HANDi-Hand Assembly Manual

Version 2.0

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Introduction

The HANDi Hand is an open-source robotic platform specifically designed for machine learning research in prosthetic control. The inexpensive and easily modifiable hardware allows versatility for research studies, and the suite of sensors provides valuable information for machine learning and prosthetics research.

This assembly manual outlines all the information required to print and source parts, and assemble the HANDi Hand as currently designed. The hand takes an estimated 30 hours to build.

The open-source release provides all solid-modelling files, .stl files, Arduino code, and assembly instruction required to construct a fully functional HANDi Hand, and should also give the maker enough flexibility to make alterations to the design as necessary to suit their own needs. Both left and right hand versions are available. To contact the original designers, or to receive support for your build, please visit BLINCdev.ca.

Version 2.0 Updates

The HANDi Hand was originally released in August 2017.[1] This updated assembly manual includes a number of changes that lower the overall cost and increase the ease of building the hand, as well as compensating for the discontinuation of the previous servo-motors. The hand's performance characteristics remain similar to that published in MEC '17. The main changes include:

- Redesign for Dymond D47 servos
- Design of in-wrist PCB
- Redesign for smaller, more inexpensive camera
- Update specifications for UV-resistant zip-tie cables
- More comprehensive build documentation, including assembly videos

[1] D. J. A. Brenneis, M. R. Dawson, P. M. Pilarski, "Development of the HANDi Hand: An Inexpensive, Multi-Articulating, Sensorized Hand for Machine Learning Research in Myoelectric Control," Proc. of MEC'17: Myoelectric Controls Symposium, Fredericton, New Brunswick, August 15-18, 2017.

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Glossary of Terms

Digits: The digits are referred to by standard numbering, beginning with the thumb as D1 as shown in Figure 1.

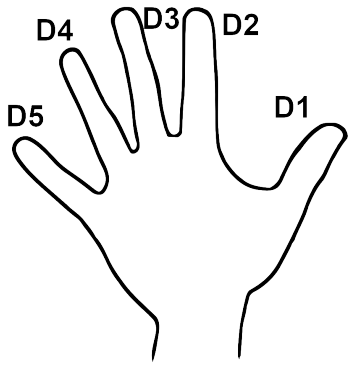

FIGURE 1: Numbering scheme used for finger naming.

Joints: The joints are named in accordance with Figure 2. The names are constructed first with a digit indicator (i.e. D2) followed by a joint indicator D, I or P, indicating distal, intermediate, or proximal respectively. Potentiometers are named for the joints that they measure. The digit D0 refers to thumb rotation.

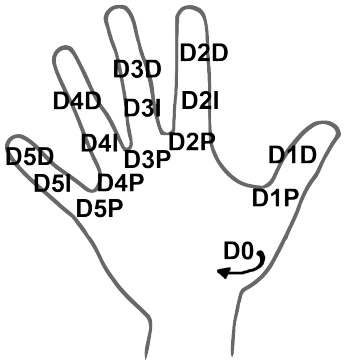

FIGURE 2: Numbering scheme used for joint naming.

Finger Parts: Each phalanx of the finger is made up of multiple parts. The part names are contrived according to the following convention:

1. Phalanx indicator. PP = Proximal Phalanx, IP = Intermediate Phalanx, DP = Distal Phalanx, MC = Metacarpal
2. Part position indicator. P = Proximal, D = Distal
3. Position modifier. There are sometimes multiple parts in the same location that must be differentiated by their function (pivot, main, lock, tip, etc).
4. Handedness indicator. R = Right Hand, L = Left Hand

An example part name would be **IP-P Pivot R**, for the proximal portion of the intermediate phalanx corresponding to the pivot, for the right-hand version of the HANDi Hand.

1 Required Materials

1.1 3D Printed Parts

The 3D printed parts are designed to be printed in PLA without support material and without rafts, except where indicated. Parts are designed for the print tolerance of a MakerBot Replicator 2. Some filing may be necessary to ensure a smooth running fit between parts.

All files required for 3D printing can be accessed via BLINCdev.ca. The suggested print specifications for each part are found in Table 1.1. The table lists all of the part sets that must be printed for a complete hand. In the event that a particular component is needed, the individual STL files can be found on BLINCdev.ca in addition to the grouped parts in Table 1.1.

TABLE 1.1: 3D Printed Parts Specifications

Part Name	**Print Specifications**	**Estimated Print Time**	**Est. Material Weight**
Dorsal Palm	0.2mm layer, 30% infill, print with raft	6h 0m	64 g
Ventral Palm	0.2 mm layer, 10% infill	1h 55m	22 g
Thumb Screw Cap	0.2 mm layer, 10% infill	0h 15m	2 g
D2 Full Finger	0.1 mm layer, 50% infill	3h 36m	11 g
D3 Full Finger	0.1 mm layer, 50% infill	3h 36m	11 g
D4 Full Finger	0.1 mm layer, 50% infill	3h 36m	11 g
D5 Full Finger	0.1 mm layer, 50% infill	3h 36m	11 g
Full Thumb	0.2 mm layer, 10% infill	2h 30m	25 g
Breadboard	0.1 mm layer, 10% infill	0h 25m	3 g
Connector Hub	0.2 mm layer, 10% infill	0h 15m	3 g
Pot Activator Set of 15	0.1 mm layer, 10% infill	0h 10m	1 g
Pot Placeholder Set of 6	0.2 mm layer, 10% infill	0h 10m	2 g
Servo Spool Full Set	0.1 mm layer, 10% infill	0h 25m	4 g
Servo Spur Gear	0.1 mm layer, 10% infill	0h 5m	1 g
TOTAL:	-	***TODO***	***TODO***

1.2 Off-The-Shelf Parts

The table below contains all the off-the-shelf parts required for building a complete HANDi Hand. Additional ordering information is provided in Appendix A.

TABLE 1.2: Off-the-Shelf Parts Specifications.

Item	**Part Number**	**QTY**
Rotary position sensor	MuRata SV03A103AEA01R00	9
Force sensitive resistor	Interlink Electronics 34-00004	5
Arduino Mega	Arduino A000067	1
AC / DC 5V 2.5A wall adapter	Qualtek QAWA-18-5-US01	2
DC barrel jack adapter (female)	Sparkfun PRT-10288	1
10 kΩ, 1/8W through-hole resistor	Stackpole Electronics CF18JT10K0	5
12-position header pin (long)	Sullins Connector PREC012SACN-RC	2
12-position header pin (short)	Sullins Connector PREC012SAAN-RC	6
12-position female socket	Sullins Connector PPTC121LFBN-RC	2
3-position female socket	Sullins Connector PPPC031LFBN-RC	14
Heat shrink tubing, assorted	Sparkfun PRT-09353	1
Analog RC servo motor	Dymond D47	6
USB Webcam	Microsoft LifeCam HD-3000	1
Textured Neoprene Rubber	McMaster-Carr 8445K61	1
Continuous Flex Wire, 26 AWG	McMaster-Carr 7071K19	50 feet
M2 x 25 mm Cheese Head Slotted Machine Screw	McMaster-Carr 91800A023	23
M2 18-8 Washer	McMaster-Carr 93475A195	16
5.9" Zip-Tie	Qualtek 17-M150N-C	9

1.3 Tools

The following tools are required during assembly.

- 3D printer
- M2 screw cutter (or bolt cutters and large flat metal file)
- Dremel tool with sanding wheel
- 120 grit sandpaper
- Small files
- Narrow flat screwdriver
- #0 Philips screwdriver
- Wire strippers / cutters
- Soldering iron and solder
- Heat gun
- Hobby knife
- Fine tweezers
- Needlenose pliers

1.4 Printed Circuit Board

A custom in-wrist printed circuit board (PCB) has been designed to handle signal and power routing in and out of the hand. The EAGLE files for the PCB are available in the HANDi-Hand release repository. Documentation regarding how to order a PCB from a board manufacturer using these files can also be found in the same location.

2 Assembly Flowchart

A particular order of operations must be followed when assembling the hand, and is outlined in the following flowchart. A process described in any bubble cannot be completed until all items attached to incoming arrows have been completed.

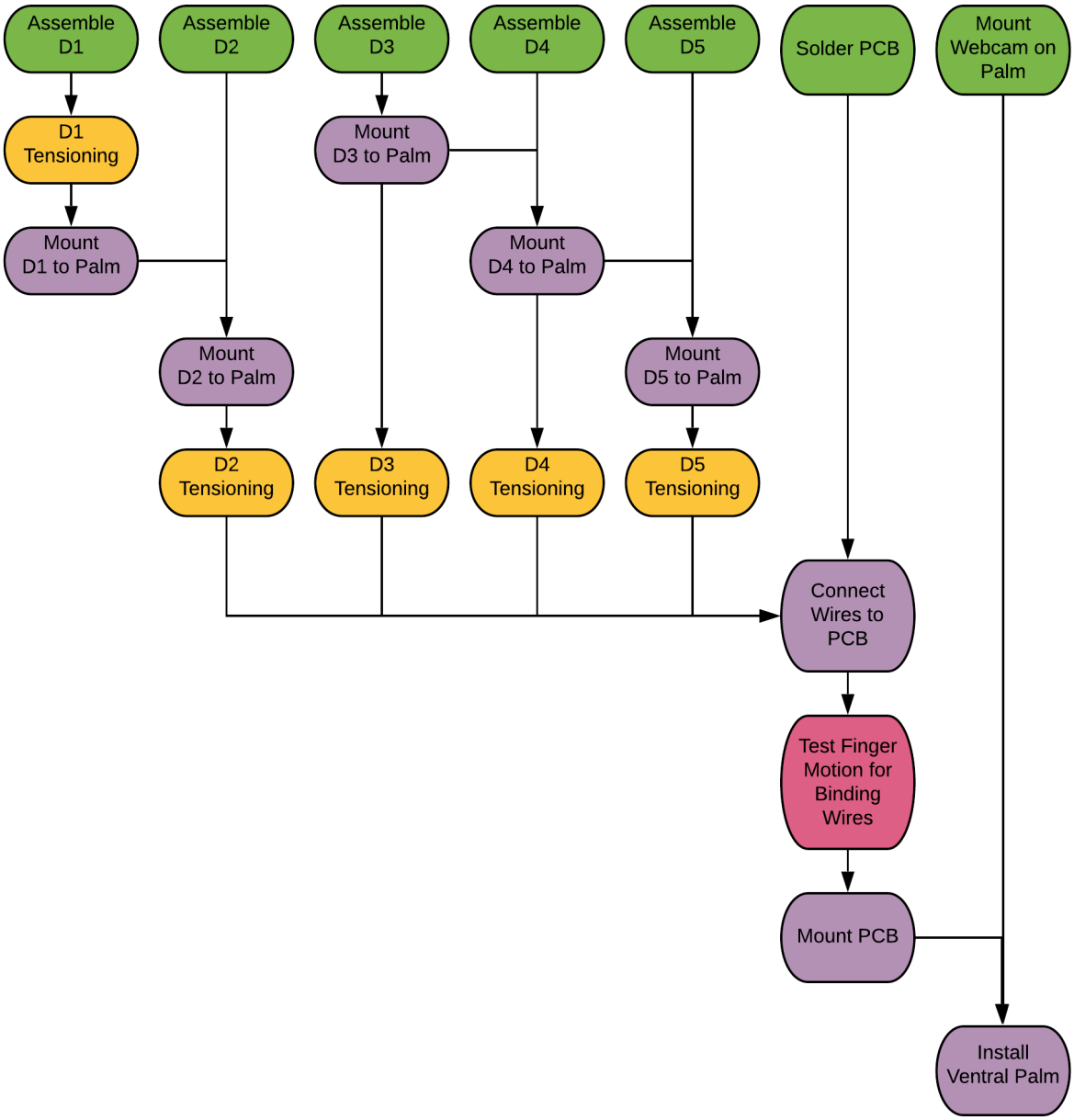

FIGURE 2.1: Flowchart depicting the order of operations in assembling the HANDi Hand.

3 Material Preparation

3.1 3D Printed Parts

Estimated time 17h 0m

3.2 Potentiometers

Estimated time 1h 45m

In the current version, there are nine potentiometers (limited due to the number of analog input pins on the Arduino Mega). The suggested lengths of the connecting wires are found in Table 3.1.

TABLE 3.1: Suggested wire lengths for potentiometers

Potentiometer ID	Suggested Wire Length
D0	150 mm
D1P	150 mm
D1D	190 mm
D2P	150 mm
D2I	190 mm
D3P	150 mm
D3I	190 mm
D4P	150 mm
D5P	150 mm

Figure 3.1 describes the polarity of the potentiometers. To prepare the potentiomters:

1. Cut off the top lone pin on the potentiometer as short as possible.
2. Solder the wires to the potentiometer and a straight pin header to the other end of each wire. See note below about D0.
3. Use black heat-shrink on the connections near the potentiometer, and coloured heat shrink on the far connections corresponding to the polarity noted in Figure 7.
4. Heat shrink the 3 wires together near the loose end using a light coloured heat shrink tubing. Label the wires here with the potentiometer ID.

Note: the straight pin headers for the D0 potentiometer must be soldered to the wires *after* the potentiometer is installed in MC – Geared Rotator, and the wires routed through the narrow channel. Black heat-shrink tubing near the potentiometer will not fit in this channel, so it is omitted.

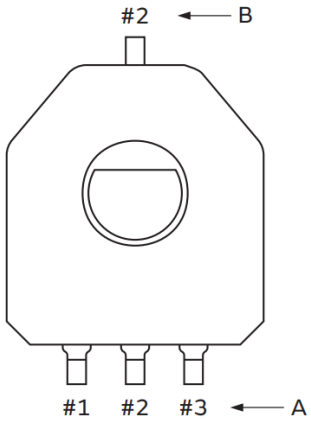

FIGURE 3.1: Potentiometer terminals diagram, viewed from the top (black side facing you). Pin #1 is GND, pins labelled #2 are SIG, and pin #3 is VCC.

3.3 FSRs

Estimated time 1h 0m

Each fingertip requires an FSR. The recommended wire length for finger FSRs is 250 mm; for the thumb FSR 200 mm is recommended.

1. Solder each wire to the solder tabs of the FSR.
2. Install FSR in fingertip (see 5.3.1).
3. Use black heat-shrink tubing on the connections near the FSR.
4. Solder the wires to straight pin headers.
5. Use yellow and red heat shrink tubing on the connections with the straight pin headers.
6. Heat shrink the two wires together using a light coloured heat shrink, and label the wires here with the ID of the finger they represent.

3.4 Screws

4 Thumb Assembly

Estimated time 1h 0m

4.1 Part Assembly

4.2 Mounting to Palm

5 Finger Assembly

Estimated time 0h 15m per finger

6 Servo Installation and Finger Tensioning

Estimated time 0h 7m per finger

7 Signal Routing Board

Estimated time 0h XXm

8 Ventral Palm Cover and USB Webcam

Estimated time 0h 20m

9 Palm Grips

Estimated time 1h 15m

10 Wiring

Estimated time 1h 0m

A Commercial Off-The-Shelf Parts Information

This appendix contains detailed ordering information for the off-the-shelf parts used in the HANDi Hand. Links to specific vendors are supplied for convenience only; no affiliation between BLINCdev and the vendors exists or is implied. Cost information is provided to give the builder an estimate of the cost of the project, and is accurate as of August 2020.

TABLE A.1: Detailed information for off-the-shelf parts used in the HANDi Hand. Click on part numbers for specific links.

Item	**Part Number**	**Vendor**	**QTY**	**Cost / Item**	**Ext. Cost**	**Curr.**
Rotary position sensor	MuRata SV03A103AEA01R00	DigiKey	9	$2.33	$20.97	CAD
Force sensitive resistor	Interlink Electronics 34-00004	DigiKey	5	$16.20	$71.08	CAD
Arduino Mega	Arduino A000067	DigiKey	1	$56.86	$56.86	CAD
AC / DC 5V 2.5A wall adapter	Qualtek QAWA-18-5-US01	DigiKey	2	$25.33	$50.66	CAD
DC barrel jack adapter (female)	Sparkfun PRT-10288	DigiKey	1	$4.36	$4.36	CAD
10 kΩ, 1/8W through-hole resistor	Stackpole Electronics CF18JT10K0	DigiKey	5	$0.16	$0.80	CAD
12-position header pin (long)	Sullins Connector PREC012SACN-RC	DigiKey	2	$0.49	$0.98	CAD
12-position header pin (short)	Sullins Connector PREC012SAAN-RC	DigiKey	6	$0.38	$2.28	CAD
12-position female socket	Sullins Connector PPTC121LFBN-RC	DigiKey	2	$1.15	$2.30	CAD
3-position female socket	Sullins Connector PPPC031LFBN-RC	DigiKey	14	$0.55	$7.25	CAD
Heat shrink tubing, assorted	Qualtek Q2-F-RK4-1/16-11-6IN-39	DigiKey	1	$2.96	$2.96	CAD
7.87" Black Zip-Tie	Advanced Cable Ties AL-08-18-0-C	DigiKey	Pack of 100[1]	$6.09	$6.09	CAD
Analog RC servo motor	Dymond 11305 D47	Dymond	6	$21.95	$131.70	USD
USB Webcam	Microsoft LifeCam HD-3000	Amazon	1	$38.59	$38.59	CAD
1/32" Textured Neoprene Rubber, 40A Durometer	McMaster-Carr 8445K61	McMaster-Carr	12" x 12"	$12.45	$12.45	USD

Continued on next page...

[1]Only 5 zip-ties required for assembly.

Item	**Part Number**	**Vendor**	**QTY**	**Cost / Item**	**Ext. Cost**	**Curr.**
Continuous Flex Wire, 26 AWG	McMaster-Carr 7071K19	McMaster-Carr	50 feet	$1.20	$60.00	USD
M2 x 25 mm Cheese Head Slotted Machine Screw	McMaster-Carr 91800A023	McMaster-Carr	Pack of 50*[2]	$8.41	$8.41	USD
M2 18-8 Washer	McMaster-Carr 93475A195	McMaster-Carr	Pack of 100[3]	$1.06	$1.06	USD
APPROXIMATE TOTAL:					$550[4]	CAD

End of table.

[2]Only 23 screws needed for assembly.
[3]Only 16 washers needed for assembly.
[4]This is a rough estimate, assuming $1.35 CAD = $1.00 USD. Delivery fees and taxes are not included.

B Grip Pattern Template

The following page contains a template you can use to cut out the neoprene rubber grips. When printing this page, be sure to check in your print settings that you are using the original scale of the document.