initial Release)

Gould Hardware Offerings

Existing Gould hardware used in the MODBUS system includes currently sold programmable controllers. Each of these PCs may function as a slave on a MODBUS system. No hardware or program logic modifications are required for use of existing Gould PCs as slaves. The ability to "access" the system is provided by Gould hardware which is easily connected to the PCs.

Specially designed Gould hardware includes:

- stand-alone modems
- slave interfaces

The stand-alone modem allows a MODBUS master to communicate with more than one slave PC over a twisted-pair cable. The modems are specifically designed for communications in an industrial environment. These modems operate at baud rates ranging from 50 baud to 19.2 K baud and offer several features not available in commercial modems. They operate at frequencies specifically selected to maintain message integrity by minimizing interference-induced errors in harsh environments. In addition, a voice channel is offered for communication between personnel at any two points in the system. The modem may be located anywhere within 50 feet of the MODBUS master or its associated PC slave.

The modem is required only for communications with more than one PC slave. In situations where a master is to communicate with a single slave, a modem is not required if the arrangement and communications parameters fall within the RS-232C EIA guidelines given below:

- Baud rate — 19.2 K or less
- Distance — 50 ft. or less
- Asynchronous Communications

At lower speeds, greater distances may be used. However, greater distances increase the risk of electromagnetic and radio-frequency interference (EMI and RFI). For this reason, applications with master to single slave communications should use a fully shielded twisted-pair cable meeting the necessary EMI and RFI specifications.

Slave interfaces allow the PCs to receive and send response messages over a MODBUS system. They are used with all types of transmission media, not just with twisted-pair cable. The interface receives and translates messages (queries and broadcasts) sent to the slave PC and sends responses to the MODBUS master. Three types of slave interfaces are offered:

- RS-232C interfaces requiring external modems
- interfaces with built-in modem
- interfaces built-in (certain PCs only)

Gould Software Offerings

Three software packages are offered under license to those users with computer masters: Communications Handler, Load/Dump/Compare and Ladder Lister. The software is written in ANSI Standard FORTRAN IV 1966 with slight modifications. It is provided in source code, the way it is written by a programmer before it is "translated" for the computer. This allows the software to be tailored, if necessary, to the requirements of the user's computer master. A knowledge of FORTRAN will allow the user to modify these programs. The use of FORTRAN makes transporting programs from one computer to another relatively simple. In addition, all software is written in such a way that the user does not need to make any changes to the operating system supplied by the computer vendor.

Communications Handler

The Communications Handler provides a user with a way to access the MODBUS network using a computer as a MODBUS Master. This program must be used with a user-supplied applications program and the computer vendor's software. Use of this program simplifies the task of communicating with Gould PCs. The user is provided with an established technique for handling MODBUS messages, so that the task of communicating with PCs is limited to programming standard MODBUS commands. The user is relieved of the time consuming tasks of designing the communications scheme. For example, the means for handling most message retry and time-out procedures and ensuring maximum message integrity are already established by the Communications Handler. This uniform software package is compatible with all Gould PC slaves and is required for all MODBUS systems using computer masters.

Load/Dump/Compare

The Load/Dump/Compare package includes these capabilities:

- load a PC memory from a master computer
- dump a PC memory to a master computer
- compare a selected portion of current PC memory to previously stored memory in a master computer
- print out differences found during comparisons
- report status and error logs

The Load/Dump/Compare (LDC) program is interactive; the user must give it a comand to perform a specific operation. Unlike the Communications Handler, a separate LDC package is required for each type of PC slave on a MODBUS network. Although this program is not a requirement for MODBUS systems, the package is necessary to use the Ladder Lister program.

Ladder Lister

The Ladder Lister package allows the user to produce annotated, cross-referenced ladder lists from the user logic in PC slaves. The "machine language" of the PC slave is translated into ladder logic diagrams. Cross-reference lists, user-supplied mnemonics, and comments are inserted into the list at the appropriate places. Like the LDC program, this package is interactive. A separate Ladder Lister package is required for each type of PC slave on a MODBUS network.

User Supplied Hardware and Software

The user must supply all transmission cables and, if necessary, any commercial modems, serial line interfaces or multiplexers, and computer or intelligent terminal masters used in the network. In systems using a computer master programmed with Gould software, the user supplies an applications program which tells the Communications Handler to perform a function. The Communications Handler uses the vendor's terminal driver software in order to interface with resident computer software.

Functional Capabilities

There are up to 21 basic functions supported by MODBUS depending on the type of MODBUS master and slaves on the network. Systems using a PC or programming panel master cannot support all MODBUS functions. Each function has a unique identifying code which is used in MODBUS messages. The function code, function name, and a brief description is shown on the following two pages.

Function Code	Function Name	Description
01	Read Output Status	Get status (ON or OFF) of logic coils from a slave PC
02	Read Input Status	Get status (ON or OFF) of discrete inputs from a slave PC
03	Read Holding Registers	Get the contents, in binary, of holding registers from a slave PC
04	Read Input Registers	Get the contents, in binary, of input registers from a slave PC
05	Modify Coil Status	Change the status (ON or OFF) of any coil in a slave PC. This command overrides the slave PC's memory protect and "disable coil" features
06	Modify Register Content	Change the binary content of any output or holding register in the slave PC. (Input register content may not be changed.) This command overrides the slave PC's memory protect feature.
07	Read Exception Status	Get the status (ON or OFF) of eight fixed logic coils from a slave PC. User logic may be programmed to place PC status or control information in these coils, such as "machine ON or OFF", or "error conditions exist". This specially designed short message allows quick retrieval of status.
08	Loop Back Diagnostic Test	Used to test system communications. This message uses subfunction codes to retrieve diagnostic information held at the slave, start/stop the slave PC, access status counters, and identify possible communication faults.
09	Program (484 PC Only)	Allows the user to remotely program and alter logic in a 484 PC slave.

Function Code	Function Name	Description
10	Poll (484 PC Only)	Allows the user to retrieve the response to a program message after the slave PC finishes processing the query. (This function is to be used only with function 09.)
11	Fetch Event Counter	Get the content of a counter which keeps a total of successful message completions.
12	Fetch Communications Event Log	Get status information on communications, such as messages received or messages sent.
13	Program (All PC Types)	Allows the user to remotely program and alter logic in a slave PC. Subfunction codes are used to identify programming actions for the various controller types.
14	Poll (All PC Types)	Allows the user to retrieve the response to a program message after the slave PC finishes processing the query. (This function is to be used only with function 13.)
15	Force Multiple Coils	Change the status (ON or OFF) of consecutive coils in a slave PC. This command overrides the slave PCs memory protect and "disable coil" features.
16	Preset Multiple Registers	Change the binary content of consecutive holding or output registers in the slave PC. (Input register contents cannot be changed.) This command overrides the slave PCs memory protect feature.
17	Report ID	Get the slave PC type and runlight status

Function Code	Function Name	Description
18	Program (884 & Micro 84)	Allows Master to simulate actions of programming panel and alter PC state logic.
19	Reset Communications Link	Resets slave to known state after non-recoverable error. Resets sequence byte.
20	Read General Reference (584 Only)	Displays information contained in extended memory files.
21	Write General Reference (584 Only)	Enters or changes information contained in extended memory files.

Note: Not all PCs support the full range of function codes.

All the functions may be implemented by sending a query-response type of message. Only messages which do not require responses may be sent as broadcast messages (modify coil status, modify register content, force multiple coils, preset multiple registers, and certain sub-functions of the Loopback Diagnostic Test, function 8).

Function 13, Program (All PC Types), has a number of subfunctions specific to each type of controller. This allows the user to perform many specific programming tasks such as reading memory, starting or stopping the controller, and programming contacts and coils.

Communications Protocol

Whenever communication is to take place, a sender and receiver must comply with mutually understood rules. This communications discipline, or protocol, defines the structure and format of the messages that are transmitted on the network. The establishment of a protocol is vital to the operation of the MODBUS system; it determines how the master and slaves establish and break off contact, how the sender and receiver are identified, how messages are exchanged in an orderly manner, and how errors are to be detected. The protocol controls the query and response cycle which takes place between master and slave devices.

The MODBUS protocol has been specifically developed by Gould to simplify communications with remote PCs on a MODBUS network. This protocol is tailored to the type of communications that an industrial user needs for a network of PCs.

To send or receive information, the user need only specify the slave address, the command to be performed, and the data required to execute the command. In addition to permitting common command functions for all Gould PCs, the protocol provides for extensive error checking, addressing for bus-type network architectures, and other transmission rules that are totally transparent to the user.

When the MODBUS protocol is selected as the communications discipline, Gould PCs can be easily attached to the network by installing a plug-in MODBUS interface unit at each PC slave.

Modes of Transmission

The mode of transmission refers to the structuring of individual characters within a message, and the character framing scheme used to transmit the data. Either of two modes of transmission are available for use in a MODBUS system. One mode is ASCII (American Standard Code for Information Interchange), the other is RTU (Remote Terminal Unit). The modes are defined on the next page. Both modes provide the same capabilities for communicating with PC slaves; the mode is selected depending on the equipment used as a MODBUS master. One mode must be used per MODBUS system; mixing of modes is not allowed.

ASCII printable characters are easy to view when troubleshooting and this mode is suited to computer masters, when programmed in a high level language such as FORTRAN or BASIC. RTU is suited to computer masters programmed in a machine language, as well as certain Gould-built masters where implementation of a communications protocol does not require user software (e.g., a P190 programming panel).

In the RTU mode, data is sent in eight data bit binary characters. In the ASCII mode, each RTU character is first divided into two, four bit parts (high order and low order) and then represented by their hexadecimal equivalent (0-9, A-F). The ASCII characters represented in hexadecimal form are used to construct the message. The ASCII mode uses twice as many characters as the RTU mode, but in the RTU mode, message characters must be transmitted in a continuous stream. In the ASCII mode, characters are transmitted at random rates. Breaks of up to 1 second can occur between characters to allow for a relatively slower master.

Message Format

Messages are structured in a standard format, regardless of mode of transmission. The format consists of 4 fields: Address, Function Code, Data, and Error Check.

Address

In a query or response message, the address field contains the address of a specific slave (1-247), as assigned by the user. Each slave must be assigned a unique address. Only the addressed slave resonds to a query with its address. When the slave sends a response, the slave address informs the master which slave is communicating. In a broadcast message, an address of zero (0) is used. All slaves interpret this as an instruction to read and take action on the message, but not to issue a response message.

Function Code

This field tells the addressed slaves what function to perform. MODBUS function codes are specifically designed for interacting with a PC on the MODBUS system.

Data

The data field contains information needed by the slave to perform the specific function. This information may be values, element address references, or limits. For example, the function code tells the slave to read a holding register, and the data field is needed to indicate which register to start at and how many to read.

Error Check

This field allows a message to be checked for errors in transmission. Sometimes, because of electrical noise or other interference, a message may be changed slightly during transmission. If more than one bit in a character is affected by noise, distortion of the message may not be detected by the parity check. In order to ensure maximum message integrity, a redundancy check is included in the message. The redundancy check consists of identical mathematical computations made at the sending and receiving units. This increases the reliability and the efficiency of the MODBUS system.

There are two forms of redundancy checks, depending upon the mode of transmission. The RTU mode uses a Cyclical Redundancy Check (CRC). The ASCII mode uses a Longitudinal Redundancy Check (LRC).

The rate of transmission errors on data communications systems depend upon noise environments, transmission speeds, and rate of use. The maximum error protection may be achieved by using one of the redundancy checks in conjunction with a parity check.

Message Frame Format

Slave Address	Function Code	Data	Error Check

Characteristic	ASCII (7 Data Bits)	RTU (8 Data Bits)
Coding System	Hexadecimal (uses ASCII printable characters 0-9, A-F)	8-binary
Number of bits per character:		
start bits	1	1
data bits (least significant first)	7	8
parity (optional)	1 (one bit sent for even or odd parity, no bits for no parity)	1 (one bit sent for even or odd parity, no bits for no parity)
stop bits	1 or 2	1 or 2
Message frame, to indicate message		
beginning and end		
start	":" character (ASCII code)	Data received following 3 consecutive character lengths with no transmission
end	"LF" & "CR" characters (ASCII code) or 1 second elapsed time with no characters received	3 consecutive character lengths with no transmission
Error checking	LRC (Longitudinal Redundancy Check)	CRC (Cyclical Redundancy Check)