PIONEERS IN NERVE STIMULATION AND MONITORING

The MAGSTIM Company Ltd

Rapid² Host Interface Communication Protocol

Revision 5.1

Contents

1. Introduction

The following document details how a Rapid² can be controlled remotely by the serial interface. The first section details important safety information that needs to be clearly understood before attempting to operate the Rapid² system using an alternate controller. The next few sections detail the information required to establish and maintain communications with the base, followed by a section which gives a detailed breakdown for each of the possible commands. The final section details a method to test that control has been established.

2. Important Safety Information

The section provides important information to allow the safe operation of the Rapid² system when using an alternate means of control. This information should be read through in its entirety and clearly understood.

2.1. Alternate Controller Electrical Requirements

- The alternate controller should be compliant with EN60601-1. On the basis that the proposed alternate controller is not compliant with EN60601-1 the following must be ensured:
    1. If a PC is used as an alternate controller, it must be certified to IEC 60950 by a reputable test laboratory and documentation must be provided to show evidence of certification to EMC (Electromagnetic Compatibility) standards EN5022 and EN5024.
    2. The alternate controller must receive electrical power by means of a medical grade isolation transformer which has been certified to EN60601-1.

2.2. Setup Requirements

- The setup configuration must be in accordance with the safety requirements for medical electrical systems, EN60601-1-1.
- The Rapid² system has been certified in accordance with EN60601-1-2 using interface cable lengths of 1.5m. Any interface cable which connects the Rapid² unit to an external piece of equipment must be no more than 1.5m in length. However, it should be noted that meeting this requirement does not give a guarantee that the final system will meet the required emissions level and be immune to interference. It is therefore a necessity that the final system configuration be re-checked with respect to EN60601-1-2 to ensure compliance.
- The final system configuration with respect to patient, touch and enclosure leakage currents must be verified and confirmed to be less than the requirement of EN60601-1 in both normal and fault conditions.
- A separate STOP button assembly must be implemented. This button must be red in colour and located in an appropriate position on the system and once depressed must force the Rapid² unit into a standby state. It is therefore recommended that this button be directly connected to the hardware stop line which is available on the rear interface connector of the Rapid² base unit. Refer to section 4.2 for more details.

2.3. Cleaning Requirements

- Cleaning instructions must be provided for the alternate controller.

2.4. Software Requirements

- The operating controls should be such that their function is clearly indicated, and should be simple enough to ensure the user is able to operate the system safely and effectively.
- The alternate controller user interface must clearly indicate the charge state of the stimulator.
- All operational system parameters must be clearly displayed. Validation should be carried out to ensure that the displayed information is clear and there is no ambiguity between parameters. Factors such as the viewing angle of any display and the colour scheme employed should be

taken into consideration. The instructions for use should fully describe the meaning of each parameter.

- The software must implement self checking routines between the alternate controller and the Rapid² stimulator. The current UI reads back all protocol parameters (power, frequency etc) from the stimulator and verifies them against the values sent down. The implementation should be formally verified for correct operation under normal and single fault conditions. Should any fault arise the system should enter a discharged state.
- The Rapid² UI provides the focal point where all system faults and warnings are clearly displayed. The alternate controller user interface must therefore provide the same level of visibility for indication of faults and warnings.

3. Energy Dissipation Requirements

In order to ensure the reliability of the Rapid² system it is important that the software developer adheres strictly to the maximum allowable energy dissipation of the system. In order to ensure this requirement, a minimum wait time must be enforced between each stimulation train. The calculation of the minimum wait time can be made using a combination of Table 1 and
Equation 1below.

To use Table 1, first select the appropriate row and then move across the appropriate units. For example, the energy per pulse for an output power of 64% is 103.2J.

Output Power	0	1	2	3	4	5	6	7	8	9
0	0.0 J	0.0 J	0.1 J	0.2 J	0.4 J	0.6 J	0.9 J	1.2 J	1.6 J	2.0 J
10	2.5 J	3.0 J	3.6 J	4.3 J	4.9 J	5.7 J	6.4 J	7.3 J	8.2 J	9.1 J
20	10.1 J	11.1 J	12.2 J	13.3 J	14.5 J	15.7 J	17.0 J	18.4 J	19.7 J	21.2 J
30	22.7 J	24.2 J	25.8 J	27.4 J	29.1 J	30.8 J	32.6 J	34.5 J	36.4 J	38.3 J
40	40.3 J	42.3 J	44.4 J	46.6 J	48.8 J	51.0 J	53.3 J	55.6 J	58.0 J	60.5 J
50	63.0 J	65.5 J	68.1 J	70.7 J	73.4 J	76.2 J	79.0 J	81.8 J	84.7 J	87.7 J
60	90.7 J	93.7 J	96.8 J	100.0 J	103.2 J	106.4 J	109.7 J	113.0 J	116.4 J	119.9 J
70	123.4 J	126.9 J	130.5 J	134.2 J	137.9 J	141.7 J	145.5 J	149.3 J	153.2 J	157.2 J
80	161.2 J	165.2 J	169.3 J	173.5 J	177.7 J	181.9 J	186.3 J	190.6 J	195.0 J	199.5 J
90	204.0 J	208.5 J	213.1 J	217.8 J	222.5 J	227.3 J	232.1 J	236.9 J	241.9 J	246.8 J
100	252.0J									

Table 1: Energy for a single pulse, specified in Joules for each output power setting.

3.1. Minimum Wait Time

The calculation of the minimum wait time, t_{wait} , is as follows:

$$t_{wait} = \frac{N_{pulses} \cdot (f_{stim} \cdot E_{pulse} - 1050)}{1050 \cdot f_{stim}}$$

where:

t_{wait} is the minimum wait time.

N_{pulses} is the number of pulses in a single train

f_{stim} is the stimulation frequency in Hz

E_{pulse} is the energy per pulse in Joules taken from Table 1

Equation 1: Calculation of minimum wait time.

It should be noted that the absolute minimum wait time is 0.5 seconds.

3.1.1. Minimum Wait Time – Calculation Example

For the following protocol: 73%, 25Hz, 10.0s ON

Number of Pulses (N_{pulses}) = 250

Energy Per Pulse from Table 1: 134.2J

Minimum Wait Time from Equation 1: 21.95 seconds

3.2. Maximum On Time

In addition to the minimum wait time, the system must not be made to dissipate more than 63000 Joules per minute. This requirement leads to a maximum train on time given below in Equation 2.

$$t_{max\ on} = \frac{63000}{E_{pulse} \cdot f_{stim}}$$

where:

$t_{max\ on}$ is the maxium train on time for a given output power

f_{stim} is the stimulation frequency in Hz

E_{pulse} is the energy per pulse in Joules taken from Table 1

Equation 2: Calculation of maximum on time.

If a value of greater than 60.0 seconds is calculated using Equation 2, it should be interpreted as a protocol which can be run continuously up to a maximum of 6000 pulses. It is possible to calculate the maximum stimulation frequency to allow for continuous operation at a given output power using the following relationship:

$$f_{stim\ (cont)} = \frac{1050}{E_{pulse}}$$

where:

$f_{stim\ (cont)}$ is the maximum stimulation frequency which allows for continuous operation for a given output power

E_{pulse} is the energy per pulse in Joules taken from Table 1

Equation 3: Calculation of continuous operation stimulation frequency

WARNING: Failure to adhere to the minimum wait time or maximum on time may result in damage to the Rapid² system.

4. Interface

The following tables detail the hardware and software interface. Note the cable used to connect to the Rapid² should only contain the three identified connections.

4.1. Serial Communication

Baud Rate	9600 bps
Data	8 bits
Stop	1 bit
Parity	None
Flow Control	None

4.2. Connection

Location		Rear of Stimulator
Type		26 Way D-Type (Female)
Signal Levels		RS232
Pin Signals	TX	Pin 13 - (Output from Stimulator)
	RX	Pin 12 - (Input to Stimulator)
	GND	Pin 1
	Tin +	Pin 5
	Tin -	Pin 6
	STOP	Pin 16 (Hardware Stop Line)

The 'Tin +' will trigger the system when a positive signal is applied to it.
The 'Tin -' will trigger the system when a negative signal is applied to it.

5. Protocol

Each command is made up of a variable length series of ASCII characters. Each command is made up of three elements, a unique command character, one or more data characters and one checksum character; see section 4 for more details.

5.1. Checksum (CRC) Calculation

The CRC calculation for each data packet sent or received will be determined by adding the sum of all the bytes in the packet (Except the CRC byte), truncating the value to use only the lower 8 bits if result is greater than 0xff, then bit inverting the result.

5.2. Padding Byte

So that all commands can be entered via a standard terminal, some of the commands contain a padding byte. The base will ignore this byte.

5.3. Response to Bad Commands

The base will respond to bad commands in the following ways:

5.3.1. If the base receives an invalid command byte then the base will respond with a '?'.

5.3.2. If the base receives a valid command byte but faulty data then the base will respond with <CMD received>?<CRC>.

5.3.3. If the base receives a valid command with valid data but it conflicts with the current system configuration then the base will respond with <CMD received>S<CRC>.

5.4. Communication Timings

Once communication is established to take control of the Rapid², the Rapid² has to receive a valid command which will return a system status every ten seconds when in the standby state, and every second in the armed state. To ensure smooth operation it is best to send a valid command every 500ms. If no configuration changes are required then re-sending the 'Enable Remote Control' command (for stimulator software versions earlier than V9.0) or the 'Get System Status' command (for stimulator software revisions V9.0 onwards) can be used to maintain the serial link and retrieve the current system status. See section 6.11 for information on the command used to retrieve the software serial number, or section 11 for an example.

5.5. Producing single pulses

By default the Rapid² runs in single pulse mode when no graphical UI is attached. In this mode the system will produce only one pulse for each trigger request sent. In this mode the system can not produce pulses faster than 1Hz when triggered via the serial link.

The following sequence of commands needs to be sent to make the system deliver a pulse;

a. Send the 'enable remote control' command first, to take control of the system.
b. Once the 'enable remote control' command has been sent and acknowledged, the 'set base mode' command can be sent to arm the system. Note the System can take up to 1 second after receiving the command, to reach the ready state, so resending a couple of 'enable remote control' commands to maintain communications may be required.
c. Once the system reports it is in the ready state, the 'set base mode' command can be sent to trigger the system.
d. The system power level may be set at any time, once remote control has been established.
e. The system can be disarmed by sending the 'set base mode' command.

5.6. Producing pulse trains

The following sequence of commands needs to be sent to make the system deliver a train;

a. Send the 'enable remote control' command first, to take control of the system.
b. Once the 'enable remote control' command has been sent and acknowledged, the 'set duration' command has to be sent with a value of 1 second. This will change the mode of operation from single pulse mode to train mode. This command can be sent when the system is armed, but it is advisable to only change modes when the system is in the unarmed state.
c. The power, frequency and number of pulses can then be set. Note there is a maximum frequency for each power setting, see Rapid² user manual for details, for this reason it is best to set the power value before the frequency value. All values may be set when the system is armed.
d. The 'set base mode' command can then be sent to arm the system. Note the System can take up to 1 second after receiving the command, to reach the ready state, so resending a couple of 'enable remote control' commands to maintain communications may be required.
e. Once the system reports it is in the ready state, the 'set base mode' command can be sent to trigger the system The Rapid² will only run one train for each trigger signal.
f. The Rapid² enforces a 500ms minimum wait time after each train and does not allow train parameters to be changed during this time.
g. The Rapid² can be switched back to single pulse mode by sending a 'set duration' command with a value of 0 seconds.

6. Base Command Interface

6.1. Set Power A

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	0	0	0	0	0	40	Command
N	N	N	N	N	N	N	N	NN	Power 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Power 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Power 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	CRC
NOTE: Maximum power allowed is 100%									
Base Controller Response									
0	1	0	0	0	0	0	0	40	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an "Enable Remote Control" command has previously been sent.

6.2. Set Frequency

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	0	0	0	1	0	42	Command
N	N	N	N	N	N	N	N	NN	Frequency 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'TENTHS' value ASCII format
N	N	N	N	N	N	N	N	NN	CRC
NOTE: Absolute maximum stimulation frequency is 100.0Hz for 240V systems, and 60Hz for 115V.									
Base Controller Response									
0	1	0	0	0	0	1	0	42	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an "Enable Remote Control" command has previously been sent.

6.3. Set Number Of Pulses

Not part of command structure for stimulator software versions prior to V9.0

See section 6.11 for command to retrieve software version from stimulator

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	0	0	1	0	0	44	Command
N	N	N	N	N	N	N	N	NN	'TEN THOUSANDS' value ASCII format
N	N	N	N	N	N	N	N	NN	'THOUSANDS' value ASCII format
N	N	N	N	N	N	N	N	NN	'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	CRC
NOTE: Maximum number of pulses per train is 6000									
Base Controller Response									
0	1	0	0	0	1	0	0	44	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an "Enable remote control" command had been sent previously.

6.4. Set Base Mode

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	0	0	1	0	1	45	Command
N	N	N	N	N	N	N	N	NN	Mode Setting Byte Format (see section 9)
N	N	N	N	N	N	N	N	NN	CRC
Base Controller Response									
0	1	0	0	0	1	0	1	45	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	CRC

Note: With the exception of sending a "Stop Mode Request", this command will only work if an "Enable Remote Control" command has previously been sent.

6.5. Enable Remote Control.

Note: Depending on the software version of the stimulator, the command structure for 'Enable Remote Control' is different. For stimulator software versions prior to V9.0, section 6.5.2 should be followed, otherwise section 6.5.1 should be followed.

6.5.1. Command structure for stimulator software V9.0 and onwards

Note: The 'unlock code' is provided by Magstim and is unique for each stimulator. Access to certain commands will be restricted until a valid 'unlock code' has been provided to the stimulator.

Host Command										
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**	**HEX**	**Description**	
0	1	0	1	0	0	0	1	51	Command	
N	N	N	N	N	N	N	N	NN	1st byte of block 1 in ASCII format	UNLOCK CODE
N	N	N	N	N	N	N	N	NN	2nd byte of block 1 in ASCII format	
N	N	N	N	N	N	N	N	NN	3rd byte of block 1 in ASCII format	
N	N	N	N	N	N	N	N	NN	4th byte of block 1 in ASCII format	
0	0	1	0	1	1	0	1	2D	Block separator '-'	
N	N	N	N	N	N	N	N	NN	1st byte of block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	2nd byte of block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	3rd byte of block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	4th byte of block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	5th byte of block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	6th byte f block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	7th byte of block 2 in ASCII format	
N	N	N	N	N	N	N	N	NN	8th byte of block 2 in ASCII format	
0	0	1	0	1	1	0	1	2D	Block separator '-'	
N	N	N	N	N	N	N	N	NN	MSB of unlock code CRC in hexadecimal	
N	N	N	N	N	N	N	N	NN	LSB of unlock code CRC in hexadecimal	
N	N	N	N	N	N	N	N	NN	CRC	
Base Controller Response										
0	1	0	1	0	0	0	1	51	Command Acknowledge	
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)	
N	N	N	N	N	N	N	N	NN	CRC	

Note: This command has to be sent to the stimulator before external control of the stimulator can take place

6.5.2. Command structure for stimulator software prior to V9.0

Host Command									
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**	**HEX**	**Description**
0	1	0	1	0	0	0	1	51	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	1	0	1	1	1	0	6E	CRC
Base Controller Response									
0	1	0	1	0	0	0	1	51	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command has to be sent to the stimulator before external control of the stimulator can take place

6.6. Disable Remote Control

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	1	0	0	1	0	52	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	1	0	1	1	0	1	6D	CRC
Base Controller Response									
0	1	0	1	0	0	1	0	52	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	CRC

Note: Sending this command to the stimulator returns control of the stimulator back to the UI.

6.7. Enable Enhanced Rapid Power Setting Mode

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	1	1	1	1	0	5E	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	1	0	0	0	0	1	61	CRC
Base Controller Response									
0	1	0	1	1	1	1	0	5E	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an “Enable Remote Control” command has previously been sent.

6.8. Disable Enhanced Rapid Power Setting Mode

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	1	1	1	1	1	5F	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	1	0	0	0	0	0	60	CRC
Base Controller Response									
0	1	0	1	1	1	1	1	5F	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an “Enable Remote Control” command has previously been sent.

6.9. Base Ignore Coil Interlock Switch

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	1	0	0	0	1	0	62	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	0	1	1	1	0	1	5D	CRC
Base Controller Response									
0	1	1	0	0	0	1	0	62	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an "Enable Remote Control" command has previously been sent.

6.10. Set Duration

Not part of command structure for stimulator software versions prior to V9.0

See section 6.11 for command to retrieve software version from stimulator

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	1	1	0	1	1	5B	Command
N	N	N	N	N	N	N	N	NN	Time (sec) 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Time (sec) 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Time (sec) 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Time (sec) 'TENTHS' value ASCII format
N	N	N	N	N	N	N	N	NN	CRC
Base Controller Response									
0	1	0	1	1	0	1	1	5B	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	CRC

Note: This command will only work if an "Enable Remote Control" command has previously been sent.

6.11. Get Stored Device Software Version Numbers

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	0	1	1	1	0	4E	Command
0	1	0	0	0	1	0	0	44	Send 'BASE' details.
0	1	1	0	1	1	0	1	6D	CRC
Base Controller Response									
0	1	0	0	1	1	1	0	4E	Command Acknowledge
N	N	N	N	N	N	N	N	NN	1st Digit of Version – ASCII Format
N	N	N	N	N	N	N	N	NN	2nd Digit of Version – ASCII Format
N	N	N	N	N	N	N	N	NN	–
N	N	N	N	N	N	N	N	NN	Nth Digit of Version – ASCII Format
0	0	0	0	0	0	0	0	00	String terminating byte.
N	N	N	N	N	N	N	N	NN	CRC

6.12. Get Current Rapid Parameter Settings

Not returned as part of response for stimulator software versions prior to V7.0

Not returned as part of response for stimulator software versions prior to V9.0

See section 6.11 for command to retrieve software version from stimulator

Host Command									
D7	D6	D5	D4	D3	D2	D1	D0	HEX	Description
0	1	0	1	1	1	0	0	5C	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	1	0	0	0	1	1	63	CRC
Base Controller Response									
0	1	0	1	1	1	0	0	5C	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	Power A 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Power A 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Power A 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Frequency 'TENTHS' value ASCII format
N	N	N	N	N	N	N	N	NN	Number of pulses 'TEN THOUSANDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Number of pulses 'THOUSANDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Number of pulses 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Number of pulses 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Number of pulses 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Duration time (sec) 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Duration time (sec) 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Duration time (sec) 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Duration Time (sec) 'TENTHS' value ASCII format
N	N	N	N	N	N	N	N	NN	Wait time (sec) 'HUNDREDS' value ASCII format
N	N	N	N	N	N	N	N	NN	Wait time (sec) 'TENS' value ASCII format
N	N	N	N	N	N	N	N	NN	Wait time (sec) 'UNITS' value ASCII format
N	N	N	N	N	N	N	N	NN	Wait time (sec) 'TENTHS' value ASCII format
N	N	N	N	N	N	N	N	NN	CRC

6.13. Get Current Error Code

Note: Refer to the Rapid² user manual for a complete list of possible error codes.

Host Command									
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**	**HEX**	**Description**
0	1	0	0	1	0	0	1	49	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	1	1	0	1	1	0	76	CRC
Base Controller Response									
0	1	0	0	1	0	0	1	49	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Error code source ASCII format (U= UI, C = coil, E = system)
N	N	N	N	N	N	N	N	NN	MSD of error code ASCII format
N	N	N	N	N	N	N	N	NN	LSD of error code ASCII format
N	N	N	N	N	N	N	N	NN	CRC

6.14. Get System Status

Note: This command is not available in stimulator software versions prior to V9.0.

Host Command									
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**	**HEX**	**Description**
0	1	1	1	1	0	0	0	78	Command
0	1	0	0	0	0	0	0	40	Padding Byte
0	1	0	0	0	1	1	1	47	CRC
Base Controller Response									
0	1	1	1	1	0	0	0	78	Command Acknowledge
N	N	N	N	N	N	N	N	NN	Instrument Status (see section 7)
N	N	N	N	N	N	N	N	NN	Rapid Status (see section 8)
N	N	N	N	N	N	N	N	NN	Most Significant Byte – Extended Instrument Status (see section 10)
N	N	N	N	N	N	N	N	NN	Least Significant Byte – Extended Instrument Status (see section 10)
N	N	N	N	N	N	N	N	NN	CRC

7. Instrument Status Byte Format

The following table details the format of the status byte used by the base controller to relay current instrument status.

BIT	Description (Active state indicated when bit set to 1).
0 LSB	Standby
1	Armed
2	Ready
3	Coil present
4	Replace coil
5	Error present
6	Error type: 1 = fatal: 0 = non fatal.
7 MSB	Remote control status.

8. Rapid Status Byte Format

The following table details the format of the status byte used by the base controller to relay rapid status.

BIT	Description (Active state indicated when bit set to 1).
0 LSB	Enhanced power mode status
1	Train status.
2	Wait status.
3	Single Pulse mode status.
4	HV PSU connected.
5	Coil ready to use.
6	Theta PSU configuration detected.
7 MSB	Modified coil algorithm active.

9. Mode Setting Byte Format

The following table details the format of the mode setting byte used by the host controller to change the status of the base controller.

BIT	Description
0 LSB	Set stimulator in Stopped mode
1	Set stimulator in Armed mode
2	Always ‘0’
3	Trigger stimulator
4	Always ‘0’
5	Always ‘0’
6	Always ‘1’
7 MSB	Always ‘0’

10. Extended Instrument Status Word Format

The following table details the format of the status byte used by the base controller to relay extended rapid status. The table here shows the extended rapid status as 16 bit word, however in reality, it is sent as two individual 8 bit bytes.

BIT		Description
Least Significant Byte	0 LSB	Plus1 Module Detected
	1	Special Trigger Mode Active
	2	Always '0'
	3	Always '0'
	4	Always '0'
	5	Always '0'
	6	Always '0'
	7	Always '0'
Most Significant Byte	8	Always '0'
	9	Always '0'
	10	Always '0'
	11	Always '0'
	12	Always '0'
	13	Always '0'
	14	Always '0'
	15 MSB	Always '0'

11. System Test Example

Assuming a PC is used as an alternate controller, the following test will ensure that the communication link is working correctly.

11.1. Retrieve the software version

11.1.1. Connect a PC to the 26 Way connector on the back of the Rapid².

11.1.2. Run Hyper Terminal on the PC.

11.1.3. Power up the Rapid² system.

11.1.4. Press the ENTER key on the PC whilst having Hyper Terminal active. You should find that you get a '?' displayed on Hyper Terminal for each press of the ENTER key. If this does not happen then either the cable is faulty/incorrectly wired or the PC has not been setup correctly.

11.1.5. With Hyper Terminal active, type in 'NDm' (without quotes). The stimulator should respond with 'NVx.y' where 'x' is the major software version and 'y' is the software subversion of the stimulator. For V9.0 software, the stimulator would respond with 'NV9.0'.

11.2. Example of CRC Calculation

The example below shows the CRC calculation when setting the output power to 50%.

	Hexadecimal Notation	ASCII Character
Command	40	@
Data	30	0
Data	35	5
Data	30	0
CRC	40+30+35+30=D5 One's Compliment of D5=2A	 *