Instructions

1 Assembly

- Tools required: $\frac{3}{16}$" hex key, $\frac{5}{32}$" hex key, M2 hex key, Philips screw driver for M3 screws, level (recommended), soldering supplies
- General notes: A list of parts and an assembly diagram with part numbers can be found in Sections 1.1 and 1.1, respectively. To attach brackets, put bolts through each hole in the bracket. Loosely attach nut and slide into desired slot, then tighten. Bolts use $\frac{3}{16}$" hex key unless noted.

I. Platform:

A. Attach lead screw nut (11) to platform (21) using 4 M3x16 flathead screws and nuts.

B. Attach 3" (7.62 cm) T-slot (17) to ends of platform using T-nuts, on same face of platform as lead screw nut. T-slot and platform should be aligned but don't need to be exact.

C. Using 5/32" hex key, attach vertical face of T-slot to bolts on wheel assembly (4). Wheels should be facing outward. On one side of the platform there is a line marked through the center of the plate; this should be aligned with the lines marking the centers of the wheel assemblies.

D. On the same side as the lead screw nut, secure NEMA 17 motor (14) to platform using M3x12 flathead screws, with wires facing nearest set of wheels.

E. Attach NEMA 17 coupler (15) to shutter (16) using M3x12 flathead screws and nuts. Mount shutter on motor shaft using included hex key to tighten set screws.

II. Base:

A. Attach limit switches (23) to switch mounts (24 & 25) using 4 black M3x20 bolts and nuts (red side of switch facing outward). On switch mount 2 (25), the set of holes along the short edge should be used to mount the switch.

B. Place 2 T-nuts and bolts onto mount. On one piece of 7.87" (20 cm) T-slot (19), secure limit switch mount 2 in the center so the lever is on top.

C. Attach 2 brackets (8) to each of the single-thickness pieces of 7.87" (20 cm) T-slot, on the same face and with one on each end. The piece with the switch should have the brackets attached to the same face as the switch.

D. Slide 7.87" (20 cm) double-thickness T-slot (20) pieces into the brackets on the thin pieces, forming a rectangle. The cut end of thin T-slot should be against the narrow side of the wide T-slot, and markings on wide pieces should be facing up and on same side of rectangle.

E. Tighten bolts well; the levelness of the base affects how well the vertical posts are aligned.

III. Upper Frame:

A. Attach 2 brackets on one end of each 16.54" (42 cm) T-slot side post (1) on opposite faces. Place one on each side on the outer rail of double wide T-slot, aligning with markings on base. Use a level to ensure the posts are vertical.

B. Slide platform wheel-side up onto vertical posts with NEMA 17 motor and shutter on right side.

C. Slide switch mount 1 (24) onto back of right post so that lever will contact platform. Do not tighten bolts.

D. Attach one bracket on the inside of the top end of each post, with the open face of the bracket in the plane of the cut face of the post.

E. Slide 13.88" (35.25 cm) crossbar (18) onto top of posts. Ensure marking for motor mount is on the front face of crossbar. Do not tighten bolts.

F. Tighten bolt on one side of the crossbar. Adjust the position of the other bracket so that the plate glides smoothly (this may take several tries). Tighten remaining side.

G. Place lead screw (13) into nut attached to platform.

IV. NEMA 23 Motor:

A. Attach narrow end of coupler (12) to NEMA 23 motor shaft (10) using M2 hex key for the set screws. Tighten well; if the set screws are too loose, the coupler can gradually slip down the motor shaft while the platform is moving.

B. Place one bolt through the top of each slot in NEMA 23 motor mount (9), attaching a square nut on reverse. Do not tighten fully.

C. Place one T-nut on each bolt and slide mount assembly into 4.5" (11.43 cm) T-slot (22). Center and tighten bolts so that mount edge is parallel with T-slot. The square nuts may need to be readjusted.

D. Secure NEMA 23 motor in mount, with wires facing back, using M4x19 screws.

E. Place a bracket on each side of the crossbar over the marking for T-slot with open faces down. Slide motor assembly onto these and center before tightening.

F. Slide lead screw into coupler and tighten set screws using M2 hex key. Secure limit switch mount so that bottom of mount is level with bottom of coupler.

V. Finishing:

A. Slide electronics box (2 & 3) into right double-thickness T-slot base, with T-nut inside the T-slot and the square nut between the T-slot and the box.

B. Solder motor and switch wires to leads on electronics box. Green wires with color names go to corresponding NEMA 23 leads, yellow numbered wires go to NEMA 17 (as long as they are in order 1-4, it doesn't matter which side the numbering starts from), and NO and COM wires go to limit switches (pins labelled on switches; it doesn't matter which COM or NO wire goes to which switch). Ensure there is enough wire for full range of vertical motion of NEMA 17.

C. Secure wires to frame, making sure nothing is fastened around posts so that wheels can move freely. Greasing the wheels is recommended.

1.1 List of Parts

Part name (part identification number):

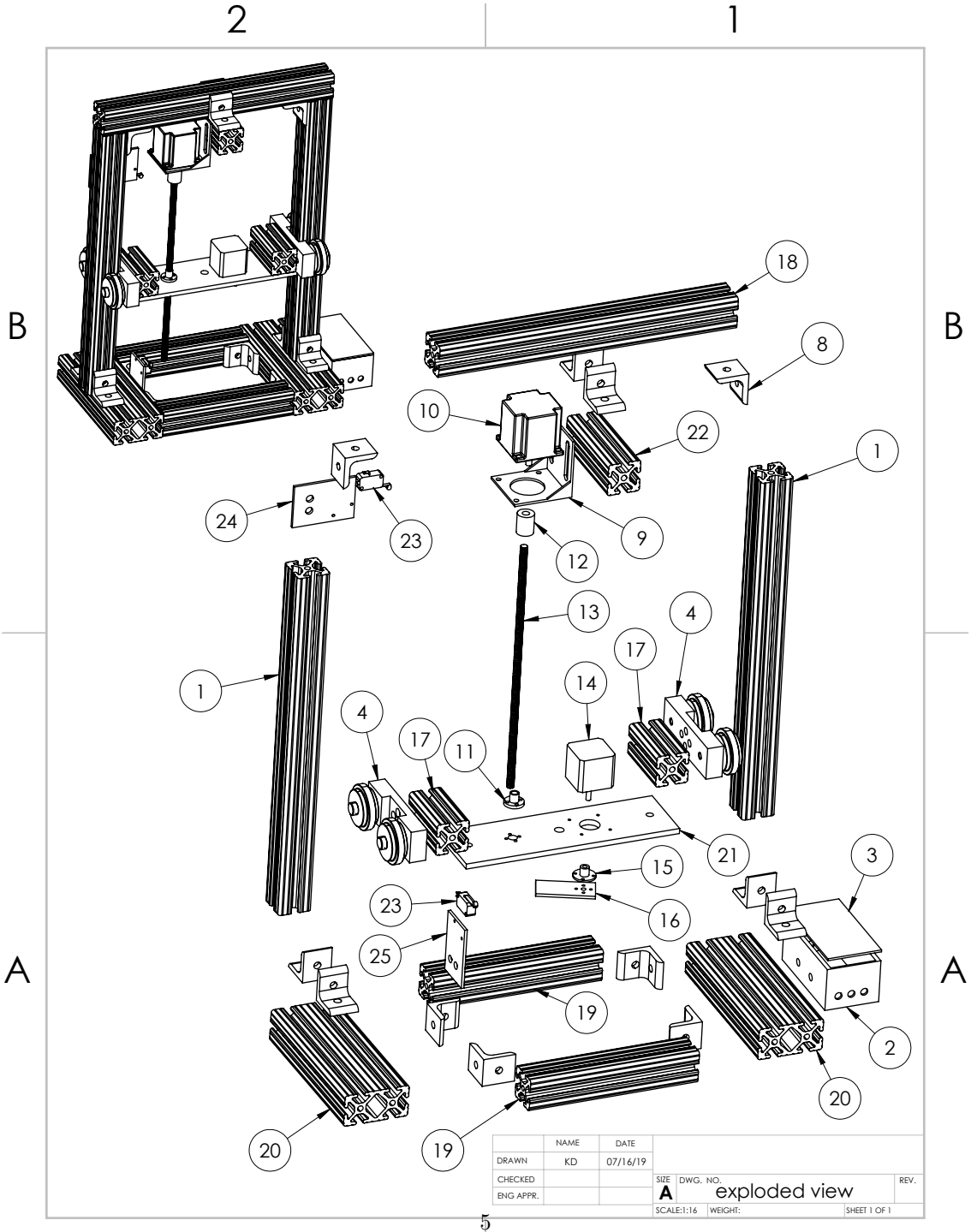
- 2 pieces 16.54" (42 cm) t-slot—side posts (1)
- 1 electronics box with lid (+2 T-nuts and bolts and 2 square nuts attached) (2 & 3)
- 2 wheel assemblies (each with 2 nuts and bolts attached) (4)
- 12 brackets (8)
- 1 NEMA 23 motor mount (9)
- 1 NEMA 23 motor (10)
- 1 lead screw nut (11)
- 1 flexible coupler (4 set screws inside) (12)
- 1 lead screw (13)
- 1 NEMA 17 motor (14)
- 1 coupler for NEMA 17 (2 set screws) inside (15)
- 1 shutter (16)
- 2 pieces 3" (7.62 cm) T-slot—wheel mounts (17)
- 1 piece 13.88" (35.25 cm) T-slot—crossbar (18)
- 2 pieces normal-wide 7.87" (20 cm) T-slot—inner base (19)
- 2 pieces double-wide 7.87" (20 cm) T-slot—outer base (20)
- 1 platform (21)
- 1 piece 4.5" (11.43 cm) T-slot—motor mount (22)
- 2 limit switches (23)
- 2 limit switch mounts (24 & 25)
- 1 USB cable

Fasteners:

- 32 T-nuts and bolts (+2 on electronics box)
- 2 square nuts (+2 on electronics box)
- 8 M3x12 flathead screws
- 4 black M3x20 hex socket screws
- 4 M3x16 flathead screws
- 4 M4x19 screws
- 16 M3 nuts
- 4 M4 nuts
- 4 bolts and nuts attached to wheel assemblies

1.2 Assembly Diagram

CAD models for Part 4, Part 8, and all T-slot components were downloaded from their manufacturer, 80/20 Inc.



2 Use

I. Install LabVIEW Interface for Arduino (LIFA) following the instructions here: `https://knowledge.ni.com/KnowledgeArticleDetails?id=kA00Z000000PAS1SAO&l=en-US`.

II. Place radiation source on platform next to the NEMA 17 motor, over the hole. Ensure shutter is positioned under the hole with its sides parallel to the edges of the plate.

III. Plug USB into square port on electronics box.

IV. Connect PSU to banana jacks—high to red, low to black, ground to black (the black ones are connected internally).

V. Turn PSU on and limit its output to 5 V and 1 A.

VI. Open *Stepper System Control.vi* in LabVIEW.

VII. Enter the serial port number of the USB connection in the "Serial Port" control.

VIII. Start the program by clicking on the white arrow on the top left of the tool bar.

IX. Click on any button to execute that function. If using the "Move" function, set desired speed (steps/sec) and distance (mm) to go.

X. Exit the program by clicking the "Stop Program" button.

XI. To add *Stepper System Control.vi* to existing code, refer to Part III of Section 3. To make custom preset routines, refer to Section 3.

Notes:

- The front panel locks when anything is executing. This is to prevent step-counting errors on the position indicator.
- When setting the "Distance To Go" indicator, positive values move the platform up and negative values move it down.
- If the current position isn't zero when the program is opened but should be, it can be manually set by typing 0 into the "Current Position" indicator before running the program.
- Recommended speed: < 120 steps/sec. The maximum allowed speed is 140 mm/sec. should the user enter a speed greater than this, the control will automatically be set to 140 steps/sec.
- Maximum range: 200 mm. The bottom of the radiation source is 75 mm above the surface of the table when in the lowest position.
- The "Stop Program" button does not stop motion of the stepper; it is locked like the rest of the front panel when a function is executing. It is only meant to quit running the program. The coded limits on range of motion will prevent the device from moving beyond its bounds (in *Move sub.vi*). Should these be incorrect, shut off the power supply unit to stop motor.
- The "Return to Start" button returns the platform to its lowest position.

3 Building Custom SubVIs

I. Build a state machine:

A. Open a new block diagram and make a while loop.

B. Add a case structure.

C. Right-click on the while loop and select "Add shift register". Add a total of two sets of shift registers.

D. Create an enum and wire it to one shift register on the left.

E. Right-click the enum and select "Edit items".

F. Add each state you need, one for each action including initialize and close. Order doesn't matter, unless you want them in an order that is intuitive for the programmer to click through.

G. Wire the left shift register (connected to the enum) to the question mark on the side of the case structure.

H. Right-click the case structure and select "Add case for every value".

I. Copy and paste the original enum into the first state and change its value to whatever the next state should be. Wire it to the corresponding right shift register. If red coercion dots appear on the shift register, you may need to delete all enums except the original, then copy and paste them all again. This may happen if you add cases after you've already wired some.

J. Repeat the previous step for each case. In the last case, wire the "Initialize" enum to the shift register.

K. Add a true constant inside the last case and wire it to the stop button. Right-click on the tunnel and select "Use default if unwired".

II. Add desired functions:

A. On the front panel, place a VISA resource control, a Boolean control to start the program, and both an indicator and a control for current position.

B. On the block diagram, place an event structure around the state machine. Right-click on the event, select "Edit events handled by this case", and select the name of your Boolean button from the "Event Sources" menu.

C. Wire the current position control to the unused left shift register, and the current position indicator to the corresponding shift register on the right.

D. Add subVIs (e.g. *Move sub.vi* and *Turn sub.vi*) for desired functions to each case and wire constants to their inputs.

E. Place setup sub.vi on the left of the diagram, outside the event, and wire it appropriately to each subVI in the diagram, including the VISA resource.

F. Outside the event, on the right, place a *close.vi* wired to a *simple error handler.vi* (found in LabVIEW function menu; *close.vi* is in the Arduino section) for each set of Arduino wires. Wire the output of the subVI to these. If a case does not use a resource, connect its wires from the left to right tunnels. This prevents undesired default cases.

G. Check that the finished program is working correctly.

III. Make into subVI:

A. Highlight everything inside the event structure.

B. From the menu at the top, go to "Edit" and select "Create subVI".

C. Save the main VI, which will prompt you to name and save the new subVI.

D. Double-click the subVI icon to open its front panel. By right-clicking the icon in the upper right you can edit the icon.

E. Terminal names can be edited on the front panel. It may be helpful to have the block diagram open to determine which terminals are which.

F. To edit the location of terminals, you can choose a different pattern by right-clicking the icon with terminals. The go into the VI where it was created, right-click the subVI, and select "Re-link to SubVI".

G. In the front panel of the subVI, hold Control and then click two terminals to swap their locations. If the terminals do not auto-fill, click on a terminal and then the desired front panel object to connect them. De-select by clicking an empty part of the front panel.

IV. Call as event in main VI:

A. On the front panel of *Stepper System Control.vi*, add a Boolean button to start the new preset function.

B. In the block diagram of *Stepper System Control.vi*, add a new event case for this button.

C. From the function menu, select the new subVI and place it in the event. Wire all terminals appropriately. If any tunnels in the event are unused, wire them through to prevent default cases.

D. Test the new preset function.