E-102

p.n. 143896

Despatch

Modbus User's Programming Manual

For

Despatch Protocol^{TM} Plus

A-51643 Rev. 6 10/06/03

Revision History

Rev.	Date	Description
0	10/6/1998	Original Release
1	01/25/1999	Major revisions to match tested software.
2	02/12/1999	Corrected temperature readout descriptions to 1 °F from 0.1 °F. Corrected misc. typos. Removed front panel security code holding register. Moved communication security code holding register to address 0.
3	03/22/1999	Corrected figure references in communication card setup sections. Added text concerning level 1 & 2 password holding registers.
4	01/24/2002	Added holding register address references for new menus for software version 3.0 and 3.1(Heat/Cool).
5	06/10/2002	Added section 7, Programming Example and General Hints
6	10/6/2003	Section 3.6, change data address information in register 449.

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1 Overview

1.1 Purpose

This document provides all application specific information necessary for developing a Modbus Master application program for interfacing with the Protocol™ Plus slave controller. The assumption is made that the programmer has at least an intermediate understanding of the Modbus Protocol. Only limited information is presented here regarding the Modbus Protocol specifications. Below is a list of relevant Modbus Protocol documents. A quick reference section is provided in this document (see section **6 Modbus Protocol Quick Reference**). A programming guideline section provides a programming example and general communications hints (see section **7 Programming Example and General Hints** for programming help).

Table 1: Modbus References

Modicon Modbus Protocol	http://www.modicon.com/techpubs/intr7.html
Schneider Automation Open Modbus/TCP Specification	http://www.modicon.com/openmbus.html/

Table 2: Protocol™ Plus References

Engineering Specification for Despatch Protocol™ Plus	A-50778

1.2 Conventions and definitions

RTU: Remote Terminal Unit

CRC: Cyclical Redundancy Check

$: Represents a hexadecimal number

XOR: Exclusive OR logic operation

LSB: Least Significant Bit

MSB: Most Significant Bit

XX: Don't Care when used in a hex number

--: Field contents are data dependent

NA: Not Applicable

TBD: To Be Determined or To Be Defined

2 Communications Specifications

2.1 Support Specifications

Device Support: Slave only.

Slave ID Code (Identifies Product Line): 1.

Transmission Mode: RTU mode only.

Communication Medium: RS232, RS422, or RS485.

Address Support: 1 – 247.

Baud Rate: 2400, 4800, 9600, 19.2K, 38.4K

Parity: None, Even, or Odd.

2.2 Timing Specifications

Message Framing: Silent period of at least 3.5 character times before the first character and after the last character of the message.

Character Framing: No more than 1.5 character times of silence between received and transmitted characters.

Message Timeout (Query Response Time): Response to queries will be made within 1 sec.

2.3 Wiring

Figure 1: RS232 Wiring

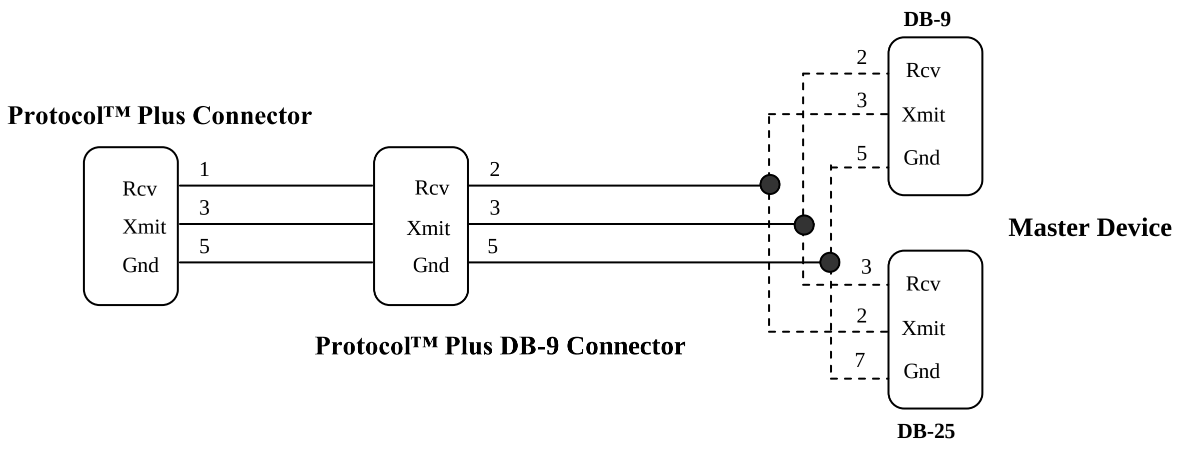


Figure 2: RS422A Wiring (4 wire)

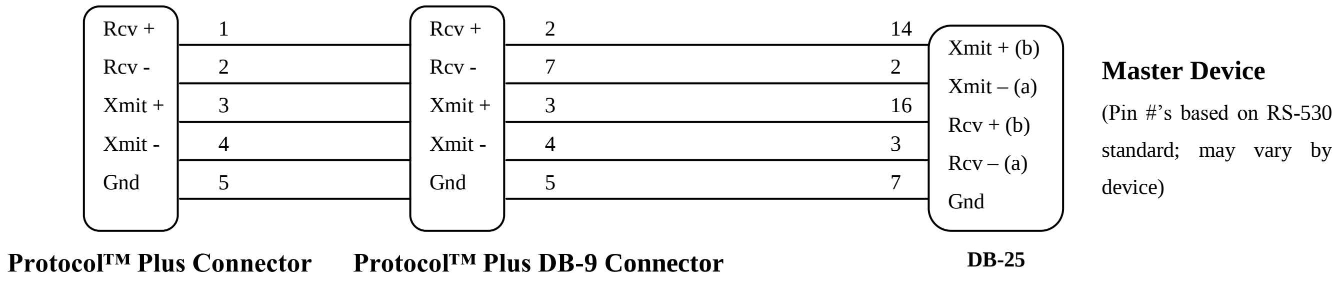
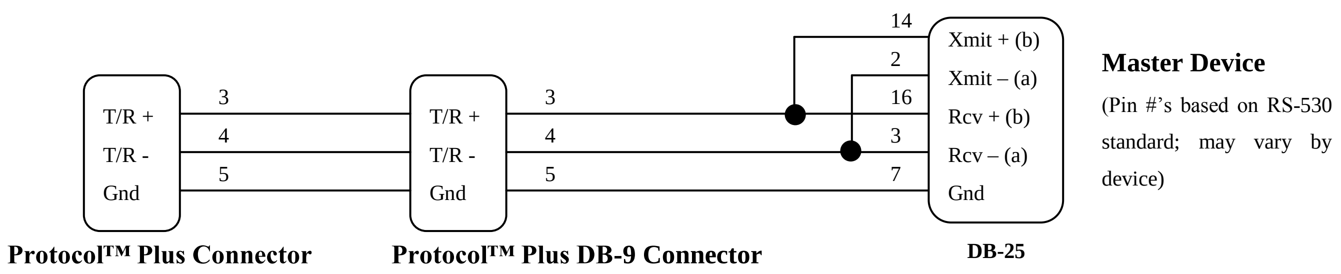


Figure 3: RS485 Wiring (2 wire)



2.4 Communication Card Installation and Jumper Settings

WARNING

Electronic Components are extremely sensitive to static electricity. Before opening the controller case, read and follow the precautions below to prevent damage from static electricity.

1. **Turn off power to the controller.**
2. **Touch a bare metal surface on the exterior of the controller.**
3. **Disconnect the power connection from the controller or unplug from the power source.**

Also follow these static electricity precautions:

❖ Avoid static-causing surfaces while working with electronic components.

❖ Remove parts from their anti-static bags only when ready for use. Do not lay parts on the outside of the anti-static bag because only the inside provides protection.

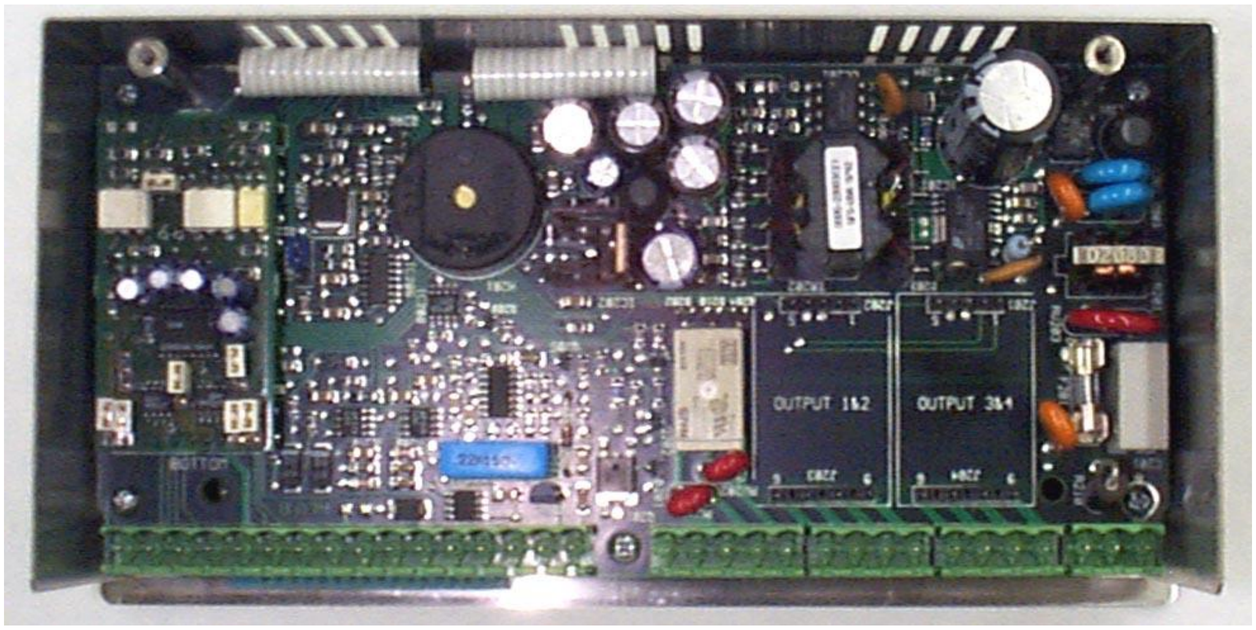
❖ Hold circuit boards by their edges or any metal mounting hardware. Avoid touching components or connectors on the circuit boards.

2.4.1 Communication Card (0113-10175) Installation

1. Turn off power to the controller.
2. Remove the back cover of the controller by removing the two screws at the top of the unit.

3. Looking into the back of the controller with the connector terminal strips at the bottom, install the communication card onto the two 5 pin headers on the rear circuit board. Be sure the jumper blocks on the communication card are positioned toward the bottom of the controller. **See Figure 4: Controller Rear View with Communication Card (Left)**. Be sure the card is seated firmly onto the headers.
4. Set the jumpers on the communication card for the desired serial communication interface based on **Figure 5: Communication Card (0113-10175) Jumper** Settings.
5. Reinstall the back cover.
6. Wire the communication connections on the rear of the unit for the desired serial communication interface based on **Figure 1: RS232 Wiring, Figure 2: RS422A Wiring (4 wire), or Figure 3: RS485 Wiring (2 wire).**
7. Reapply all power connections to the controller.

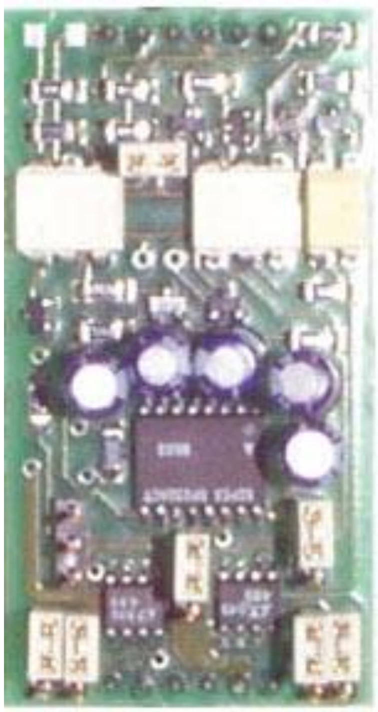
Figure 4: Controller Rear View with Communication Card (Left)

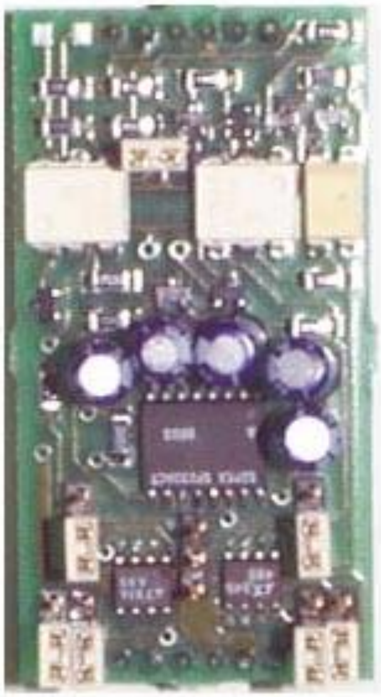


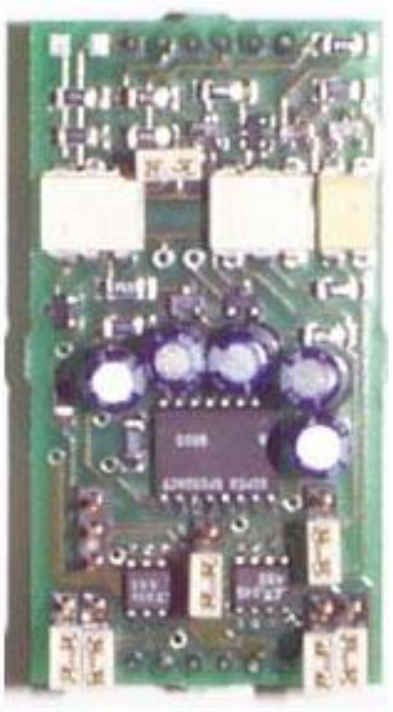
2.4.2 Communication Card Jumper Settings

1. Turn off power to the controller.
2. Remove the back cover of the controller (if it is not already removed) by removing the two screws at the top of the unit.
3. Set the jumpers on the communication card for the desired serial communication interface based on **Figure 5: Communication Card (0113-10175) Jumper** Settings.
4. Reinstall the back cover.
5. Reapply power to the controller.

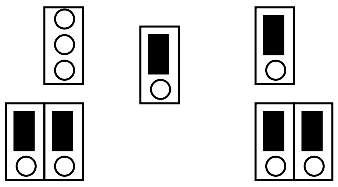
Figure 5: Communication Card (0113-10175) Jumper Settings



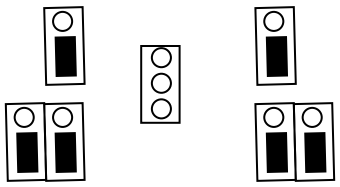




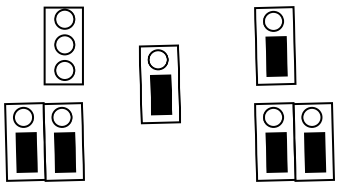
RS232 Jumper Settings



RS422 Jumper Settings



RS485 Jumper Settings



3 Register and I/O Mapping

3.1 Unmapped and Reserved Registers

Reserved and NA registers will be read as zero with no exception error being generated. Thus, the host can request data from multiple addresses with gaps between and still receive a valid response. Illegal and undefined register address blocks will always generate an illegal data address exception.

Reserved and NA registers may be written without generating an exception, however the data is ignored for these registers and no write takes place. Illegal and undefined register address blocks will always generate an illegal data address exception.

3.2 Register Quantity Limitations

The number of registers that can be accessed in one query is limited to 50.

3.3 Discrete Input Assignments

The status of the four event inputs can be read as discrete inputs in Modbus format.

Table 3: Protocol^{TM} Plus Discrete Input Address Map

Data Address	Hex Address	Description	Security
0	$0000	Event Input 1	0
1	$0001	Event Input 2	0
2	$0002	Event Input 3	0
3	$0003	Event Input 4	0
4 -- 7	$0004 -- $0007	Illegal, Reserved for future inputs	0
8 -- 65535	$0008 - $FFFF	Undefined, available for application assignment	0

3.4 Discrete Output Assignments

The status of the four relay outputs can be read as discrete outputs in Modbus format. Writes to the outputs are not supported, that is, the functions “Write Single Output” (06) and “Write Multiple Outputs” (15) are not implemented.

Table 4: Protocol™ Plus Discrete Output Address Map

Data Address	Hex Address	Description	Security
0	$0000	Relay Output 1	0
1	$0001	Relay Output 2	0
2	$0002	Relay Output 3	0
3	$0003	Relay Output 4	0
4 -- 7	$0004 -- $0007	Illegal, Reserved for future inputs	0
8 -- 65535	$0008 - $FFFF	Undefined, available for application assignment	0

3.5 Input Register Assignments

Input registers are intended for read only information and functions that cannot or should not be controlled remotely. Much status information is mapped as holding registers so that operations can be controlled remotely. Examples are control output commands, ramp/soak status (run, hold, stop), and ramp/soak program number.

Table 5: Protocol^{TM} Plus Input Register Address Map

Data Address	Hex Address	Description	Page[menu] Association or Range	Security Level	Comments
Control Loop Input Registers					
0	0	PV	Sensor range	0	read as xxxx deg. F
1	1	Active SP	Sensor range	0	read as xxxx deg. F
2	2	Active Hi Limit SP	Sensor range	0	read as xxxx deg. F
3	3	PV Status	-1, 0, 1	0	-1 = underrange, 0 = in range, 1 = overrange
4	4	NA	0	0	
5	5	Hi Limit PV	Sensor Range	0	read as xxxx deg. F
6	6	Hi Limit PV Status	-1, 0, 1	0	-1 = underrange, 0 = in range, 1 = overrange
7	7	Control Output Command	0 - 100.0	0	value has an implied decimal pt. of 1
8	8	Hi Limit Output	0, 1	0	0 = Off, 1 = On
9	9	Max Hi Limit SP	Control[Hi-Lim SP]	0	read as xxxx deg. F
10	A	NA	0	0	
11	B	PV Max	Sensor Range	0	read as xxxx deg. F
12	C	PV Min	Sensor Range	0	read as xxxx deg. F
13	D	Reserved for factory use			
14	E	Reserved for factory use			
15	F	Reserved for factory use			
16 -- 127	10 -- 7F	Illegal, Reserved standard reg.			
Timer/Profile Input Registers					
128	80	Segment Number	1-99	0	Current segment number
129	81	Timer/Ramp/Soak Interval Time Remaining	00:00 - 99:59	0	Time remaining in ramp/soak interval
130	82	Segment Loops Remaining	0 - 99	0	Number of loops remaining in the ramp/soak program.
131	83	Ramp/Soak Interval Indicator	0, 1	0	0 = ramp interval of segment, 1 = soak interval of segment
132 -- 143	84 -- 8F	Illegal, Available to application			
Global Input Registers					
144	90	Terminal Temp (CJC)	Ambient Range	0	read as xxx.x deg. F
145	91	N/A	0	0	
146	92	Reset Counter	0 - $FFFF	0	Number of processor resets.
147	93	Power Down Counter	0 - $FFFF	0	Number of power down interrupts.
148	94	Alarms Status	0 - $F	0	Bits 0-3 = Alarms 1-4. Bit value: 0 = Off, 1 = On

149	95	Events Status	0 - $F	0	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
150	96	Cycle Complete Status	0, 1	0	0 = Off, 1 = On
151	97	Audible Annunciator Status	0, 1	0	0 = Off, 1 = On
152 -- 155	98 -- 9B	Reserved, available to application	0	0	
156 – 157	9C – 9D	Reserved for factory use			
158 -- 159	9E – 9F	N/A	0	0	
A/D Input Registers					
160 -- 165	A0 -- A5	Reserved for factory use			
166 -- 167	A6 -- A7	Illegal, Reserved standard reg.			
168 -- 175	A8 -- AF	Illegal, Available to application			
Allocated Blocks					
176 -- 255	B0 -- FF	Illegal, Reserved standard reg.			
256 -- 65535	100 -- FFFF	Undefined			

3.6 Holding Register Assignments

Holding registers are intended for information and functions that can be read or written. Each holding register has a corresponding internal memory variable in the slave device. This association is shown in the address map table.

Table 6: Protocol^{TM} Plus Holding Register Address Map

Data Address	Hex Address	Description	Page[menu] Association or Range (default value)	Security Level	Comments
Global Holding Registers					
0	0	Communications Security Code	0-999 (0)	0	Security code setting for remote interface.
1	1	Temperature Display Units	PID[Temp Unit]	1 or 2 (Note 1)	0 = deg. F, 1 = deg. C.
2	2	Reserved for factory use			
3	3	Reserved for factory use			
4	4	Reserved for factory use			
5	5	Keypad Lockout	0 = normal, 1 = locked (0)	2	Disables front panel keypad
6	6	Controller Mode	Read: 1 – 5 Write: 1 - 4	0	1=Manual, 2=Timer, 3=Profile, 4=Autostart, 5=Setup
7	7	Alarm Acknowledge	0 - $FFFF	0	0 = No Action, >0 = Alarm Acknowledge
8	8	Level 1 Password	Enable[Password 1]	2	0 – 999 (Write not allowed while in setup mode)
9	9	Level 2 Password	Enable[Password 2]	2	0 – 999 (Write not allowed while in setup mode)
10	A	Key Press Beep	Control[Key Beep]	1 or 2 (Note 1)	0 = off, 1 = on
11	B	End of Cycle Beep	Control[EOC Beep]	1 or 2 (Note 1)	0 = off, 1 = on
12	C	Alarm Beep	Control[Alarm Beep]	1 or 2 (Note 1)	0 = off, 1 = on
13	D	Setpoint Change Enable	Enable[SPChange]	2	0 = no, 1 = yes
14	E	Analog output type	Enable[Aout]	2	0 = Control (Default), 1 = Process
15	F	Reserved, Available to application	0	0	
Control Loop Holding Registers					
16	10	Manual SP	Manual[setpt]	0	read/written as xxxx deg. F.
17	11	Manual High Limit SP	Manual[Hi-Lim SP]	0	read/written as xxxx deg. F.
18	12	Manual Event 1-4 Setup	$0 - $F ($0)	0	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
19	13	NA	0	0	
20	14	Proportional Band (Heat)	PID[P (H)]	1 or 2 (Note 1)	read/written as xxxx deg. F.
21	15	Integral Reset (Heat)	PID[I (H) Rep/Min]	1 or 2 (Note 1)	value is in repeats/min
22	16	Derivative Rate (Heat)	PID[I (H) in sec]	1 or 2 (Note 1)	value is in seconds
23	17	Hysteresis	Control[Hysteresis]	1 or 2 (Note 1)	read/written as xxxx deg. F.
24	18	High Limit Band	Control[Hi-Lim Band]	1 or 2 (Note 1)	read/written as xxxx deg. F. 4 = Off.
25	19	Cycle Time	Control[Cycle Time Sec]	1 or 2 (Note 1)	value is in seconds
26	1A	Proportional Band (Cool)	PID[P(C)]	1 or 2 (Note 1)	read/written as xxxx deg. F. **(H/C Version 3.1 Only)**
27	1B	Integral Reset (Cool)	PID[I (C) Rep/Min]	1 or 2 (Note 1)	value is in repeats/min. **(H/C Version 3.1 Only)**
28	1C	Derivative Rate (Cool)	PID[D(C) in Sec]	1 or 2 (Note 1)	Value is in Seconds. **(H/C Version 3.1 Only)**
29	1D	Heat Offset	PID[Heat Offset]	1 or 2 (Note 1)	read/written as xxxx deg. F. (+/- P Band H) **H/C Only**
30	1E	Cool Offset	PID[Cool Offset]	1 or 2 (Note 1)	read/written as xxxx deg. F. (+/- P Band H) **H/C Only**

31	1F	Control Type	Control[Ctrl]	1 or 2 (Note 1)	0 = Heat, 1 = Cool, 2 = Heat/Cool. **H/C Only**
32 – 34	20 – 22	NA	0	0	
35	23	Auto Tune Enable	PID[Auto Tune]	1 or 2 (Note 1)	0 = Disabled, 1 = Enabled
36	24	Power Up Start Enable	Control[PwrUpStrt]	1 or 2 (Note 1)	0 = Disabled, 1 = Enabled
37	25	Power Up Start Mode	Control[StrtMode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
38 – 39	26 – 27	NA	0	0	
40	28	Power Fail Recovery	Control[PwrFRec]	1 or 2 (Note 1)	0=Stop, 1=Restart, 2=Hold, 3=Resume
41	29	Recovery Time Limit	Control[PFRTime]	1 or 2 (Note 1)	00h00m to 99h59m
42 – 44	2A – 2C	NA	0	0	
45	2D	SP Low Limit	Enable[SPLowerLim]	2	read/written as xxxx deg. F.
46	2E	SP Upper Limit	Enable[SPUpperLim]	2	read/written as xxxx deg. F.
47	2F	High Limit Over Head	Enable[HiLimOH]	2	read/written as xxxx deg. F.
48 – 53	30 – 35	NA	0	0	
54	36	Process Out Scale Low	Control[RetOutLo]	1 or 2 (Note 1)	read/written as xxxx deg. F.
55	37	Process Out Scale High	Control[RetOutHi]	1 or 2 (Note 1)	read/written as xxxx deg. F.
56 – 63	38 – 3F	Illegal, Available to application			
Timer Holding Registers					
64	40	Timer SP	Timer[Setpt]	0	read/written as xxxx deg. F.
65	41	Timer High Limit SP	Timer[Hi-Lim SP]	0	read/written as xxxx deg. F.
66	42	Timer Event 1-4 Setup	$0 - $F ($0)	0	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
67	43	Timer Value	Timer[Time Set]	0	read/written as xx:xx hrs:min or min:sec
68	44	Timer Guaranteed Soak Band	Timer[TmrGuarSoak]	0	read/written as xxxx deg. F. 0 = Off.
69 -- 399	45 -- 18F	Illegal, Reserved standard reg.			
Control Operation and Profile Holding Registers					
400	190	NA	0	0	
401	191	Profile Number	0 - 8	0	Current Profile number; 0= none;
402	192	Run/Hold/Stop Control	0 - 2	0	0 = Stop key, 1 or 2 = Run/Hold key
403	193	Time Scale	Control[TimeScale]	1 or 2 (Note 1)	0 = mm:ss, 1 = hh:mm
404	194	Segment Advance	0 - $FFFF	0	0=no action; >0 = advance to next segment
	Profile 1				
405	195	Segment 1 Ramp Time	Seg-1 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
406	196	Segment 1 Ramp Event 1-4 Setup	Seg-1 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
407	197	Segment 1 Soak Temp	Seg-1 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
408	198	Segment 1 Soak Time	Seg-1 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
409	199	Segment 1 Soak Event 1-4 Setup	Seg-1 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
410	19A	Segment 2 Ramp Time	Seg-2 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
411	19B	Segment 2 Ramp Event 1-4 Setup	Seg-2 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
412	19C	Segment 2 Soak Temp	Seg-2 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
413	19D	Segment 2 Soak Time	Seg-2 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
414	19E	Segment 2 Soak Event 1-4 Setup	Seg-2 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
415	19F	Segment 3 Ramp Time	Seg-3 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
416	1A0	Segment 3 Ramp Event 1-4 Setup	Seg-3 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
417	1A1	Segment 3 Soak Temp	Seg-3 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
418	1A2	Segment 3 Soak Time	Seg-3 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
419	1A3	Segment 3 Soak Event 1-4 Setup	Seg-3 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
420	1A4	Segment 4 Ramp Time	Seg-4 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec

421	1A5	Segment 4 Ramp Event 1-4 Setup	Seg-4 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
422	1A6	Segment 4 Soak Temp	Seg-4 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
423	1A7	Segment 4 Soak Time	Seg-4 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
424	1A8	Segment 4 Soak Event 1-4 Setup	Seg-4 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
425	1A9	Segment 5 Ramp Time	Seg-5 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
426	1AA	Segment 5 Ramp Event 1-4 Setup	Seg-5 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
427	1AB	Segment 5 Soak Temp	Seg-5 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
428	1AC	Segment 5 Soak Time	Seg-5 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
429	1AD	Segment 5 Soak Event 1-4 Setup	Seg-5 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
430	1AE	Segment 6 Ramp Time	Seg-6 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
431	1AF	Segment 6 Ramp Event 1-4 Setup	Seg-6 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
432	1B0	Segment 6 Soak Temp	Seg-6 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
433	1B1	Segment 6 Soak Time	Seg-6 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
434	1B2	Segment 6 Soak Event 1-4 Setup	Seg-6 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
435	1B3	Segment 7 Ramp Time	Seg-7 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
436	1B4	Segment 7 Ramp Event 1-4 Setup	Seg-7 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
437	1B5	Segment 7 Soak Temp	Seg-7 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
438	1B6	Segment 7 Soak Time	Seg-7 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
439	1B7	Segment 7 Soak Event 1-4 Setup	Seg-7 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
440	1B8	Segment 8 Ramp Time	Seg-8 Ramp[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
441	1B9	Segment 8 Ramp Event 1-4 Setup	Seg-8 Ramp[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
442	1BA	Segment 8 Soak Temp	Seg-8 Soak[Temp]	1 or 2 (Note 1)	read/written as xxxx deg. F.
443	1BB	Segment 8 Soak Time	Seg-8 Soak[Time]	1 or 2 (Note 1)	read/written as xx:xx hrs:min or min:sec
444	1BC	Segment 8 Soak Event 1-4 Setup	Seg-8 Soak[Event1-4]	1 or 2 (Note 1)	Bits 0-3 = Events 1-4. Bit value: 0 = Off, 1 = On
445	1BD	High Limit SP	[Hi-Lim SP]	1 or 2 (Note 1)	read/written as xxxx deg. F.
446	1BE	Loop From Segment #	[Loop From Seg No]	1 or 2 (Note 1)	0 = None; 1-8 = Loop from segement.
447	1BF	Loop to Segment #	[Loop To Seg No]	1 or 2 (Note 1)	0 = None; 1-8 = Loop to segement.
448	1C0	Loop # of Times	[Loop Number]	1 or 2 (Note 1)	0-99
449	1C1	Link to Profile	[Link To Pro]	1 or 2 (Note 1)	-1=Stop, 0=Hold, 1-8=Profile 1-8, -2=Standby.
450	1C2	Guaranteed Soak Band	[Guar Band]	1 or 2 (Note 1)	read/written as xxxx deg. F. 0 = Off.
	Profile 2				
451 -- 496	1C3 -- 1F0	Profile 2 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
	Profile 3				
497 -- 542	1F1 -- 21E	Profile 3 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
	Profile 4				
543 -- 588	21F -- 24C	Profile 4 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
	Profile 5				
589 -- 634	24D -- 27A	Profile 5 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
	Profile 6				
635 -- 680	27B -- 2A8	Profile 6 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
	Profile 7				
681 -- 726	2A9 -- 2D6	Profile 7 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
	Profile 8				
727 -- 772	2D7 -- 304	Profile 8 Holding Registers (same as Profile 1)		1 or 2 (Note 1)	
Auto Start Holding Registers					
773	305	Auto Start Enable	Auto Start[Enable]	1 or 2 (Note 1)	0 = Disabled, 1 = Enabled

774	306	Sunday Run Mode	Auto Start Sun[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
775	307	Sunday Run Time	Auto Start Sun[Time]	1 or 2 (Note 1)	00h00m to 23h59m
776	308	Monday Run Mode	Auto Start Mon[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
777	309	Monday Run Time	Auto Start Mon[Time]	1 or 2 (Note 1)	00h00m to 23h59m
778	30A	Tuesday Run Mode	Auto Start Tue[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
779	30B	Tuesday Run Time	Auto Start Tue[Time]	1 or 2 (Note 1)	00h00m to 23h59m
780	30C	Wednesday Run Mode	Auto Start Wed[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
781	30D	Wednesday Run Time	Auto Start Wed[Time]	1 or 2 (Note 1)	00h00m to 23h59m
782	30E	Thursday Run Mode	Auto Start Thu[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
783	30F	Thursday Run Time	Auto Start Thu[Time]	1 or 2 (Note 1)	00h00m to 23h59m
784	310	Friday Run Mode	Auto Start Fri[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
785	311	Friday Run Time	Auto Start Fri[Time]	1 or 2 (Note 1)	00h00m to 23h59m
786	312	Saturday Run Mode	Auto Start Sat[Mode]	1 or 2 (Note 1)	0=Off, 1=Manual, 2=Timer, 3-10=Profile 1-8
787	313	Saturday Run Time	Auto Start Sat[Time]	1 or 2 (Note 1)	00h00m to 23h59m
788 -- 1023	314 -- 3FF	Illegal, Available to application			
Relay Outputs Holding Registers					
	Relay Output 1				
1024	400	Output 1 Type	Relay 1[Relay Type]	1 or 2 (Note 1)	0=Off, 1=Alarm, 2=Cycle, 3=Event
1025	401	Relay 1 Action	Relay 1[Relay Action]	1 or 2 (Note 1)	0=NDE, 1=NE, 2=NDEL, 3=NEL
1026	402	Alarm 1 Type	Relay 1[Alarm Type]	1 or 2 (Note 1)	0 = High, 1 = Low, 2 = +Dev, 3 = -Dev, 4 = +/-Dev
1027	403	Alarm 1 Setpoint	Relay 1[AlmHi/LoSP]	1 or 2 (Note 1)	read/written as xxxx deg. F.
1028	404	Alarm 1 Deviation Setpoint	Relay 1[AlmDevBand]	1 or 2 (Note 1)	read/written as xxxx deg. F.
1029	405	Alarm 1 Inhibit	Relay 1[AlmInhibit]	1 or 2 (Note 1)	0=Disabled, 1=Enabled
1030	406	Event 1 Type	Relay 1[Event Type]	1 or 2 (Note 1)	0=Time, 1=Temp
1031	407	Event 1 Setpoint	Relay 1[Event SP]	1 or 2 (Note 1)	read/written as xxxx deg. F.
	Relay Output 2				
1032 -- 1039	408 -- 40F	Output 2 Holding Registers (same as Output 1)		1 or 2 (Note 1)	
	Relay Output 3				
1040 -- 1047	410 -- 417	Output 3 Holding Registers (same as Output 1)		1 or 2 (Note 1)	
	Relay Output 4				
1048 -- 1055	418 -- 41F	Output 4 Holding Registers (same as Output 1)		1 or 2 (Note 1)	
Test Mode Holding Registers					
1056 -- 1062	420 -- 426	Reserved for factory use			
1063 -- 1135	427 -- 46F	Illegal, Available to application			
Communication Holding Registers					
1136	470	Controller Address	Communication[Unit Addr]	1 or 2 (Note 1)	1-247
1137	471	Communications Mode	Communication[Enable]	1 or 2 (Note 1)	0=Disabled, 1=Enabled
1138	472	Baud Rate	Communication[BaudRate]	1 or 2 (Note 1)	0=2400, 1=4800, 2=9600, 3=19.2K, 4=38.4K
1139	473	Parity	Communication[Parity]	1 or 2 (Note 1)	0=None, 1=Odd, 2=Even
1140	474	Reserved, Available to application	0	0	
Real Time Clock Holding Registers					
1141	475	Week Day	Clock[Day]	1 or 2 (Note 1)	1=Sunday, 2=Monday, . . . 7=Saturday
1142	476	Time	Clock[hh:mm]	1 or 2 (Note 1)	00h00m to 23h59m
1143	477	Enter	Clock[UP to Reset CLK]	1 or 2 (Note 1)	0 = No action, >0 = Set Clock
1144 -- 1151	478 -- 47F	Illegal, Reserved for standard reg.			
Calibration Holding Registers					

1152 -- 1159	480 -- 487	Reserved for factory use			
1160 -- 1183	488 -- 49F	Illegal, Available to application			
1184 -- 1188	4A0 -- 4A4	Reserved for factory use			
1189 -- 1199	4A5 -- 4AF	Illegal, Available to application			
1200 -- 1279	4B0 -- 4FF	Illegal, Reserved for standard reg.			Reserved for future standard assignments.
Page Enable Holding Registers					
1280	500	Program Page 1-8	Enable[Profile 1-8]	2	1 = Yes (security level 1); 0 = No (security level 2)
1281	501	Auto Start Page	Enable[Auto Start]	2	1 = Yes (security level 1); 0 = No (security level 2)
1282	502	PID Parameters Page	Enable[PID]	2	1 = Yes (security level 1); 0 = No (security level 2)
1283	503	Control Page	Enable[Control]	2	1 = Yes (security level 1); 0 = No (security level 2)
1284	504	Communications Page	Enable[Communication]	2	1 = Yes (security level 1); 0 = No (security level 2)
1285	505	Real Time Clock Page	Enable[Clock]	2	1 = Yes (security level 1); 0 = No (security level 2)
1286	506	Relay Output Page 1-4	Enable[Relay 1-4]	2	1 = Yes (security level 1); 0 = No (security level 2)
1287	507	Test Page	Enable[Test]	2	1 = Yes (security level 1); 0 = No (security level 2)
1288	508	Zone Calibration	Enable[Zone Cal]	2	1 = Yes (security level 1); 0 = No (security level 2)
1289	509	Sensor Calibration	Enable[Sensor Cal]	2	1 = Yes (security level 1); 0 = No (security level 2)
Allocated Blocks					
1290 -- 65535	50A -- FFFF	Undefined			Available for application assignment.

NOTES

1 Dependent on enable page setting

4 Application Operations

This section defines application operations in Protocol^{TM} Plus controller and how they are achieved through Modbus.

4.1 Security Level and Discrete Inputs, Discrete Outputs, and Register Access

Access to discrete I/O and registers addresses are guarded via a security level. The communications security code holding register ($0000) contains the current security setting for accessing data in the controller through the communications port. Each I/O or register address has an associated preset security level that controls access. If the current communication security code does not match the register's security level, access is denied. An illegal data address exception is generated and data is not changed. For multiple reads and writes, if any address is inaccessible, an exception response occurs and data is not affected in the slave.

The communications security operation mirrors the security operation for adjusting parameters through the front panel keypad. Security levels for each I/O and register address are shown in the I/O and register mapping tables. The access passwords for security levels 1 and 2 are set via the security level holding registers ($0008, $0009). The communications security code is set to 0 whenever the controller is powered up or reset. The access password registers ($0008, $0009) cannot be written to while the controller is in setup mode to protect adjustments in progress via the front panel keypad.

Table 7: Communication Security Levels

Security Level	Description	Access Code
0	Global Access	Any
1	User Access Level 1	Password Level 1 Menu
2	User Access Level 2	Password Level 2 Menu
3	Factory Only Access	---

4.2 Multiple Register Write Limitations

The Modbus Protocol requires all addresses and all data in a multiple write to be valid for any write to occur. If an exception response occurs none of the registers are modified. Because all addresses and data must be verified before the data is actually written, a limitation exists for multiple writes to registers whose values are interdependent. The verification of data may fail because data to be written to one register is invalid until data for another register is actually written. In these cases, successive single register writes must be performed.

An example is the Manual Setpoint and Manual High Limit Setpoint holding registers. If the registers are currently set to 500 °F and 509 °F respectively, then a multiple write of 300 °F and 350 °F respectively will fail. During data verification, the high limit value of 350 °F is invalid because the setpoint is set to 500 °F. A single write of 300 °F to Manual Setpoint followed by a single write of 350 °F to Manual High Limit Setpoint will work.

4.3 Control Operation and Run/Hold/Stop Functions

The 4 control states of the controller (Manual, Timer, Profile, and Autostart) can be set via the Controller Mode holding register ($0006). The controller mode cannot be changed unless the controller is stopped. Before changing modes, the STOP value must be written to the Run/Hold/Stop holding register ($0192), then the desired mode value can be written to the Controller Mode holding register. When reading the Controller Mode holding register ($0006), a fifth mode (Setup) can be detected. The user cannot place the controller into setup mode via Modbus because the setup mode applies only to adjusting parameters via the front panel keypad.

When the controller is in Manual, Timer, or Profile control mode, the Run/Hold/Stop register ($0192) is used to Run, Hold, or Stop the controller. A value of 0 simulates the STOP key; a value of 1 or 2 simulates the RUN/HOLD key. When in Profile control mode, the Profile Number ($0191) and the Segment Advance ($0194) holding registers control which profile and segment are being executed. The Profile Number holding register can only be written when the controller is stopped. A value of 0 sets the desired profile to none. Writing any non-zero value to the Segment Advance register simulates pressing the Select/Up Arrow combination while running a profile to advance to the next profile segment.

The Profile Number holding register, along with the Profile Input Registers $0080-$0083 can be read to monitor the status of the controller. The Segment Number input register ($0080) provides the current segment number. Input register $0081 provides the time remaining in the current interval and input register $0082 the number of segment loops remaining. The Ramp/Soak Interval Indicator ($0083) input register indicates whether the current interval is a ramp or soak interval (0=ramp, 1=soak).

4.4 Controller Mode and Data Access

Most holding registers can only be written to if the controller is stopped. The exceptions are listed below. All registers can be read in any mode as long as the communications security code is set to the proper level. An illegal data address response is generated if the controller is not in the correct state to access a register. The following registers can be written while the controller is running.

REGISTER ADDRESS	REGISTER DESCRIPTION
$0000	COMMUNICATIONS ACCESS CODE
$0005	KEYPAD LOCKOUT
$0007	ALARM ACKNOWLEDGE
$0008	LEVEL 1 PASSWORD (write not allowed while in setup mode)
$0009	LEVEL 2 PASSWORD (write not allowed while in setup mode)
$0010	MANUAL SETPOINT
$0040	TIMER SETPOINT
$0192	RUN/HOLD/STOP
$0194	SEGMENT ADVANCE

4.5 Monitoring and Acknowledgement of Alarms, Events, and Cycle Complete, Discrete Inputs, and Discrete Outputs

Two input registers allow monitoring of the alarm ($0094) and event ($0095) functions associated with relay outputs 1-4. The corresponding input register represents a binary pattern that indicates the state of each function. Bits 0-3 of the holding register value represent item 1-4 respectively. A bit value of 0 indicates off, while a bit value of 1 indicates on. Example: A read of holding register $0098 returns a value of $0006. This would indicate that alarms 2 and 3 are active.

The cycle complete status is monitored by reading input register $0096. A value of 0 indicates the cycle is active, while a value of 1 indicates the cycle is complete.

Reading the discrete input addresses-$0000 - $00003 monitors the hardware states of the external inputs Event 1-4. For details on the return values see **5.2.2 [02] Read Input Discretes.** Since these inputs are active low switch inputs, a returned value of 1 (or on) means the input is active (electrically pulled low).

Reading the discrete output addresses-$0000 - $00003 monitors the hardware states of relays 1-4. For details on the return values see **5.2.1 [01] Read Outputs.**

The audible annunciator can be monitored via input register $0097. A value of 0 indicates the audible annunciator is off, while a value of 1 indicates on. Acknowledgement of alarms and cycle complete audible annunciation is handled through the alarm acknowledge holding register ($0007). Writing any non-zero value to this register will acknowledge the alarm. This register emulates the pressing of the Page/Reset key during an audible alarm condition.

4.6 Event Setup Values

For Manual, Timer, and Profile events setup, the corresponding holding register represents a binary pattern that determines each event output state. Bits 0-3 of the holding register value represent Event outputs 1-4 respectively. A bit value of 0 sets the event output to be off, while a bit value of 1 sets the output to be on.

4.7 Keypad Lockout

The front panel keypad can be disabled (locked out) by writing the value 1 to the Keypad Lockout holding register ($0005). A write of 0 will unlock the keypad. The keypad lockout register is always set to 0 during a power-up or reset of the controller to ensure that the keypad can never be permanently locked out.

4.8 Temperature Values

Temperature values read from input and holding registers and written to holding registers are always in °F and assume no decimal place. An exception is the ambient temperature input register ($0090) which assumes 1 decimal place. A value read or written as 750 would represent 75.0 °F.

4.9 Time Values

Time values are read and written in a format that adheres to the to Modbus standard of two bytes per data item. The high byte is a hex number representing hours or minutes while the low byte is a hex number representing minutes or seconds. The units of the two bytes (hhmm or mmss) are dependent of the format of the specific register being accessed. Example: 12h00m ⇒ $0C00; 36m42s ⇒ $242A.

4.10 High Limit Setpoint and Band Registers

The Despatch Protocol™ Plus has several special cases involving the adjustment and display of high limit parameters. Since only values can be returned via Modbus (no special strings), the read/write of these parameters has been implemented in the simplest manner that still allows for complete functionality.

All high limit setpoint and band registers read and write directly to the parameter associated with the register address—regardless of whether that value is active due to the setting of another high limit register (as in the high limit band holding register $0018). To determine the high limit setpoint currently being used for control, read the Active High Limit Setpoint register $0002.

4.11 Broadcasting with Guaranteed Delivery

Broadcast messages are processed by all slaves and do not generate a response. In order to verify the delivery, acceptance, and processing of broadcast messages the following procedure can be used.

1. Send an individual function code 08, sub-function 10 queries (clear communication counters) to each slave on the network.
2. Perform desired broadcast functions.
3. Send an individual function code 08, sub-function 14 queries (return slave message count) to each slave on the network.
4. If the number of processed messages in each slave matches the number of broadcasts sent then the broadcast messages were sent reliably.

4.12 Communication Parameter Adjustments

If the communication parameters (slave address, mode, baud rate, or parity) are changed through the front panel or through the Modbus link, the controller need not be reset. The new parameters (in the controller) will become effective on the next query/response cycle. However, in some cases, the first query after changing the settings may not generate a response as this query is used to reset the communication setup. The user is responsible for setting the master device to the proper settings.

Setting the communications mode to “disabled” will immediately disable communications. Communications can only be re-enabled through the front panel keypad. Use the force listen mode command (5.3.1.4 [08 04] Force Listen Mode Only) to temporarily disable communications.

5 Function Set Details

This section details the Modbus functions supported in the Protocol™ Plus controller.

5.1 Function Set Overview

Table 8 Protocol™ Plus Function and Exception Code Set

Function Code	Function Name
01	Read Outputs
02	Read Input Discretes
03	Read Holding Register (Read Multiple Registers)
04	Read Input Registers
06	Write Single Register
08	Diagnostics
16	Write Multiple Registers
17	Report Slave ID

Table 9 Protocol™ Plus Diagnostic (Function Code 08) Sub-function Set

Sub-function Code	Sub-function Name	Comments
00	Return Query Data	Loop Back
01	Restart Communications Options	Reset the slave. Cancels Listen Only Mode.
02	Return Diagnostic Register	Contents of slave's 16-bit diagnostic register.
04	Force Listen Only Mode	Reset by Restart Communications Option
10	Clear Counters and Diagnostic Register	Also cleared at power up. Clears only the counters
12	Return Bus Communication Error Count	Slave CRC errors only.
13	Return Bus Exception Error Count	Slave Exception Response count.
14	Return Slave Message Count	Number of messages addressed to the slave and successfully processed. Includes broadcast messages.

15	Return Slave No Response Count	Number of messages addressed to the slave for which no response was returned.
18	Return Bus Character Overrun Count	Number of overrun and framing errors.

Table 10 Protocol™ Plus Exception Code Set

Exception Code	Description	Comments
01	Illegal Function	The function code received is not valid or is not supported.
02	Illegal Data Address	The data address received is invalid or is not accessible due to security setting.
03	Illegal Data Value	The data value received is invalid.

5.2 Register and I/O Function Set Description for Protocol™ Plus

5.2.1 [01] Read Outputs

Class 1 command. Reads the On/Off status of discrete outputs in the slave. Broadcast is not supported.

Query

The query message specifies the starting output and quantity of outputs to be read. Outputs are addressed starting at 0.

Example: Query to read outputs 20 . . . 56 from slave address 17.

Field Name	Data
Slave address	$11
Function	$01
Starting address hi	$00
Starting address lo	$13
Number of outputs hi	$00
Number of outputs lo	$25
CRC	$----

Response

The output status in the response is packed as one output per bit of the data field. Status is indicated as 0 = Off, 1 = On. The LSB of the first data byte contains the output addressed in the query. The other outputs follow toward the high order end of this byte, and from low order to high order in subsequent bytes. If the returned output quantity is not a multiple of eight, the remaining bits in the final data byte will be padded with zero (toward the high order end). The Byte Count field specifics the quantity of complete bytes of data.

Example response:

Field Name	Data
Slave address	$11
Function	$01
Byte count	$05
Data (outputs 27 . . . 20)	$CD
Data (outputs 35 . . . 28)	$A0
Data (outputs 43 . . . 36)	$36
Data (outputs 51 . . . 44)	$FB
Data (outputs 56 . . . 52)	$05
CRC	$----

5.2.2 [02] Read Input Discretes

Class 1 command. Reads the On/Off status of discrete inputs in the slave. Broadcast is not supported.

Query

The query message specifies the starting input and quantity of inputs to be read. Inputs are addressed starting at 0.

Example: Request to read inputs 1 . . . 7 from slave address 8.

Field Name	Data
Slave address	$08
Function	$02
Starting address hi	$00
Starting address lo	$00

Number of outputs hi	$00
Number of outputs lo	$07
CRC	$----

Response

The input status in the response message is packed as one input per bit of the data field. Status is indicated as 0 = Off, 1 = On. The LSB of the first data byte contains the input addressed in the query. The other inputs follow toward the high order end of this byte, and from low order to high order in subsequent bytes. If the returned input quantity is not a multiple of eight, the remaining bits in the final data byte will be padded with zero (toward the high order end). The Byte Count field specifics the quantity of complete bytes of data.

Example response:

Field Name	Data
Slave address	$08
Function	$02
Byte count	$01
Data (inputs 7 . . . 1)	$74
CRC	$----

5.2.3 [03] Read Holding Registers (Read Multiple Registers)

Class 0 command. Reads the contents of holding registers in the slave. Broadcast is not supported.

Query

The query message specifies the starting register and quantity of registers to be read. Registers are addressed starting at 0.

Example: Request to read registers 108 . . . 110 from slave address 1.

Field Name	Data
Slave address	$01
Function	$03
Starting address hi	$00
Starting address lo	$6B

Number of registers hi	$00
Number of registers lo	$03
CRC	$----

Response

The register data in the response message are packed as two bytes per register (one word). For each register, the first byte contains the high order bits and the second contains the low order bits.

Example response:

Field Name	Data
Slave address	$01
Function	$03
Byte count	$06
Data (register 108 hi)	$00
Data (register 108 lo)	$1E
Data (register 109 hi)	$10
Data (register 109 lo)	$26
Data (register 110 hi)	$02
Data (register 110 lo)	$AC
CRC	$----

5.2.4 [04] Read Input Registers

Class 1 command. Read the contents of input registers in the slave. Broadcast is not supported.

Query

The query message specifies the starting register and quantity of registers to be read. Registers are addressed starting at 0.

Example: Request to read input register 10 from slave device 17.

Field Name	Data
Slave address	$11
Function	$04
Starting address hi	$00

Starting address lo	$09
Number of registers hi	$00
Number of registers lo	$01
CRC	$----

Response

The register data in the response are packed as two bytes per register (one word). For each register, the first byte contains the high order bits and the second contains the low order bits.

Example response:

Field Name	**Data**
Slave address	$11
Function	$04
Byte count	$02
Data (register 10 hi)	$00
Data (register 10 lo)	$23
CRC	$----

5.2.5 [06] Write Single Register

Class 1 command. Writes a value into a single holding register. When broadcast, the value is written to the same register reference in all slaves on the network. Use of broadcast with this command should be used with caution as the register addressed may differ in function on each slave device in the network.

Note: The written value will remain valid until the controller's next write to the register through its keypad or internal logic.

Query

The query message specifies the register reference to be written. Registers are addressed starting at zero. The requested value is specified in the query data field in two bytes (one word). The first byte represents the high order bits and the second byte represents the low order bits.

Example: Request to preset register 2 to the value 3 in slave device 14.

Field Name	Data
Slave address	$0E
Function	$06
Register address hi	$00
Register address lo	$01
Data hi	$00
Data lo	$03
CRC	$----

Response

The normal response is an echo of the query, returned after the register has been written.

Example response:

Field Name	Data
Slave address	$0E
Function	$06
Register address hi	$00
Register address lo	$01
Data hi	$00
Data lo	$03
CRC	$----

5.2.6 [16] Write Multiple Registers

Class 0 command. Write values into a sequence of holding registers. When broadcast, the values are written to the same register references in all slaves on the network. Use of broadcast with this command should be used with caution as the registers addressed may differ in function on each slave device in the network.

Note: The written values will remain valid until the controller's next write to the register through its keypad or internal logic.

Query

The query message specifies the register references to be written. Registers are addressed starting at zero. The number of registers to be written are transmitted in two bytes (one word) with the first byte being the high order bits and the second byte the low order bits. Next, the actual number of data bytes is transmitted (one byte). The requested values are specified in the query data field in two bytes (one word) per register. The first byte represents the high order bits and the second byte represents the low order bits of the register value.

Example: Request to preset two registers starting at register 5 to the values of 10 and 258 respectively in slave device 14.

Field Name	Data
Slave address	$0E
Function	$10
Starting register address hi	$00
Starting register address lo	$04
Number of registers hi	$00
Number of registers lo	$02
Byte count	$04
Data hi (register 5)	$00
Data lo (register 5)	$0A
Data hi (register 6)	$01
Data lo (register 6)	$02
CRC	$----

Response

The normal response returns the slave address, function code, starting address, and quantity of registers written.

Example response:

Field Name	Data
Slave address	$0E
Function	$10
Starting register address hi	$00
Starting register address lo	$04
Number of registers hi	$00
Number of registers lo	$02
CRC	$----

5.3 Diagnostics and Support Description for Protocol^{TM} Plus

All of the diagnostic and support functions are unclassified commands that tend to be application dependent. The Modbus diagnostic function provides a series of tests and information exchange for checking the integrity of the controller, the communication link, and the status of the controller. Broadcast is not supported.

5.3.1 [08] Diagnostics

The function uses a two-byte sub-function code field in the query to define the type of test to be performed. Most of the diagnostic queries use a two-byte data field to send diagnostic data or control information to the slave. In sub-functions where the data is not required, $0000 is transmitted as data and is ignored by the slave.

The slave echoes both the function code and sub-function code in a normal response as well as returning any requested data. The diagnostic query form is shown below. The response is sub-function dependent and may be application dependent. In cases where no return data is required and the data field was included in the query, the query data field is echoed in the slave response.

Diagnostic Query Form

Field Name	Data
Slave address	$XX
Function	$08
Sub-function hi	$XX
Sub-function lo	$XX
Data hi	$XX
Data lo	$XX
CRC	$----

5.3.1.1 [08 00] Return Query Data

The data passed in the query data field is to be returned (looped back) in the response. The entire response message should be identical to the query.

Example: Return Query Data $AA55 from slave device 2.

Query		Response	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$02	Slave address	$02
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$00	Sub-function lo	$00
Data hi	$AA	Data hi	$AA
Data lo	$55	Data lo	$55
CRC	$----	CRC	$----

5.3.1.2 [08 01] Restart Communications Option

The slave is reset, its communication port initialized and restarted, and all of its communications event counters cleared. If the slave is currently in Listen Only mode, no response is returned. This function is the only one that brings the port out of Listen Only mode. If the port is not currently in Listen Only mode, a normal response is returned. This occurs before the reset is executed. When the slave receives the query, it attempts a restart and executes its power-up confidence tests. Successful completion of the tests will bring the port online.

Example: Restart Communications on slave device 2.

Query		Response	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$02	Slave address	$02
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$01	Sub-function lo	$01
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$00
CRC	$----	CRC	$----

5.3.1.3 [08 02] Return Diagnostic Register

The contents of the slave's 16 bit diagnostic register are returned in the response. The assignment of diagnostic register bits in Protocol^{TM} Plus controllers is shown below. In the register, bit 15 is the high-order bit. The description is TRUE when the corresponding bit is set to logic 1.

Table 11: Protocol^{TM} Plus Diagnostic Register Bit Assignment

Bit #	Description
0	NA
1	NA
2	EEPROM Data Error
3	NA
4	NA
5	NA
6	NA
7	A/D
8	Not Used – Loop Error
9	Not Used – Tune Error
10	Not Used -- Available for Application Specific Support
11	Not Used -- Available for Application Specific Support
12	Not Used -- Available for Application Specific Support
13	Not Used -- Available for Application Specific Support
14	Not Used -- Available for Application Specific Support
15	Not Used -- Available for Application Specific Support

Example: Return the diagnostic register from slave device 2 (with an EEPROM error).

Query		Response	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$02	Slave address	$02
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$02	Sub-function lo	$02
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$04
CRC	$----	CRC	$----

5.3.1.4 [08 04] Force Listen Mode Only

Forces the slave into Listen Only Mode. This isolates it from the other devices on the network, allowing them to continue communicating without interruption form the addressed slave. No response is returned. When the slave enters this mode, all active communications are turned off. All messages broadcast or addressed to the slave are monitored, but no action is taken and no responses sent. The Restart Communications Option function is the only command that will bring the slave out of Listen Only Mode.

Example: Force slave device 23 into Listen Only Mode.

Query		**No Response**
Field Name	**Data**	
Slave address	$17	
Function	$08	
Sub-function hi	$00	
Sub-function lo	$04	
Data hi	$00	
Data lo	$00	
CRC	$----	

5.3.1.5 [08 10] Clear Communication Counters

Clears all communication diagnostic counters. Counters are also cleared upon a controller reset.

Example: Clear communication counters in slave device 23.

Query		**Response**	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$17	Slave address	$17
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$0A	Sub-function lo	$0A
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$00
CRC	$----	CRC	$----

5.3.1.6 [08 12] Return Bus Communication Error Count

The response data field returns the quantity of CRC errors encountered by the slave since its last reset or clear counters command.

Example: Return bus communication error count in slave device 9.

Query		Response	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$09	Slave address	$09
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$0C	Sub-function lo	$0C
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$07
CRC	$----	CRC	$----

5.3.1.7 [08 13] Return Bus Exception Error Count

The response data field returns the quantity of Modbus exception responses returned by the slave since its last reset or clear counters command. For a description of exception responses see **5.4 Exception Response Description.**

Example: Return bus exception count in slave device 3.

Query		Response	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$03	Slave address	$03
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$0D	Sub-function lo	$0D
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$02
CRC	$----	CRC	$----

5.3.1.8 [08 14] Return Slave Message Count

The response data field returns the quantity of messages addressed to the slave, or broadcast, that the slave has successfully processed since its last reset or clear counters command.

Example: Return slave message count in slave device 5.

Query		Response	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$05	Slave address	$05

Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$0E	Sub-function lo	$0E
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$6C
CRC	$----	CRC	$----

5.3.1.9 [08 15] Return Slave No Response Count

The response data field returns the quantity of messages addressed to the slave for which it returned no response since its last reset or clear counters command. No response due to errors are not counted.

Example: Return slave no response count in slave device 9.

Query		**Response**	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$09	Slave address	$09
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$0F	Sub-function lo	$0F
Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$02
CRC	$----	CRC	$----

5.3.1.10 [08 18] Return Bus Character Overrun Count

The response data field returns the quantity of messages addressed to the slave that it could not handle because of communication port overrun, framing errors, or parity errors since its reset or clear counters command.

Example: Return bus character overrun count in slave device 1.

Query		**Response**	
Field Name	**Data**	**Field Name**	**Data**
Slave address	$01	Slave address	$01
Function	$08	Function	$08
Sub-function hi	$00	Sub-function hi	$00
Sub-function lo	$12	Sub-function lo	$12

Data hi	$00	Data hi	$00
Data lo	$00	Data lo	$03
CRC	$----	CRC	$----

5.3.2 [17] Report Slave ID

Requests the slave to return its ID code. The ID code identifies the product line of which the slave is a member. The Slave ID for Protocol™ Plus is 1. Besides the ID code, the slave's software version number is also returned as an ASCII string. The version number will be sent in the format "VXX.X".

Query

Example: Report Slave ID from slave address 15 whose software version is 5.0.

Field Name	Data
Slave address	$0F
Function	$11
CRC	$----

Response

The normal response is to echo the slave address and function code, supply a data byte count, return the slave ID code, and return the software version number string.

Example: Response.

Field Name	Data	Comment
Slave address	$0F	
Function	$11	
Byte Count	$06	
Slave ID	$01	Protocol™ Plus ID code
Version number hi byte	$56	'V'
	$30	'0'
.	$35	'5'
.	$2E	'.'
Version number lo byte	$30	'0'
CRC	$----	

5.4 Exception Response Description

Except for broadcast messages, when a master device sends a query to a slave it expects a normal response. One of four possible events can occur from the master query:

1. If the slave device receives the query without a communication error, and can handle the query normally, it returns a normal response.
2. If the slave does not receive the query due to a communication error, no response is returned. The master program will eventually process a timeout condition for the query.
3. If the slave receives the query, but detects a communication error (parity, CRC), no response is returned. The master program will eventually process a timeout condition for the query.
4. If the slave receives the query without a communication error, but cannot handle it (for example, if the request is to read a nonexistent output or register), the slave will return an exception response informing the master of the nature of the error.

The master device's application program has the responsibility of handling exception responses. Typical processes are to post subsequent retries of the message, to try diagnostic messages to the slave, and to notify operators. The exception codes supported in the Protocol^{TM} Plus controller are summarized in **Table 10 ProtocolTM Plus Exception Code Set.**

In an exception response, the slave sets the MSB of the function code to 1. This makes the function code value in an exception response exactly $80 higher than the value in the query. With function code's MSB set, the master's application program can recognize the exception response and can examine the data field for the exception code.

In an exception response, the slave returns an exception code in the data field. The code defines the condition that caused the exception.

Example of a query with an exception response:

Query

Field Name	RTU Example Data	Description
Slave Address	$06	Slave number 6
Function	$01	Read Output Status
Starting Address Hi	$00	Start reading at output 119
Starting Address Lo	$76	
No. of Outputs Hi	$00	Read 8 successive outputs

No. of Registers Lo	$08	
CRC	$----	

Exception Response Format

Field Name	RTU Example Data	Description
Slave Address	$06	Slave number 6
Function	$81	Read output status with MSB set
Exception Code	$02	Illegal Data Address Exception code
CRC	$----	

5.4.1 [01] Illegal Function

The function code received in the query is not an allowable action for the slave.

5.4.2 [02] Illegal Data Address

The data address received in the query is invalid or is not accessible due to the current communication security setting. For queries involving multiple registers, if any address is invalid in the entire query, the entire query is rejected, no action is taken, and an exception is generated.

5.4.3 [03] Illegal Data Value

The query data field is invalid or contains an illegal value. This exception can occur when the query data exceeds the maximum or minimum allowable value for a register or the data does not agree with the query function. For queries involving multiple registers, if any data is invalid, the entire query is rejected, no data is written, and an exception is generated.

6 Modbus Protocol Quick Reference

This section highlights portions of the Modbus Protocol that may provide useful quick reference information to the programmer as it applies to the Protocol™ Plus slave implementation.

6.1 Protocol Format

The master's query contains the device address (or broadcast address), a function code defining the requested action, any data to be sent, and an error-checking field. The slave's response message contains fields confirming the action taken, any data to be returned, and an error-checking field. The Modbus transmission stream is sent in bytes. When a numerical quantity of data is larger than a byte, the most significant byte is sent first.

The function code in the query tells the addressed slave device what kind of action to perform. The data bytes contain any additional information that the slave will need to perform the function. If the slave makes a normal response, the function code in the response is an echo of the function code in the query. The data bytes contain the data collected by the slaves, such as register values or status.

6.2 RTU Transmission Mode

In RTU mode, each 8-bit byte in a message contains two 4-bit hexadecimal characters. Each message must be transmitted in a continuous stream.

6.2.1 Coding System

- 8-bit binary, hexadecimal: $0 . . . $9, $A . . . $F.
- Two hexadecimal characters contained in each 8-bit field of the message.

6.2.2 Serial Byte Setup

- 1 start bit.
- 8 data bits, LSB sent first.
- 1 bit for even/odd parity; no bit for no parity.
- 1 stop bit if parity is used; 2 bits for no parity.

Note: mark parity, 1 stop bit is equivalent to no parity, 2 stop bits and can be a substitute setting in the master device.

With Parity Checking

Start	D0	D1	D2	D3	D4	D5	D6	D7	Parity	Stop

Without Parity Checking

Start	D0	D1	D2	D3	D4	D5	D6	D7	Stop	Stop

6.2.3 Error Checking Field

- 16-bit CRC

6.2.4 Message Framing

In RTU mode, messages start with a silent interval of at least 3.5 character times. This is most easily implemented as multiple idle character times at the baud rate chosen for the network. The first field transmitted is the device address. Following the last transmitted character, a similar interval of at least 3.5 character times marks the end of the message. A new message can begin after this interval.

The entire message frame must be transmitted as a continuous stream. If a silent interval of more than 1.5 character times occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte will be the address field of a new message. Similarly, if a new message begins earlier than 3.5 character times following a previous message, the receiving device will consider it a continuation of the previous message. This will set an error, as the value in the final CRC field will not be valid for the combined messages. A typical message frame is shown below.

START	ADDRESS	FUNCTION	DATA	CRC CHECK	END
T1-T2-T3-T4	8 BITS	8 bits	n * 8 bits	16 bits	T1-T2-T3-T4

6.3 Address Field

Valid slave device addresses are in the range of 0-247 ($0-$F7). The individual slave devices are assigned addresses in the range of 1-247. Address 0 is used for broadcast address, which all slave devices recognize. No response is made to a broadcast message.

6.4 Function Field

Valid function codes are in the range of 1-127 ($1-$7F). When a message is sent from a master to a slave device the function code field tells the slave what kind of action to perform. When the slave responds, it uses the function code field to indicate either a normal (error-free) response or an exception response (an error occurred). For normal response, the slave simply echoes the original function code. For an exception response, the slave returns the original function code with the MSB set to logic 1.

6.5 Data Field

The data field contains additional information that the slave must use to take action defined by the function code. If no error occurs, the data field of a response from the slave contains the data requested. If an error occurs, the filed contains an exception code that the master application can use to determine the next action to be taken. The data field can be nonexistent in certain kinds of messages. All data addresses in Modbus messages are referenced to 0.

6.6 Error Checking Field

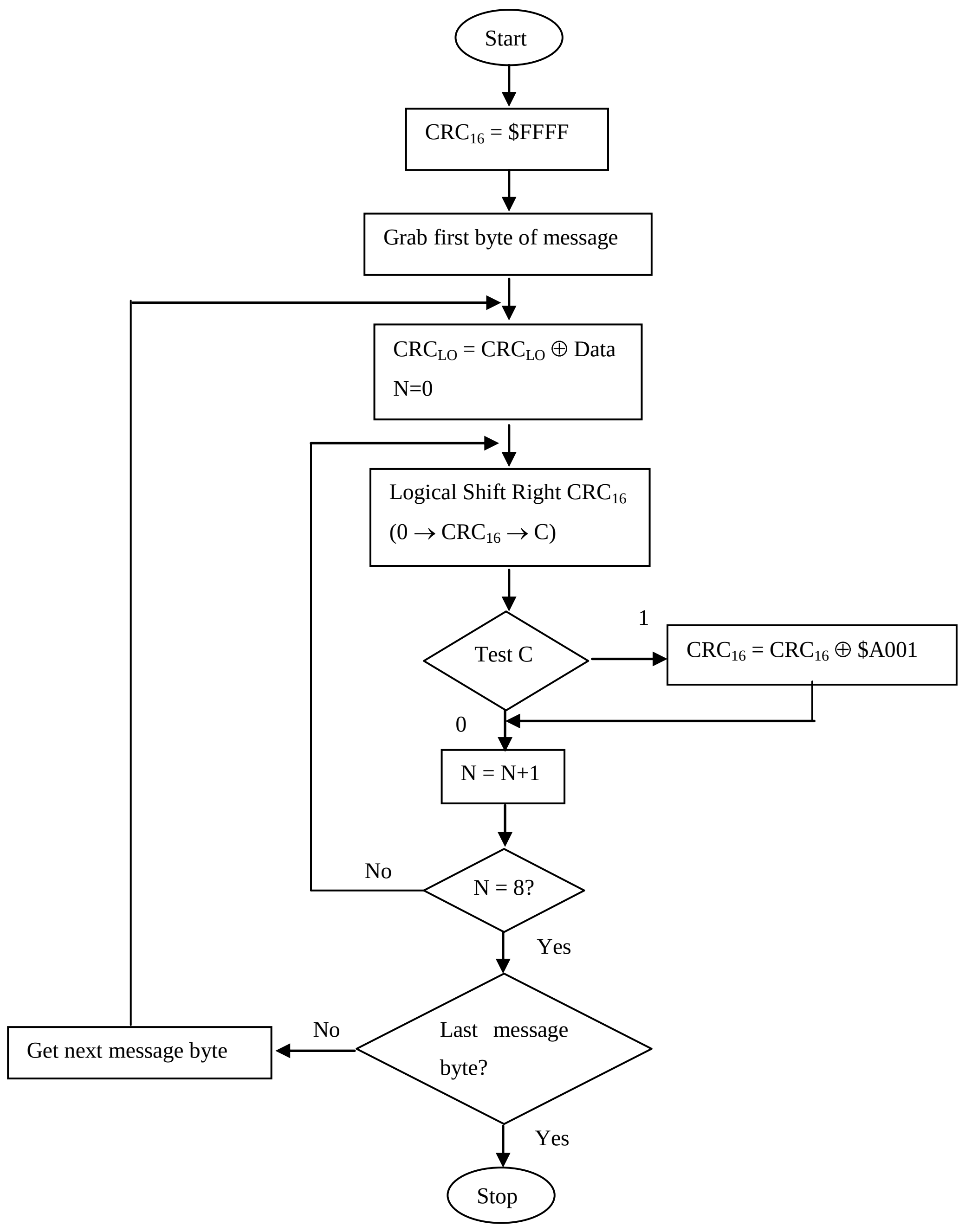
In RTU mode, the error-checking field contains a 16-bit value implemented as two 8-bit bytes. The error check value is the result of a CRC calculation performed on the message contents. The CRC field is appended to the message as the last field in the message. When this is done, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte to be sent in the message.

The CRC field checks the entire contents of the message and is applied regardless of any parity check method chosen. The transmitting device calculates the CRC. The receiving device recalculates the CRC and compares it to the transmitted CRC value. If the two values are not equal, an error results.

The CRC is initialized by pre-loading a 16-bit register to all 1's. Then a process of applying successive 8-bit bytes of the message to the current contents of the register. Only the 8 bits of the data in each character are used for generating the CRC. The start and stop bits and the parity bit do not apply to the CRC. During generation of the CRC, each 8-bit character is XORed with the register contents. Then the result is shifted right (toward the LSB), with a 0 filled into the MSB position and the previous LSB loaded into the carry bit. The carry bit is examined. If the carry bit is a 1, the register is then XORed with the polynomial value $A001. If the carry bit is 0, no action is taken. This process is repeated until eight shifts have been performed.

After the last (eighth) shift, the next byte is XORed with the register's current value, and the process repeats as described above. The final register contents are the CRC value. The low-order byte is appended first, followed by the high-order byte. See **Figure 6 CRC Flowchart.**

Figure 6   CRC Flowchart



6.7 Field Contents in Modbus Messages

The following tables show examples of a Modbus query and a normal response in RTU mode.

Query

Field Name	RTU Example Data	Description
Header	> 3.5 idle characters	Start characters
Slave Address	$06	Slave number 6
Function	$03	Read multiple registers
Starting Address Hi	$00	Start reading at holding register 108
Starting Address Lo	$6B	
No. of Registers Hi	$00	Read 3 successive holding registers
No. of Registers Lo	$03	
CRC Lo	$75	CRC = $A075
CRC Hi	$A0	
Trailer	> 3.5 idle characters	End characters

Response

Field Name	RTU Example Data	Description
Header	> 3.5 idle characters	Start characters
Slave Address	$06	Slave number 6
Function	$03	Read multiple registers
Byte Count	$06	Number of data bytes to follow
Data Hi	$02	Contents of holding register 108
Data Lo	$2B	
Data Hi	$00	Contents of holding register 109
Data Lo	$00	
Data Hi	$00	Contents of holding register 110
Data Lo	$62	
CRC Lo	$88	CRC = $8862
CRC Hi	$49	
Trailer	> 3.5 idle characters	End characters

6.7.1 The Byte Count Field

When constructing responses in buffers, use a Byte Count value that equals the count of 8-bit bytes in your message data. The value is exclusive of all other field contents, including the Byte Count field.

7 Programming Example and General Hints

This section provides an example of Microsoft Visual Basic™ code used to communicate with a Protocol™ Plus controller. In addition, some general programming hints are provided.

7.1 Code Example

The following Visual Basic™ code example assumes that an MSComm control named 'comMain' has been placed on a form named 'frmComm'. The form also contains a command button named 'Command1', and a text box named 'Text1'. Code is shown below in **Bold** type.

The example code sends a Modbus message to a Protocol™ Plus controller when the command button is clicked. The text box is cleared when the command button is clicked, and displays "OK" when a good reply is received from the controller. The received message data byte values are also displayed in the text box.

The following form declarations are made:

```
Option Explicit

Dim TxMessage As String
Dim RxMessage As String
```

TxMessage and RxMessage will be used as message data buffers for sending and receiving, respectively.

The following code procedure is also added to the form to calculate the Modbus CRC value:

```
Private Function GetCRC(MBuffer As String) As Long
Dim CRCValue As Long
Dim MLength As Long
Dim i As Integer
Dim j As Integer
Dim LsbSet As Boolean

'get message length:
MLength = Len(MBuffer)
```

```
'initialize the CRC register:
CRCValue = 65535
For i = 1 To MLength
    'this routine is called for each character of a message
    CRCValue = CRCValue Xor CInt(Asc(Mid(MBuffer, i, 1)))
        'for each bit in the new character,
        'do this loop:
        For j = 1 To 8
            'determine if LSB is now a 1:
            LsbSet = ((CRCValue And 1) = 1)
            'shift the crc (buffer) one bit to the right:
            CRCValue = Int(CRCValue / 2)
            'if LSB was a 1,
            If LsbSet Then
                'XOR buffer value with the CRC polynomial:
                CRCValue = CRCValue Xor 40961 '&HA001
            End If
        Next j
Next i

GetCRC = CRCValue

End Function
```

The following code, called in the form’s Load procedure, is used to initialize the COM port:

```
Private Sub Form_Load()

'make sure the port is closed:
If frmComm.comMain.PortOpen Then frmComm.comMain.PortOpen = False

'select desired COM port:
frmComm.comMain.CommPort = 1 '1=COM1, etc.
```

```
'set the Settings to select Baud Rate, Parity, Data bits, and Stop bits.
'Note that Baud Rate and Parity must match the Controller's settings,
'always use 8 Data bits and 2 Stop bits.
frmComm.comMain.Settings = "38400,N,8,2"

'set other parameters:
frmComm.comMain.InputLen = 0
frmComm.comMain.Handshaking = comNone
frmComm.comMain.InputMode = comInputModeText
frmComm.comMain.InBufferSize = 1024
frmComm.comMain.RThreshold = 1
frmComm.comMain.InputLen = 0
frmComm.comMain.OutBufferSize = 512
frmComm.comMain.SThreshold = 1
frmComm.comMain.EOFEnable = False
frmComm.comMain.ParityReplace = "?"
frmComm.comMain.NullDiscard = False
frmComm.comMain.RTSEnable = False
frmComm.comMain.DTREnable = True

'open the port:
frmComm.comMain.PortOpen = True

End Sub
```

The following procedure, placed to respond to the command button's click event, is used to build and transmit a "Read Holding Registers" message to read three registers starting at register 16:

```
Private Sub Command1_Click()
Dim CRCWord As Long 'CRC calculation result buffer

'initialize message with address, function, and function data bytes:
TxMessage = Chr(1) & Chr(3) & Chr(0) & Chr(16) & Chr(0) & Chr(3)

'call the CRC calculation:
```

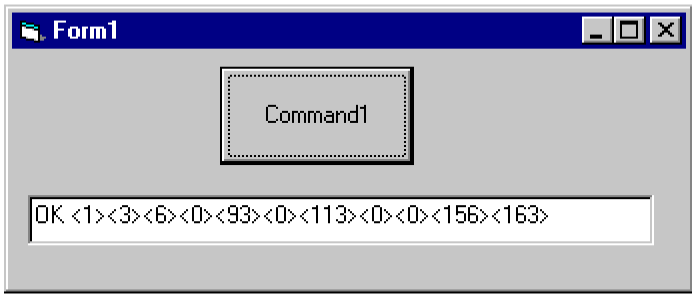
```
CRCWord = GetCRC(TxMessage)

'add the CRC bytes to the message:
TxMessage = TxMessage & Chr(CRCWord - Int(CRCWord / 256) * 256)
TxMessage = TxMessage & Chr(Int(CRCWord / 256))

'clear status text display:
Text1 = ""

'clear the receive data buffer:
RxMessage = ""

'send the message out the COM port:
frmComm.comMain.Output = TxMessage

End Sub
```

The reply message is received using the following code placed to respond to the MSComm device's 'OnComm' event:

```
Private Sub comMain_OnComm()
Dim CRCValue As Long
Dim NewBuffer As String
Dim RxCount As Integer
Dim i As Integer

Select Case comMain.CommEvent
Case comEvReceive
   'Read serial data bytes:
   NewBuffer = comMain.Input
   'Build up RxMessage
   RxMessage = RxMessage & NewBuffer

   '
   'Check RxMessage to see if it's complete - the length of each expected reply
```

```
    'can be calculated before the TxMessage is sent, when RxMessage contains
    'the expected message length, then reception is complete.
    '

    'Check for valid message CRC:
    RxCount = Len(RxMessage)
    CRCValue = GetCRC(Mid(RxMessage, 1, RxCount - 2))
    'compare result with received CRC:
    If (CLng(Asc(Mid(RxMessage, RxCount - 1, 1))) + _
      (CLng(Asc(Mid(RxMessage, RxCount, 1))) * 256)) = CRCValue Then
        'CRC result matches OK (process data in RxMessage as needed)
        Text1 = "OK "
        'display values of message's data bytes:
        For i = 1 To RxCount
        Text1 = Text1 & "<" & Asc(Mid(RxMessage, i, 1)) & ">"
        Next i
    Else
        'bad CRC result!
    End If
End Select

End Sub
```

With the PC connected to a Protocol^{TM} Plus controller on COM1, and the controller is set for Address 1, Baud Rate 38400, No Parity, clicking the command button produces the following display:



```
OK <1><3><6><0><93><0><113><0><0><156><163>
```

The data shows a good reply, with data values of 93, 113, and 0 for Holding Registers 16, 17, and 18, respectively.

7.2 Additional Communications Troubleshooting Hints

Communications problems occur primarily due to physical wiring problems or mismatched settings. It is important to verify that the Protocol™ Plus controller's Communication Card is properly installed, and its jumpers are properly set to match the wiring option used (RS-232, RS-422, or RS-485). Make sure the controller has MODBUS communications enabled, and that communications is programmed to match the controller's Address, Baud Rate, and Parity settings.

For programming communications, make sure that the serial data format uses two stop bits as mentioned above; using one stop bit will not work.

Programming should allow silent intervals between messages as described in the Modbus User's guide, in addition to transmitting bytes within a message continuously.

Finally, the Protocol™ Plus controller requires that the "Communications Security Code", Holding Register 0, be properly set before accessing some registers via Modbus. A program may want to set this register initially, with the Level 1 or 2 password associated with the controller, in order to avoid errors trying to read critical registers later on.

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