Sartorius rLine

Technical User Manual

Includes rLine models:

rLine 1-ch 5-200ul LS
rLine 1-ch 50-1000ul LS
rLine 1-ch 100-5000ul

Version history

Version	Date / Author	Reason
1.0	14.12.2017 / Mhe	Approved first version
1.1	04.04.2018 / Mhe	Added RBxxx command for new firmwares

1 Contents

2 Introduction

Sartorius rLine is a unique liquid handling dispenser module designed for various liquid handling automation applications.

All rLine models are extremely small and lightweight. They use disposable tips for zero carry-over and thanks to novel electronic tip ejector the tip can be disposed anywhere – or even returned back for reuse. The modules are fixed with 2 screws and require only the power supply and interface connections for use.

The control of the operation is performed with ASCII-commands which contain both built-in pipetting and dispensing commands as well as open piston movement control for special applications. The basic software is common for all models with only the differing volumes requiring model-specific parameters.

This manual is for the single channel rLine models 5-200ul LS, 50-1000ul LS and 100-5000ul.

Figure 1. rLine 1-ch 50-1000ul LS with tip

3 Basics of liquid handling

The liquid handling of the rLine module is based on the air displacement technique where a piston movement creates a vacuum in the air chamber between the piston and the disposable tip thus aspirating the fluid. Due to that air cushion certain standard procedures should be followed in order to secure good performance.

Below are the descriptions of some general terms used in liquid handling. The lengths of the piston movement, i.e. the number of steps run, for each operation varies from model to model.

Pipetting
The sample is drawn into the tip and dispensed out, optionally with a blow-out.

Multiple dispensing
An amount of fluid is drawn into the tip and several smaller aliquots of identical size are dispensed. Due to the air cushion and mechanical characteristics of the pipette, typically a small amount of fluid is also dispensed prior (Reset) and after (Residual) the actual aliquot dispensing.

Blow-out
The amount of air dispensed after the sample dispensing to ensure that all sample get out of the tip. Optimally the travel between the Home and Zero position.

Lowest position
When resetting the module, it drives the piston all the way down to a mechanical stop of the movement. This position is called lowest position. This is an internal position only, and can only be used through RZ and RE commands.

Zero position
Zero position is the lowest point for all liquid handling operations. It is located just above the start of the tip eject movement. Zero position is the reference point for all movement definitions; steps below are marked as negative values and steps above it as positive values.

Tip eject movement
All rLine modules are provided with a unique electronic tip ejection. As the piston is driven downwards from the Zero position to the lowest position, the tip ejector is activated thus removing the tip. After the tip eject the piston is automatically returned to Zero position.

Home position
The aspiration of the fluid starts (usually) from the home position. Different modes and models have different defined home positions for optimal performance.

Reset
A small amount of fluid is dispensed (Reset) in order to eliminate the mechanical play of the linear actuator.

Residual (Empty)

When the aliquots of the dispensing or reverse pipetting operations have been dispensed a small amount of fluid is left in the tip (in order to ensure accurate dispensing of the last aliquot). The removal of the fluid with a blowout is called Residual. Note: when using residual, it is recommended to use a starting point below standard home position equal to the amount used as residual.

Air gap

When performing dilutions (both the sample and the diluents are aspirated into the tip and dispensed together) a small air gap is recommended between the two samples in order to minimize the carryover.

Pull back

A short piston movement upwards in order to create a small air gap at the end of the tip. This is recommended if rLine module is subjected to relatively high accelerations to avoid accidental dripping of the fluid.

4 rLine terminology

4.1 Step

Piston movements are defined in steps for all rLine family modules. Positional control of the piston is handled by detecting the angular movement of a 7-segment wheel (Figure 2). The number of steps is converted to linear movement by the screw pitch. Table 1 illustrates the conversion between step and volume in each rLine models.

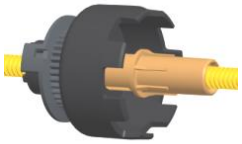


Figure 2. 7-segment wheel

4.2 Address

The term address refers to the absolute position of the piston in steps as shown in Figure 3. Any address within the operating range is reached with the command RP*nnn*, where *nnn* is the desired position as an integer.

4.3 Position

Position is either a relative placement of the piston or a preprogrammed address. Table 1 illustrates the home, max and tip eject positions of each rLine models.

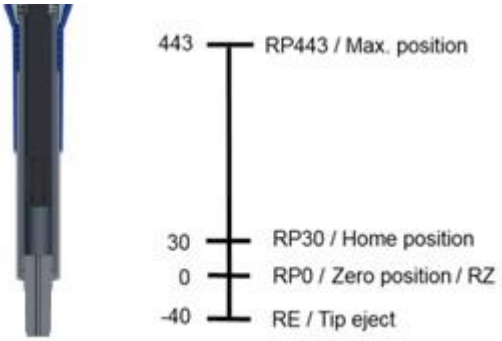


Figure 3. Base addresses and positions for rLine 50-1000ul LS

Table 1. Resolution and positions of each rLine models

Model	Volume / step	Home position	Max position	Tip eject position
rLine 1-ch 5-200ul LS	0,5 ul	30	443	-40
rLine 1-ch 50-1000ul LS	2,5 ul	30	443	-40
rLine 1-ch 100-5000ul	10 ul	30	580	-55

4.4 Drive cycle

Each end of a drive movement marks one drive cycle (from drive on to drive off). A tip eject counts as one drive cycle also. Drive cycles are stored in permanent memory in rLine modules and can only be reset during maintenance.

4.5 Level sensing, LS

Sartorius rLine models 5-200ul LS and 50-1000ul LS integrates capacitive liquid level detection (cLLD) or another word, level sensing (LS). To use that feature, conductive tips must be used to generate detection circuit capacitance change when tip is connected and tip is in touch with liquid. Feature can be used in automation systems to automatically recognize tip presence and liquid levels in specific applications.

5 Technical Specifications

5.1 Liquid handling specifications

Sartorius rLine liquid handling performance is defined using gravimetric testing with distilled water performed in accordance with ISO 8655. Table 2 illustrates the performance of each rLine models.

Table 2. rLine performance in different test volumes

Model	Test mode	Test volume	Test steps	Systematic Error		Random Error	
		(ul)		(%)	(ul)	(%)	(ul)
rLine 1-ch 5-200ul LS	P	200	400	1,00	2,00	0,25	0,50
	P	100	200	0,80	0,80	0,25	0,25
	P	20	40	2,00	0,40	1,00	0,20
	P	5	10	4,00	0,20	2,00	0,10
	d	10 x 20	40	2,00	0,40	2,00	0,40
rLine 1-ch 50-1000ul LS	P	1000	401	0,45	4,50	0,15	1,50
	P	500	201	0,60	3,00	0,20	1,00
	P	100	41	2,00	2,00	0,50	0,50
	P	50	21	4,00	2,00	1,00	0,50
	d	10 x 100	40	2,50	2,50	2,00	2,00
rLine 1-ch 100-5000ul	P	5000	502	0,50	25,0	0,15	7,50
	P	2500	252	0,70	17,5	0,20	5,00
	P	500	52	1,60	8,00	0,40	2,00
	P	100	11	8,00	8,00	2,00	2,00
	d	10 x 500	50	2,40	12,00	2,40	12,00

5.2 Aspirating and dispensing speeds

There are 6 level aspiration and dispensing speed settings in rLine models. Table 3 shows the nominal speeds of each rLine models using distilled water.

Table 3. rLine nominal dispensing and aspiration speeds

Speed setting	Speed steps / s	rLine 5-200 (ul/s)	rLine 50-1000 (ul/s)	rLine 100-5000 (ul/s)
1	60	31	150	550
2	106	52	265	1000
3	164	80	410	1500
4	260	115	650	2500
5	378	150	945	3650
6	448	190	1120	4350

5.3 Repeatability

Mechanical and physical variables of the rLine module, air, liquid, tip used and environment will cause small variations in both the amount of liquid aspirated and time taken. Illustrated typical drive profiles are shown in Figure 4.

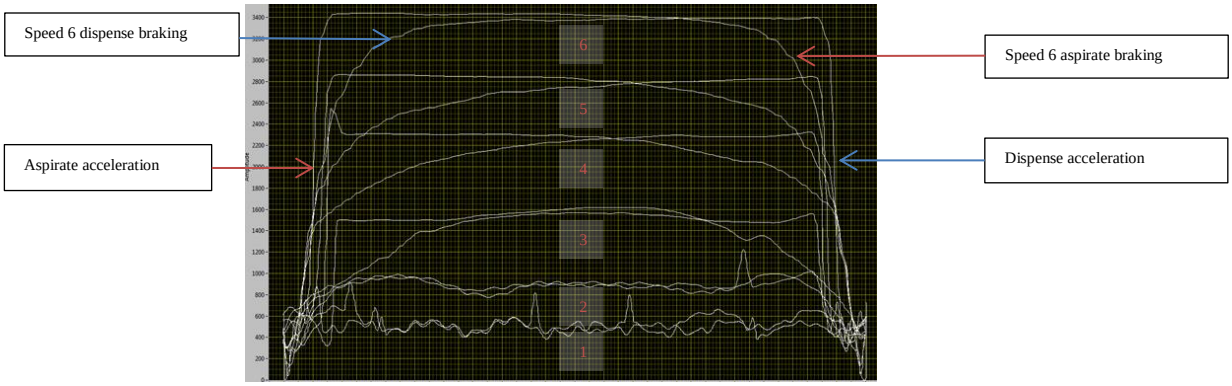


Figure 4. Typical drive profiles in rLine 1-ch 5-200ul LS

5.4 Mechanical

Mounting

The housing has two holes for two 4 mm mounting screws. Figures 5-6 illustrates the key mechanical dimensions of the rLine models. The weight of the modules is approx. 140 g.

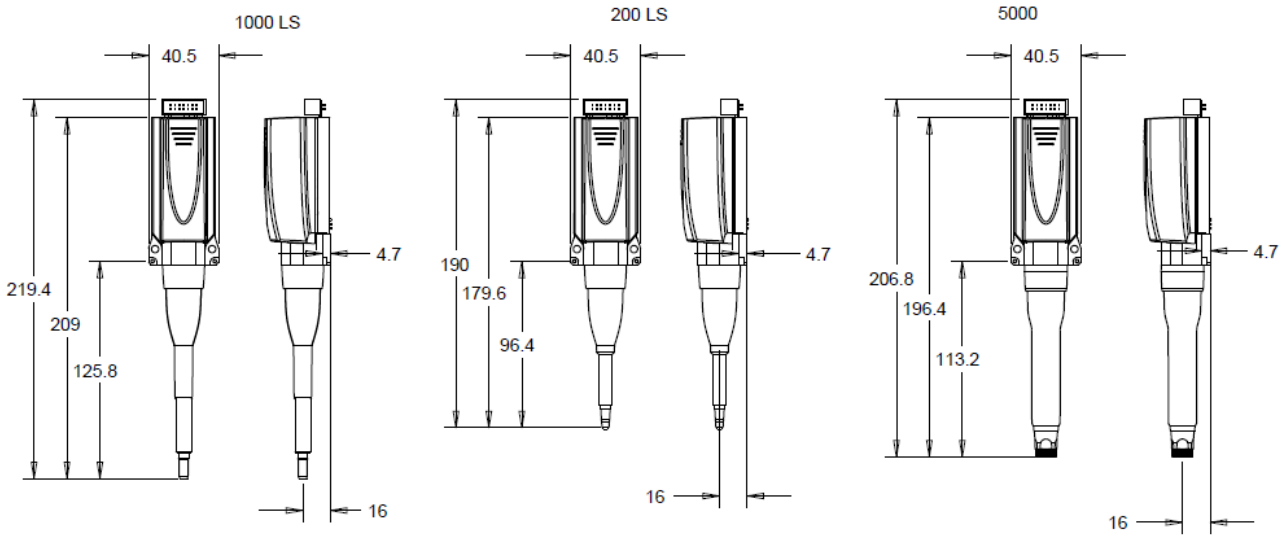


Figure 5. rLine models dimensions without tips

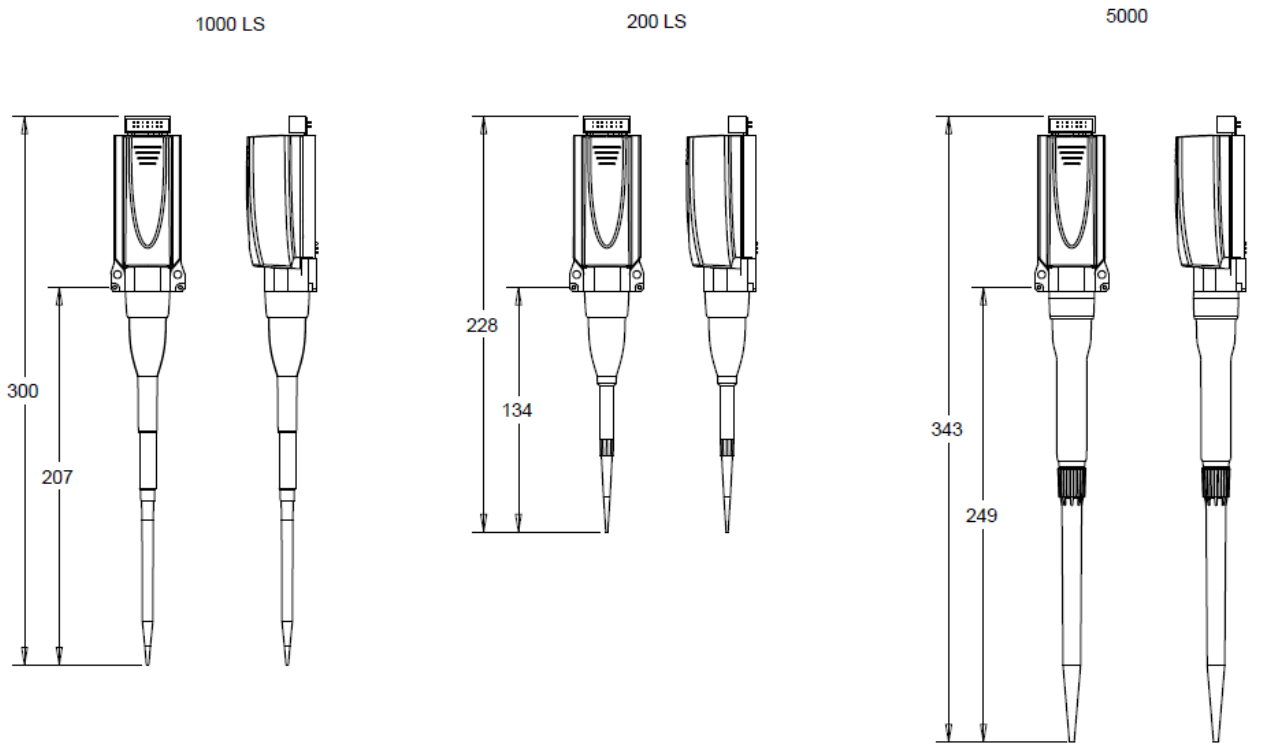


Figure 6. rLine models dimensions with tips

Locating

There are two positioning holes (ø 2,01 ± 0,01 tolerance) as indicated in Figure 7. Another option for locating is the precision machined groove at the bottom of the aluminum base.

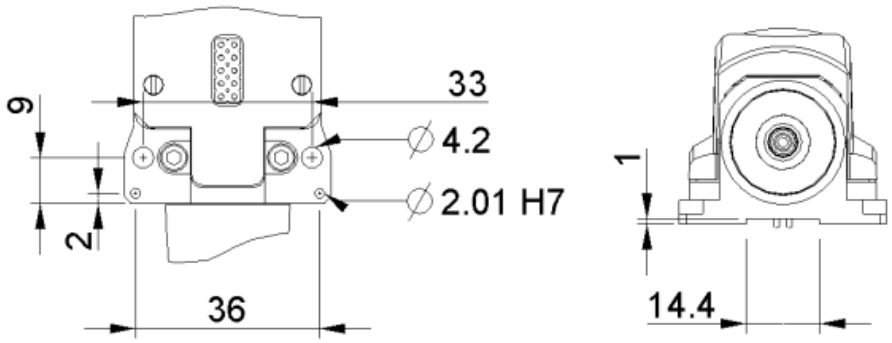


Figure 7. rLine location guide dimensions

Tip pick up force

For the rLine models, it is recommended to use specific force to pick up a tip from the tray. The pickup force must be directed along the module axis to avoid permanent damage to the module's lower parts. Table 4 shows the recommended tip pick up forces of each rLine models.

Table 4. Recommended tip pick up forces of each rLine models

Model	Tip pick up force (N)
rLine 1-ch 5-200ul LS	12-25
rLine 1-ch 50-1000ul LS	18-25
rLine 1-ch 100-5000ul	15-45

Maximum acceleration

Installed module can be subjected to accelerations up to 3*g*.

5.5 Electrical specifications

Operating voltage	9 -12 VDC
Required power supply	min. 10 VA
Current consumption, idle	< 100 mA
Average current consumption	< 500 mA
Current consumption, peak	2 A
Communication protocols	RS232
Connector	Tyco 609-1427
Serial communication	9600-115200 kbps, 8, 1, none

Please notice following:
Electronics ground is not in contact with the housing. Both digital as well as analog parts share the same common ground.

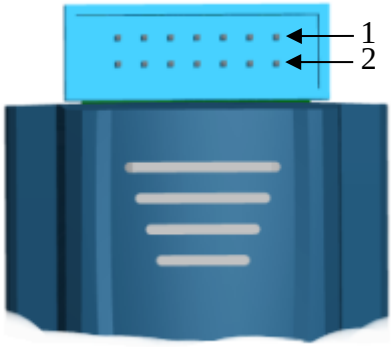
5.6 Serial communication

The rLine module is equipped with serial interface RS232. The interface is composed of Receive data (RxD), Transmit Data (TxD) and signal ground (GND). A host, like a PC with RS232 interface (COM-port) is communicating via these lines. The baud rate can be configured to any of the six options. 9.6 kbps, 19.2 kbps, 28.8 kbps, 38.4 kbps, 57.6 kbps and 115.2 kbps.

The data bits, stop bits and parity are fixed to 8, 1, none, respectively.

5.7 Cable connector

rLine top connector is a male, 14-pin, dual row, low profile with 2,54mm pitch. The connector type is Tyco 609-1427. Compatible female connector is e.g. FAS1401-21012OAF. Figure 8 illustrates the rLine connector and pin descriptions.



1-4	GND	Supply ground
5	RxD	RS232 Receive data
6	TxD	RS232 Send data
7	LS	Level sensing output
8	NOP	Reserved
9	NOP	Reserved
10	NOP	Reserved
11-14	VDC	Supply voltage

Figure 8. rLine connector pin descriptions

5.8 Liquid level detection (LS models only)

Liquid level detection is based on a capacitance change. The detection signal is created using an oscillator with a nominal frequency at approx. 50 kHz.

From the change in frequency it is possible to detect if the tip is in liquid. However, the sensor is sensitive to all changes in the environment, including the type of the of tip rack, attachment fixtures etc. Typical frequency values are between 3 kHz – 55 kHz.

Level detection signal is routed to the connector pin 7 (LS output). Signal is frequency modulated square wave according to the capacitive change.

Level detection value can be queried also with software using specific command (DN). Typical value without the tip is 240-300, with an increase with tip attached and in liquid. Values will be application specific with a typical range of 160 – 400.

6 Messaging and initialization

rLine uses custom, proprietary real-time firmware. Most user-configurable settings must be set after each power-up (such as speed if not default) but some settings can be stored in permanent memory. Firmware upgrade cannot be performed without removing the module and requires special programming tools.

6.1 Non configurable settings

Minimum and maximum positions

Minimum and maximum positions are determined by mechanical limits and are showed in table 1.

Minimum number of steps

Two (2) steps is the minimum allowed travel. Recommended minimum for typical liquid operations is 10 steps.

Speeds

Users have six preset speeds (1-6) at their disposal, selected with the SI/SO commands. The actual speeds of these presets cannot be altered by user programming. The selected preset speed cannot be changed during a single drive operation - the drive must be stopped to change the speed.

Acceleration/deceleration

All drive movements start with rapid acceleration and end with similar but not identical rapid deceleration. The actual speed varies very slightly during drive due to changes in e.g. friction. Typical acceleration and deceleration times are a few tens of milliseconds and less than 10 steps.

Module reaction time

Using default values for communication the module will enable the drive within approx. 50 milliseconds from receiving the drive command. Physical position and tolerances will cause a further and variable delay of a few milliseconds before the piston moves.

Repeatability

Mechanical and physical variables of the rLine modules, air, liquid, tip used and environment will cause small variations in both the amount of liquid aspirated and time taken.

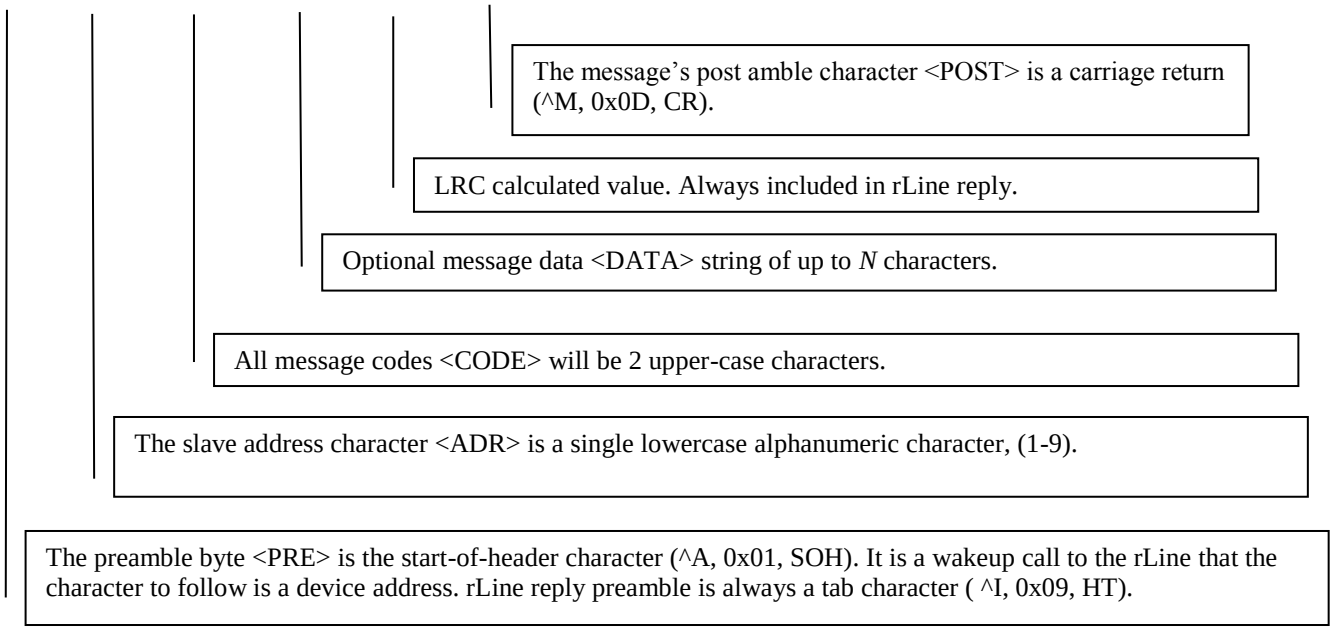
6.2 Messaging

The protocol is intended foremost to be simple with a reasonable measure of reliability. It is based on a synchronous master/slave model in which all communication occurs between the master and a single rLine. Messages from the master to the rLine are categorized as either a *command* to do something, or a *query* for data.

Message structure

The message structure for all messages between the master and rLine response messages are similar in that they always have a preamble, rLine address, a message code, possibly some message data, a checksum value, and is terminated by a postamble. As much as possible, 7-bit ASCII characters are used to construct human-readable/printable message strings. The message format is as follows:

<PRE><ADR><CODE><DATA><LRC><POST>



The optional **LRC** (Longitudinal Redundancy Check) <LRC> value is used to validate the integrity of a message packet. This value is formed from the exclusive OR all characters following the preamble character and up to the LRC byte. Then, to avoid contention with the 7-bit ASCII character set, the most significant bit is set, yielding a value in the range from 0x80 to 0xFF. Shown below is an example LRC calculation for Run Zero (RZ) sent to a unit with address 1. Message string without pre- and postamble: "1RZ"

LRC = '1' **XOR** 'R' **XOR** 'Z' **OR** 0x80
= 0x31 **XOR** 0x52 **XOR** 0x5A **OR** 0x80
= 0xB9

Unless excessive noise or other communication problems require its use, it is recommended to not enable LRC. rLine will always calculate and include the LRC value for it's replies.

6.3 Communicating with the module

Communicating with rLine is based on commands and queries. Commands will be acknowledged when received but not on completion. Queries will be answered. Therefore the completion of a command must be checked with a query. Response message structure is identical to send messages.

General

rLine will respond to every message it receives and recognizes as addressed to it. Unrecognized messages, e.g. typically without a correct address will be discarded. An incoming message will be placed into a buffer (only one message, further messages will be disregarded).

All messages must be sent using upper case and all responses will be lowercase. Otherwise rLine will respond with an error message"er1".

Immediate general error responses

For all messages there are four possible immediate error responses er1-4. These are detailed in 7. Error handling.

Typical command procedure

- send command
- wait for "ok" or "er*n*" response
- if no response is received after 400 ms, resend the command or check module status
- check command result with query "DS"
- wait for response up to 400ms. If no response is received, resend the query.
- if status is "ds0" (no errors), send next command. Otherwise, analyze error using the
- parameter in "ds*n*" or through error query "DE"

Attempting messaging before response

rLine communication is built on the principle that a response from the module must always be received and read. If attempting to send messages before the module has responded it must be noted that

- messages will be responded to in the order received
- two or more consecutive commands will most like result in an "er4", drive is busy immediate error
- queries and command-query series will be generate responses at the same order the messages have been received
- most likely result is serial line communication corruption

6.4 Configuration commands

The following sets of commands are used to configure each module and are usually carried out before installing the module.

*A*n*

Set rLine slave address (default: 1)
n=1-9
Example: *A2
Response: "ok" or "er1-4"

*B*n*

Set RS232 baud rate (default 0)
n=0: 9600 bps
n=1: 19.2 kbps
n=2: 28.8 kbps
n=3: 38.4 kbps
n=4: 57.6 kbps
n=5: 115.2 kbps
Example: *B1
Response: "ok" or "er1-4"
NOTE! The new baud rate will become active after resetting the module.

*C*n*

Enable LRC check for incoming messages (default 0)
n=0: LRC disabled
n=1: LRC enabled
Example: *C1
Response: "ok" or "er1-4"

6.5 Initialization commands

After every power-up, each module must be initialized.

RZ Run to the Zero position
RZ initializes the piston and parameters (position = 0).
Response: "ok" or "er1-4"

Locates the mechanical lower limit of piston travel and returns the piston to the pre-programmed zero position. **The tip should not be attached when executing the command, either the tip will be ejected or an incorrect zero position located.**

RZ command can be issued at any time also during operation and it can be used periodically to confirm the zero position during extremely prolonged module use. However, it must be remembered that issuing RZ with tip attached will result in tip eject and may result in inaccurate zero position. Its use without a power on-off cycle is normally not needed nor recommended.

On error: if module is unable to determine the lowest position, it will try up to three (3) times. If this fails, module will respond with "er1" and stop. In this case the module most likely requires maintenance.

6.6 Drive commands

SI*n* — Inward speed (1-6)
Selects the aspirating speed. 1 represents the slowest speed and 6 the fastest speed. Drive must be stopped to change the speed.
Response: "ok" or "er1-4"

SO*n* — Outward speed (1-6)
Selects the dispensing speed. 1 represents the slowest speed and 6 the fastest speed. Drive must be stopped to change the speed.
Response: "ok" or "er1-4"

RP*nnn* — Run to *position nnn*. Drives piston to the step position *nnn*.
RP is used to drive the piston to *absolute* position within the full operating range. Steps must be given without leading zeros, e.g. RP30 is correct, RP030 is incorrect.
Response: "ok" or "er1-4"

RI*nnn* — Run inwards *nnn* steps from current position. Steps must be given without leading zeros.
Response: "ok" or "er1-4"

RO*nnn* — Run outwards *nnn* steps from current position. Steps must be given without leading zeros.
Response: "ok" or "er1-4"

RE — Run tip eject cycle.
From any position, runs to the absolute minimum position at high energy, removing the tip. After the high energy run, performs an automatic check run to verify tip removal. Returns to position 0.
Response: "ok" or "er1-4"

RE*nnn* — Run tip eject cycle and return to positon *nnn.*
Position *nnn* can be any allowed position for the model. Recommended is 30.
Response: "ok" or "er1-4"

RB — Run blowout
Response: "ok" or "er1-4"

RB*nnn* — Run blowout and return to positon *nnn.*
Position *nnn* can be any allowed position for the model. Recommended is 30.
Response: "ok" or "er1-4"
NOTE! Only in rLine models with firmware version 1025 or newer.

6.7 Status commands

These queries will only be answered at idle.

DV Display version
Return message: dv*nnnn, where nnnn is software version as a string*
On error: er1-4

DM Display model
Return message: dm*nnnn, where nnnn is rLine model as a string*
On error: er1-4

DX Display cycles
Return message: dx*nnnn, where nnnn is cycles performed in lifetime*
On error: er1-4

DI Display inwards speed setting
Return message: di*n, where n is the inward speed setting (1-6)*
On error: er1-4

DO Display outwards speed setting
Return message: do*n, where n is the outward speed setting (1-6)*
On error: er1-4

DR Display resolution
Return message: drnnnn, where nnnn is the resolution in nl
On error: er1-4

These queries will be answered both at idle and drive on (if not in black-out phase).

DS Display status
Return current module status.
Return message: ds*n, where n is the status*
On error: er1-4

Module status is formed using digital registers. The output is the sum of these registers. Some statuses are may be seen only as replies to a cached DS-query since the module does not communicate during the "black-out" period. Table 5 shows the different status values.

Table 5. Responded status values

Status	Hex	Binary	Decimal	
Normal	0x00	0000 0000	0	no errors
Braking	0x01	0000 0001	1	drive brake is on
Running	0x02	0000 0010	2	command received
Drive Busy	0x04	0000 0100	4	drive is on
General Error	0x08	0000 1000	8	error flag set

Most common return messages are:

ds0 no errors, module ready for commands
ds6 Running + Drive busy, module is active
ds8 general error. Drive has not successfully completed last command

DE

Display errors
Displays error registers as a list. Error registers are reset after response.
Return message: de*nnn, where nnn is the error list*
On error: er1-4

Table 6 shows different error registers.

Table 6. Error registers

Status	Hex	Binary	Decimal	
No errors	0x00	0000 0000	0	no errors
Drive jam	0x01	0000 0001	1	piston movement problem
Over run	0x02	0000 0010	2	piston end position incorrect
Reset	0x80	1000 0000	128	RZ not completed after last reset or power-on

DP

Display position
Displays current piston position.
Return message: dp*nnn, where nnn is the position of the piston*
On error: er1-4

DP response during drive operations will be reported approximately 4 ms after receiving the query (in addition to serial communication delay)

DN

Displays liquid level sensor value
Return message: dn*nnn, where nnn is the liquid level sensor value*
On error: er1-4
NOTE! Only in rLine LS models. Models that does not have LS functionality always returns 0.

7 Error handling

For all recognized error events rLine will respond with an error message.

For all messages there are four possible immediate error responses, *er1, er2, er3 and er4*

"er1" will be sent when the command has not been understood by the module.

Example: "RPx200" has an extra character, Module will respond with "er1"

"er2" will be sent if the command has been understood but would result in out-of-bounds state

Example: "RP543" exceeds the maximum upper limit of 443

"er3" Will be sent when LRC is configured to be used and the checksum does not match.

"er4" will be reported when the drive is on and the command or query cannot be answered.

Example: "RP200" is attempted while the drive is on.

8 Maintenance

Lubrication

It's recommended to either replace the lower parts or at a minimum lubricate the cylinder seals and screw every 750000 drive cycles or 12 months, whichever comes first. Lubricant used is a specially formulated high-performance grease and should not be substituted without consulting Sartorius.

Autoclaving

All rLine models are not autoclavable.

9 Troubleshooting

Over- or understep

On rare occasions the mechanism may either stop one step later or earlier than intended. Possibility for an over/understep does not have a direct relation to the used speed or volume. However, slow speeds and small volumes increase the risk for an over/understep. rLine will respond to a "DS" query with the general error "ds8". When "DE" is queried, "ds2", piston end position incorrect will be returned. In most cases this has no effect on the application and normal operation can be resumed after the "DE" query. Frequent and repeatable under- or over runs are an indication the module requires maintenance.

Sticking

When the module is not used for a long period - typically or a minimum of days - the cylinder seals may set. This can cause a sticking effect, which in turn may affect accuracy of the dispensing for first couple of operations. Since a power up of rLine module always requires a RZ command, this problem *only* matters *if* a liquid is aspirated into the tip and the module is left to wait for a long period of time.

Drive jam

A drive jam may be caused either by (external) obstruction of the piston movement or an internal drive failure. Most typical cause is a brake actuator error. In most cases functionality may be restored through power on-off cycle. If there is a problem in moving from the start, rLine will attempt twice to activate the drive before signaling an error. If the drive cannot move within approx. 1 second, general error "ds8" and specific error "de1" will be observed. Should the drive stop after start but before target, it is treated as an understep.

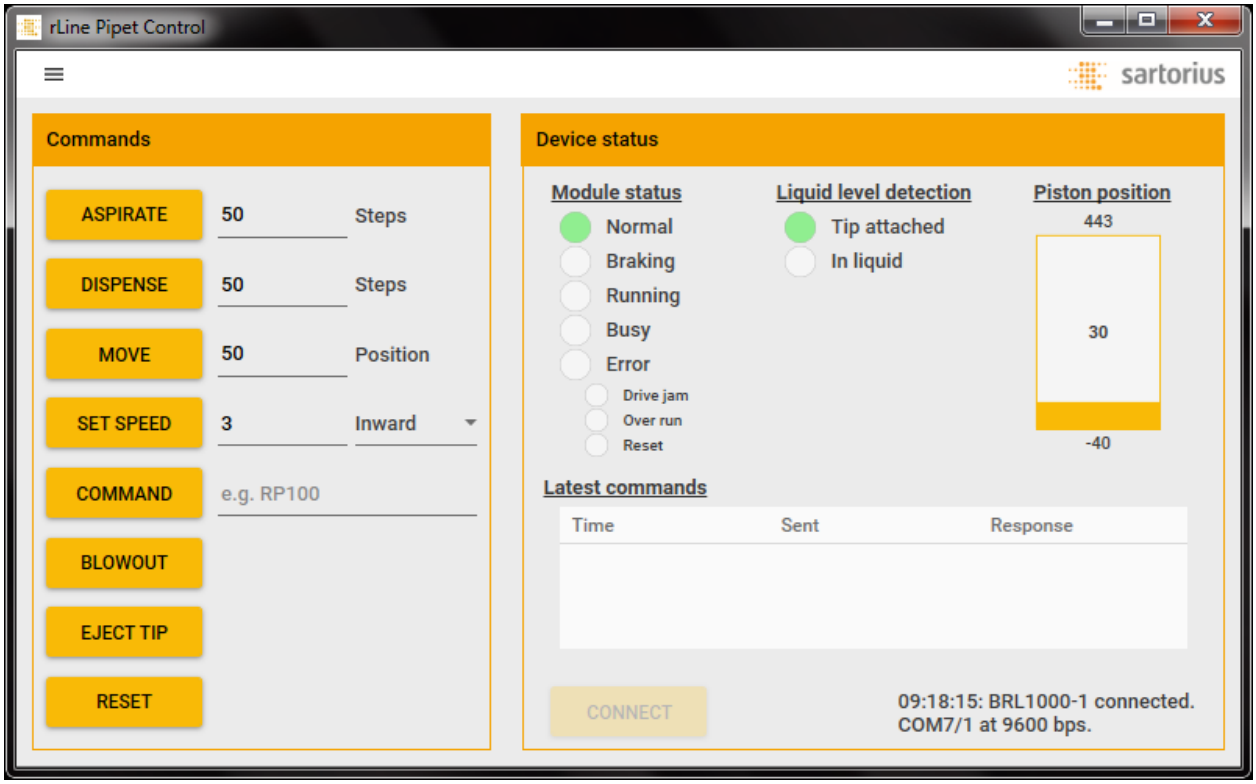
Dispensing liquid with high ethanol content

When dispensing liquids with over 70% ethanol the lubrication in the cylinder may lose its effectiveness. This is evidenced by uneven motion and possibly noise emitting from the lower end of the module. In most cases problems can be avoided by using filter tips and slower cycles (letting the alcohol evaporate from the cylinder between work cycles).

10 PC Software

The easiest way to get connected to rLine and tests it's features is to use Sartorius rLine Pipette Control PC application. It is standalone application running on Windows 7 and newer platforms.

More information about the software can be found from software user guide.



11 Order information

rLine models and all accessories can be purchased using the following order codes:

rLines

Model	Order codes / CAT numbers
rLine 1-ch 5-200ul LS	710993
rLine 1-ch 50-1000ul LS	710995
rLine 1-ch 100-5000ul	710969

Tips

Model	Order codes / CAT numbers
5-200ul optifit tips	790200
5-200ul filter tips	790201F
5-250ul conductive tips	783073
50-1000ul conductive tips	LH-781000
100-5000ul optifit tips	780304

Development kits

Model	Order codes / CAT numbers
rLine 1-ch 5-200ul LS KIT	LH-710993KIT
rLine 1-ch 50-1000ul LS KIT	LH-710995KIT
rLine 1-ch 100-5000ul KIT	LH-710969KIT