Connectivity to the ASCO® Group G Controller via Modbus®

Introduction

This design specification describes the *Modbus* communications protocol as supported by the *ASCO* transfer switch Group G controller. For packet details and examples, refer to Appendix I of this document. The Group G controller must have the communication port active and configured properly; refer to the Group G Controller User's Guide.

Supported Protocol Parameters

Implementation Basics

- Group G controller operates as slave device only
- The maximum number of bytes contained within one packet of communications is 255. This equates to supporting a read request for 125 registers.

Transmission Format

Only Modbus RTU mode is supported by the Group G. The controller only supports the following format:

- 8 data bits
- no parity
- 1 stop bit
- Refer to register map for baud rate supported
- Device address 1 - 247

Packet Framing and Timing

Three timing intervals associated with the Group G device is as follows:

- Maximum time between two consecutive bytes within a packet < 3.5 character times
- Minimum time between two consecutive packets is > 3.5 character times
- Maximum response time from a Master request to a slave response is < 50 milliseconds

Supported Function Codes

Function # 03 (03h) – Read Holding Registers

This function code allows the master to read one or more consecutive data registers (**up to 125**) from the Group G controller. Refer to *Register Map* section for details

Function #06 (06h) – Preset Single Register

This function code allows the master device to modify the contents of a single configuration register within the Group G controller.
The Group G controller currently only supports the following Preset Single Register addresses (decimal): 40045, 40080, 40102-40105, 40113, 40149-40154.
If a function code #06 command is issued to registers outside of these corresponding register ranges, the Group G controller will respond with an invalid address range Exception.

Function #16(10h) – Preset Multiple Registers

This function code allows the master device to modify the contents of consecutive configuration registers within the Group G controller.

The Group G controller currently only supports the following Preset Multiple Register addresses (decimal): 40102-40103, 40109-40112, 40165-40174 and 40215-40224. **The maximum allowable write data registers are 10.** If a function code #16 command is issued to registers outside of these corresponding register ranges, the Group G controller will respond with an invalid address range Exception.

Exception Responses

If the Modbus master device sends an unsupported command, attempts to read an invalid holding register, or attempts to write invalid data, the Group G controller will issue an exception response. The Group G controller currently supports error codes of 01, 02, 03 and 04. Refer Appendix I for details.

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Modbus Register Map

This table describes the mapping of the registers within the Group G device defined in the Modbus protocol.

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40001- 40011		Undefined		
40012	RO	Phase shift between normal & emergency	-1800 to 1800	degrees x 10
40013	RO	Normal frequency	0 to 7000	Hz x 100
40014	RO	Emergency frequency	0 to 7000	Hz x 100
40015-Bit 0	RO	Main on normal	Boolean	
40015-Bit 1	RO	Main on emergency	Boolean	
40015-Bit 2	RO	Auxiliary on normal	Boolean	
40015-Bit 3	RO	Auxiliary on emergency	Boolean	
40015-Bit 4	RO	Normal source available	Boolean	
40015-Bit 5	RO	Emergency source available	Boolean	
40015-Bits 6 - 15		Undefined		
40016-Bits 0 - 3		Reserved		
40016-Bit 4	RO	Engine exerciser with load active	Boolean	
40016-Bit 5		Reserved		
40016-Bit 6	RO	External F17 is active	Boolean	
40016-Bits 7 - 15		Undefined		
40017	RO	Normal voltage phase AB	0 to 7000	V x 10
40018	RO	Normal voltage phase BC	0 to 7000	V x 10
40019	RO	Normal voltage phase CA	0 to 7000	V x 10
40020	RO	Normal voltage unbalance	0 - 99	%
40021 - 40022		Reserved		
40023	RO	Emergency voltage phase CA	0 to 7000	V x 10
40024		Reserved		
40025	RO	Nominal voltage	0 to15	See **5.0.1**
40026-Bit 0	RO	Nominal frequency	Boolean	0 – 50 Hz, 1 – 60 Hz
40026-Bit 1	RO	Normal source 3 phase sensing	Boolean	0 – single, 1 – three
40026-Bit 2		Reserved		
40026-Bits 3-4	RO	Transfer switch type (OTTS,DTTS)	0, 1, 2, or 3	See **5.0.2**
40026-Bits 5 - 6		Reserved		
40026-Bits 7 - 15		Undefined		
40027	RO	Transfer switch ampere rating	0 to 18	See **5.0.3**
40028-40032	RO	Controller software version	10 char. string	
40033		Undefined		
40034-40038	RO	Controller software date	10 char. string	
40039		Undefined		
40040-Bits 0 - 3		Reserved		
40040-Bit 4	RO	External parameter lock is active	Boolean	
40040-Bit 5	RO	Engine running	Boolean	
40040-Bits 6 - 7		Reserved		
40040-Bits 8 - 15		Undefined		
40041	RO	Controller state	0 to 255	See **5.0.8**
40042	RO	Controller status state data	0 to 65535	See **5.0.8**
40043-Bit 0	RO	Timer bypass (Feature 6B) status	1 active, 0 not active	
40043-Bit 1		Reserved		
40043-Bit 2	RO	Remote transfer (Feature 17) status	1 active, 0 not active	
40043-Bits 3 - 4		Reserved		
40043-Bit 5	RO	Load shed (Feature 30) status	1 active, 0 not active	
40043-Bit 6		Reserved		
40043-Bit 7	RO	Transfer inhibit to emergency (Feature 34B) status	1 active, 0 not active	
40043-Bits 8 - 15		Undefined		
40044-Bits 0 - 3		Reserved		
40044-Bit 4	RO	Local test (Feature 5) status	1 active, 0 not active	
40044-Bit 5	RO	Manual transfer to emergency (Feature 6ZE) status	1 active, 0 not active	
40044-Bit 6		Reserved		

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40044-Bits 7 - 15		Undefined		
40045	RW	Event number	1 to 300	function code 06h See **3.0**
40046	RO	Event year	0 to 99	
40047	RO	Event month	1 to 12	
40048	RO	Event day of month	1 to 31	
40049	RO	Event day of week	0 – Sunday 1– Monday 2 – Tuesday 3 – Wednesday 4 – Thursday 5 – Friday 6 – Saturday	
40050	RO	Event hour	0 to 23	hr.
40051	RO	Event minute	0 to 59	min.
40052	RO	Event second	0 to 59	sec.
40053	RO	Event type		See **5.0.5**
40054	RO	Event cause		See **5.0.6**
40055	RO	Number of entries in the control panel event log	0 to 300	
40056	RO	Event tenths of second	0 to 9	
40057	RO	Current sensing	0-Disabled 1- 1CT 2- 2CT 3- 3CT	
40058	RO	CT ratio lookup table	0-15	See **5.0.4**
40059	RO	Phase A current (A). With 1 or 2 CT selected this is labeled as I1	0 -30000	A
40060	RO	Phase B current (A)	0 -30000	A
40061	RO	Phase C current (A). With 2 CT selected this is labeled as I2	0 -30000	A
40062		Reserved		
40063	RO	Failure to accept timer	0 – 3659 (with external battery*) 0 – 6 (without ext. battery*)	sec * Refer to register 40234 for external battery status
40064-Bit 0		Reserved		
40064 – Bits 1-15		Undefined		
40065 – Bit 0	RO	Normal to emergency pretransfer time delay (Feature 31) bypass enabled	Boolean	
40065 – Bit 1	RO	Emergency to normal pretransfer time delay (Feature 31) bypass enabled	Boolean	
40065 – Bit 2	RO	Commit to transfer enabled	Boolean	
40065 – Bit 3	RO	Bypass DTTS source failure enabled – data for DTTS and Group1 emulation is NOT enabled	Boolean	
40065 – Bit 4	RO	Inphase transfer enabled – only for OTTS	Boolean	
40065 – Bit 5	RO	Inphase monitor for load shed (Feature 30) enabled	Boolean	
40065 – Bit 6	RO	Fail accept timer enabled	Boolean	
40065 – Bit 7	RO	Transfer/retransfer time delay bypass (Feature 6B) input enabled	Boolean	
40065 – Bit 8	RO	Remote transfer (Feature 17) input enabled - data for transfer switch in auto mode only	Boolean	
40065 – Bit 9	RO	Retransfer to normal mode selector (Feature 6DL) enabled	Boolean	
40065 – Bit 10	RO	Serial remote transfer (Feature 17) enabled	Boolean	
40065 – Bit 11	RO	Voltage unbalance enabled	Boolean	
4006 –Bits 12-15		Undefined		
40066 – Bit 0	RO	Current sensing module present	Boolean	

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40066 – Bit 1	RO	Alert LED active	Boolean	
40066 – Bit 2	RO	Not in Auto LED active	Boolean	
40066 – Bits 3-15		Undefined		
40067-40073		Reserved		
40074-40078		Undefined		
40079-Bits 0-4	RO	Transfer switch ampere size	0-18	See **5.0.3**
40079 – Bit 5	RO	Manual transfer only enabled	Boolean	
40079 – Bit 6	RO	External inputs active high	Boolean	
40079 – Bits 7-15		Undefined		
40080	RW	Daylight savings	0 – Disabled 1 – Mar/Nov 2 – Apr/Oct	Support function code 06h
40081 – Bits 0 - 7	RO	APAC port address	1 - 127	
40081 – Bit 8	RO	APAC port enable	Boolean	
40081 – Bits 9 - 12	RO	APAC port baud rate	0 - Disabled 1 - 125K 2 - 250K 3 – 500K 4 - 1000K	
40081 – Bits 13 - 15		Undefined		
40082	RO	User interface date format	0 – US (mm/dd/yy) 1 – EU (dd/mm/yy) 2 – ISO (yy/mm/dd)	
40083 – Bit 0	RO	Loss of emergency when connected to emergency alarm enabled	Boolean	
40083 – Bit 1	RO	Expiration of failure to accept timer alarm enabled	Boolean	
40083 – Bit 2	RO	Load disconnect enabled (DTTS only)	Boolean	
40083 – Bits 3 - 15		Undefined		
40084 – Bit 0	RO	OP1 is Feature 31	Boolean	
40084 – Bit 1	RO	OP1 is common alarm	Boolean	
40084 – Bit 2	RO	OP1 is NR2	Boolean	
40084 – Bit 3	RO	OP1 is not in auto	Boolean	
40084 – Bits 4 - 15		Undefined		
40085 – Bit 0	RO	OP2 is Feature 31	Boolean	
40085 – Bit 1	RO	OP2 is common alarm	Boolean	
40085 – Bit 2	RO	OP2 is NR2	Boolean	
40085 – Bit 3	RO	OP2 is not in auto	Boolean	
40085 – Bit 4	RO	OP2 1G enabled	Boolean	
40085 – Bits 5 - 15		Undefined		
40086 – Bit 0	RO	OP3 is Feature 31	Boolean	
40086 – Bit 1	RO	OP3 is common alarm	Boolean	
40086 – Bit 2	RO	OP3 is NR2	Boolean	
40086 – Bit 3	RO	OP3 is not in auto	Boolean	
40086 – Bits 4 - 15		Undefined		
40087 - 40092		Undefined		
40093-40098	RO	Controller serial number	12 char string	
40099-40100		Undefined		
40101-108		Reserved		
40109-40112	RW	Controller name	8 char string	Support function code 10h
40113	RW	Engine exerciser (F11C) advanced schedule number	1 to 7	Support function code 06h See **4.0**
40114-Bit 0	RO	Engine exerciser (F11C) enabled	Boolean	
40114-Bit 1	RO	Engine exerciser (F11C) test with load transfer enabled	Boolean	

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40114-Bits 2-4	RO	Engine exerciser (F11C) start week	Advanced: (0 – 6) 0 – All 1 – Alternate 2 – 1st 3 – 2nd 4 – 3rd 5 – 4th 6 – 5th Standard: (0 – 1) 0 – Weekly 1 – Bi-weekly	
40114-Bits 5-7	RO	Engine exerciser (F11C) day of week	0 – Sunday 1– Monday 2 – Tuesday 3 – Wednesday 4 – Thursday 5 – Friday 6 – Saturday	
40114 – Bits 9 - 15		Undefined		
40115	RO	Engine exerciser (F11C) start time hours	0 - 23	hr.
40116	RO	Engine exerciser (F11C) start time minutes	0 - 59	min.
40117	RO	Engine exerciser (F11C) run time hours	0 - 23	hr.
40118	RO	Engine exerciser (F11C) schedule run time minutes	0 - 59	min.
40119	RO	Normal voltage dropout	70 - 98	%
40120	RO	Normal voltage pickup	85 - 100	%
40121	RO	Normal over voltage trip	0 – Off, 102 – 115	%
40122	RO	Normal frequency dropout	85 - 98	%
40123	RO	Normal frequency pickup	86 -100	%
40124	RO	Normal over frequency trip	0 – Off, 102 -110	%
40125-Bits 0-4		Reserved		
40125-Bits 5-7		Undefined		
40125-Bits 8-13		Reserved		
40125-Bits 14-15		Undefined		
40126	RO	Emergency voltage dropout	70 - 98	%
40127	RO	Emergency voltage pickup	85 -100	%
40128	RO	Emergency over voltage trip	0 – Off, 102 - 115	%
40129	RO	Emergency frequency dropout	85 - 98	%
40130	RO	Emergency frequency pickup	86 - 100	%
40131	RO	Emergency over frequency trip	0 – Off, 101 - 111	%
40132		Reserved		
40133	RO	Timer 1C engine start time delay	0 – 3659 (with ext. battery*) 0 – 6 (without ext. battery*)	sec. * Refer to register 40234 for external battery status
40134	RO	Timer 1F engine fail time delay	0 – 3659 (with ext. battery*) 0 – 6 (without ext. battery*)	sec. * Refer to register 40234 for external battery status
40135	RO	Timer 2B transfer N to E time delay	0 - 3659	sec.
40136	RO	Timer 2E engine cool down time delay	0 - 3659	sec.
40137	RO	Timer 3AF transfer E to N on source fail time delay	0 - 3659	sec.
40138	RO	Timer 3A T transfer E to N on test time delay	0 - 35999	sec.
40139	RO	Timer 31F N to E pre transfer signal time delay	0 - 359	sec.
40140	RO	Timer 31M N to E post transfer signal time delay	0 - 359	sec.
40141	RO	Timer 31G E to N pre transfer signal time delay	0 - 359	sec.
40142	RO	Timer 31N E to N post transfer signal time delay	0 - 359	sec.
40143 - 40146		Reserved		

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40147	RO	DTTS load disconnect time delay	0 - 359	sec.
40148- Bit 0	RO	Commit to transfer after engine start	Boolean	
40148- Bits 1 - 6		Reserved		
40148- Bits 7 - 15		Undefined		
40149	RO	Real time hour	0 - 23	hr. Support function code 06h
40150	RO	Real time minute	0 - 59	min. Support function code 06h
40151	RO	Real time second	0 - 59	sec. Support function code 06h
40152	RO	Calendar year	0 - 99	Year-2000 Support function code 06h
40153	RO	Calendar month	1 - 12	Support function code 06h
40154	RO	Calendar day of month	1 - 31	Support function code 06h
40155	RO	Calendar day of week	0 – Sunday 1–Monday 2 – Tuesday 3 – Wednesday 4 – Thursday 5 – Friday 6 – Saturday	
40156	RO	Total time E has been acceptable (high word)	0-5,999,999	min.
40157	RO	Total time E has been acceptable (low word)		
40158	RO	Total time N has been acceptable (high word)	0-5,999,999	min.
40159	RO	Total time N has been acceptable(low word)		
40160	RO	Total number of days CP has been energized	0-9,999	days
40161	RO	Total number of TS transfers	0-9,999	transfers
40162	RO	Total number of TS transfers due to source failures	0-9,999	transfers
40163 - 40164		Undefined		
40165-40174	RW	Controller location	20 char string	Support function code 10h
40175 - Bit 0	RO	External Feature 5 enabled	Boolean	
40175 - Bit 1	RO	External Feature 34 enabled	Boolean	
40175 - Bit 2	RO	In-phase filter enabled	Boolean	
40175 - Bits 3 - 6		Reserved		
40175 - Bit 7	RO	Current sensing option installed	Boolean	
40175 - Bits 8 - 15		Reserved		
40176 - Bit 0	RO	Advanced 11C option Installed	Boolean	
40176 - Bit 1	RO	Event log option Installed	Boolean	
40176 - Bit 2	RO	RS485 communication option Installed	Boolean	
40176 - Bit 3	RO	OP1 common alarm option Installed	Boolean	
40176 Bits 4 - 15		Reserved		
40177	RO	Total time load connected to normal (high word)	0-5,999,999	min.
40178	RO	Total time load connected to normal (low word)	0-5,999,999	min.
40179	RO	Total time load connected to emergency (high word)	0-5,999,999	min.
40180	RO	Total time load connected to emergency (low word)	0-5,999,999	min.
40181 Bits 0 – 7	RO	RS-485 port address	1 – 247	
40181 Bits 8 – 10	RO	RS-485 port baud rate	0 – Disabled 1 – 9600 2 – 19200 3 – 38400 4 – 57600 5 – 115200	
40181– Bits 11 – 12	RO	RS-485 port protocol	0 – ASCOBusI 1 – ASCOBusII 2 – Modbus	
40181 – Bit 13	RO	Emulate Group 1	Boolean	
40181 Bits 14-15		Reserved		

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40182	RO	DTTS load disconnect recovery mode – manual or auto	1 – Manual 2 – Auto	
40183	RO	Timer 2B transfer N to E on test time delay	0 – 3659	sec.
40184	RO	Inphase monitor time delay	0 – 30	sec. x 10
40185-198		Reserved		
40199	RO	ATS total transfer time in 10^{th} seconds (real value in seconds requires division by 10)	0-65535	0.1 sec. Increments
40200	RO	Dongle installed	Boolean	
40201 - 40205		Reserved		
40206	RO	Language selection setting	0 – 10	See 5.0.7
40207-40208		Reserved		
40209	RO	LCD contrast setting	1-20	
40210-40214		Reserved		
40215-40224	RW	Controller name	20 char string	Support function code 10h English only
40225-40229	RO	Boot loader version	10 char string	
40230	RO	Voltage display phase label selection	0 - Vab/Vbc/Vca 1 - Uuv/Uvw/Uwu 2 - Uab/Ubc/Uca	
40231	RO	Source 1 or source 2 selection for different English format	0 – Normal / Emergency 1- Source1 / Source2	
40232 - 40233		Reserved		
40234	RO	External battery enabled	Boolean	
40235 - 40247		Reserved		
40248	RO	TS data gen start date	1 – 31	Day
40249	RO	TS data gen start month	1 – 12	Month
40250	RO	TS data gen start year	0 – 99	Year - 2000
40251	RO	TS data gen start hour	0 – 23	hr.
40252	RO	TS data gen start minutes	0 – 59	min.
40253	RO	TS data gen start seconds	0 – 59	sec.
40254	RO	TS data gen start 10^{th} of seconds	0 – 9	
40255	RO	TS data gen start elapsed time in seconds	0 – 65535	sec.
40256 – Bit 0	RO	Alarm condition none (DATA 0 ONLY)		
40256 – Bit 1	RO	Loss E when connect to E	Boolean	
40256 – Bit 2	RO	Failure to accept timer	Boolean	
40256 – Bit 3	RO	Load disconnected	Boolean	
40256 – Bit 4	RO	Transfer failure	Boolean	
40256 – Bit 5	RO	Position error	Boolean	
40256 – Bit 6	RO	Failure of sensing circuit	Boolean	
40256 – Bit 7	RO	Internal event 1	Boolean	
40256 – Bit 8	RO	Internal event 2	Boolean	
40256 – Bit 9	RO	Internal event 3	Boolean	
40256 – Bit 10	RO	Internal event 4	Boolean	
40256 – Bit 11	RO	Internal event 5	Boolean	
40256 – Bit 12	RO	Internal event 6	Boolean	
40256 – Bit 13-15		Reserved		
40257	RO	Total active alarm number	0 – 12	
40258 – 40262		Reserved		
40263-Bits 0 - 1	RO	Load shed direction	0 – Disabled 1 – From N 2 – From E	
40263-Bit 2	RO	DTTS only – load shed on source failure	Boolean	

Reg. Address	Reg. Type	Parameter Description	Data Range	Units / Remarks
40263-Bit 3	RO	DTTS only – load shed on request F17	Boolean	
40264		Reserved		
40265	RO	LCD backlight on time	0 – 60 (Off – 0, On – 60)	min.
40266	RO	Normal voltage unbalance dropout Parameter settings display for 3 phase only	5 - 20	%
40267	RO	Normal voltage unbalance pickup Parameter settings display for 3 phase only	3 - 18	%
40268		Emergency voltage unbalance dropout Parameter settings display for 3 phase only	5 - 20	%
40269		Emergency voltage unbalance pickup Parameter settings display for 3 phase only	3 - 18	%
40270 - 40299		Undefined		
40300 - 40337		Reserved		

Modbus Register Map Notes

1.0 Register Address Scheme

The addresses in the format of 4xxxx follow the MODICON MODBUS protocol for point addressing. The actual address sent is the Register Address shown in the map minus the value **40001**.

2.0 Modbus Transfer Control

Factory use only.

3.0 Event log data access

To access the Log Events data at Holding Register addresses **40045-40056**, first the selected Log Event number has to be written into Register **40045** using function 06h command and then the data of that Event can be read from Registers **40046-40056** using function 03h command.

4.0 F11C Schedules data access

To access the Feature F11C Schedules data at Holding Registers addresses **40113-40118**, first the selected Schedule number to access (read or write) has to be written into Register **40113** using function 06h command and then the data of that Schedule can be read from Registers **40114-40118** using function 03h.

5.0 Data and Configuration Register Lookup Tables

5.0.1 Nominal Voltage Lookup Table

Data	Voltage
0	115V
1	120V
2	208V
3	220V
4	230V
5	240V
6	277V
7	380V
8	400V
9	415V
10	440V
11	460V
12	480V
13	550V
14	575V
15	600V

5.0.2 Switch Type Lookup Table

Data	Switch Type
0	OTTS
1	DTTS
2	Not used
3	OTTS

For this table, Data = 2 is invalid.

5.0.3 Switch Amp Rating Lookup Table

Data	Amp Rating
0	30A
1	70A
2	100A
3	150A
4	260A
5	400A
6	600A
7	800A
8	1000A
9	1200A
10	1600A
11	2000A
12	3000A
13	4000A
14	OTHER
15	xxxx
16	200
17	230
18	2600

5.0.4 CT Ratio Table

Data	CT Ratio
0	50:5
1	75:5
2	100:5
3	150:5
4	200:5
5	250:5
6	300:5
7	400:5
8	600:5
9	800:5
10	1000:5
11	1200:5
12	1600:5
13	2000:5
14	3000:5
15	4000:5

5.0.5 Event Type Lookup Table

Data	Event Type
0	N/A - Undefined
0	Reserved
1	Engine Start
2	Engine Stop
3	Transfer Normal to Emergency
4	Transfer Emergency to Normal
5	Emergency Source Accepted
6	Emergency Source Not Accepted
7	Normal Source Accepted
8	Normal Source Not Accepted
9	Transfer Abort
10	Reserved
11	Reserved
12	DTTS Load Connected
13	DTTS Load Disconnected
14	Not in Automatic
15	Return to Automatic
16	Alarm Reset
17	Timer 2B Bypass
18	Timer 3A Bypass
19	Timer 31 Bypass.
20	Initial Switch Position (on boot up)
21	Clear Events Data Base
22	Clear Statistics Data Base
23	Clock Set
24	DST Turned ON
25	DST Turned OFF
26	In-Phase Turned ON
27	In-Phase Turned OFF
28	Failure to Accept Timer
29	NVM Defaults Loaded
30	Upload Mode Entered
31	Firmware Updated
32	OTTS Type Set
33	DTTS Type Set
34	Password Changed
35	Transfer Committed
36	Local Transfer Override
37	Alarm transfer fail
38	Alarm position error
39	Internal error

5.0.6 Event Cause Lookup Table

Data	Event Cause
0	N/A - No Event Cause
1	Load Shed
2	Normal Source Accepted
3	Manual Transfer
4	Test 5
5	Test 17
6	Serial 17
7	Engine Exercise
8	Emergency Source Not Accepted
9	Normal Under Voltage
10	Normal Over Voltage
11	Normal Under frequency
12	Normal Over frequency
13	N/A - No Event Cause
14	N/A - No Event Cause
15	Emergency Under voltage
16	Emergency Over voltage
17	Emergency Under frequency
18	Emergency Over frequency
19	N/A - No Event Cause
20	N/A - No Event Cause
21	Feature 6 NE Aborts Transfer
22	N/A - No Event Cause
23	N/A - No Event Cause
24	Position Error
25	Manual Mode Enabled
26	Feature 34B Activated
27	Test Cancel
28	Local User
29	Remote User
30	Switch on normal
31	Switch on emergency
32	Switch on center off (disconnected)
33 to 41	- 001 to -009
42	Acknowledge alarms
43 to 50	-010 to -017

5.0.7 Language lookup table

Data	Language
0	English
1	Spanish
2	French
3	French Canadian
4	Portuguese
5	Italian
6	German
7	Russian
8	Turkish
9	Chinese
10	Korean

5.0.8 Controller State & State Data Lookup Table

State	TS Position	State Description	State Data
00	N	load on N, N ok	if 11C without load is running, then time left in minutes, else null
01	N	timer 1C (TDES) running	time left in seconds
02	N	waiting for E acceptable	null
03	N	transfer to E inhibited by F6Z	null
04	N	transfer to E inhibited by F34B	null
05	N	timer 2B (TDNE) running	time left in seconds
06	N	timer 31F (N to E pre transfer signal) running	time left in seconds
07	N	in phase monitor time delay (OTTS N to E transfer)	time left in seconds
08	N	waiting for in phase (OTTS N to E transfer)	phase difference in degrees x 10
09-14	--	Reserved	--
15	N	load disconnected (DTTS N to E transfer)	time left in seconds
16	--	Reserved	--
17	E	timer 31M (N to E post transfer signal) running	time left in seconds
18	E	load on E waiting for removal of transfer requests	if 11C with load is running, then time left in seconds else null
19	E	timer 3A (TDEN) running	time left in seconds
20	--	Reserved	--
21	--	Reserved	--
22	E	timer 31G (E to N pre transfer signal) running	time left in seconds
23	E	in phase monitor time delay (OTTS E to N transfer)	time left in seconds
24	E	waiting for in phase (OTTS E to N transfer)	phase difference in degrees x 10
25-30	--	Reserved	--
31	E	load disconnected (DTTS E to N transfer)	time left in seconds
32	--	Reserved	--
33	N	timer 31N (E to N post transfer signal) running	time left in seconds
34	N	timer 2E (TDEC) running	time left in seconds
35	N	timer 1C (TDES) while timer 2E (TDEC) running	time left in seconds
36	?	power up inhibit	1 if sources not acceptable, 2 if TS position unknown, 3 if transfer inhibit signal
255	-	transition state (maintain last state)	null

Appendix I

Modbus RTU Overview

This section describes some of the details of the *Modbus* communications protocol as supported by the *ASCO* Group G Controller. It includes instructions on how to communicate with devices via the Modbus network. This documentation should be used by individuals wishing to integrate Group G into their facility by developing software to communicate with it. Additional detail of Modbus specification can be found on the Modbus organization's Web site http://www.modbus.org/specs.php.

Modbus Protocol

Modbus RTU Packet Format

Every Modbus Packet consists of the following fields:

- Device Address Field
- Function Code Field
- Data Field
- Error Check Field

Device Address Field. This is the first byte of each Modbus RTU transmission. Group G device address is a number limited to the range of 1 - 247 and is associated with a single device configured with a matching address. Only the slave device whose address matches the value in this field will respond to the specified command.

Function Code Field. This is a second byte of each transmission and represents the commanded action to the slave device (for queries from the master) or the action that was taken by the slave device (for responses from the slave). Codes between 1 and 127 are defined as Modbus RTU functions. The function codes supported by the Group G are detailed on section "Supported Function Codes for Group G".

Data Field. The data field varies in length depending on whether the message is a request or a response packet. This field typically contains information required by the slave device to perform the command specified in a request packet or data being passed back by the slave device in a response packet.

Error Check Field. The error check field consists of a 16 bit (2 byte) Cyclical Redundancy Check (CRC16). It allows the receiving device to detect a packet that has been corrupted with transmission errors. Refer to *CRC-16 Algorithm* on page 2 for details.

Packet Framing and Timing

Because the Modbus RTU protocol does not define any explicit packet synchronization bytes, synchronization is accomplished implicitly with the use of silent intervals. According to the Modbus RTU standard, all messages must start with a silent interval of at least 3.5 character times. This means that every byte within a packet must follow the previous byte by fewer than 3.5 character times based on the baud rate. And every new packet of data must wait at least 3.5 character times after the packet that had preceded it.

CRC-16 Algorithm

Procedure. The algorithm essentially treats the entire data packet (less the start, stop, and, if used, parity bits) as one continuous binary number. Since we are doing a 16-bit CRC calculation, the binary number (entire packet) is multiplied by 2^{16} and then divided by the generator polynomial. In the case of the Modbus protocol, the generator polynomial is $x^{16} + x^{15} + x^2 + 1$. The 16-bit remainder of the division, which is the 16-bit CRC checksum, is then appended to the end of the packet. The resulting data packet including the 16-bit CRC checksum, when divided by the same Generator Polynomial at the receiver, will give a zero remainder if no transmission errors have occurred.

The binary value of the Generator Polynomial is **A001** hex. This is obtained by first dropping the most-significant-bit of the polynomial and then reversing the bit order. This yields 1010000000000001 or A001h. The steps for generating the 16-bit CRC checksum are:

1. Initially, load the 16-bit CRC register with the value FFFF hex.
2. Exclusive OR the 16-bit CRC register with the first data byte of the packet and store the result in the 16-bit CRC register.
3. If the Least Significant Bit (LSB) of the 16-bit CRC register is equal to one, then shift the 16-bit CRC register to the right by one bit and then Exclusive OR the result with the generator polynomial, A001 hex. Otherwise, just shift the 16-bit CRC register to the right by one bit.
4. Repeat step 3 until 8 right shifts have been performed.
5. Exclusive OR the 16-bit CRC register with the next data byte of the packet.
6. Repeat steps 3-5 until all the bytes of the data packet have been used in step 5.
7. The 16-bit CRC register contains the new checksum to be appended to the end of the packet, Least Significant Byte first.

CRC-16 Pseudo code.
Below is the pseudo code for generating the 16-bit CRC checksum. XOR is the Exclusive-OR function:
CRC16REG = FFFF hex
GENPOLY = A001 hex

```
FOR X = 1 to number of bytes in packet
    BEGIN
        XOR CRC16REG with the Xth data byte
        FOR Y = 1 to 8
            BEGIN
                IF [(the least-significant-bit of CRC16REG) = 1] THEN
                    SHIFT CRC16REG one bit to the RIGHT
                    XOR CRC16REG with GENPOLY
                OTHERWISE
    SHIFT CRC16REG one bit to the RIGHT
            END
        NEXT Y
    END
NEXT X
```

The resulting **CRC16REG** contains the 16-bit CRC checksum

CRC-16 C Programming Language Example. **CRC16_checksum** is a C language function that calculates and returns the 16-bit CRC checksum of a string of characters. This is the brute force method as it consumes a lot of processing power performing numerous bit shifts. A table look-up method based on this function would be more suitable for embedded systems where processing power is at a premium. These four parameters are passed as part of the function:

1. pointer to string
2. length of string (in bytes)
3. initial CRC value
4. desired Generator polynomial
   Included to make this CRC-16 function generic for any generator polynomial

The following C-language type definitions (typedef's) are assumed:

1. typedef unsigned int uint;
2. typedef unsigned char uchar;

The function is defined as follows:

```
uint CRC16_checksum(uchar *Buffer, uint Length, uint CRC, uint Genpoly) {

uint index;

   While (Length--) {                          /* for each data byte in string */

CRC = CRC ^ (uint) *Buffer++;          /* exclusive OR data byte */

For (index = 0; index < 8; index++) {/* for each of the 8 bits */
   If ((CRC & 0x0001) == 1) CRC = (CRC >> 1) ^ Genpoly;
   Else (CRC = CRC >> 1);

} /* for statement */

   } /* while statement */

   return(CRC);
}
```

An ASCO Example.
Let's assume the transmitting device desired to send the ASCII string "**ASCO**". Using an ASCII character look-up table, we have the following hexadecimal codes for each of the ASCO letters:
A = 0x65
S = 0x83
C = 0x67
O = 0x79

The transmitter would determine the 16-bit CRC checksum as follows (in C, both methods are equivalent):
CRC16_checksum("ASCO", 4, 0xFFFF, 0xA001) which returns CRC = 0xCD94
CRC16_checksum("\x65\x83\x67\x79", 4, 0xFFFF, 0xA001) which returns CRC = 0xCD94

Before sending the string, the transmitter would append the CRC checksum (in byte reverse order) to the string as follows:
"**ASCO\x94\xCD**" or the equivalent in hexadecimal notation **"\x65\x83\x67\x79\x94\xCD"**

If the receiving device received the string without any transmission errors, then doing the 16-bit CRC checksum on the entire received string would yield (again, both methods are equivalent):

CRC16_checksum("ASCO\x94\xCD", 4, 0xFFFF, 0xA001) which returns CRC = 0x0000
CRC16_checksum("\x65\x83\x67\x79\x94\xCD", 4, 0xFFFF, 0xA001) which returns CRC = 0x0000

Since the CRC checksum is equal to **zero**, the transmission is deemed valid.

Had an error been induced during the transmission, such as the ASCII character 'A' being inadvertently changed to the character 'B' (which is hexadecimal 0x66), the receiving device would determine the new checksum as:

CRC16_checksum("BSCO\x94\xCD", 4, 0xFFFF, 0xA001) which returns CRC = 0x3300
CRC16_checksum("\x66\x83\x67\x79\x94\xCD", 4, 0xFFFF, 0xA001) which returns CRC = 0x3300

Since the CRC is **NON-ZERO (0x3300),** the receiver would assume an error had occurred and discard the packet

Supported Function Codes for Group G Controller

Function # 03 (03h) – Read Holding Registers

This function code allows the master to read one or more consecutive data registers (up to 125) from the Group G controller. The data registers are always 16 bit (two byte) values, transmitted high order byte first. Refer to *Register Map* section for details about the data register definitions of the Group G controller. Transmit/ Receiving packet formats are described as below:

Master Transmission

Packet Format
Slave address
Function code
Data starting address (high byte)
Data starting address (low byte)
Number of registers (high byte)
Number of registers (low byte)
CRC16 (low byte)
CRC16 (high byte)

Slave Response
(For the number of register read request)

Packet Format
Slave address
Function code
Byte count
Data word #1 (high byte)
Data word #1 (low byte)
Data word #2 (high byte)
Data word #2 (low byte)
Data word #3 (high byte)
Data word #3 (low byte)
…..
CRC16 (low byte)
CRC16 (high byte)

Function #06 (06h) – Preset Single Register

This function code allows the master device to modify the contents of a single configuration register within the Group G controller. The data registers are always 16 bit (two byte) values, transmitted high order byte first. Refer to *Register Map* section for details about the data register type definitions of the Group G controller. Only those registers with the register type RW defined are allowed to process with function code #06. If a function code #06 command is issued out of these corresponding register ranges, Group G will respond with an invalid address range Exception Response (see section of *Exception Responses)*.

Master Transmission

Packet Format
Slave address
Function code
Data address (high byte)
Data address (low byte)
Data word (high byte)
Data word (low byte)
CRC16 (low byte)
CRC16 (high byte)

Slave Response

Packet Format
Slave address
Function code
Data address (high byte)
Data address (low byte)
Data word (high byte)
Data word (low byte)
CRC16 (low byte)
CRC16 (high byte)

Function #16(10h) – Preset Multiple Registers

This function code allows the master device to modify the contents of consecutive configuration registers within the Group G controller. The data registers are always 16 bit (two byte) values, transmitted high order byte first. Refer to *Register Map* for details about the data register type definitions of the Group G controller. Only those registers with the register type RW defined are allowed to process with function code #16. If a function code #16 command is issued out of these corresponding register ranges, Group G will respond with an invalid address range Exception Response (see section of *Exception Responses)*.

The maximum number of registers that can be preset with a single 10H command in Group G is 10. Transmit/Receiving packet formats are described below:

Master Transmission

(For the number of registers requested)

Packet Format
Slave address
Function code
Data starting address (high byte)
Data starting address (low byte)
Number of registers (high byte)
Number of registers (low byte)
Byte count
Data word #1 (high byte)
Data word #1 (low byte)
Data word #2 (high byte)
Data word #2 (low byte)
Data word #3 (high byte)
Data word #3 (low byte)
…….
CRC16 (low byte)
CRC16 (high byte)

Slave Response

Packet Format
Slave address
Function code
Data starting address (high byte)
Data starting address (low byte)
Number of registers (high byte)
Number of registers (low byte)
CRC16 (low byte)
CRC16 (high byte)

Exception Responses

If the Modbus master device sends an unsupported command, attempts to read an invalid holding register, or attempts to write invalid data, the Group G Controller (Modbus slave) issues an exception response. The format for the exception response is as follows:

1. SLAVE ADDRESS
2. FUNCTION CODE (with the most-significant-bit set to a 1)
3. ERROR CODE
4. CRC16 – low order byte
5. CRC16 – high order byte

*Note: The high order bit of the function code has been set to one to indicate an exception response has been generated.

The following table is a list of the exception codes supported by the Group G Controller.

Error Code	Error Name	Group G Controller Implementation
01	Illegal function	The slave does not support the function code contained in the master query packet.
02	Illegal data address	The slave does not support the Holding Register address referenced in the data field of the master query packet.
03	Illegal data value	The slave does not support the data referenced in the data field of the master query packet.
04	Device failure	The addresses slave is unable to perform the action requested due to an internal failure or malfunction.