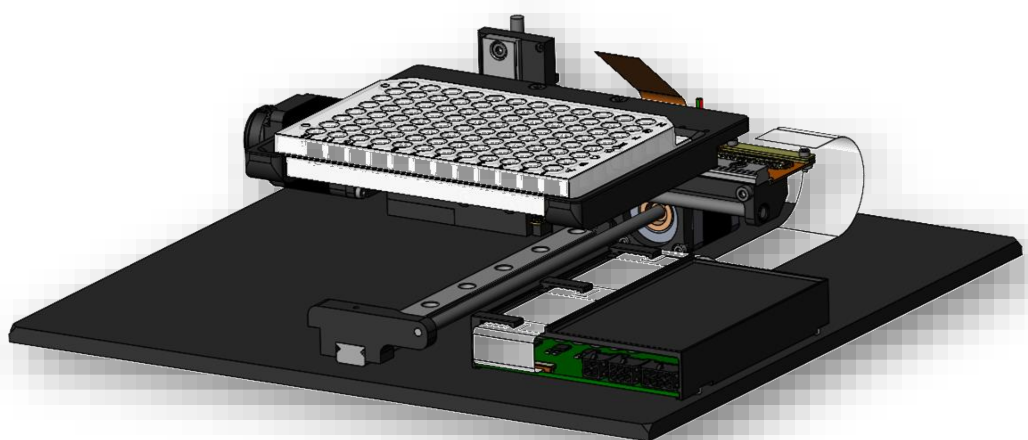
PR01 Series
Microplate Handling Robot
User's Guide



TPA Motion
Fort Mill, SC

Preliminary, January 5, 2022

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Revision History

Date	Version	Robot Revision	Document Changes
Jan 2022	1.0	RevX and X1	Created

Cautions

Copying all or any part of this manual without written approval is prohibited.

The specifications and features of this robot may be changed to improve performance or quality without prior notice.

Although this manual was produced with the utmost care, you may find content that is unclear, contains inadequate descriptions, or have errors. If so, please let TPA Motion know.

We are not responsible for any results that occur from using this robot or robot controller, regardless of the accuracy or suitability of this documents content or the design of the robot.

TPA Motion’s Microplate Robot is designed for use in commercial apparatus (office machines, lab equipment, measuring devices, etc.) Do not use this robot in applications where faults or malfunctions may directly affect human survival or injure humans. TPA Motion. If you violate this restriction, the user must provide their own safety measures to ensure proper function and protect anyone involved with the robot. TPA Motion will not be liable for any problems that arise from use of this product.

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1.0 Introduction

The TPA Motion Microplate Robot is an all-inclusive robot designed to transport microplates and other payloads around inside a laboratory instrument or other machine. It includes all the major motion control elements (motors, bearings, feedback, limit sensors, and wiring harness) needed to achieve this task in a single, pre-engineered, pre-tested robot. These elements are packaged together in a way that is ideal for the instrument application and avoids many of complications and pitfalls of designing such a device from scratch.

In addition to the mechanical robot, TPA Motion also offers an optional motion controller for the robot. The mechanical robot utilized industry standard components, so you do truly have the option to use your own controller. We expect most small OEMs will want to use our controller because of its ease of use. We also expect most large OEMs will be designing boards anyway and will choose to integrate the robot controls into the instrument controls. Either way, TPA Motion can support your instruments control architecture. This manual will assume use of TPA's controller.

The Microplate Robot is intended for both small and large Original Equipment Manufacturers (OEMs). It is commonly used by companies or individuals with new chemistry/biology/microscopy or other IP that they are working to bring to the market. The off-the-shelf, pre-engineered solution enables the user to focus on their IP and not be distracted by figuring out how to build a compact, highly reliable robot to handle a microplate.

In short, we enable you to focus on the chemistry/biology/microscopy/etc. that you are good at by taking care of the robotics that we are good at.

2.0 Major Features

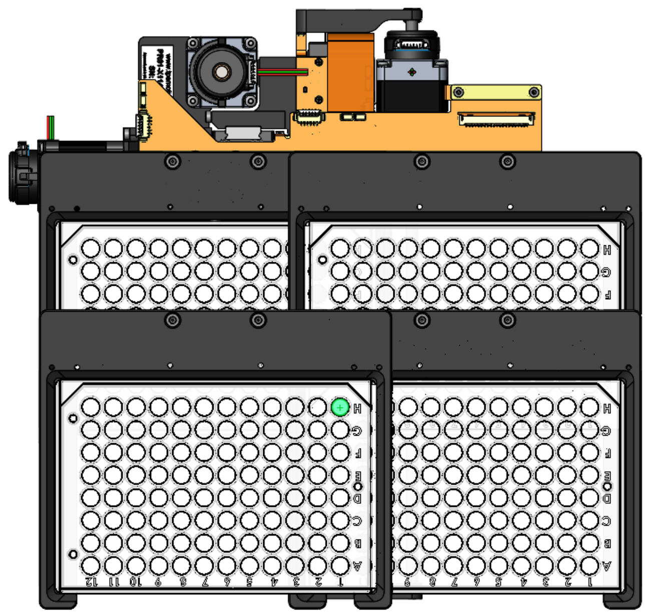
The Microplate Robot contains several key features relevant to the instrument application which are detailed here.

All Inclusive

TPA Motion's Microplate Robot fully integrates all the elements needed for operation meaning there is nothing to add to start operation. The robot and controller can be pulled from the box, mounted, and connected to power and USB in about 15 minutes. An available Windows utility allows you to start moving the robot immediately.

Microplate Access and Compact Footprint

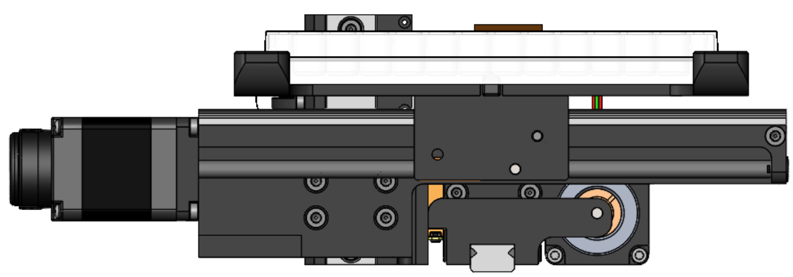
The image (right) illustrates how the Microplate Robot can position a microplate under a fixed pipet (green dot) for access to the 4 corner wells of the microplate (A1, A12, H1, H12). Accessing all four corners means it can access all other wells. Note that generally, the Robot fits within the envelope needed for movement of the microplate. To the left the Robot protrudes 12mm. To the rear there is 85mm.



In short, your process will drive the size of your instrument, not the Robot used to carry the microplate around. A minimum footprint of 264mm x 250mm is needed for the Robot to handle the microplate.

Low Height

The Microplate Robot can position the bottom of the microplate in a range from ~50mm to ~85mm above deck. No part of the Robot stands taller than 70mm unless the Z-axis moves into that space.



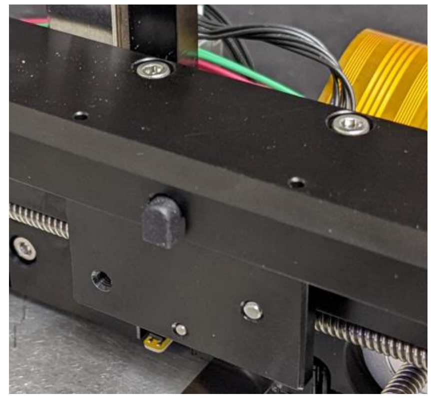
Again, the height of your instrument will be driven by the process, not the robot.

Loading/Unloading a Microplate

The Y-axis travel and Microplate Holder configuration enables the microplate to extend out the front of the instrument for load/unload operations.

Microplate Detection

The Microplate Holder area has a small spring-loaded button that serves two functions. The process of loading a microplate depresses the button and signals the controller a microplate is present.



Microplate Registration

Additionally, the spring force of the button against the microplate registers the microplate to the front of the Microplate Holder for more consistent positioning.

Microplate Orientation

A microplate's rectangular shape allows it to be loaded in two orientations. The Microplate Holder has a pair M2 threaded holes in both back corners that allow attachment of a keying feature. Typically, this will be a triangular shaped tab that leverages a chamfered corner of the microplate. This corner tab is somewhat unique to the specific brand of microplate used.

Easy Installation

Installation is very straightforward. 8x M3x6 socket head cap screws are used to mount the robot to an instrument base. 4x M3x8 socket head cap screws are used to mount the controller to the base. A flat flex cable (FFC) is connected between the Controller and Robot. Connect 24VDC via a screw terminal connection. Plug in USB and snap the controller cover on and you are ready to go. We also have a software utility that allows you to jog the system around and begin programming.

High Reliability

As a pre-engineered system, we have already tested and proven the design to be robust. The testing included a 1 million XY-axis and 2 million Z-axis cycle test, so longevity is also proven.

Dedicated Motion Controller

Available with the Microplate Robot is a motion controller designed for easy integration with the Robot and into an instrument. With a single FFC connection, the Robot is fully wired to the highly capable controller. Only power and USB connections remain to be ready for operation.

The controller is a 4-axis device where 3-axes are directed to the Robot with a 4th axis available to perform another function in your instrument. The motor, limit, and encoder features of the 4th axis are accessible via 3 connectors next to the FFC connector. The controller offers a comprehensive feature set and can operate standalone or be easily integrated into a higher-level control scheme.

Other Controller Options

Because the Microplate Robot uses industry standard motion components, it can be driven by a wide variety of controllers and is not limited to only TPA Motion's controller. Most large OEMs will develop dedicated controls for their instruments and will want to integrate the motion control functions into that board. Appendix A provides full details of the connection requirements. OEMs can develop their board and integrate the same FFC connector to maintain the same simple connectivity.

Another control option is an off-the-shelf third-party controller. TPA Motion offers a screw terminal breakout board for the FFC that facilitates connection to other devices.

3.0 Product Overview

Power Input

- Robot Controller: 24VDC Nominal (18VDC to 36VDC) at 2-3 amps
- Robot Power derived from Robot Controller
  - Motors: 24VDC Nominal (18VDC to 36VDC) at 0.5 amps/phase
  - Sensors: 2.5VDC to 38VDC at 125mA max
  - Encoders: 5VDC at 130mA max

Communications

- USB 2.0, HID compatible, no driver signature required via USB Mini-B connector
- RS485 ASCII, baud rate selectable via screw terminals

Programming

- Control via streamed commands from PC over USB/RS485
- Standalone control available via basic like language (A-Script)
- Utility software available
- DLLs available for 32-bit and 64-bit systems

Travel

- X-Axis (left-to-right): 114mm sensor-to-sensor; 118mm stop-to-stop
- Y-axis (front-to-back): 164mm sensor-to-sensor; 168mm stop-to-stop
- Z-axis (vertical): 32mm sensor-to-sensor; 36mm stop-to-stop
- Typical 96 Well Microplate requires 99mm x 63mm travel to access opposite corners.
- Typical well depth is less than 11mm

Robot Components

- Controller Microstepping: 16x
- Motors: 2-phase, bipolar, 1.8° step motors, 0.5 amp/phase
- Encoders: 800-line, quadrature encoders, differential output
- Leadscrew: 2.54mm lead (travel per revolution)
- Travel Limit Sensors: Hall Effect, 2.5VDC to 38VDC, 30mA max sink with 10K pullup
- Microplate Detect Sensor: Hall Effect, 2.5VDC to 38VDC, 30mA max sink with 10K pullup

System

- Motor Resolution: 1260 motor usteps per mm (200 steps/rev * 16 ustep/step / 2.54mm/rev)
- Encoder Resolution: 1260 motor steps per mm (800 lines/rev * 4 counts/line / 2.54mm/rev)
- Accuracy: Appropriate for accessing a 96 well plate with a typical pipet (<0.125mm)

4.0 Installation

The TPA Motion Microplate Robot is easily installed with a row of fasteners to mount the base rail and a few more to mount the controller. This is followed by installation of the FFC to make the electrical connection between robot and controller. Finally, with power and communications, the system is ready to operate.

4.1 Mounting Patterns

We recommend the Mechanical Robot is mounted to a flat, machined surface with M3x6 socket head cap screws. This will require a row of M3x0.5 threaded holes on 25mm centers. Alignment of the robot may not be important in prototypes and development systems, but in production this is likely to be more important.

The robot can be aligned to the base with either a reference edge or two dowel pins. A reference edge can be created by machining a rail seat that is slightly wider than the 9mm rail. The rail seat should not be greater than 1mm deep and be straight and flat within 25 microns (.001"). During installation, the robot is banked against the side of the rail seat as fasteners are tightened.

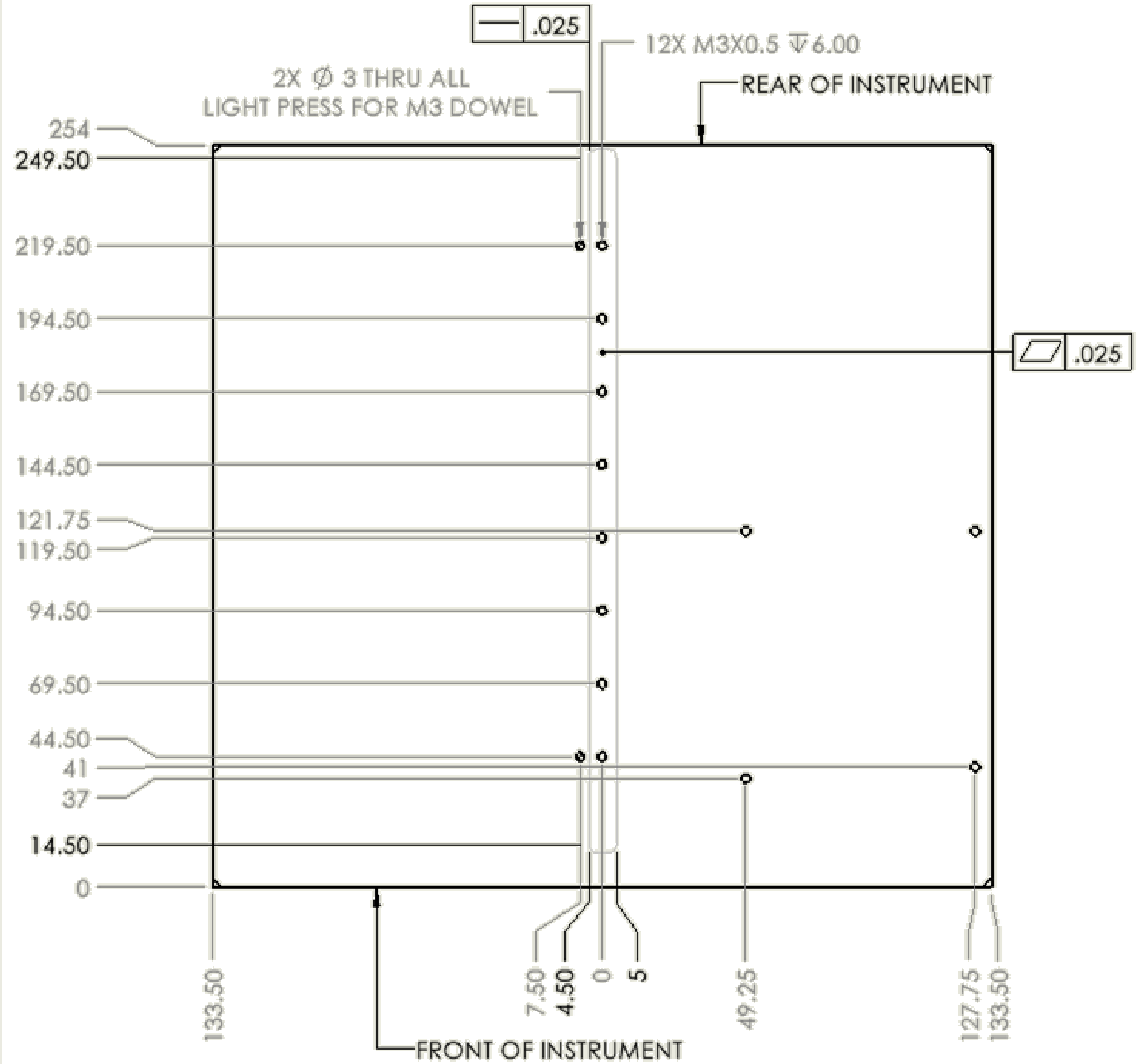
Alternatively, the mounting surface can be completely flat but include dowel pins as reference points to align the rail/robot. We recommend M3 dowel pins 150mm to 175mm apart. The dowel pins should not protrude more than 1mm above the surface as there is only ~2mm of clearance.

Because the rail will somewhat take the shape of whatever it is mounted to, the mounting surface should be flat to within 25 microns (.001"). Surfaces that are not flat, such as sheet metal can reduce the robot's precision by causing the robot to roll and pitch as it travels over the topology of the now deformed rail.

The motion controller can be mounted on the deck beside the robot. The controller can be mounted in other places within the instrument if you prefer and is perfectly acceptable. If not on the deck, then on the ceiling above the robot is an easy place. Many will choose to mount the controller in an electrical enclosure within the instrument. An important consideration when selecting the controller location is routing of the Flat Flex Cable (FFC). Mounting on the deck as shown provides for simple FFC routing. Mounting on the ceiling could be just as simple. Mounting elsewhere will require some thought related to FFC length and routing.

The following drawing provides suggested hole locations for robot and controller.

- The rail mounting pattern coincides with the center of the X-axis travel.
- The "Front of Instrument" location allows full access to the microplate and a few millimeters clearance to the front wall.
- A rail seat must extend at least 30mm beyond the end mounting holes.
- The controller mounting pattern is not precisely square, one hole is offset in Y.
- Only a rail seat or dowel pins would be used for alignment, not both.



M3x6 socket head fasteners used to fasten the rail should be tightened to 1.0 Nm. Over tightening the fasteners can deform the rail and cause smooth running issues.

The control can be mounted to the right of the robot using 4x M3x8 SHCS. A robot controller kit will include the controller, 4x fasteners, 4x spacers, and a cover. The fasteners pass through the controller PCA, through a spacer, into the treaded mounting hole. The spacers prevent pins from thru hole components from contacting the deck and shorting out.

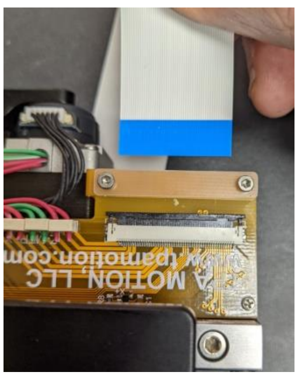
4.2 FFC Connection

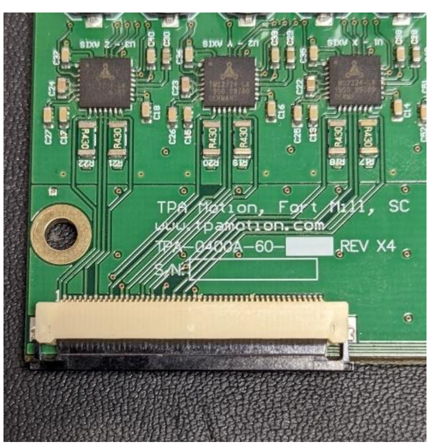
The electrical connection between the Robot and Controller is via a 50 conductor FFC which carries all the motor phases, encoder power and signals, sensor power and signals. The FFC connectors are slide lock ZIF connectors for easy installation.

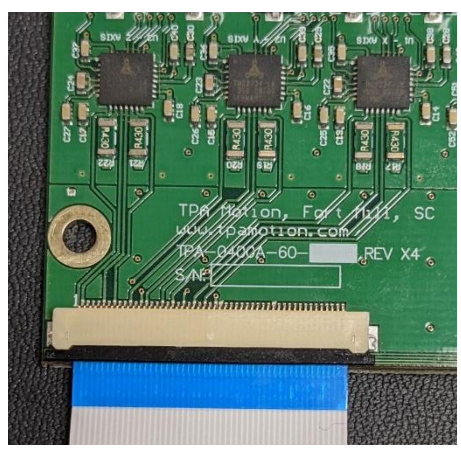
Connection to the robot process

1. Loosen the two M2 SHCS of the FFC clamp. They do not need to be fully removed.
2. Pull out the slide lock.
3. Insert FFC between the FFC clamp with contacts down until it is fully seated in the connector.
4. Press the slide lock back in to secure the FFC ensuring both edges are fully seated.
5. Visually inspect to ensure the FFC is properly seated and locked. On the robot, a thin thread of white can be seen along the edge of the clamp showing the FFC is fully seated.
6. Retighten the clamp fasteners.
7. Repeat the connection process on the controller end of the FFC.

WARNING: IT IS IMPORTANT TO NEVER DISCONNECT THE FFC FROM THE ROBOT OR CONTROLLER WITH THE CONTROLLER POWERED AS THIS CAN CAUSE DAMAGE.





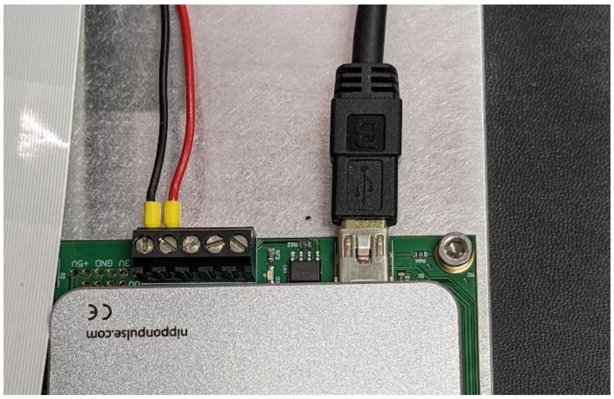


4.3 Power and USB Connection

Power is connected via the two left most screw terminal connectors. The GND is the end terminal (black) and +VDC is the next terminal (red). We commonly use 65W, 24VDC brick power supplies to power a single robot.

USB communications is connected via the USB Mini-B.

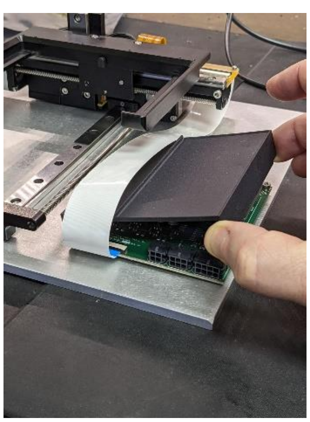
RS485 communications is available via the three remaining screw terminals: GND B- A+ (left-to-right).

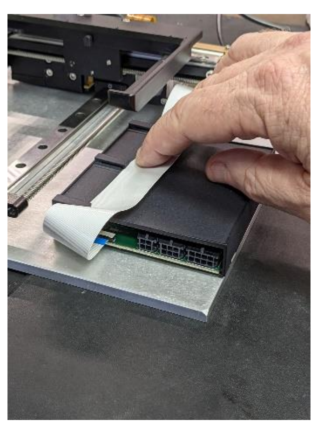


4.4 Controller Cover Installation

Because the controller is on the deck below the microplate, there are opportunities for liquid to spill/drip on to the controller circuitry. The controller cover provides basic protection from minor spills. A second function is to hold the FFC down out of the way of the robot.

Once both the robot and controller are mounted and FFC, power, and comms connected, the controller cover simply hooks on the left edge of the controller and wraps over and hooks on the right edge. The cover will deflect enough to enable installation and removal. After installation, the FFC is slid under the fingers that hold it in place. It is adjusted to have a very short loop in front of the controller.






5.0 Programming the Robot Controller

The TPA Robot Controller utilizes a Commander motion control core as the heart of our controller. The Commander core is manufactured by Nippon Pulse America (NPA). NPA's decades of motion control experience and highly capable motion ICs enables this technology. The Commander core has an easy-to-use command language with extensive capabilities.

Most instruments will stream commands from a PC to the motion controller and poll for status. The Commander core also has a standalone language that can be written, compiled, downloaded, and run without the need for a higher-level controller within the instrument.

Commander User's Guides and Command Reference Manuals may be found on the Nippon Pulse website as shown below.

Nippon Pulse also provides a GUI interface to enable interacting with the controller while you are developing your instrument software.

Website: www.nipponpulse.com

Product Page: https://www.nipponpulse.com/products/controllers/commander

User's Guide: https://www.nipponpulse.com/assets/files/Nippon%20Pulse%20CMD-4CR%20Controller%20Manual.pdf

Command Reference:
https://www.nipponpulse.com/assets/files/Nippon%20Pulse%20CMD%20Controller%20Command%20Reference%20Manual.pdf

Utility Software: https://www.nipponpulse.com/assets/files/NPA_Commander_GUI_Installer.exe

5.1 Controller Configuration for the Robot

There are a few settings and general principles that will help speed development. For any commands referenced, we recommend reading the full description in the Software Reference Manual. Note that all commands should be in ALL CAPS.

POL Command

The POLX, POLY, and POLZ commands configure a variety of things related to sensor active levels, encoder interpolation, axis directions, etc. These are set to 4664 (POLX=4664, POLY=4664, POLZ=4664, POLU=4664, STORE) and stored in nonvolatile memory at the factory.

IERR Command

When an axis activates a limit sensor, it generates and error condition which further limits all motion on that axis until the error is cleared with a CLEAR command. This is useful for handling errors during normal operation but can be a nuisance during development. The IERR=1 command will turn off the error generation. The motion into the limit sensor will still be inhibited but no error state is created and motion off the sensor is achieved with a motion command. The IERR=1 state is temporary and will revert to IERR=0 state when power is cycled but can be made the default with the STORE command which will store the setting in nonvolatile memory.

EO Command

On power up, all the axes are disabled meaning no current is sent to the motor. It is possible to command moves and see motor counters counting without any motion occurring.

Issuing the EO=7 command will enable all three axes. The EO=0 command will disable all axes. Typically, the EO=7 command is issued early in the initialization sequence and the axes are left enabled from that point on.

Motors and Encoders

By default, all motion is in motor steps such that there are 1260 motor steps per millimeter. 96 well microplates have 9mm centers between wells meaning there are 11340 motor steps between adjacent wells.

By enabling StepNLoop features in the Commander, the encoders on the motors can be utilized to monitor for motor stalls and make corrections if desired. The motor resolution and encoder resolution are the same at 1260 motor steps or encoder counts per millimeter.

Search for StepNLoop in the Software User's Guide and Software Reference Manual for specific commands. As this is a more advanced feature of the Commander.

Homing the Robot

When the controller is powered up, it does not know where any of the axes are physically positioned, and the system needs to go through a "homing" routine to establish a reference coordinate system. The design intent is to use the negative limit sensor of each axis as the reference.

Because the robot could be in any position, care must be taken in the homing sequence to ensure success and not collide or cause damage to other parts of the instrument. For example, if the instrument lost power while the microplate was engaged with a pipet, when the robot powered on again, it would still be engaged with the pipet. A horizontal move in X or Y would cause a collision with the pipet. Similarly, if the robot was in a load/unload position with the microplate extended out the front of the instrument, an X-axis move could collide with the side of the opening.

Generally, our recommendation is to home Z first, Y second, and X third. When placing the front door of your instrument, choose an elevation low in the Z-axis travel such that Z can find home with the robot extended out the front of the instrument.

There are other sequences and door locations that can work. Our encouragement is to think this through ahead of time.

There are multiple automatic homing routines built into the firmware. We recommend using Homing Mode 6. Use the H[axis]-6 command (or HOME[axis]-6 if programming in standalone mode) to initiate homing toward the negative limit sensor. For example, HZ-6 initiates homing of the Z axis.

A homing routine might look like the following:

```
EO=7          ;ENABLE X, Y, AND Z AXES
ABS           ;SET POSITIONING MODE TO ABSOLUTE
HSPD=10000    ;SET HIGH SPEED TO 10000 steps/sec
LSPD=1000     ;SET LOW SPEED TO 0
ACC=100       ;SET ACCELERATION RAMP TIME TO 100ms
HZ-6          ;HOME Z-AXIS TOWARD NEG LIMIT SENSOR USING MODE 6
WAITZ         ;WAIT FOR Z-AXIS TO COMPLETE MOVE
HY-6          ;HOME Y-AXIS TOWARD NEG LIMIT SENSOR USING MODE 6
WAITY         ;WAIT FOR Y-AXIS TO COMPLETE MOVE
HX-6          ;HOME X-AXIS TOWARD NEG LIMIT SENSOR USING MODE 6
WAITX         ;WAIT FOR X-AXIS TO COMPLETE MOVE
PX=-1000      ;SET X-AXIS MOTOR POSITION TO THE NEGATIVE DISTANCE TO WELL A1
EX=-1000      ;SET X-AXIS ENCODER POSITION TO THE NEGATIVE DISTANCE TO WELL A1
PY=-2000      ;SET Y-AXIS MOTOR POSITION TO THE NEGATIVE DISTANCE TO WELL A1
EY=-2000      ;SET Y-AXIS ENCODER POSITION TO THE NEGATIVE DISTANCE TO WELL A1
PZ=-500       ;SET Z-AXIS MOTOR POSITION TO THE NEGATIVE DISTANCE TO AN ELEVATION
EZ=-500       ;SET Z-AXIS ENCODER POSITION TO THE NEGATIVE DISTANCE TO AN ELEVATION
X0            ;MOVE TO 0, WELL A1
Y0            ;MOVE TO 0, WELL A1
Z0            ;MOVE TO 0, SET ELEVATION ABOVE THE DECK
WAITX         ;WAIT FOR X-AXIS TO COMPLETE MOVE
WAITY         ;WAIT FOR Y-AXIS TO COMPLETE MOVE
WAITZ         ;WAIT FOR Z-AXIS TO COMPLETE MOVE
```

Position Offsets after Homing

Homing the Robot establishes a reference coordinate system based on the limit sensor positions; however, most instruments do not care about sensor positions but instead the position of microplate wells. We recommend adjusting the coordinate system such that XY coordinates 0,0 are aligned with well A1 (or other well of your choice). From this reference point, the location of any other well is easily calculated.

After the Robot finds the limit sensors, well A1 will be some distance from the Pipet, for example 1000 motor steps in X and 2000 motor steps in Y. Set the motor and encoder positions to the negative of these distances, for example, PX=-1000 EX=-1000 PY=-2000 EY=-2000. Now a move to 0,0 (X0 Y0 WAITX WAITY) will align well A1 with the pipet.

The same offset principle applies to the Z-axis except the reference should be an elevation above deck or distance below the pipet.

The Robot establishes the zero-position based on a magnet triggering a hall sensor. This position is very repeatable; however, from robot to robot, the offset distance can vary slightly due to subtle differences in placement of the hall sensor on the PCA, placement of the PCA on the Robot, magnet strength, robot placement, pipet placement, etc. When building a single instrument, these offsets can be determined and programmed but when producing multiple instruments, these offsets need to be variables unique for the specific instrument. The XY offsets are the distance to A1. The Z offset is some distance above deck or distance below the pipet. These offsets enable 0,0,0 to always be the same physical location across all instruments.

ABS versus INC

The controller has two positioning modes. We suggest using the absolute mode (ABS) and not incremental mode (INC). In ABS mode the command X1000 to move till the motor counter equals 1000. If it starts at 0 then it will move in the positive direction and if it starts at 2000, it will move in the negative direction to reach position 1000. In INC mode, the command X1000 will initiate a 1000 step move in the positive direction. If it starts at 0 then it will finish at 1000. If it starts at 2000 then it will finish at 3000.

ABS mode mean you only need to calculate the location of a well and pair those values with the X and Y commands. In INC mode you must calculate the location of the well so that you can calculate how far to travel, etc. You can switch between ABS and INC modes where INC is used to repeatedly jump from one well to the next but then switch to ABS mode to return to A1.

MST[axis] and Microplate Detect

The MST[axis] command returns a wealth of information. Read full details of this command in the Software Reference Manual. This commands response will reveal if the axis is moving or not; or if a limit sensor is active and a few other error conditions. Additionally, the Robot contains a Microplate Detect sensor which is routed to the Z-axis Home Input and can be read via MSTZ bit 6.

ASCII versus A-Script

The Controller has two approaches to programming it: ASCII and A-Script. We expect most users will utilize ASCII as this is the most flexible approach; however, A-Script can be useful during development and in certain situations.

The ASCII approach is to simply stream ASCII commands to the Controller from a PC. Software on the PC constructs ASCII command strings and sends them to the Controller as needed. It will also poll the Controller for motor position and status information to make decisions.

A-Script is a BASIC like standalone command set. Programs are created, compiled, downloaded, and stored in the Controller. Once stored, they can execute without a connection to a PC or other higher-level controller. Most functionality is available within A-Script.

Note that most A-Script commands are identical to the ASCII command butt a few are not. For example, the home command is different where ASCII is H and A-Script is HOME.

It is possible to use a combination of ASCII and A-Script where a GS command is sent to the Controller to execute a stored subroutine.

Appendix A – Robot FFC Pinout

If designing your own motion controller or using another commercially available motion controller you will need the following FFC pinout. Note that the pin numbers apply to the FFC connectors not the FFC itself as Robot Pin 1 is connected to Controller Pin 50 because of the way the FFC interacts with the connectors at both ends. The outside most trace is Robot Pin 1 and carries an encoder signal.

Motors are industry standard, 2 phase, bipolar, 1.8° step motors rated at 0.5 amp/phase.

Encoder signals are industry standard differential, quadrature signals.

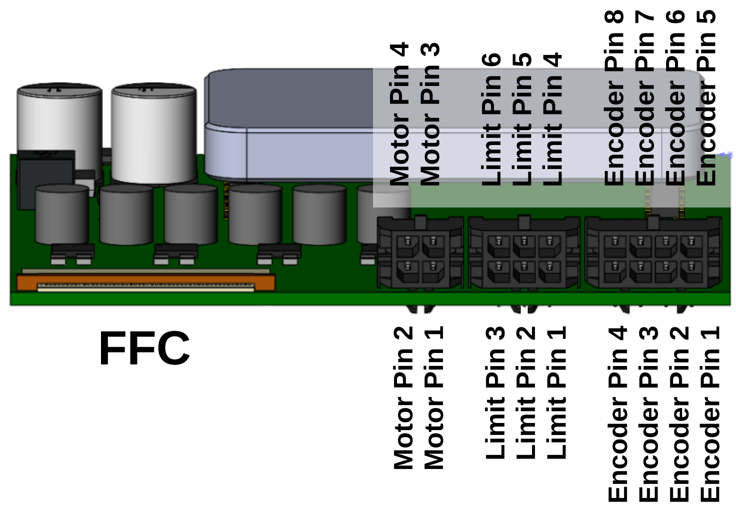
Hall sensors are active low signals and have a 10 Kohm pullup resistor to Sensor Power.

Robot	Controller		Signal Type
1	50	X ENC B-	Differential Quadrature Signal (RS422)
2	49	X ENC B+	Differential Quadrature Signal (RS422)
3	48	X ENC A-	Differential Quadrature Signal (RS422)
4	47	X ENC A+	Differential Quadrature Signal (RS422)
5	46	Y ENC B-	Differential Quadrature Signal (RS422)
6	45	Y ENC B+	Differential Quadrature Signal (RS422)
7	44	Y ENC A-	Differential Quadrature Signal (RS422)
8	43	Y ENC A+	Differential Quadrature Signal (RS422)
9	42	Z ENC B-	Differential Quadrature Signal (RS422)
10	41	Z ENC B+	Differential Quadrature Signal (RS422)
11	40	Z ENC A-	Differential Quadrature Signal (RS422)
12	39	Z ENC A+	Differential Quadrature Signal (RS422)
13	38	ENC GND	Encoder GND
14	37	ENC PWR	Encoder Power (4.5V to 5.5V, 130mA max)
15	36	SENSOR X IDLER	Hall Sensor, Active Low, 38V max, 30mA max
16	35	SENSOR X DOCK	Hall Sensor, Active Low, 38V max, 30mA max
17	34	SENSOR X MTR	Hall Sensor, Active Low, 38V max, 30mA max
18	33	SENSOR Y FRONT	Hall Sensor, Active Low, 38V max, 30mA max
19	32	SENSOR Y REAR	Hall Sensor, Active Low, 38V max, 30mA max
20	31	SENSOR Z UPPER	Hall Sensor, Active Low, 38V max, 30mA max
21	30	SENSOR Z LOWER	Hall Sensor, Active Low, 38V max, 30mA max
22	29	PLATE DETECT	Hall Sensor, Active Low, 38V max, 30mA max
23	28	SPARE	NC
24	27	SENSOR PWR	Sensor Power (2.5-38 VDC, 125mA max)
25	26	SENSOR GND	Sensor GND
26	25	EARTH	Tied to Robot Chassis
27	24	X MTR B-	Motor Phase (0.5 A shared with other trace)
28	23	X MTR B-	Motor Phase (0.5 A shared with other trace)
29	22	X MTR B+	Motor Phase (0.5 A shared with other trace)
30	21	X MTR B+	Motor Phase (0.5 A shared with other trace)
31	20	X MTR A-	Motor Phase (0.5 A shared with other trace)

32	19	X MTR A-	Motor Phase (0.5 A shared with other trace)
33	18	X MTR A+	Motor Phase (0.5 A shared with other trace)
34	17	X MTR A+	Motor Phase (0.5 A shared with other trace)
35	16	Y MTR B-	Motor Phase (0.5 A shared with other trace)
36	15	Y MTR B-	Motor Phase (0.5 A shared with other trace)
37	14	Y MTR B+	Motor Phase (0.5 A shared with other trace)
38	13	Y MTR B+	Motor Phase (0.5 A shared with other trace)
39	12	Y MTR A-	Motor Phase (0.5 A shared with other trace)
40	11	Y MTR A-	Motor Phase (0.5 A shared with other trace)
41	10	Y MTR A+	Motor Phase (0.5 A shared with other trace)
42	9	Y MTR A+	Motor Phase (0.5 A shared with other trace)
43	8	Z MTR B-	Motor Phase (0.5 A shared with other trace)
44	7	Z MTR B-	Motor Phase (0.5 A shared with other trace)
45	6	Z MTR B+	Motor Phase (0.5 A shared with other trace)
46	5	Z MTR B+	Motor Phase (0.5 A shared with other trace)
47	4	Z MTR A-	Motor Phase (0.5 A shared with other trace)
48	3	Z MTR A-	Motor Phase (0.5 A shared with other trace)
49	2	Z MTR A+	Motor Phase (0.5 A shared with other trace)
50	1	Z MTR A+	Motor Phase (0.5 A shared with other trace)

Appendix B – Controller Pinout

TPA Motion's Controller has 6 connectors as detailed below.

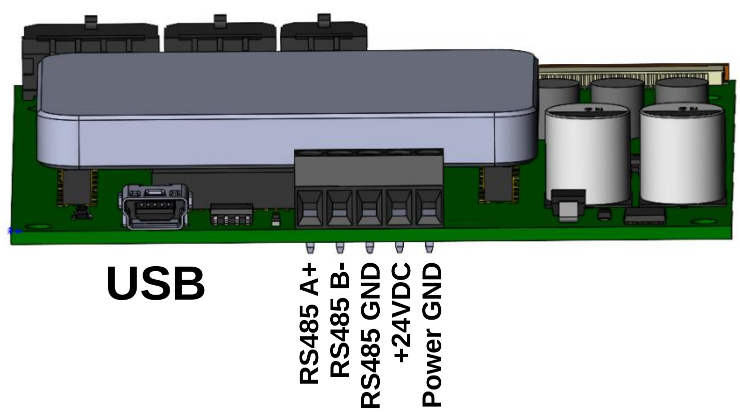


FFC – See Appendix A

Motor Pin 1 – B+
Motor Pin 2 – A+
Motor Pin 3 – B-
Motor Pin 4 – A-

Limit Pin 1 – +5VDC
Limit Pin 2 – Home
Limit Pin 3 – Neg Lim
Limit Pin 4 – Pos Lim
Limit Pin 5 – NC
Limit Pin 6 – GND

Encoder Pin 1 – A+
Encoder Pin 2 – B+
Encoder Pin 3 – Z+
Encoder Pin 4 – +5VDC
Encoder Pin 5 – A-
Encoder Pin 6 – B-
Encoder Pin 7 – Z-
Encoder Pin 8 – GND



USB – USB Mini-B

Power/Comms Pin 1 – Power GND
Power/Comms Pin 2 – +24VDC (+18VDC to +36VDC)
Power/Comms Pin 3 – RS485 GND
Power/Comms Pin 4 – RS485 B-
Power/Comms Pin 5 – RS485 A+

FFC Connector: Amphenol 62684-501100ALF or MOLEX 54132-5033

FFC Jumper: MOLEX 15166-0555 or similar 50 conductor, 0.5mm pitch, 12" length

Mating Motor Connector Housing: MOLEX 43025-0400

Mating Limit Connector Housing: MOLEX 43025-0600

Mating Encoder Connector Housing: MOLEX 43025-0800

Appendix C – Robot Modifications

While we have attempted to include features necessary for most microplate handling applications. There are of course applications with unique requirements. In most cases, TPA Motion can accommodate these special requirements. The following is a discussion of what is possible/practical. If your requirement is outside the scope of this discussion, please contact TPA Motion.

Level 1 modifications are easy to accommodate without significant effort or cost.

Level 2 modifications are more involved but possible with modifications to a limited number of parts. Typically, the product cost is not significantly impacted but an engineering charge is required.

Level 3 modifications require significant design effort and will only be considered if there are opportunities to manufacture larger quantities of the custom design in the future. Engineering charges are required.

Travel

X-Axis – Increasing X-axis travel is a Level 2 modification.

Y-Axis – Increasing or decreasing Y-axis travel is a Level 1 modification.

Z-Axis – Decreased Z-axis travel is an already designed feature. A small increase in Z-axis travel is a Level 2 modification (travel <50mm). A larger increase in Z-axis travel is a Level 3 modification (travel>50mm).

Microplate Holder

The Microplate Holder is designed for most Microplates. The holder is removeable and easily replaced with an alternate that holds a different size microplate, test tubes or vials, glass slides, or other payloads. Similarly, the holder could simply reorient or offset a standard microplate.

The standard Microplate Holder travels from about 50mm above deck to 85mm above deck (bottom surface of microplate). A special holder can be designed to shift that range up or down ~25mm.

In most cases an alternate holder is a Level 1 modification

Max Velocity

Typically, high performance moves are not desired when handling microplates because of a need to keep liquids within the microplate wells. The standard microplate robot has acceleration and velocity capabilities commensurate with this goal. If higher velocities are needed to achieve desired throughput we have many options including alternate motors, faster leadscrew leads, and servo controls. This is not an exhaustive list. Contact TPA Motion with your requirements.

In most cases increasing linear movement rates is a Level 1 modification.

Precision

The standard microplate robot is designed around accessing a 96 well microplate with a pipet tip. Think accuracies in the 100um range. If accessing a higher density microplate, performing microscopy, or otherwise have positioning requirement tighter that this, contact TPA Motion. Options include finer lead leadscrews, preloaded leadscrew nuts, linear position feedback, slope corrections, position mapping, use of ground ballscrews, higher grade linear gearings, etc. Please contact TPA Motion with your requirements as this can be very complex.

In most cases improved precision is a Level 2 or Level 3 modification.

Power and Signals to the Payload

In some cases, more than just a presence sensor is needed at the microplate. Requirements for additional sensors, thermocouples, heaters and the like could be necessary. Contact TPA Motion with your requirements.

The addition of signals to the payload is typically a Level 2 modification.

Controller Modifications

The existing TPA Motion Controller is a 4-axis controller where three axes are need for the microplate robot. The 4^{th} axis is available to control an additional motor within the instrument. Motor, encoder, and limit sensor connections are available via the three Molex Microfit 3.0 connectors next to the FFC connector. By default, the current is set to 0.5 amps/phase. Changing the current is a Level 1 modification.

The TPA Motion Controller utilizes only the basic I/O necessary for controlling motor axes. Internally, there are additional 36x digital I/O point, 2x 10-bit analog inputs, and 2x PWM outputs that are not utilized. Providing access to these I/O points is a Level 1 or Level 2 modification.

The TPA Motion Controller provide USB and RS485 communications. I2C and SPI interfaces are also available as a Level 2 modification.

Corrosion and Moisture Resistance

The TPA Microplate Robot is constructed of mostly Aluminum, stainless steel, and a little plastic. As such it is fairly corrosion resistant; however, if the environment is very high humidity, there are some Level 1 and Level 2 modifications to improve corrosion resistance and better handle condensing moisture. Contact TPA with your requirements.

Appendix D – The Certificate of Conformance

The following is an example of the Certificate of Conformance and an explanation of some of the details. Note that your certificate may vary slightly as testing procedures are refined.

Production PN and Revision

When and who performed the final quality test

Precision of axes as measured by a laser interferometer

Measurement of how parallel the microplate holder is with the base mounting surface

Certificate of Compliance

Customer:

TPA Part Number: TPA-0400A-00; Robot: RevX1; Controller: RevX4

Serial Number: ***SN000000***

This is to certify that the product identified by the above part number and serial number has been manufactured, processed and inspected in accordance with requirements of the purchase order.

TPA-0400A-00 Quality System Validation Data

- Test Completed by Technician: ETK on Dec 01 2021 at 12:00 AM; Fixture Revision: N/A

		PASS/FAIL Criteria	Actual	PASS/FAIL
	Motor Direction:	All Function	PASS	PASS
	Encoder Direction:	All Function	PASS	PASS
	Limit Sensors:	All Function	PASS	PASS
	Plate Detect Sensor:	All Function	PASS	PASS
	Minimum Speed Test:	XYZ >= 20mm/sec	PASS	PASS
Travel (sensor-to-sensor)	X-Axis:	PASS>=111	111.33 mm	PASS
	Y-Axis:	PASS>=160	162.76 mm	PASS
	Z-Axis:	PASS>=31	33.13 mm	PASS
X-Axis Precision	Accuracy:	.125mm (full travel)	0.123 mm	PASS
	Bi-dir Repeatability:	.125mm (full travel)	0.026 mm	PASS
Y-Axis Precision	Accuracy:	.125mm (full travel)	0.094 mm	PASS
	Bi-dir Repeatability:	.125mm (full travel)	0.036 mm	PASS
Z-Axis Precision	Accuracy:	.125mm (full travel)	0.057 mm	PASS
	Bi-dir Repeatability:	.125mm (full travel)	0.015 mm	PASS

TPA-0400A-00 Plate Holder Alignment Validation Data

X Rail Alignment:	<=0.087mm TIR	-0.010 mm	PASS
Plate Holder Alignment:	<=0.087mm TIR	0.080 mm	PASS

Barry Bruhns, General Manager — Date: 12/15/2021

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