3.6 Error Codes and Pump Status

The error code and pump status (ready or busy) is returned in the response message for every command sent to the device when using the serial communication interface. The pump status is not available when using the CAN communication interface.

The [Q] command can be used to read the error code for the last executed command and to query pump status. The user should send a [Q] command before sending a program string or individual command to ensure that the pump has completed the previous command successfully.

3.6.1 Status Byte

The status byte has the following format:

Serial Interface:

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	RDY	0	ERR3	ERR2	ERR1	ERR0

RDY = 0 The device is busy and will only accept report and terminate commands.

RDY = 1 The device is ready and will accept new commands.

CAN Interface:

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	1	0	ERR3	ERR2	ERR1	ERR0

Note: *The device status bit is available only in the serial communication interface. To obtain the device status in CAN, use the [?29] command.*

The last four bits represent the error code. In serial communication, commands addressed to multiple pumps at once cannot be used to obtain pump status; pumps must be queried separately.

Note: *In serial communication, the answer block for all commands contains a status bit and can be used to determine pump status (busy or ready). In CAN communication, the pump responds with an answer message and error code upon completion of the currently loaded command or command string.*

3.6.2 Error Codes

Error codes describe problem conditions that may be detected in the device (excluding error code 0). Error codes are returned in the least significant four bits of the status byte. If an error occurs, the pump stops executing commands, clears the command buffer, and returns the status byte with the appropriate error code.

Some errors continue to appear, such as plunger overloads, until they are cleared by the initialization command. On a plunger overload, the device will not execute another syringe move command until the device is reinitialized.

Table 3-10 *Error Codes*

Error Code	Error Type	Description
0	-	Error Free Condition.
1	Type 2	Initialization Error. This error occurs when the pump fails to initialize. Check for blockages and loose connections before attempting to reinitialize. The pump will not accept commands until it has been successfully initialized. This error can only be cleared by successfully initializing the pump.
2	Type 1	Invalid Command. This error occurs when an unrecognized command is issued. Correct the command and operation will continue normally.
3	Type 1	Invalid Operand. This error occurs when an invalid parameter <n> is given with a command. Correct the parameter and pump operation will continue normally.
7	Type 2	Device Not Initialized. This error occurs when the pump is not initialized. To clear the error, initialize the pump.
8	Type 1	Valve Configuration Invalid. This error occurs if the valve is configured to “NONE” and [Z], [Y], [I], [O], [B], or [E] commands are sent or valve does not support the [B] or [E] positions. Set the correct valve configuration.
9	Type 3	Plunger Overload. This error occurs when movement of the syringe plunger is blocked by excessive backpressure. The pump must be reinitialized before normal operation can resume.
10	Type 3	Valve Overload. This error occurs when the valve drive loses increments by blockage or excess backpressure. The pump must be reinitialized before normal operation can resume. Sending another Valve command reinitializes the valve and sets it to the correct location. Continual valve overload errors are an indication the valve should be replaced.
11	Type 1	Plunger Move Not Allowed. Plunger move commands are not allowed when the valve is in the bypass position or valve has not been initialized.

Error Code	Error Type	Description
12	Type 1	Extended Error Present. Use command [Q<n>] to read the extended error code. See section “Extended Error Codes” for details on extended errors
13	Type 1	NVMEM access failure. Unable to read or write to the NVRAM.
14	Type 4	Command buffer empty or executed (cannot use [R]) or not ready for repeat (cannot use [X]). Also, if the command buffer is empty or command strings in NVRAM are empty, issuing ?99 or ?80…?95 returns this error code.
15	Type 4	Command Buffer Overflow. This error occurs when new commands are sent to the pump before it has completed the execution of current command. Commands in the buffer must be executed before more commands can be sent.

Table 3-11 *Error Codes and ASCII and Hexadecimal Values*

Error Code	Status byte (Serial)						Description
	Hexadecimal		Decimal		ASCII		
	Ready	Busy	Ready	Busy	Ready	Busy	
0	60h	40h	96	64	’	@	No Error
1	61h	41h	97	65	a	A	Initialization Error
2	62h	42h	98	66	b	B	Invalid Command
3	63h	43h	99	67	c	C	Invalid Operand
7	67h	47h	103	71	g	G	Device Not Initialized
8	68h	48h	104	72	h	H	Invalid Valve Configuration
9	69h	49h	105	73	i	I	Plunger Overload
10	6Ah	4Ah	106	74	j	J	Valve Overload
11	6Bh	4Bh	107	75	k	K	Plunger Move Not Allowed
12	6Ch	4Ch	108	76	l	L	Extended Error Present
13	6Dh	4Dh	109	77	m	M	Nvmem Access Failure
14	6Eh	4Eh	110	78	n	N	Command Buffer Empty or Not Ready
15	6Fh	4Fh	111	79	o	O	Command Buffer Overflow

Note: *Ready/Busy status applies only for serial communication. For CAN, the first 4 significant bits are always set to 2 (0010'b).*

Caution! *All errors reported by the pump should be captured by the user software and the physical cause corrected before continuing operation. Failure to do so may result in damage to the pump or adversely affected pump performance, and void the warranty*

3.6.3 Error Types

There are four error types, which are described below.

Immediate Errors, Type 1

These errors are returned with the answer block immediately. When a valid command is sent, the pump will continue to function normally. In this case, the [Q] command is not required.

Note: *There is no need to reinitialize the pump following this error type.*

Initialization Errors, Type 2

This error is returned if the pump fails to initialize or if a plunger move command is sent without prior initialization the plunger. To ensure that the pump initializes successfully, send a [Q] command after the Initialization command.

- If the [Q] command indicates both a successful initialization and that the pump is ready, subsequent move commands can be sent.
- If the [Q] command indicates the pump has not initialized, the pump must be reinitialized until the [Q] command indicates successful initialization.
- If initialization is not successful, a "Device Not Initialized" error is returned as soon as the next move command is sent. A successful re-initialization must be executed before subsequent move commands can be sent.

Overload Errors, Type 3

These include the "Plunger Overload" and "Valve Overload" errors (errors 9 and 10). If the pump returns a plunger overload error, the pump must be reinitialized before continuing. If the pump reports a valve overload error, further plunger moves will not be allowed until the valve is successfully initialized again. The pump will automatically perform valve initialization if a valve move command is issued after the occurrence of a valve overload.

Command Buffer Error, Type 4

These include the "Command buffer empty/not ready" (Error 14) and "Command buffer overflow" (Error 15). Error 15 occurs if a move command, set command (except [V]), or valve command is sent while the pump is busy executing a previously loaded command. The pump ignores the new command and issues

Error 15. The [Q] command allows the controller to determine when the command execution is complete and the pump is ready to accept new commands.

Error 14 occurs if the command buffer is empty and an execute command [R] or repeat last command [X] is sent or a report command is used to read the loaded command string [?99] or any of the stored command string from NVRAM [?80…?95].

Note: *There is no need to reinitialize the pump following this error type.*

Report commands, Terminate command [T] (or in CAN, command type 2, data byte ASCII-4), and the Set Top Speed command [V] will not return an error 15. Report commands are considered valid commands while the pump is busy. As the pump can change speed while the plunger is moving, the [V] commands will not return a “Command Overflow” error.

3.6.4 Heartbeat message

The heartbeat message is an answer frame sent over CAN periodically based on the interval selected using the [b] command. The heartbeat message can be enabled or disabled using the [U60] or [U61] command, respectively. This function is disabled by default and is not available in the serial communication interface.

The heartbeat message consists of three or more bytes; the first two bytes are reserved for plunger and valve errors and the following characters are for general device errors. Since more than one device error can exist at the same time, the device errors are sent in multiple ASCII characters.

The error codes and description for plunger, valve, and device errors in the heartbeat message are identical to the extended error code.

3.6.5 Extended Error Codes

Extended error codes provide additional information regarding the error condition. These include additional error codes not included in the standard error codes of the status message. If the pump returns an extended error code (Error 12) in the status message, this means there is an error condition not specified in the standard error codes. The extended error code can be read using the [Q<n>] command. The extended error code includes errors specific to the plunger, valve, and general device errors.

The last 100 error codes can be read using the [:<n>] command. The response is an error string whose format is the same as the heartbeat message response, where the first two characters are reserved for plunger and valve, respectively, and the following ASCII characters correspond to general device errors.

Plunger Errors

The table below lists all extended error codes for plunger and reason for error generation. This can be read using the [Q1] command and is also the first byte in the heartbeat message response.

Table 3-12 *Plunger Error Codes*

Error Code	ASCII character	Error Message/ Description	Caused by
0	@	No plunger errors detected	Plunger initialization complete. No plunger errors detected and plunger is ready for operation
1	A	Plunger initialization error	Initialization commands [Z], [Y], or [W] failed
7	G	Plunger not yet initialized	[A], [P] or [D] issued before plunger initialization command
9	I	Plunger overload	Step loss detected for [A], [P], or [D]
11	K	Plunger move not allowed	[A], [P], or [D] issued when valve is in bypass position or valve not initialized
27	[	Plunger move terminated	Plunger move terminated due to Terminate command
33	a	No plunger steps detected	No plunger movement detected on linear encoder for [Z], [Y], [W], [A], [P,] or [D] command
34	b	Step loss detected	Step loss detected on linear encoder for [Z], [Y], [W], [A], [P], or [D] command
35	c	Plunger Home flag error	Plunger Home flag not detected during [Z], [Y], or [W] command
36	d	Plunger drive reference voltage check failure	Built-in self test- Plunger drive reference voltage check failure or incorrect
37	e	Plunger diagnostics error	Error while executing plunger diagnostics [d0]

Valve Errors

The table below lists all extended error codes for valve and reason for error generation. This can be read using the [Q2] command and is also the second byte in the heartbeat message.

Table 3-13 *Valve Error Codes*

Error Code	ASCII character	Error Message/ Description	Caused by
0	@	No valve errors detected	Valve initialization complete. No valve errors detected and valve is ready for operation
1	A	Valve initialization error	Initialization commands [Z], [Y], [w], [I], [O], [B, and [E] failed
7	G	Valve not initialized	[A], [P], [D], or [W] issued before valve initialization command
8	H	Valve not configured	Valve not configured (Type = NONE) and [Z], [Y], [I], [O], [B], or [E] received
10	J	Valve overload	Valve overload for [I], [O], [B], or [E] command
40	h	Valve move terminated	Valve move terminated due to terminate command
41	i	No valve steps detected	No valve movement detected on valve encoder for [Z], [Y,] [W], [I], [O], [B], and [E] command
42	j	Step loss detected	Step loss detected on valve encoder for [Z], [Y,] [w] [I,] [O[, [B], and [E]
43	k	Valve Index slot error	Valve index slot not detected during [Z, [Y, or w or when [I,] [O], [B], or [E] is sent without initializing valve
44	l	Valve drive reference voltage check failure	Built-in self test - Valve drive reference voltage check failure or incorrect
45	m	Valve diagnostics error	Error while executing valve diagnostics

Device Errors

The table below lists all general extended error codes for the pump and reason for error generation. This can be read using the [Q3] command and is also the third byte in the heartbeat message. If more than one error is present, they are sent in a string.

Table 3-14 *Device Error Codes*

Error Code	ASCII character	Error Message/ Description	Caused by
0	@	No device errors detected after initialization.	Plunger and valve initialization complete. No errors detected and device ready for operation
1	A	Initialization error	Plunger or valve initialization error
7	G	Device not yet initialized	Plunger and valve not initialized since last reset
17	Q	FRAM or boot code checksum failure	FRAM checksum fail. Factory default loaded or boot code checksum failure (cannot launch boot code)
20	T	Power-on self test fail	Power-on self test failed – memory test, voltage, reference voltage check ,etc.
21	U	Watchdog reset	Watchdog reset triggered due to internal error
22	V	Low voltage	Low line voltage detected during normal operation
23	W	Boot code checksum failure	Boot code checksum failure (cannot launch boot code)

In addition to the above, the following error codes are reported when reading error log using the [:<n>] command:

Error Code	ASCII character displayed	Error Message/ Description	Caused by
2	B	Invalid command	Invalid command or command type (CAN)
3	C	Invalid operand	Wrong command parameters received for a command
13	M	FRAM access error	Write/read verify to FRAM failed
15	O	Command overflow	Move command to valve or plunger received when move already in progress
16	P	Command not implemented	Command not implemented in firmware
18	R	Too many loops or loop command nesting imbalance	Too many loop nesting or loop command nesting imbalance; fewer [G] commands than [g] in commands in the string
19	S	Internal command execution error	Error in executing command due to internal error

Error Reporting Examples

[A400000R]	Returns an invalid parameter error (error 3) immediately after the command.
[A3000A350000R]	Returns an invalid parameter error (error 3) immediately after the command. Does not move the plunger.
[t2000R]	Returns an invalid command error (error 2) immediately after the command. Does not move plunger.
[A100t2000R]	Returns an invalid command error (error 2) immediately after the command. Does not move plunger.
Valve in Bypass [A100R]	Returns an error (error 11) immediately after the command. Does not move plunger.

Note: *For all error conditions, when queried using the [Q] command, the last registered error code is returned irrespective of the type of error.*

4 Setting Up the Centris Pump for Your Application

The Centris pump is capable of providing precision pumping in a wide variety of hardware and fluid systems. The interplay of fluid viscosity, aspiration and dispense speeds, and system geometry (syringe size, tubing inner diameter, and valve inner diameter) determine the behavior of the Centris pump in a particular application. Following is a description of the hardware, fluid, and pump control parameters to be evaluated and optimized in managing these interdependencies for optimal pump performance.

4.1 Glossary

air gap

A small volume of air at the end of the output tubing or sandwiched between two fluids in the pump system tubing. Air gaps may be created by aspirating air (programmed air gaps) or by the spring action of the fluid system (inertial air gaps).

aspirate/dispense tubing

Connects the valve output port to a sample source and destination. To ensure good breakoff, aspirate/dispense tubing tends to have a smaller I.D. than reagent tubing, and a necked-down or tapered end.

backlash

Mechanical play in the syringe drive created by accumulated mechanical clearances.

backpressure

The pressure which must be exceeded to move fluid through tubing. Backpressure is created by a combination of fluid inertia and friction.

breakoff

Describes how the last droplet of fluid exits the end of the output tubing following a dispense. Rapid or sharp breakoff means that the droplet exits cleanly with high inertia.

breakup

Undesired air gaps created by overly rapid aspiration.

carryover

Contamination of a volume of fluid by residual fluid from a previous aspiration or dispense. Carryover causes variability in final volume and concentration.