User Manual for the
HE693RTU900
HE693RTU940

RTU
Interface Modules

Eighth Edition
03 June 2003

MAN0077-08

PREFACE

This manual explains how to use the Horner APG RTU Interface Cards for use with GE Fanuc Series 90-30 PLCs and CEGELEC Alspa 8000 PLCs.

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To obtain warranty service, return the product to your distributor with a description of the problem, proof of purchase, post paid, insured and in a suitable package.

ABOUT PROGRAMMING EXAMPLES

Any example programs and program segments in this manual or provided on accompanying diskettes are included solely for illustrative purposes. Due to the many variables and requirements associated with any particular installation, Horner APG cannot assume responsibility or liability for actual use based on the examples and diagrams. It is the sole responsibility of the system designer utilizing RTU Interface Module to appropriately design the end system, to appropriately integrate the RTU Interface Module and to make safety provisions for the end equipment as is usual and customary in industrial applications as defined in any codes or standards which apply.

Note: The programming examples shown in this manual are for illustrative purposes only. Proper machine operation is the sole responsibility of the system integrator.

Revisions to This Manual

This version (MAN0077-08) of the **RTU Interface Module User Manual** contains the following revisions, additions and deletions:

Added Section 1.2: Technical Support.

Revised Table 2.2.

Revised Figure 3.5.

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CHAPTER 1: INTRODUCTION

1.1 Product Description

Congratulations on your purchase of a Horner APG RTU Interface module. The HE693RTU900 is a Modbus slave interface which allows modbus communications with either RS232 or RS485. The HE693RTU940 is equivalent to the HE693RTU900 with the addition of a 14.4k bps modem.

The RTU Module allows a Modbus master to access PLC reference data as though it were Modbus I/O. This data may be accessed using standard Modbus commands such as Read / Force Coils and Read / Preset Registers. To access most of the PLC data types with the limited set of Modbus commands, references provided in these commands are subdivided into regions which allow access to a particular data table. Accessible data types are: %M, %I, %Q, %T, %R, %AI, %AQ.

Reading and writing data is always allowed. Read and Write packets of up to 2000 discrete or 125 analog values are supported. Message reception LED's and Modbus Diagnostic and Exception commands are also supported to provide easy setup and troubleshooting. The HE693RTU940 has the Report-By-Exception feature. This feature gives the module the ability to originate commands and monitor call status.

Configuration of the port type and associated frame protocol parameters is easily accomplished through the Hand Held Programmer or providing the included information of a foreign I/O module definition with PLC configuration software. Both the HE693RTU900 and HE693RTU940 support baud rates of up to 115.2K for RS232 or RS485 in either ASCII or RTU modes. The HE693RTU940 supports a baud rate up to 14.4k for the modem port. Please note that there are limitations in the number of stop bits and parity selections.

1.2 Technical Support

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NOTES

CHAPTER 2: INSTALLATION

2.1 Mounting Requirements

The RTU Module is designed to plug into any 90-30 series or CEGELEC Alspa 8000 backplane slot. Please refer to the PLC Installation manual for information on installing the module.

2.2 Power requirements

250mA @ 5VDC

2.3 Module Installation

1. Remove power from the PLC CPU/Rack.
2. Install the module in a free slot.
3. Apply power to the PLC.
4. Configure the communication port parameters with the HHP or PLC configuration software.
5. Select an appropriate %I reference for DCS monitoring.
6. Connect the Modbus master to the appropriate port.
7. Start Modbus master application.

2.4 Module Configuration

Before the module is connected to the Modbus Master, it should be configured with the appropriate parameters. You may use either the Hand Held Programmer (HHP) or PLC software to configure the parameters. This module can be used with any CPU but requires a PLC CPU version 5.01 or later to configure. If you are not familiar with the Modbus frame protocol or the RTU Module options, first read chapter 3: Operation.

2.4.1 Configuration with the Hand Held Programmer

1. Install the RTU Interface module into the PLC.
2. Apply power to the PLC rack. The PLC will perform its power-up diagnostics and a menu will appear on the Hand Held Programmer's display.
3. Enter the following key sequence on the Hand Held Programmer.

Display	Keystroke	Comments
1. PROGRAM <S 2. DATA	MODE	Press the MODE key to reach this screen.
4 1. PROGRAM <S 2. DATA	4	Press the 4 key, a 4 will appear as the first character in the display.
R0: 00 PLC <S KEY CLK : OFF	ENTER	Press the ENTER key, the display will now show the PLC CPU status.

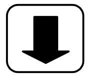
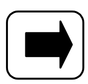
Display	Keystroke	Comments
R0: 01 EMPTY <S		Press the DOWN ARROW key until the slot number containing the RTU Interface Module appears following the "R0:". This example assumes the module resides in slot 1, therefore the DOWN ARROW key is only pressed once.
R0: 01 READ <S	READ/VRFY	Press the READ/VRFY key.
R0: 01 RTU9XX <S I08 : I	ENTER	Press the ENTER key, this will cause the PLC to "read" the RTU Interface Module. The model number of the module will be displayed.
R0: 01 RTU9XX <S I08 : I0001-0008	1 ENTER	The PLC now prompts for the starting address of the 8 %I bits. Pressing the 1 key will cause the %I registers to be mapped from %I0001 to %I0008. Pressing the ENTER key will cause the PLC to accept the %I address.
R0: 01 RTU9XX <S Slave Addr : 1		Pressing the RIGHT ARROW key will cause the next configuration parameter to be displayed. All of the additional parameters can be modified by entering the numeric data or pressing the +/- key then pressing enter.
R0: 01 RTU9XX <S Port Type : RS232	+/- ENTER	These additional parameters are described below and in greater detail in chapter 3.

Table 2.1	
Additional Parameters	**Limits / Options**
Slave Address	1-247 (Hexadecimal values)
Port	RS232, RS485, Modem
Protocol	ASCII, RTU, ASCII-A, RTU-A
Baud *	300 – 115.2K (all common rates)
Parity	None, Odd, Even
Stop Bits *	1, 2
Handshake	None, Software, Hardware, Multi-drop, Radio Modem
Modem Turn-Around Time	None, 0.25, 0.5, 0.75, 1.0 Second
DCS Time-out	0-12 Seconds (off if time = 0)
* Certain fields will generate a CNF_ERR on the Hand Held Programmer if they are invalid for the mode of operation.	

2.4.2 Configuration with the PLC Software

1. Install the RTU Interface module as described in the PLC documentation.

2. Execute the PLC Configuration Software.

3. Enter the Configuration Package from the Main Menu <F2>.

4. Select the proper folder.

5. Choose I/O Configuration from the Configuration Menu <F1>.

6. Cursor over to the slot containing the RTU Interface module.

7. Select Other <F8> and Foreign <F3>.

8. The following screen should be displayed.

```
>
                    MODULE IN RACK 0 SLOT 3
                         SOFTWARE  CONFIGURATION
 SLOT   Catalog #: FOREIGN                FOREIGN MODULE
   3

 FRGN
        Module ID  :    3
        %I Ref Adr :   %I0001  Byte 1     : 00000001  Byte 9     : 01
        %I Size    :     8     Byte 2     : 10010110  Byte 10    : 01
        %Q Ref Adr :   %Q0001  Byte 3     : 00        Byte 11    : 01
        %Q Size    :     8     Byte 4     : 01        Byte 12    : 02
        %AI Ref Adr:  %AI0001  Byte 5     : 01        Byte 13    : 00
        %AI Size   :     0     Byte 6     : 01        Byte 14    : 00
        %AQ Ref Adr:   %AQ001  Byte 7     : 0B        Byte 15    : 00
        %AQ Size   :     0     Byte 8     : 00        Byte 16    : 00

                                 OFFLINE
                             PRG: RTU9XX                  CONFIG VALID
```

9. Cursor down to the %I starting address and enter the starting address for the 8 %I bits.

10. Cursor down to the %I size and enter the number of %I bits for the RTU Interface Module (8).

11. Repeat steps 9 and 10 for the %Q starting address and size.

12. Cursor over to byte 1 and enter a 1 (00000001). This signifies to the PLC that the RTU Module is an intelligent module.

13. Bytes 2 and 3 are used for the location of the dial number for the HE693RTU940 (Section 3.7). ***Note: This only applies to the HE693RTU940.***

14. Bytes 2 through 12 should be setup according to Table 2-2 on the following page.

15. All remaining bytes should be set to 0.

Table 2.2 -

Byte	Parameter	Setting
2 and 3	Dial %R	The Dial %R reference must be divided into a high (byte 3) and low (byte 2) and then converted into the appropriate binary number which will be placed in byte 2. *See page 18 for more detail.*
4	Slave Address	**1 – 247**
5	Port	RS232 = **0**, RS485 = **1**, Modem = **2**
6	Protocol	ASCII = **0**, RTU = **1**, ASCII-A = **2**, RTU-A = **3**
7	Baud Rate	300 = **0**, 600 = **1**, 1200 = **2**, 2400 = **3**, 4800 = **4**, 9600 = **5**, 14400 = **6**, 19200 = **7**, 28800 = **8**, 38400 = **9**, 57600 = **0Ah**, 115200 = **0Bh**
8	Parity	None = **0**, Odd = **1**, Even = **2**
9	Stop Bits	1 = **0**, 2 = **1**
10	Handshake	None = **0**, Software = **1**, Hardware = **2**, Multi-drop = **3**, Radio Modem = **4**
11	DCS Time-out (seconds)	**0 – 12**
12	Modem TAT (seconds)	0 = **0**, 0.25 = **1**, 0.5 = **2**, 0.75 = **3**, 1.0 = **4**

CHAPTER 3: OPERATION

3.1 Modbus Protocol

The Modbus protocol uses a Master/Slave protocol that can support a common bus of one master and up to 247 Modbus Slaves. However, note that the media (RS-485) typically used for Modbus is limited to 32 units. As a Modbus slave, the RTU Interface Module must be assigned a unique address. Address zero is reserved for broadcasting a message to all units. The RTU Interface Modules will process broadcast messages but no response packet will be returned.

The Modbus master will issue a command to start the transaction. The command will contain a unit address specifying the slave which should respond. The slave will process the command and will return a single response. Message integrity is assured through use of checksums included in the messages. The Slave ignores all messages which have invalid checksums and assumes the Master has received any responses sent. It is the Master node application's responsibility to provide time-out and retry provisions.

Before the RTU Modules will respond appropriately to Modbus commands it must be configured to the frame protocol used by the other unit on the common line. This includes items such as the media (RS-485, RS-232, or modem), frame protocol such as (ASCII, RTU, ASCII-A, or RTU-A), baud rate, parity, stop bits, and, finally, optional handshaking.

3.2 Port Selection

The user may select either the RS-232, RS-485, or modem to use for communications through the PLC software configuration. The pinouts for the RS-232 and RS-485 ports are shown below. The pinout for the modem port is on page 14.

Table 3.1 – 9-Pin RS-232 Port

Pin #	Signal Name	Direction
1	[DCD] Always High	Output
2	[TXD] Transmit Data	Output
3	[RXD] Receive Data	Input
4	No Connection	N/A
5	[GND] Signal Ground	N/A
6	[DSR] Always High	Output
7	[CTS] Clear To Send	Input
8	[RTS} Request to Send	Output
9	[RI] Always High	Output

Table 3.2 – 15-Pin RS-485 Port

Pin #	Signal Name	Direction
5	[PWR] 5 VDC Power	N/A
6	[RTS-] Request To Send	Output
7	[GND] Signal To Ground	N/A
8	[CTS+] Clear To Send	Input
9	[TERM] Termination	Input
10	[RXD-] Receive Data	Input
11	[RXD+] Receive Data	Input
12	[TXD-] Transmit Data	Output
13	[TXD+] Transmit Data	Output
14	[RTS+] Request To Send	Output
15	[CTS-] Clear To Send	Input

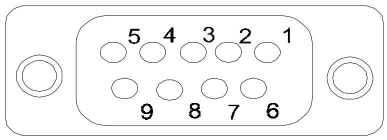


Figure 3.1 – RS-232 9-pin Connector

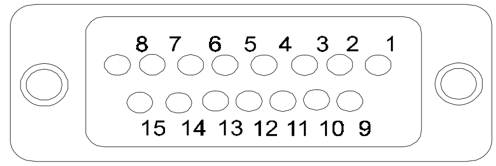


Figure 3.2 – RS-485 15-pin Connector

3.2.1 RS-232 Connections

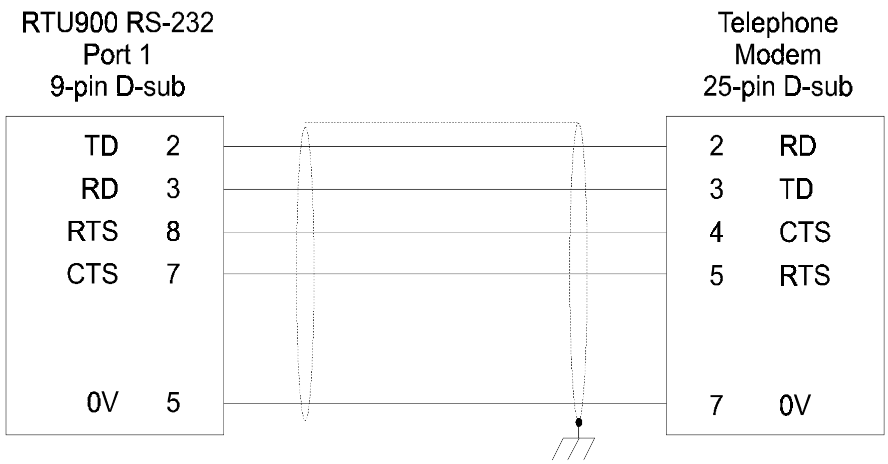


Figure 3.3 – RTU900 RS-232 to Telephone Modem Wiring

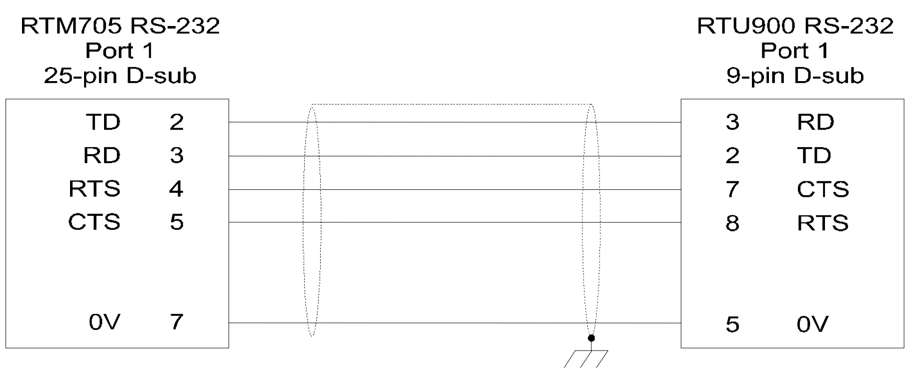


Figure 3.4 – RTM700/705 RS-232 to Horner APG RTU900 RS-232 (Port 1) Wiring

3.2.2 RS-485 Connections

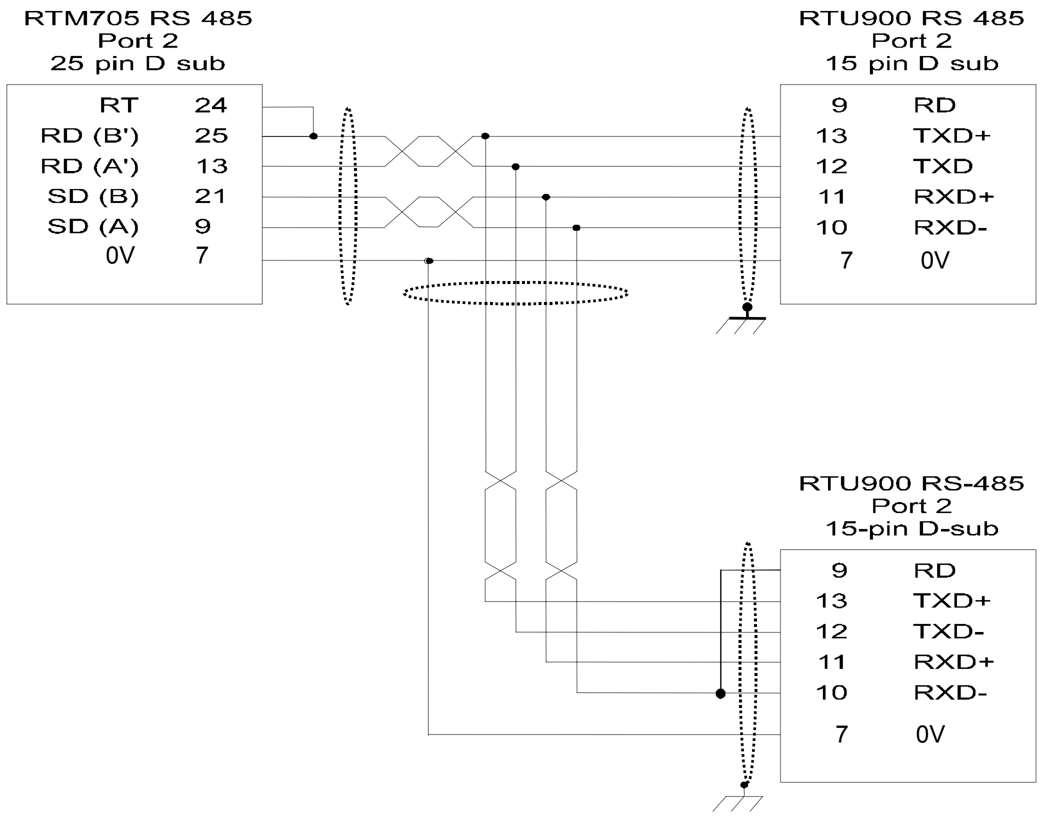


Figure 3.5 – RTM700/705 RS-485 to Horner APG RTU900 RS-485 Wiring (Two-Wire)

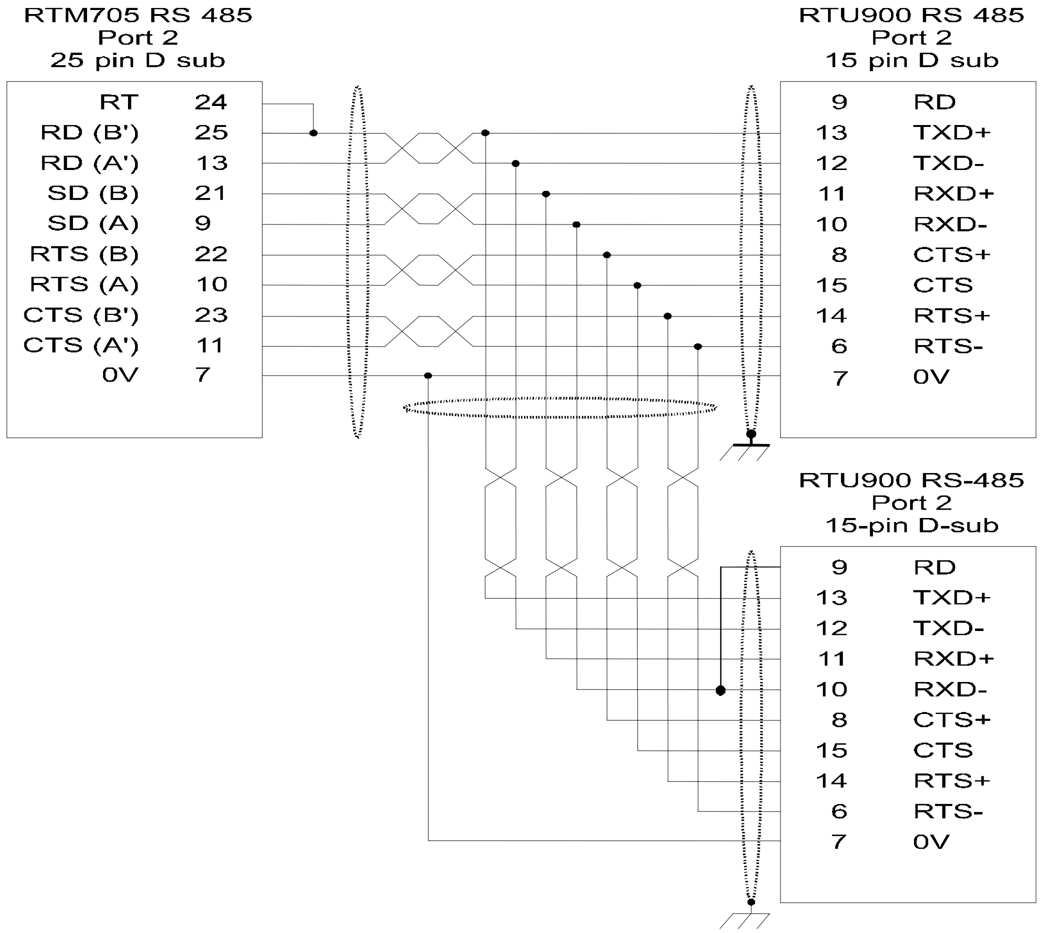


Figure 3.6 – RTM700/705 RS-485 to Horner APG RTU900 RS-485 Wiring (4-Wire Multi Drop)

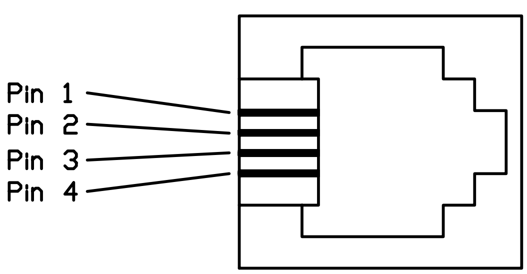


Table 3.3 – Pin Out	
Pin #	**Signal Name**
1	No Connection
2	Ring
3	Tip
4	No Connection

Figure 3.7 – Standard RJ-11 Connector

Activity on these ports may be monitored by the LED's on the front panel. See Front panel diagnostic LED's section 3.7.

3.3 Frame Protocol

RTU mode sends each byte of information in binary form thus requiring 8-bits of transmitted data. ASCII mode divides a byte of information into two nibbles and transmits each as a 7-bit hexadecimal character. The ASCII mode uses twice as many transmitted characters; however, debugging with printable ASCII characters can be much easier. Therefore, setting the mode to either ASCII or RTU indirectly sets whether the data size is 7 or 8 bits. The second (alternate) set, ASCII-A AND RTU-A, selects a new Modbus address to PLC address mapping (see pages 20-22).

In addition to the mode, the user must also know the baud rate, parity and the number of stop bits used by the other units on the common line. All these parameters are changeable with PLC software configuration.

The following frame protocol combinations are not completely interchangeable on the HE693RTU900 or HE693RTU940 and should be considered in selecting the Modbus master's frame protocol. See the highlighted paragraph below.

The configuration "ASCII mode, 1 Stop Bits and No Parity" will actually require 2 stop bits before the RTU900 will accept characters. The configuration "RTU mode, 2 Stop Bits and either Even or Odd Parity" will actually generate only 1 stop bit which may or may not affect the application's reception of characters.

3.4 Handshaking

The HE693RTU9x0 provides five different handshaking modes to provide for multi-drop configurations or to limit data flow back to masters with hardware/software limitations.

NONE - No handshaking is provided. If the slave returns data at a rate and value the master is unable to handle, data will be lost. If the RS-485 is used, the transmit driver will be enabled continuously.

SOFTWARE - The RTU Interface module suspends sending data on the reception of a XOFF character. Transfer will thereafter continue on the reception of a XON character. ***(This mode should not be used with RTU mode).***

HARDWARE - The RTU Interface asserts RTS continuously to sender. CTS is monitored during RTU transmissions. If the master drops the CTS line low, the RTU will suspend the transfer. Transfer will thereafter continue when the master raises the CTS line.

MULTI-DROP - Multi-drop handshaking is required for RS-485 multiple unit (either single or half duplex) or single unit half-duplex configurations. This enables the transmit driver only when the RTU is transmitting. For RS-232, this mode controls the CTS signal for compatibility with RS232-to-RS485 converters which can be operated in a half-duplex mode. When multi-drop handshaking is enabled, no other handshaking is available.

RADIO MODEM - Similar to hardware handshaking with the exception that RTS is only asserted when the RTU has data to send. Thereafter, the RTU sends or suspends data transfer based on the CTS line.

The radio modem mode also provides an optional modem turn-around-timer (TAT). If the modem does not respond to the RTS line within a specified period, then the transmit buffer is flushed, RTS is dropped and the frame is lost. TAT is enabled by specifying in the configuration one of the (.25, .50, .75 and 1.00 Second) time intervals. Setting the time interval to NONE disables the TAT.

3.5 DCS Active Detection

The RTU Interface Module provides the capability to optionally monitor the activity from the Modbus master. Should that activity drop off, a bit is set in both the configured %I reference (Bit 0) and the Modbus exception status byte; furthermore, the DCS LED will begin to flash at a 1 second rate. This provides a method for the CPU, maintenance operator and the master to determine if the master is functioning properly.

To enable this feature, set the DCS configuration entry to the amount of time you wish the RTU Module to wait after the last communications frame was sent before setting the indication bit. The time-out value is limited to 1 through 12 Seconds. Setting the Time-out value to zero disables this feature.

The %I reference (Bit 0) and the DCS LED are reset immediately when master communications is restored. The bit in the Exception status byte remains set until after the Modbus Read Exception command is received.

In instances where the HE693RTU940 is used in conjunction cellular phones, the baud rate should be set to 300 to avoid data corruption due to noise and the DCS will need to be adjusted according to message size. Configuring the DCS to a setting of 5 or more should eliminate any data errors.

3.6 Front Panel Diagnostic LED's

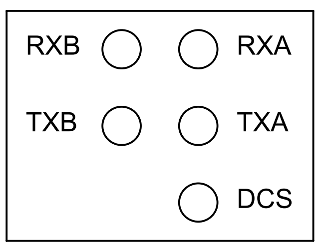


Figure 3.7 – Front Panel Diagnostic LEDs

RXA, TXA will flicker when there is activity on the associated lines for the RS-232 port. If the RS-485 port is active, RXB, TXB will flicker when there is activity on the associated lines for that port. If the modem port is selected, RXA will flicker indicating off-hook activity and TXA will flicker indicating an incoming call.

If DCS has not timed out or is not enabled, the DCS LED will momentarily light when a valid Modbus message has been received and is being processed by the RTU Interface Module. If the RX light is flashing and the DCS is not, this generally indicates that the frame protocol is incorrect. If DCS is enabled and timed out, this LED flashes at a constant 1 Second rate.

3.7 Dial %R (HE693RTU940 only)

The Dial %R parameter is the reference address that specifies the registers that are used to store the phone number (dial string) the user wishes to dial. This setting varies in the number of registers used according to the length of the dial string. **The registers used for the Dial %R parameter must not**

conflict with the use of any other module. Discrete input (%I) and output (%Q) registers are used to monitor status and initiate calls, respectively.

3.7.1 Use and Configuration of Dial %R

The Dial %R is the last parameter using the HHP and the second and third Byte when configuring with the PLC Software. Using the HHP, the Dial %R parameter is entered in decimal form. Using the PLC Configuration Software, the Dial %R setting must be divided into a high (Byte 3) and a low (Byte 2) Byte value and then converted to the appropriate binary format. Once the value has been converted to binary form, it is placed in Byte 2 of the configuration.

The number of registers used by the Dial %R parameter depends upon the length of the number the user wishes to dial. Each register contains a maximum of up to two characters. For example, if the user is calling a 7-digit number, then 4 consecutive registers are used.

The 8 %I registers configured give the status of the modem. Of 8 %Q registers configured, only the first is used. %Q1 is used to initiate the call. A high transition (1) initiates the call. A low transition (0) clears the status register. The following page contains a detailed list of the status and control registers and their uses. Also see the *Dial %R Example* section for help.

Table 3.4 – Status Bits

%I BITS	
%I1	DCS time-out
%I2	Bad string or modem rejection
%I3	Local busy
%I4	Remote busy
%I5	No dial tone
%I6	No answer
%I7	No carrier
%I8	Connection complete

Table 3.5 – Control Bits

%Q BITS	
%Q1	Initiates call
%Q2	Not used
%Q3	Not used
%Q4	Not used
%Q5	Not used
%Q6	Not used
%Q7	Not used
%Q8	Not used

3.7.2 Dial %R Example

This example is designed to originate a call from the HE693RTU940, taking advantage of the Report-By-Exception feature. The Dial %R parameter is configured beginning at %R150. The telephone number that is called is **123-4567**. The call is being initiated from within a building that requires the use of a '**9**' at the beginning of telephone number to access outside calls. Because of the local exchange needed to access outside lines, a delay must be entered to allow for proper modem response. Any time a local exchange takes place, a delay must be entered. The complete number that must be entered beginning at %R150 is **9,1234567**.

The Dial %R parameter is the last configuration setting using the HHP. The setting is directly entered at the prompt. Using the HHP, the dial string can only be entered in hexadecimal format. Following the example above, if the Dial %R is to be configured at %R150, then the value 150 is entered at the parameter prompt. If using the PLC Configuration Software, the Dial %R value of 150 has to be converted from ASCII (decimal) to binary format and entered in
Byte 2.

Following the example, If ASCII **150** = Binary **10010110,** then **Byte 2 = 10010110**

3.7.3 Dial String

The dial string is a group of characters used by the Dial %R command to initiate a call. The example telephone number being dialed is 9 characters in length. Each register holds a maximum of two digits. Therefore, 5 registers are needed for the dial string (%R150 - 154).

Two ways are used to enter the dial string using the PLC Programming Software: ASCII and hexadecimal. The ASCII field must be selected from the Programming menu and quotation marks have to be used before and after each pair of dial string values entered. For example, if the user was entering the values **9** and **,** into %R150, then the process would be:

1. From the PLC Programming Software, select 'Reference Tables' (F2).
2. Cursor to each %R that will contain dial string characters and select 'ascii' (F7) format.
3. Select the %R150 and type **"9,"** (include quotation marks). Strike the 'Enter' key to input the values to the appropriate registers.

Follow this process for the remaining dial string.

If entering the dial string in hexadecimal format using the PLC Programming Software, then select 'hex' (F5) and convert the group of registers to a hexadecimal format. Each dial string character would then be entered according to it's ASCII equivalent, no quotation marks needed. See Appendix A on page 22 for an ASCII/HEX conversion chart.

Using the HHP, the dial string can only be entered in hexadecimal format. Simply go to %R150 and enter the dial string in the consecutive registers in hexadecimal format. See Tables 3-6, 3-7, and 3-8 for Configuration Examples and Appendix B on page 23 for Special Dial String Characters. **Note: The dial string is entered into the PLC Programming Software and the Hand Held Programmer from right to left. Example: The number "1" followed by "2" would be entered into these two devices, "3231."**

Table 3.6 – Configuration Possibilities				
Dial %R	Dial String	PLC Programming Software		HHP
		ASCII	Hexadecimal	Hexadecimal
150	9	9	39	39
150	,	,	2C	2C
151	1	1	31	31
151	2	2	32	32
152	3	3	33	33
152	4	4	34	34
153	5	5	35	35
153	6	6	36	36
154	7	7	37	37

Table 3.7 – Dial %R for PLC Configuration Software					
	%R154	%R153	%R152	%R151	%R150
Decimal	7	6 5	4 3	2 1	,9
Hexadecimal	0037	3635	3433	3231	2C39

Table 3.8 – Dial %R for HHP (hex)				
%R154	%R153	%R152	%R151	%R150
0037	3635	3433	3231	2C39

3.7.4 Call Initialization

Once the dial string has been entered into the appropriate registers, then the first discrete output (%Q) configured for the HE693RTU940 is toggled to initiate a call. Entering a '**1**' into the register calls the dial string at the Dial %R reference, in our previous example, %R150. Entering a '**0**' into the register clears the status register and disconnects the call.

Once the %Q has been set high and the telephone number dialed, the Report-By-Exception command is sampled to see if the call was accepted. If the call was accepted, the Master will issue a Modbus request for the station ID. The Master will then request data at a predetermined location. When the Master hangs up, the local modem will drop the Carrier Detect (DCD) and the slave will set status OK (%I8). **The connection is broken each time a command is completed. The modems do not stay connected.**

3.8 Supported Modbus Commands

Table 3.9 – supported Modbus Commands						
Code	**Meaning**	**I/O**	**Unit**	**Min**	**Max**	**Duplicates**
01	Read Coil Status	I	Bit	1	2000	
02	Read Input Status	I	Bit	1	2000	[01]*
03	Read Holding Registers	I	Word	1	125	
04	Read Input Registers	I	Word	1	125	[03]*
05	Force Single Coil	O	Bit	1	1	
06	Preset Single Register	O	Word	1	1	
07	Read Exception Status	I	Bit	8	8	
08	Loopback Diagnostic Test	N/A	N/A	N/A	N/A	
15	Force Multiple Coils	O	Bit	1	2000	
16	Preset Multiple Registers	O	Word	1	125	
* Indicates that this command duplicates that function code listed. The reference accessed is instead determined by the specified reference (Address).						

3.8.1 Modbus Command Descriptions

The format of the commands are as in the Modbus specification with the exception of reference (Address) field. See Section 3.10: *PLC to Modbus I/O Mapping* for more information.

It is not in the scope of this document to describe each command in detail. For more specific information on the standard Function Codes, Sub-function Codes and exception responses, refer to the "Gould Modbus Protocol Reference Guide" (PI-MBUS-300 Rev. B) published by Gould, Inc. or "GE Fanuc Series 90 PLC Serial Communications User's Manual" (GFK-0582B).

RTU Module specific information is described on the following page for the Read Exception Status and the Loopback Diagnostic Test.

3.8.2 Read Exception Status Command (RTU Module specifics)

The Modbus Read Exception Status command returns a byte value which indicates the status of the RTU Interface Module. The following defines each bit in the status byte.

Table 3.10 -							
7	6	5	4	3	2	1	0
MTE	MRS	PLH	PLL	I/O FLTS	PLC FLTS	I/O ENAB	RUN

MTE	DCS timeout has occurred; cleared after the Read Exception Status command done.
MRS	CPU/RTU Interface Module has been reset since last Read Exception Status command.
PLH/PLL	2-bit designation of privilege level. Level 1 indicates privilege to only read data tables. Level 2 indicates privilege to read and write data tables.
I/O FLTS	Indicates CPU has I/O faults in the fault table.
PLC FLTS	Indicates CPU has CPU faults registered in the fault table.
I/O ENAB	Indicates CPU has I/O enabled.
RUN	Indicates CPU is in run mode.

3.8.3 Loopback Diagnostics Test Command (RTU Module specifics)

The RTU Module supports the following standard Diagnostic Codes for Loopback Diagnostics Test command:

Table 3.11 – Loopback Diagnostic Test Commands	
Code	**Meaning**
00	Return 2 byte data field (loopback test)
01*	Reset RTU Module
02*	Return 16-bit RTU Module diagnostic register (last major error)
04	Force Slave into listen only mode
10	Clear counters and diagnostic register
11	Return 16-bit bus message count
12	Return 16-bit bus invalid error check count
13	Return 16-bit Bus exception count
14	Return 16-bit Slave message count
15	Return 16-bit Slave no response count

*RTU Module Specific Diagnostic Codes [01 and 02]:

[01] Reset RTU Module only resets listen-only-mode if it was set earlier with diag code 04.
[02] Return Diagnostics register returns the major error code if a failure-in-device exception response is returned.

If a failure-in-device exception response is returned, the application should issue the Loop-back Diagnostics Test with diagnostic code 02 command to return the RTU Interface Module diagnostics register. The following returned values are typical:

0002 - Invalid Privilege. The CPU has a password assigned for writing to the Data tables. See Passwords.
0007 - SR Queue Full. The CPU service requester is overloaded, reduce CPU communications traffic.
0008 -SR Queue Ovfl. The CPU service requester is overloaded, reduce CPU communications traffic.

Frequent occurrences of any other diagnostic word value indicates an internal error and should be reported to Technical Support.

3.9 Modbus Responses

Modbus Commands and Responses consist of "message frames" which contains the following information:

Slave Address
Function Code
Data
Error Check Code

If a Modbus command's address matches a Modbus Slave's address and the received data is validated by the Error Check Code, then that slave executes the indicated function. The slave will also issue a response based on that function. Alternately, if a Modbus Command's address is zero (broadcast), all Modbus slaves will execute the command; however, no slave will issue a response. Note that only Function Codes of 5, 6,15,16, 72 and some sub-functions of Function 8 may be "broadcast" in this way. A normal response will contain the same slave address and function code as the request; however, the individual data field(s) may vary according to the function.

If the Modbus slave detects an error either internally or in the command parameters, the command will not be executed and the function will return an Exception Response. An exception response is indicated by setting the high bit in the returned function code and returned data byte describing the exception.

The RTU Module supports the standard Exception codes listed below:

Table 3.12 – Standard Exception Codes

Code	Name	Meaning
01	Illegal function	Invalid command function was sent
02	Illegal data address	Invalid reference, or size exceeded table bounds
03	Illegal data value	Not valid data for a particular reference
04	Failure in device	See Loopback Diagnostic Test command for details

3.10 PLC to Modbus I/O Mapping

The Modbus commands which read and write to data tables require a reference (starting point) and, in some cases, the number of points. The Modbus command reference provided and the PLC data table element accessed by the RTU module in the PLC are not necessarily equal as described below.

Originally, the Modbus protocol was only meant to access 4 different data tables with limited writing of data. The RTU module expands these limitations by performing reference mapping. The RTU module contains a map of PLC data tables and assigns a range of associated Modbus references to each data table.

Table 3.13 – Discrete Data Accesses		
For Reads		Read Input Status [single or multiple]
		Read Coil Status [single or multiple]
For Writes		Force Single Coil
		Force Multiple Coils
Modbus Reference Selection		
PLC Reference		Modbus Reference
%M	1 – 4096	0 – 0FFFH
%I	1 – 2048	A000 – A7FFH
%Q	1 – 2048	C000 – C7FFH
%T	1 – 256	E000 – E0FFH

Table 3.14 – Analog Data Accesses		
For Reads		Read Holding Register [single or multiple]
		Read Input Register [single or multiple]
For Writes		Preset Register
		Preset Multiple Registers
Modbus Reference Selection		
PLC Reference		Modbus Reference
%R	1 – 9999	0 – 270EH
%AI	1 – 2048	A000 -= A7FFH
%AQ	1 – 512	C000 – C1FFH
%PWL	N/A	F000H

Therefore, the user can access more than one PLC data table with a single Modbus command by simply changing the reference. The tables above describe the sub-divided regions of the Modbus reference to access the appropriate data table.

For example - To read %AQ20...

Use Modbus Read Holding Register with reference:

%AQ start	-	C000h
offset 20 - 1 = 19 (13h)	-	13h
		C013h

Each model of the PLC CPU contains a different maximum number of points for each data table. During initialization of the RTU module, the CPU is interrogated for the size of each of its data tables. Should a Modbus reference and

Table 3.15 – Discrete Data Access – Map Mode (A)lternate

Modbus Command Supported	PLC Reference (Decimal)		Modbus Reference (Hex)	Conventional Modbus Addressing (Decimal)
Read Input Status (2)	%I	1 - 2048	0 – 7FF	10001 - 12048
Read Coil Status (1), Force Single Coil (5), Force Multiple Coils (15)	%Q	1 - 2048	0 – 7FF	00001 - 02048
	%M	1 - 4096	1000 – 1FFF	04097 – 08192
	%T	1 - 256	2200 – 2299	08705-08960

Table 3.16 – Analog Data Access – Map Mode (A)lternate

Modbus Command Supported	PLC Reference (Decimal)		Modbus Reference (Hex)	Conventional Modbus Addressing (Decimal)
Read Analog Input (4)	%AI	1 – 2048	0 – 7FF	30001 - 32048
Read Holding Register (3), Preset Single Register (6), Preset Multiple Registers (16)	%R	1 – 8192	0 – 1FFF	40001 - 48192
	%AQ	1 – 512	2200 – 2399	48705 - 49216

NOTES

APPENDIX A: ASCII / HEXIDECIMAL TABLE

The following is a list of the ASCII (American Standard Code for Information Interchange) character set.

<table>
<tr><th>DEC</th><th>HEX</th><th>Character</th></tr>
<tr><td>00</td><td>00H</td><td>NULL</td></tr>
<tr><td>01</td><td>01H</td><td>SOH</td></tr>
<tr><td>02</td><td>02H</td><td>STX</td></tr>
<tr><td>03</td><td>03H</td><td>ETX</td></tr>
<tr><td>04</td><td>04H</td><td>EOT</td></tr>
<tr><td>05</td><td>05H</td><td>ENQ</td></tr>
<tr><td>06</td><td>06H</td><td>ACK</td></tr>
<tr><td>07</td><td>07H</td><td>BELL</td></tr>
<tr><td>08</td><td>08H</td><td>BS</td></tr>
<tr><td>09</td><td>09H</td><td>HT</td></tr>
<tr><td>10</td><td>0AH</td><td>LF</td></tr>
<tr><td>11</td><td>0BH</td><td>VT</td></tr>
<tr><td>12</td><td>0CH</td><td>FF</td></tr>
<tr><td>13</td><td>0DH</td><td>CR</td></tr>
<tr><td>14</td><td>0EH</td><td>SO</td></tr>
<tr><td>15</td><td>0FH</td><td>SI</td></tr>
<tr><td>16</td><td>10H</td><td>DLE</td></tr>
<tr><td>17</td><td>11H</td><td>DC1</td></tr>
<tr><td>18</td><td>12H</td><td>DC2</td></tr>
<tr><td>19</td><td>13H</td><td>DC3</td></tr>
<tr><td>20</td><td>14H</td><td>DC4</td></tr>
<tr><td>21</td><td>15H</td><td>NAK</td></tr>
<tr><td>22</td><td>16H</td><td>SYN</td></tr>
<tr><td>23</td><td>17H</td><td>ETB</td></tr>
<tr><td>24</td><td>18H</td><td>CAN</td></tr>
<tr><td>25</td><td>19H</td><td>EM</td></tr>
<tr><td>26</td><td>1AH</td><td>SUE</td></tr>
<tr><td>27</td><td>1BH</td><td>ES1</td></tr>
<tr><td>28</td><td>1CH</td><td>FS2</td></tr>
<tr><td>29</td><td>1DH</td><td>GS</td></tr>
<tr><td>30</td><td>1EH</td><td>RS</td></tr>
<tr><td>31</td><td>1FH</td><td>US</td></tr>
<tr><td>32</td><td>20H</td><td>SPACE</td></tr>
<tr><td>33</td><td>21H</td><td>!</td></tr>
<tr><td>34</td><td>22H</td><td>“</td></tr>
<tr><td>35</td><td>23H</td><td>#</td></tr>
<tr><td>36</td><td>24H</td><td>$</td></tr>
<tr><td>37</td><td>25H</td><td>%</td></tr>
<tr><td>38</td><td>26H</td><td>&</td></tr>
<tr><td>39</td><td>27H</td><td>‘</td></tr>
<tr><td>40</td><td>28H</td><td>(</td></tr>
<tr><td>41</td><td>29H</td><td>)</td></tr>
<tr><td>42</td><td>2AH</td><td>*</td></tr>
<tr><td>43</td><td>2BH</td><td>+</td></tr>
<tr><td>44</td><td>2CH</td><td>’</td></tr>
<tr><td>45</td><td>2DH</td><td>-</td></tr>
<tr><td>46</td><td>2EH</td><td>.</td></tr>
<tr><td>47</td><td>2FH</td><td>/</td></tr>
<tr><td>48</td><td>30H</td><td>0</td></tr>
<tr><td>49</td><td>31H</td><td>1</td></tr>
<tr><td>50</td><td>32H</td><td>2</td></tr>
<tr><td>51</td><td>33H</td><td>3</td></tr>
<tr><td>52</td><td>34H</td><td>4</td></tr>
<tr><td>53</td><td>35H</td><td>5</td></tr>
<tr><td>54</td><td>36H</td><td>6</td></tr>
<tr><td>55</td><td>37H</td><td>7</td></tr>
<tr><td>56</td><td>38H</td><td>8</td></tr>
<tr><td>57</td><td>39H</td><td>9</td></tr>
<tr><td>58</td><td>3AH</td><td>:</td></tr>
<tr><td>59</td><td>3BH</td><td>;</td></tr>
<tr><td>60</td><td>3CH</td><td><</td></tr>
<tr><td>61</td><td>3DH</td><td>=</td></tr>
<tr><td>62</td><td>3EH</td><td>></td></tr>
<tr><td>63</td><td>3FH</td><td>?</td></tr>
<tr><td>64</td><td>40H</td><td>@</td></tr>
<tr><td>65</td><td>41H</td><td>A</td></tr>
<tr><td>66</td><td>42H</td><td>B</td></tr>
<tr><td>67</td><td>43H</td><td>C</td></tr>
<tr><td>68</td><td>44H</td><td>D</td></tr>
<tr><td>69</td><td>45H</td><td>E</td></tr>
<tr><td>70</td><td>46H</td><td>F</td></tr>
<tr><td>71</td><td>47H</td><td>G</td></tr>
<tr><td>72</td><td>48H</td><td>H</td></tr>
<tr><td>73</td><td>49H</td><td>I</td></tr>
<tr><td>74</td><td>4AH</td><td>J</td></tr>
<tr><td>75</td><td>4BH</td><td>K</td></tr>
<tr><td>76</td><td>4CH</td><td>L</td></tr>
<tr><td>77</td><td>4DH</td><td>M</td></tr>
<tr><td>78</td><td>4EH</td><td>N</td></tr>
<tr><td>79</td><td>4FH</td><td>O</td></tr>
<tr><td>80</td><td>50H</td><td>P</td></tr>
<tr><td>81</td><td>51H</td><td>Q</td></tr>
<tr><td>82</td><td>52H</td><td>R</td></tr>
<tr><td>83</td><td>53H</td><td>S</td></tr>
<tr><td>84</td><td>54H</td><td>T</td></tr>
<tr><td>85</td><td>55H</td><td>U</td></tr>
<tr><td>86</td><td>56H</td><td>V</td></tr>
<tr><td>87</td><td>57H</td><td>W</td></tr>
<tr><td>88</td><td>58H</td><td>X</td></tr>
<tr><td>89</td><td>59H</td><td>Y</td></tr>
<tr><td>90</td><td>5AH</td><td>Z</td></tr>
<tr><td>91</td><td>5BH</td><td>[</td></tr>
<tr><td>92</td><td>5CH</td><td>\</td></tr>
<tr><td>93</td><td>5DH</td><td>]</td></tr>
<tr><td>94</td><td>5EH</td><td>^</td></tr>
<tr><td>95</td><td>5FH</td><td>_</td></tr>
<tr><td>96</td><td>60H</td><td>‘</td></tr>
<tr><td>97</td><td>61H</td><td>a</td></tr>
<tr><td>98</td><td>62H</td><td>b</td></tr>
<tr><td>99</td><td>63H</td><td>c</td></tr>
<tr><td>100</td><td>64H</td><td>d</td></tr>
<tr><td>101</td><td>65H</td><td>e</td></tr>
<tr><td>102</td><td>66H</td><td>f</td></tr>
<tr><td>103</td><td>67H</td><td>g</td></tr>
<tr><td>104</td><td>68H</td><td>h</td></tr>
<tr><td>105</td><td>69H</td><td>i</td></tr>
<tr><td>106</td><td>6AH</td><td>j</td></tr>
<tr><td>107</td><td>6BH</td><td>k</td></tr>
<tr><td>108</td><td>6CH</td><td>l</td></tr>
<tr><td>109</td><td>6DH</td><td>m</td></tr>
<tr><td>110</td><td>6EH</td><td>n</td></tr>
<tr><td>111</td><td>6FH</td><td>o</td></tr>
<tr><td>112</td><td>70H</td><td>p</td></tr>
<tr><td>113</td><td>71H</td><td>q</td></tr>
<tr><td>114</td><td>72H</td><td>r</td></tr>
<tr><td>115</td><td>73H</td><td>s</td></tr>
<tr><td>116</td><td>74H</td><td>t</td></tr>
<tr><td>117</td><td>75H</td><td>u</td></tr>
<tr><td>118</td><td>76H</td><td>v</td></tr>
<tr><td>119</td><td>77H</td><td>w</td></tr>
<tr><td>120</td><td>78H</td><td>x</td></tr>
<tr><td>121</td><td>79H</td><td>y</td></tr>
<tr><td>122</td><td>7AH</td><td>z</td></tr>
<tr><td>123</td><td>7BH</td><td>{</td></tr>
<tr><td>124</td><td>7CH</td><td>|</td></tr>
<tr><td>125</td><td>7DH</td><td>}</td></tr>
<tr><td>126</td><td>7EH</td><td>~</td></tr>
<tr><td>127</td><td>7FH</td><td>DEL</td></tr>
</table>

NOTES

APPENDIX B: SPECIAL DIAL STRING CHARACTERS

Dial the Number Immediately Following this Command

Where ***n*** = digits 0 to 9, the symbols # and *, and may include the dial modifiers listed below.

The modem will dial the number specified in the manner determined by the dial modifiers. The dial modifiers may appear anywhere within the dial string with the exception of the ; modifier which must appear at the end of the string.

Dial Modifiers:

P	Pulse dial
T	Tone dial
,	Pause
@	Wait for quiet before dialing

Example: P9T713,123-4567;

In this example the modem pulse dials a 9-digit number, waits for a dial tone, then tone dials the digits 713. It then dials the number 123-4567. Finally, the modem returns to the command mode after the final digit has been dialed.

The **P** modifier causes the modem to pulse or rotary dial at a fixed rate of 10 pulses per second.

The **T** modifier causes the modem to dial using DTMF (Dual-tone multifrequency) signals (the same as those used by “touch-tone” telephones).

The "," modifier causes the modem to pause. When dialing a long distance service, for example, the modem must first dial the local access number, then pause long enough for the services dial tone. The "," is also useful when dialing from a PBX system where considerable time may elapse between requesting and getting a secondary dial tone or "outside" line.

The **@** modifier causes the modem to wait for 3 seconds for one or more rings followed by 5 seconds of silence before processing the next symbol in the dial string. This is useful when accessing systems that do not provide a dial tone.

NOTES