

Appendix E: Serial Communications Protocol

General

The Mark[⊕] series Serial Communications Protocol has two command types: a *query* command and a *set* command. Each command must include a four character checksum, followed by a carriage return [CR] to be sent successfully. The command format is:

[Cmd][4-ch Checksum][CR]

The controller responds with an acknowledgement containing a response code (or string), a timestamp, and a checksum, followed by a carriage return [CR] and a line feed [LF]. The timestamp and checksum are reported in ASCII hexadecimal format. The response arrives in one of the following two formats:

ACK: A[Response String],[8-ch Timestamp],[4-ch Checksum][CR][LF]

NAK: N[1-ch NAK Code],[8-ch Timestamp],[4-ch Checksum][CR][LF]

Table E.1: NAK Codes

Code	Description
0	Invalid Checksum
1	Invalid Command
2	Parameter Too High
3	Parameter Too Low
4	Cannot Execute Command (Typically Wrong Mode)
5	Receive Buffer Overflow
6	Receive Framing Error
7	Receive Overrun Error
8	Receive Parity Error
9	Not enough characters to be a valid command
:	Non-hexadecimal character in checksum field

Table E.1: NAK Codes (Continued)

;	Function Code Number out of range
<	Event Type Number out of range
=	Too many characters to be a valid command (18 characters maximum)
>	Invalid character in the event type/function code field
?	Command is not valid for this controller configuration

The carriage return and line feed are defined as:

[CR] = 0x0D

[LF] = 0x0A

Checksum Algorithm

The checksum offers packet integrity for routine data communications. The checksum algorithm is:

1. Sum all bytes in a 16 bit register using an ‘add with carry’ operation (consider the first byte to be index 0, the even bytes are the lower-order portion of the 16 bit add and the odd bytes are the higher-order bits).
2. Invert all bits in the sum.
3. Convert the result to a four digit ASCII hexadecimal string.

For transmitted commands, include all characters in the command section in the sum. To verify received responses, include all characters up to the checksum (but not including it) in the sum. A sample checksum calculation implementation in the C++ programming language is: unsigned short CalculateChecksum (const unsigned char* pData, int DataLen).

```
{
  unsigned long CS = 0;
  unsigned short* psData = (unsigned short*)pData;
  for (int Index = 0; Index < (DataLen / 2); Index++, psData++)
    CS += *psData;
  If (DataLen % 2 != 0)
    CS += pData[DataLen - 1];
  CS = (CS >> 16) + (CS & 0xFFFF);
  CS += (CS >> 16);
  return (unsigned short) ~CS;
}
```

Query Commands

Table E.2: Query Commands

Name	Syntax	Response
Read Target Minimum Value	MN	See Read Target State, RT
Read Target Maximum Value	MX	See Read Target State, RT
Read No. of Event Types	NE	Aa,[Timestamp],[Checksum][CR][LF] where a = Number of Event types
Read Actual State	RA	Aa,bc,defghijk,lmnp,rs,ttttt,uuuuu,vvvvv,wwwww,xxxxx,yyyyy,zzzzz,11111,22222,33333,44444, [Timestamp], [Checksum][CR][LF] where a = Events Available, '0' = No, '1' = Yes b = Control Mode, '0' = Manual, '1' = Auto c = Control Mode Last Set By, 0 = Set by controller 1 = Set by front panel RS232 2 = Set by user RS232 3 = Set by user digital I/O d = Beam On/Off e = Anode Module On/Off f = Source Gas 1 On/Off g = Source Gas 2 On/Off h = Source Gas 3 On/Off

Table E.2: Query Commands (Continued)

Name	Syntax	Response
Read Actual State (continued)	RA	<p> i = Emission Module On/Off j = Keeper Module On/Off k = HCES Gas On/Off l = Beam/Control State m = Anode Module State n = Emission Module State o = Keeper Module State p = Gas State r = Controller State </p> <p> Bit 0 = On/Off Bit 1-2 = 0 = Set by controller 1 = Set by front panel RS232 2 = Set by user RS232 3 = Set by user digital I/O Bits 4-7 = 0x3 Bit 0 = Interlock Made? Bit 1 = Undervoltage Sensed? Bit 2 = In Gas Purge Mode? Bit 0 = Over temp Bit 1 = Over current Bits 4-7 = 0x3 Bit 0 = Source Gas 1 Not at Target? Bit 1 = Source Gas 2 Not at Target? Bit 2 = Source Gas 3 Not at Target? Bit 3 = HCES Not at Target? Bits 4-7 = 0x3 Bit 0 = Legacy Installed? Bit 1 = Remote Run Active? Bit 2 = Locked? Bit 3 = Test Mode On/Off Bits 4-7 = 0x3 </p>

Table E.2: Query Commands (Continued)

Name	Syntax	Response
Read Actual State (continued)	RA	<p>s = Master Gas Channel,</p> <p>t = Anode Voltage u = Anode Current v = Source Gas 1 Flow w = Source Gas 2 Flow x = Source Gas 3 Flow y = Emission Voltage z = Emission Current 1 = Neutralizer Current 2 = Keeper Current 3 = Keeper Voltage 4 = HCES Gas Flow</p> <p>0 = No Gases Installed 1 = MFC 1 is Master Gas Channel 2 = MFC 2 is Master Gas Channel 3 = MFC 3 is Master Gas Channel</p>
Read Current Event	RE	<p>Aaaa:bbb:ccc...c, d,[Timestamp],[Checksum][CR][LF] where:</p> <p>a = Event Tag (increments with each event) b = Event Code (See "Event List" on page 68.) c = Event Data (See "Event List" on page 68.) d = More Events? '0' = No, '1' = Yes</p>
Read Power Supply Model	RM	<p>Aabcd,[Timestamp],[Checksum][CR][LF] where:</p> <p>a = Source Type: '1' = End Hall Gridless Source b = Anode Type: '1' = Mark I, '2' = Mark II, '3' = Mark II High Output, '4' = Mark III c = Cathode Type: '1' = Filament, '2' = HCES d = Number of Source Gases Installed: '0' = None, '1' = 1, '2' = 2, '3' = 3</p>

Table E.2: Query Commands (Continued)

Name	Syntax	Response
Read Target State	RT	<p>Aaaaa,bbbb,cccc,dddd,eeee,ffff,gggg,hhhh,iiii,jjjj,kkkk,llll,mmmm,nnnn,oooo,pppp,qqqq,rrrr,ssss,tttt,uuuu,[Timestamp],[Checksum][CR][LF] where</p> <ul style="list-style-type: none"> a = Anode Voltage b = Anode Current c = Source Gas 1 Flow d = Source Gas 1 Start Flow e = Source Gas 1 Flow Limit f = Source Gas 1 Run Proportion g = Source Gas 2 Flow h = Source Gas 2 Start Flow i = Source Gas 2 Flow Limit j = Source Gas 2 Run Proportion k = Source Gas 3 Flow l = Source Gas 3 Start Flow m = Source Gas 3 Flow Limit n = Source Gas 3 Run Proportion o = Emission Current p = Emission Current Limit q = Neutralization Ratio [xxxx%] or Neutralizer Current [xxxx] (mA) r = Keeper Current s = HCES Run Gas Flow t = HCES Start Gas Flow u = HCES Gas Flow Limit
Read Version	RV	<p>Avv.vv,[Timestamp],[Checksum][CR][LF] where vv.vv = Software Version Number</p>

Set Commands

Table E.3: Set Commands

Name	Syntax	Units	Description
Set Anode On/Off	A	n.a.	Turns the anode on and off when the controller is in the MANUAL mode.
Set Anode Current	AI	amperes	Sets the anode current when the controller's AI SETPOINT feature is active in the AUTO mode.
Set Anode Voltage	AV	volts	Sets the target voltage for the anode.
Set Beam On/Off	B	n.a.	Turns the beam on and off when the controller is in the AUTO mode.
Clear Current Event	CE	n.a.	CEaaa[Checksum][CR] where a = Event Tag Clear Event will occur only if this tag matches the tag of the top event in the queue.
Disable All Event Types	DA	n.a.	Deactivate all event reporting.
Disable Event Type	DE	n.a.	DEaaa[Checksum] [CR] where aaa = Event Type to disable: 000 = Module On/Off Change 001 = Module Fault Status Change 002 = Source Startup Events 004 = Controller Fault Events
Set Emission On/Off	E	n.a.	Turns the emission current on and off when the controller is in the MANUAL mode.
Enable Event Type	EE	n.a.	EEaaa[Checksum] [CR] where: aaa = Event Type to enable. See DE above.
Set Emission Current	EI	amperes	Sets the emission current when the controller's EI SETPOINT feature is active in the AUTO mode.
Set Emission Current Limit	EL	amperes	Sets the maximum allowable emission current.
Set Source Gas 1 On/Off	GIA	n.a.	Turns Source Gas channel 1 on and off when the controller is in the MANUAL mode.
Set Source Gas 1 Flow	GIF	sccm	Sets Source Gas channel 1 flow when the controller's SG SETPOINT feature is active in the AUTO mode or when the controller is in MANUAL mode.
Set Source Gas 1 Flow Limit	GIL	sccm	Sets the maximum allowable gas flow for Source Gas channel 1.
Set Master Gas to MFC 1	GIM	n.a.	Sets Source Gas channel 1 as the master gas channel.
Set Source Gas 1 Flow Run Proportion	GIP	%	Sets Source Gas channel 1 flow as a proportion (percentage) of the Master Gas channel flow when the controller is in the AUTO mode.

Table E.3: Set Commands (Continued)

Name	Syntax	Units	Description
Set Source Gas 1 Start Flow	G1S	sccm	Sets Source Gas channel 1 start flow when the controller is in the AUTO mode.
Set Source Gas 2 On/Off	G2A	n.a.	Turns Source Gas channel 2 on and off when the controller is in the MANUAL mode.
Set Source Gas 2 Flow	G2F	sccm	Sets Source Gas channel 2 flow when the controller is in MANUAL mode.
Set Source Gas 2 Flow Limit	G2L	sccm	Sets the maximum allowable gas flow for Source Gas channel 2.
Set Master Gas to MFC 2	G2M	n.a.	Sets Source Gas channel 2 as the master gas channel.
Set Source Gas 2 Flow Run Proportion	G2P	%	Sets Source Gas channel 2 flow as a proportion (percentage) of the Master Gas channel flow when the controller is in the AUTO mode.
Set Source Gas 2 Start Flow	G2S	sccm	Sets Source Gas channel 2 start flow when the controller is in the AUTO mode.
Set Source Gas 3 On/Off	G3A	n.a.	Turns Source Gas channel 3 on and off when the controller is in the MANUAL mode.
Set Source Gas 3 Flow	G3F	sccm	Sets Source Gas channel 3 flow when the controller is in MANUAL mode.
Set Source Gas 3 Flow Limit	G3L	sccm	Sets the maximum allowable gas flow for Source Gas channel 3.
Set Master Gas to MFC 3	G3M	n.a.	Sets Source Gas channel 3 as the master gas channel.
Set Source Gas 3 Flow Run Proportion	G3P	%	Sets Source Gas channel 3 flow as a proportion (percentage) of the Master Gas channel flow when the controller is in the AUTO mode.
Set Source Gas 3 Start Flow	G3S	sccm	Sets Source Gas channel 3 start flow when the controller is in the AUTO mode.
Set HCES Gas On/Off	H	n.a.	Turns Source Gas channel 4 on and off when the controller is in the MANUAL mode
Set HCES Run Gas Flow	HF	sccm	Sets Source Gas channel 4 flow when the controller is in MANUAL mode.
Set HCES Gas Flow Limit	HL	sccm	Sets the maximum allowable gas flow for the HCES Gas channel.
Set HCES Start Gas Flow	HS	sccm	Sets Source Gas channel 4 start flow when the controller is in the AUTO mode.
Set Keeper On/Off	K	n.a.	Turns the keeper current on and off when the controller is in the MANUAL mode.
Set Keeper Current	KI	amperes	Sets the keeper current target that maintains the HCES discharge after HCES ignition.
Set Lock Mode	L	n.a.	('0' = Unlocked, '1' = Locked)

Table E.3: Set Commands (Continued)

Name	Syntax	Units	Description
Set Control Mode	M	n.a.	('0' = Manual, '1' = Auto)
Set Neutralizer Current	NI	amperes	Sets the neutralizer current when the controller's NI SETPOINT feature is active in the AUTO mode.
Set Neutralization Ratio	NR	%	Sets the neutralizer current as a proportion (percentage) when the controller's NI SETPOINT feature is active in the AUTO mode.

Event List

Table E.4: Event List

Type	Name	Code	Data	Description
Module On/Off Status (type 000)	'Module On/Off Change'	3	ABC	A = (Hex) New On/Off State (0 = Off, 1 = On)
			D	B = (Hex) Module ID (see above) C = (Hex) Source of change: 1 = Controller 2 = Front Panel RS232 3 = User RS232 4 = User Digital I/O
Module Fault Status (type 001)	'Module Over Temp'	1	AB	A = (Hex) New OverTemp State (0 = Off, 1 = On) B = (Hex) Module ID, 1 = Anode 2 = Filament Cathode 3 = Emission 4 = Keeper 5 = Source Gas 1 6 = Source Gas 2 7 = Source Gas 3 8 = HCES Gas 9 = Beam
			2	AB

Table E.4: Event List (Continued)

Type	Name	Code	Data	Description
Source Startup (type 002)	'Source Startup'	4	A	<p>A = (Hex) Info:</p> <ul style="list-style-type: none"> 1 = Source Gas Ramping To Start Target 2 = Anode Voltage Ramping to Start Target 3 = Filament Current Ramping to Start Target 4 = Ramping Filament Current to Ignite Source 5 = Source Discharge Has Started 6 = Switching Gas Mix to Run Proportions 7 = Servo Loops are Active 8 = Source Unable to Start Discharge 9 = Source Discharge Went Out A = Source Discharge Has Restarted C = Waiting for HCES to Start F = HCES Has Started (Auto Mode) 10 = HCES Unable to Start Discharge
Controller Fault (type 004)	'Controller Fault'	6	A	<p>A = (Hex) Info:</p> <ul style="list-style-type: none"> 1 = Source Discharge Has Gone Out 2 = Cathode Filament is Open 3 = Source Unable to Start Discharge 4 = Source Discharge Too Unstable 5 = Cathode Current has reached the limit 6 = Source Gas has reached the limit 7 = Power module has an overtemperature fault 8 = Cathode Current is not servoing to the requested target 9 = Source Gas is not servoing to the requested target A = Anode Voltage not at target B = Cathode Current not at target C = Source Gas not at target D = Keeper Current not at target E = HCES Gas not at target F = Interlock Broken 10 = Undervoltage Fault 11 = HCES Unable to Start Discharge 12 = HCES Gas is not servoing to the requested target