
XD-M

Datasheet



Xeryon Multi-axis Driver (XD-M)
Revision 1.4 dd. 04/11/2019

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Content

Content.....	2
1. Introduction.....	3
2. Inputs & outputs.....	4
3. Communication	6
Format	6
Addressing axes.....	6
Values	7
Info sent back from the XD-M	10
Visual feedback.....	12
4. User interface	13
Files.....	14
Example config file (config.txt).....	15
Example settings file (settings_default.txt).....	15
Example program file (demo.txt)	15
5. Customer service	17

1. Introduction

The XD-M provides a complete solution for controlling multiple Xeryon stages, in particular Xeryon's XLS and XRT-U stages, and more in general ultrasonic stages. The controller reads the stage's integrated encoders, generates and amplifies the driving signals and communicates with a host controller or PC through a simple ASCII protocol. The driver comes with a user-friendly Windows interface and LabVIEW driver to steer the stage in open and closed loop. Important steering parameters can be tuned digitally via the user interface.



Specifications:

Size:	160 x 165 x 53 mm
Power supply:	15 V DC
Piezo signals:	0 – 30 V (0 – 300 kHz)
Control:	Open and closed loop
Serial communication:	Virtual COM over USB-B 2.0 / RS-232 (optional)

The driver is delivered with a power adapter, USB cable and USB-stick with software to control the piezo stage.

2. Inputs & outputs

On the XD-M driver, following in- and outputs can be found on the front and back panel:

Front panel	
No IO	
Back panel	
Power supply	DC power jack 15 V DC
Multiple stage connectors	D-sub HD 15 (female) Contains power supply for the encoder, encoder signals and piezo signals.
Virtual COM-port	USB-B 2.0 port
Optional RS-232	D-Sub 9 (female)
Optional GPIO	D-sub 15 (female)

Each axis is provided with a D-sub HD15 connector comprising the piezo signals and encoder signals of a particular axis. The encoder supply voltage can be set individually for each axis, with choice between 3.3 and 5 V (internal jumper). The default voltage is 5 V.

The piezo drive signals have an amplitude of 30 Vpp and frequency range between 0 and 300 kHz, sufficient to drive Xeryon's ultrasonic linear and rotary stages.

- **Pin layout for the stage connectors (D-sub 15 HD female)**

All stage connectors have identical pin layouts.

PIN #	SIGNAL	PIN #	SIGNAL
1	/	9	Encoder error *
2	Encoder power (5V)	10	Ground piezo 1 & 2
3	Encoder ground	11	Encoder index - *
4	Piezo 2	12	Encoder A - *
5	Piezo 1	13	Encoder B - *
6	Encoder index +	14	/
7	Encoder A +	15	/
8	Encoder B +		

* The encoder in the XRT-U rotary stage is single ended and has thus no I - / A - / B - signal. Neither has the XRT-U an encoder error signal.

▪ **GPIO (D-sub 15 female two rows)**

PIN #	SIGNAL	PIN #	SIGNAL
1	Analog input 1 for axis 1	9	Index found for axis 1
2	Analog input 2 for axis 1	10	Position reached for axis 1
3	Analog input 1 for axis 2	11	Index found for axis 2
4	Analog input 2 for axis 2	12	Position reached for axis 2
5	Analog input 1 for axis 3	13	Index found for axis 3
6	Analog input 2 for axis 3	14	Position reached for axis 3
7	Ground	15	Not connected
8	3.3 V		

Position reached is defined as follows: either the position error is zero (exact position) or the stage remains within a range of +/- PTOL (positioning tolerance) of the target position for a time interval defined by TOUT (timeout). The stage is switched off followed by a delay period defined by DLAY. During this waiting period the stage should not leave the range set by PTOL (otherwise the position controller switches on again). After this waiting period the 'position reached' flag is raised. When the stage exits the range set by PTOL or when a new setpoint is selected, the 'position reached' flag is lowered immediately without delay.

A more detailed explanation of the command set is given in paragraph 5.

Warning: Do not open the driver. In case of a damaged connector or cable, please contact Xeryon for repair or replacement.

3. Communication

A host computer or controller can communicate with the XD-M via the USB configured as a virtual COM port, or directly via RS-232 (optional). The baudrate is standard set to 115200 baud. The protocol uses 8 data bits, 1 stop bit, no parity bit, no handshaking.

Format

A command line consists of maximally 16 characters followed by a 'new line' character (ASCII code 10). The command has the following format:

X:DPOS=-12345678

- 1 character defining the axis, followed by a colon.
- 4 characters for the command.
- '=' sign separating the command from the corresponding value.
- Optional sign.
- Decimal value of 8 decimal places (9 if the sign is omitted).
- Maximum total of 16 characters.

The characters have to be sent from left to right, in the example above starting with 'X' and ending with '8'. The command tags are in upper case. The instruction should be terminated with a 'new line' character (ASCII code 10). The driver processes the instruction immediately after receiving this 'new line' character.

Some instructions such as 'ZERO' and 'RSET' require no value. In that case, it is sufficient to send only the command itself, e.g. 'ZERO' followed by the 'new line' character.

Addressing axes

To address an axis, put the axis name (1 letter followed by a colon) before the command. When no axis is specified, the command goes to the first axis (stage 1). In case of a single-axis system, no axis designation is required.

Multiple-axis system:

- Y:DPOS=-1000 -> positioning of the Y-axis only.
- DPOS=0 -> first axis is sent to its zero-coordinate.
- RSET -> reset the X-axis driver
- Y:RSET -> reset the Y-axis driver

Single-axis system:

- DPOS=-1000

Axis naming:

- Axis 1: X
- Axis 2: Y
- Axis 3: A

Values

There are 9 characters reserved for the value including its sign. For signed values 8 decimal places are available, giving a range from -99 999 999 to +99 999 999. For positive numbers, the '+' sign can be omitted, increasing the positive range to 999 999 999. No spaces, commas or periods should be added to the numbers. Only integers are allowed.

- X:DPOS=-99999999
- X:DPOS=+99999999
- X:DPOS=99999999

Units are as follows:

Type	Rotation stage	Translation stage	Resolution
Time, delays	ms		1 ms
Target position, step size	encoder units		1 encoder increment
Speed	deg/s (*)	µm/s	0.01 deg/s or 1 µm/s
Frequency	Hz		1 Hz

(*) Conversion factor of 100 required: e.g. enter SSPD=10000 for 100 deg/s.

Instruction set

Command	Range	Mode	Explanation
XRTU	3,73, 109		Configure the driver for a XRT-U rotation stage. XRT-U-30 with 109 µrad resolution: XRTU=109 XRT-U-40 with 73 µrad resolution: XRTU=73 XRT-U-40 with 3 µrad resolution: XRTU=3
XLS_	78, 312		Configure the driver for a XLS linear stage. XLS with 78 nm resolution: XLS_=78 XLS with 312 nm resolution: XLS_=312
RSET	-	-	Reset the driver. All piezo signals go to zero and settings are set to their default value.
INDX	-	-	Find the index. After finding the index, go to the index position.
HOME	-	Closed loop	Go to the home position.
DPOS	24 bits	Closed loop	Set target position. Closed-loop control is used to reach and maintain the new position. The position is expressed in encoder units. Positive and negative values are allowed within the range of the stage.
STEP	24 bits	Closed loop	Move relative to the current position, over a specified distance. When already in closed loop, the current desired position is used as a reference. When in open loop, the actual position (encoder value) is used as a reference. The command value specifies the step size in encoder increments. Positive values send the stage towards higher encoder values, negative values send the stage towards

			lower encoder values. Closed-loop control is used to reach and maintain the new position.
MOVE	-1,0,1	Open loop	Continuously move in open loop. Phase and duty factor influence the speed, but speed is not controlled. A positive number sends the stage towards increasing encoder values, a negative number sends the stage towards decreasing encoder values. A zero value stops the stage.
SCAN	-1,0,1	Closed loop	Continuously move with fixed speed. The speed is maintained by closed-loop control. A positive number sends the stage towards increasing encoder values, a negative number sends the stage towards decreasing encoder values. A zero value stops the stage.
STOP	-	Open and closed loop	Stop the stage.
CONT	-	Open and closed loop	Continue movement after a stop command.
LLIM	24 bits	Open and closed loop	Set low-side soft end stop. Expressed in encoder units.
HLIM	24 bits	Open and closed loop	Set high-side soft end stop. Expressed in encoder units.
ZERO	-	Open & closed loop	Force the piezo signals to zero volt.
SSPD	24 bit	Closed loop	Set speed. Used as scanning speed (SCAN command) and as target speed towards the next target position (DPOS and STEP). Unit is 1 $\mu\text{m/s}$ or 0.01 deg/s. Default: 10000 (10 mm/s or 100 deg/s).
PHAS	16 bit	Open loop	Set the phase offset between the excitation signals. Can be used to control the speed in open loop. Input values 0-65535 correspond to a phase shift of 0-360°. Below 32768 (180°) the phase corresponds with a MOVE=1 direction, above 32768 it corresponds to a MOVE=-1 direction.
PHAC	16 bit	Open & closed loop	Phase correction. Corrects an imbalance in the motor. Such imbalance may cause a rattling or scratching noise when the stage moves at low speed. Practical values are in the range of a few 1000, positive or negative. Default: 0 (no correction)
DUTY	16 bit	Open loop	Set the duty factor of the excitation signals: width of the pulses. This instruction can be used to reduce the driving force and speed of the motor. Values 0-32767. 0: pulse width 50%, 32767: pulse width 0%. Default: 0.
DUCO	1 bit	Closed loop	A duty factor is used in closed loop if set to 1. If set to 0, a fixed duty factor of 50% is used. Default: 1.
FREQ	24 bits	Open and closed loop	Set the frequency of the excitation signals. Unit is Hz. Default: 166000 (Hz).

HFRQ	24 bits	Open and closed loop	Set the maximum piezo excitation frequency. Unit is Hz. Used as the upper boundary for finding the optimal frequency. Default: 170 kHz.
LFRQ	24 bits	Open and closed loop	Set the minimum piezo excitation frequency. Unit is Hz. Used as the lower boundary for finding the optimal frequency. Default: 160 kHz.
FFRQ	3 bits		Find optimal frequency. The driver will try to find the optimal excitation frequency for the piezo motor within the range between LFRQ and HFRQ. Bit 0: 0 for searching with increasing frequency, 1 for decreasing frequency Bit 1: determines the direction in which the stage moves during the test (left or right). Bit 2: determines whether the test is done while moving in alternating directions (oscillating) (bit 2 = 1) or while moving in a fixed direction (bit 2 = 0). e.g. FFRQ=4 will search for the optimal frequency starting from LFRQ towards HFRQ (increasing frequency) and by alternating the direction (oscillating).
OFRQ	24 bits	Open and closed loop	Set offset between search frequency obtained by FFRQ and the actual frequency to use. Unit is Hz. Default: 500.
PROP	16 bits	Closed loop	The phase and duty factor of the excitation signals are varied in proportion to this factor and the position error. Default: 7.
CFRQ	16 bits	Closed loop	Control frequency. Adapt this value to obtain stable closed-loop control. The optimal control frequency depends on the mass or inertia of the load. Default: 30000 (30 000 Hz) for zero load.
ELIM	20 bits	Closed loop	Limit on the position error used in closed-loop control. Expressed in encoder units. Default: 10000.
PTOL	16 bits	Closed loop	Position tolerance. Values are expressed in encoder units and should be in the range 0 – 32767. The range is applied symmetrically with respect to positive and negative position errors. e.g. PTOL=2 allows position errors between -2 and +2 encoder units. Small vibrations around the desired position can be suppressed by use of the position tolerance and timeout. Default: 2. See TOUT for more detail.
TOUT	16 bits	Closed loop	Set timeout time. Small vibrations around the desired position can be suppressed by use of the position tolerance and timeout. When the stage is within +/- position tolerance of the desired position for a period set by timeout time, then the control is switched off. The time is expressed in milliseconds. The default value is 50 (50 ms). Also check PTOL.

PTO2	16 bits	Closed loop	Second position tolerance, similar to PTOL. Comes into action if first position tolerance PTOL fails within a second timeout time TOU2. The default value is 10.
TOU2	16 bits	Closed loop	Second timeout time. To be used in combination with PTO2. The default value is 500 (500 ms).
DLAY	16 bits	Closed loop	Sets the delay between the moment the stage reaches its target position and the moment the 'position reached' flag is raised. Expressed in milliseconds. Default: 100 (100 ms).
ENCD	1 bit	Open and closed loop	Set the encoder direction. Set the counting direction with respect to the A/B signals of the incremental A-quadrant-B encoders. Flip this bit to swap left and right, or clockwise and counter-clockwise. Default value is 0.
ENCO	32 bits	Open and closed loop	Sets the encoder offset: distance between the index position and the desired zero position. In encoder units. Default value is 0.
ACTD	1 bit	Open and closed loop	Set the actuation direction. If not set correctly, the stage will move away from the desired position. Default value is 0.
PATH	1 bit	Closed loop	For rotation stages only. Selects whether the stage will follow the shortest path (PATH=1) to the target position or follow a linear approach, respecting high to low or low to high (PATH=0). Default: 1 for rotation stages, 0 for linear stages
INFO	4 bits		Select type of info to be transmitted from the driver to the master (PC). 0: Stop broadcasting info 1: SRNO, SOFT, STAGE, STAT, SYNC 2: SRNO, SOFT, STAGE, STAT, FREQ, OFRQ, SYNC, EPOS, DPOS, TIME 3: EPOS, DPOS, STAT 4: EPOS, STAT, DPOS, TIME 5: STAT, FREQ, OFRQ, EPOS, DPOS, TIME 6: FREQ, OFRQ, CURR 7: EPOS, STAT Default: 2 e.g. INFO=7 will alternately send EPOS & STAT values.

Info sent back from the XD-M

Information is sent back from the XD-M to the master (PC) in ASCII format. The format is as follows:

1. One character identifying the axis, followed by a colon.
2. Four characters describing the type of information
3. '=' sign separating the command from the corresponding value
4. Signed value associated with that information (sign + 8 decimal places). The message is terminated with a 'new line' character (ASCII code 10).

e.g. X:EPOS=+12345678

The different types of information:

Command	Explanation
SRNO	Serial number of the driver (hardware)
SOFT	Software version installed on the driver. e.g. 20103 -> 2.1.3
STAGE	Type of stage (XRTU / XLS and its resolution)
STAT	Status (see below)
FREQ	Excitation frequency currently in use
OFRQ	Optimal frequency as determined by FFRQ
CURR	Current consumed by the piezomotor
SYNC	Fixed value "12345678". Can be used for debugging communication issues.
EPOS	Encoder position
DPOS	Desired position
TIME	Time stamp

The command INFO determines which information is sent back. First, all selected info is sent for the first axis, then all selected info for the second axis, and so on. After reporting the last axis, the driver switches automatically to the first axis.

The status word contains 24 bits:

Status bit	Name	Explanation
0	-	Always 1
1	-	Always 1
2	-	Always 0
3	-	Always 0
4	Force zero	Indicates whether the driving signals to the motor are currently forced to zero.
5	Motor on	Indicates whether the motor is on.
6	Closed loop	Indicates whether the motor is currently in closed loop control.
7	Encoder index	Indicates whether the stage is positioned exactly at the encoder indices.
8	Encoder valid	Indicates whether the encoder index has been passed and therefore the encoder value reflects the absolute position, not the relative position with respect to the startup position.
9	Searching index	Indicates whether the stage is currently searching the index position.
10	Position reached	Indicates whether the target position is reached (within tolerance limits).
11	-	Always 0
12	Encoder error	Indicates an error produced by the encoder.
13	Scanning	Indicates whether the stage is in a scanning mode.
14	Left end stop	Indicates that the left end stop is passed.
15	Right end stop	Indicates that the right end stop is passed.
16	Error limit	Indicates that the position error has reached the limit set by ELIM. This can indicate a collision or mechanical limit (end of stroke).
17	Searching optimal frequency	Indicates the driver is searching for the optimal excitation frequency of the piezo motor.
18-24	-	Not used

Visual feedback

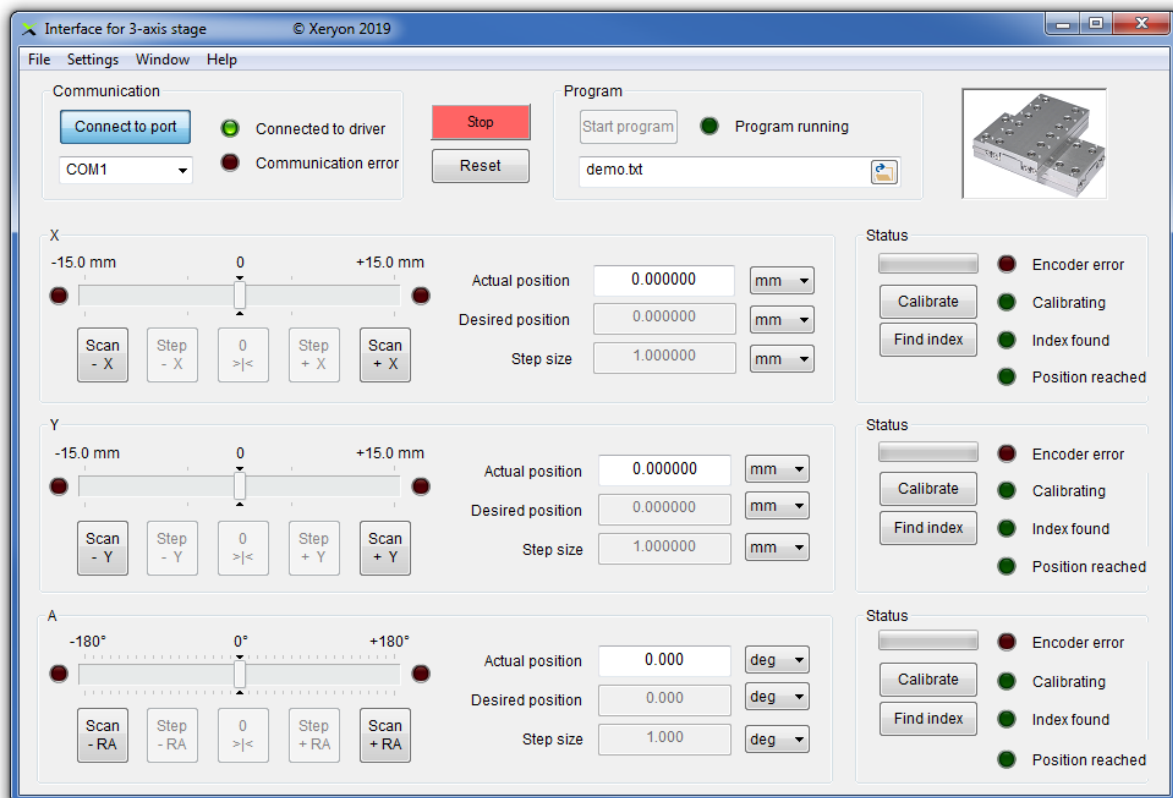
The on-off button has integrated LEDs that light up when the driver is powered on.

4. User interface

To provide the user with a quick way to interact with the driver and the connected stage, a user interface is delivered with the XD-M. This interface comes in several variants depending on the type and number of axes. An example for an XY-stage is shown below. The use is simple and self-explanatory. It can be used for manual input and to run simple programs. More information regarding this user interface is given in the user manual of the stage.

This user interface is not intended for interaction with other programs written in C, Labview, Matlab, etc. These programs should directly interact with the driver via the protocol described above. On request, C++ or Labview code is provided to ease interfacing.

Remark: before one can use the user interface “Xeryon_Dialog.exe”, one has to install the driver installation files. Copy the “xd-c.inf” and “xd_c_win.cat” files from the USB-stick to a folder on your hard disk, preferably in the same folder as the user interface “Xeryon_Dialog.exe” file. Don’t install the driver installation files from a USB-stick or network disk. Then, when both driver installation files are copied to your hard disk, install the files by a right mouse click on “xd-c.inf” and choose “Install”. The installation can take a while, please follow the next steps in the popup window. Reconnect the XD-M driver to your PC after installation of the driver installation files. Now, you are ready to open and use the user interface “Xeryon_Dialog.exe”.



Files

The User Interface makes use of the following files:

- The executable of the User Interface: Xeryon_Dialog.exe
- A configuration file named “config.txt”. This file should not be edited by the user.
- A default settings file named “settings_default.txt”. The User Interface reads this file for initial settings at start up. Replace or modify this file to alter the default settings.
- A settings file named “settings_user.txt”. The user can save and load alternative settings files via the menu. The filename is free to choose, but the file dialog window presents “settings_user.txt” as default filename.
- Several program files for which the name and content can be freely chosen. The file dialog window presents “demo.txt” as default filename.

config.txt and settings_default.txt are required files and have to be in the same folder as Xeryon_Dialog.exe.

The settings file and program files are composed of the same commands that are used to directly talk to the XD-M (see paragraph 3). An important difference is that the User Interface uses position data in degrees, millimetre etc., while encoder units have to be used when talking directly to the XD-M. The conversion is automatically made by the User Interface. Similar conversions are made for speed (deg/s or mm/s). A few additional commands exist that affect the program flow and connection. With the exception of “MASS”, these are not axis specific.

Command	Explanation
BAUD	Set the baudrate for communication.
DPOL	Delay used when polling for a ‘position reached’ signal after a new target position is set. When DPOL is too small, the Windows Interface may trigger on the ‘position reached’ status flag of the previous target position due to communication delay. In that case, a succeeding WAIT command will start the timer at the start of the movement instead of after the target has been reached.
HELP	Switch help on or off. HELP=1 switches the info tips on. HELP=0 switches the info tips off.
HALT	Stop the program. (Not to be confused by the STOP command for the driver.)
LABL	Label in the program used by REPT.
LOG	Start or stop logging of data. LOG=1 switches logging on. LOG=0 switched logging off. Data is stored in datalog.csv. When datalog.csv already exists, new data is appended.
MASS	Specifies the mass/inertia of the load on the stage. The User Interface calculates the optimal control parameters to obtain stable operation.
PORT	Default port number to appear in the User Interface.
REPT	Repeat the above program a specified number of times. The first argument specifies the number of loops. The second argument specifies the label to jump to (label range 0 – 99). If the label does not exist, then the program jumps back to the first line. The REPT command should be placed at the end of the block to be repeated. Nesting of REPT blocks is allowed. Example: REPT=10 2 does 10 loops starting from label 2.
WAIT	Wait a specified time before proceeding to the next command. Time expressed in milliseconds. When WAIT follows a STEP or DPOS command, the timer is started when reaching the target position.

Comment text should be preceded by a percentage sign.

Example config file (config.txt)

This config file is written by Xeryon for your specific setup and should normally not be changed by the user.

```
GUI=20          % Version of graphical user interface
AXES=3 XYA     % Number of axes in the system and their names
X:XLS=312     % Type of X-stage, e.g. XLS with 312 nm resolution
Y:XLS=312     % Type of Y-stage, e.g. XLS with 312 nm resolution
A:XRTU=109    % Type of A-stage, e.g. XRT-U-30 with 109 µrad resolution
X:RANGE=30    % Range of the X-stage, e.g. 30 mm
Y:RANGE=30    % Range of the Y-stage, e.g. 30 mm
A:RANGE=360   % Range of the A-stage, e.g. 360 degrees
LEVEL=0       % User level (0-2)
CL=1          % Scan buttons for closed loop (1) instead of Move buttons for open loop (0)
```

Example settings file (settings_default.txt)

```
PORT=2         % Select COM-port 2 as default
INFO=2         % Select info, identical for all axes
X:ENCD=0       % Encoder direction for X-axis
Y:ENCD=1       % Encoder direction for Y-axis
X:FREQ=167000 % Piezo excitation frequency for X-axis
Y:FREQ=167000 % Piezo excitation frequency for Y-axis
X:SSPD=10     % Speed of X-axis
Y:SSPD=20     % Speed of Y-axis
X:PROP=3      % Proportional control factor for X-axis
Y:PROP=3      % Proportional control factor for Y-axis
X:LLIM=-28    % Lower position limit for X-axis
X:HLIM=28     % Upper position limit for X-axis
Y:LLIM=-28    % Lower position limit for Y-axis
Y:HLIM=28     % Upper position limit for Y-axis
X:MASS=100    % Load on X-axis
Y:MASS=50     % Load on Y-axis
X:PTOL=3      % Positioning tolerance in X-direction
Y:PTOL=5      % Positioning tolerance in Y-direction
```

Example program file (demo.txt)

```
X:SSPD=10     % Speed of X-axis
Y:SSPD=20     % Speed of Y-axis

LABL=2        % Set label 2

Y:DPOS=-500   % Move to Y=-500
X:DPOS=-500   % Move to X=-500
WAIT=5000    % Wait 5 seconds

X:DPOS=0
WAIT=2000
```

X:DPOS=500
WAIT=2000

Y:DPOS=0
WAIT=2000
X:DPOS=0
WAIT=2000
X:DPOS=-500
WAIT=2000

Y:DPOS=500
WAIT=2000
X:DPOS=0
WAIT=2000
X:DPOS=500
WAIT=2000

REPT=3 2 % Repeat 3 times the code above, starting from label 2
X:DPOS=0 % Finish in the centre
Y:DPOS=0 % Finish in the centre

5. Customer service

- General contact: info@xeryon.com
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