Quick Start Guide

[06 June 2020]

1 Introduction

DIGIT [1], is an inexpensive, compact, and high-resolution tactile sensor geared towards in-hand manipulation. DIGIT improves upon past vision-based tactile sensors by miniaturizing the form factor to be mountable on multi-fingered hands, and by providing several design improvements that result in an easier, more repeatable manufacturing process, and enhanced reliability. To provide the robotic community access to reliable and low-cost tactile sensors, we open-source the DIGIT design at `www.digit.ml`.

This white paper aims to provide manufacturing, assembly and quick start instructions for the DIGIT tactile sensor.

2 Repositories

There are two main repositories which contain the open-sourced sensor design, and a Python library for interfacing with the DIGIT sensor.

`https://github.com/facebookresearch/digit-design`

`https://github.com/facebookresearch/digit-interface`

3 Required Materials

3.1 Components List

DIGIT assembly requires the following tools and off-the-shelf components:

Part No.	Description	Quantity
1	1.5 mm Metric Hex Driver	1
2	Hex Socket Screw M2 x 0.4 mm Thread, 5 mm Long	3
3	Hex Socket Screw M2 x 0.4 mm Thread, 3 mm Long	1

The following components compose the DIGIT main electrical and mechanical design, which are manufactured through internal or external vendors.

Part No.	Description	Quantity
1	DIGIT Printed Circuit Board (PCB)	1
2	DIGIT Lighting PCB	1
3	DIGIT Rear Housing	1
4	DIGIT Main Housing	1
5	DIGIT Acrylic Clip Housing	1
6	Acrylic Window	1
7	Gel	1

4 Manufacturing Recommendations

4.1 Electrical

Two components are required which can be manufactured via a turnkey printed circuit board assembly service, or by hand populating manufactured PCBs.

- Main PCB containing camera system
- Lighting flex PCB

The Gerber design files are found within the digit-design repository and are manufactured with the following specifications:

	Specification
Layer Count	4
Material	370HR or FR4
Min Track/Spacing	4mil/4mil
Thickness	1.6mm
Solder Mask	Black
Silk Screen	Top and Bottom
Silk Screen Color	White
Surface Finish	ENIG
Via Process	Tented Via
Finished Copper	1 oz.

(a) Main PCB specifications

	Specification
Layer Count	2
Material	Polymide Flex
Min Track/Spacing	3mil/3mil
Thickness	0.23mm
Solder Mask	Black
Silk Screen	Top
Silk Screen Color	White
Surface Finish	ENIG
Via Process	Tented Via
Finished Copper	1.5 oz.

(b) Flex PCB specifications

The PCB stackup for the 4 layer main PCB board is as follows,

- Top Layer - digit_copper_signal_top.gtl
- Internal Layer 1 - digit_copper_signal_1.g1
- Internal Layer 2 - digit_copper_signal_2.g2
- Bottom Layer - digit_copper_signal_bot.gbl

4.2 Mechanical

The DIGIT mechanical body consists of three 3D-printed parts and one laser cut part. The 3D printed parts are the main, back, and acrylic clip housings shown in figure 1.

(a) Rear (b) Main (c) Acrylic Holder

Figure 1: Mechanical housing components

We recommend using the following 3D printer specifications,

	Specification
3D Printer	Stratasys J750
Layer Height	Default
Material	Vero Black Plus
Finish	Glossy

Additionally, the gel acrylic window is laser cut from a sheet of 4 mm thick optically clear acrylic.

5 Assembly

Upon manufacturing both the mechanical and electrical parts, DIGIT can be assembled within 5 minutes.

Step 1

Press fit the DIGIT PCB into the back housing as shown in figure.x.

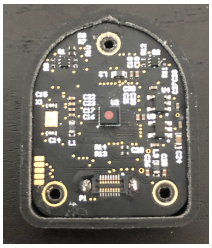

Figure 2: PCB inserted into back housing

Step 2

Bend the flex PCB connector 90 degrees and insert the DIGIT flex PCB into the perimeter of the main housing as shown in Figure 3.

Figure 3: Flex PCB inserted into main housing

Step 3

Press fit the back and main housings together,

Figure 4: Back and main housing coupled together

Using your finger connect the flex PCB to the main PCB with a firm push, you should feel the connector snapping into place.

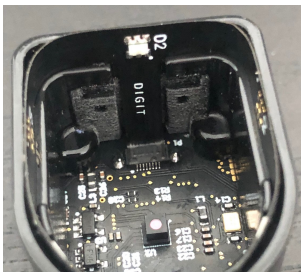

Figure 5: Flex PCB connected to main PCB

Step 4

Insert the gel into the acrylic holder housing,

Figure 6: Gel and acrylic holder housing

Following this, snap fit the acrylic holder to the main housing,

Figure 7: Main housing with acrylic housing

Step 5

Insert and fasten the three 5 mm hex screws into the back housing,

Figure 8: Back housing with inserted screws

Insert and fasten one 3mm hex screw into the acrylic housing,

Figure 9: Acrylic housing with inserted screw

6 Gel Manufacturing

The DIGIT design repository contains the 3D files for the gel mold. This mold can either be produced via subtractive or additive manufacturing. The DIGIT gel mold consists of a 3x3 array of gels, it is best recommended to machine this mold out of aluminum. If manufacturing by 3D printing, sand each gel well in post to remove any layer lines.

It is recommended to start out with a small batch until all mixtures and results achieve the desired results for the end application. Following this, a large set of DIGIT gels can be produced by increase the number of molds and running larger batches.

The following tools, parts and chemicals are required for the manufacture of DIGIT gels.

Part No.	Description	Quantity
1	DIGIT Gel Mold (gel/Digit Gel Mold.stp)	1
2	2 x Airbrush Systems or 1 System with 2 Heads	1
3	Heat Source (Heat Gun or Blowdryer)	1
4	Smooth-On Solaris Shore 10A	1
5	Smooth-On Inhibit X	1
6	Smooth-On EcoFlex 00-10	1
7	Smooth-On White Silicone Pigment	1
8	Smooth-On Sil-Poxy Optically Clear Adhesive	1
9	Smooth-On NOVOCS Matte	1
10	99% Isopropyl Alcohol	1

6.1 Preparing White Paint Mixture

Step 1

Mix an equal part A/B solution of EcoFlex 00-10.

Step 2

Add the white silicone pigment such that it is 3% of the total weight of the previous mixture.

Step 3

Thin out the mixture to 20% of the total weight using NOVACS and mix well until smooth. You may test out the mixture by observing how well the it is applied via the airbrush. Increase the amount of NOVACS until a uniform stream of white paint is expelled from the airbrush against a surface.

6.2 Manufacturing the DIGIT Gel

Step 1

Clean the molds thoroughly with 99% isopropyl alcohol and let dry.

Step 2

Apply Solaris 10A silicone into the molds and let cure on a flat surface, and inside a contained space with no turbulent air movement.

Step 3

Remove the gels from the mold and clean with 99% isopropyl alcohol.

Step 4

Arrange the gels on a flat plastic (sheet of acrylic) surface with the curved surfaces facing upwards.

Step 5

Setup one airbrush with Smooth-On Inhibit-X and apply a layer evenly across all the gels.

Step 6

Within 30 minutes of Step 5, prepare the second airbrush with the white paint mixture. Spray an even coating across the gels.

Step 7

After spraying the white paint onto the gels, use a heat source to quickly cure the first layer and then repeat Step 6 and Step 7 once more for a total of 2 layers. The amount of paint layers applied determines the spatial resolution transfer of objects touching the gel surface. This may be repeated once more for a total of 3 coats, or more depending on the application needs of the sensor.

Step 8

Let fully dry in an enclosed area to prevent any dust from adhering to the surface of the white paint layers.

Step 9

Apply the gel using an optically clear adhesive to the acrylic window and set to dry. It is best to apply a pea sized amount to the center of the acrylic window and depress the gel squeezing out any excess adhesive. Remove excess adhesive with a foam swap or by wiping away.

7 Flashing Firmware

The DIGIT sensor can be programmed with any DFU flashing utility. We have provided such utility inside the digit-design repository.

Upon manufacturing your DIGIT, connect the device to a host computer. The sensor should enumerate in DFU mode.

Flash the firmware with a unique integer only serial number.

```
$ python3 flash.py digit.serial=45
```

When finished flashing, cycle the power on the device by removing and re-inserting the USB cable to the host computer. The sensor will first enumerate in DFU mode for 3 seconds and then re-enumerate as a DIGIT device.

8 Quick Start Example

Install the digit-interface Python package and connect the DIGIT sensor to a host computer using a Micro USB cable and specify the DIGIT serial number.

Record the serial number which is either located on the sensor label, or specified through the programming tool.

The following example can be used to connect to a DIGIT and acquire live sensor output, additional examples are located in the digit-interface repository.

```python
from digit_interface.digit import Digit
from digit_interface.digit_handler import DigitHandler

# Change D12345 to your DIGIT serial number,
# and specify a friendly name
digit = Digit("D12345", "Left Gripper")
digit.connect()

# Print device info
print(digit.info())

# Display stream obtained from DIGIT
digit.show_view()

# Disconnect DIGIT stream
digit.disconnect()
```

References

[1] Mike Lambeta, Po-Wei Chou, Stephen Tian, Brian Yang, Benjamin Maloon, Victoria Rose Most, Dave Stroud, Raymond Santos, Ahmad Byagowi, Gregg Kammerer, Dinesh Jayaraman, and Roberto Calandra. DIGIT: A novel design for a low-cost compact high-resolution tactile sensor with application to in-hand manipulation. *IEEE Robotics and Automation Letters (RA-L)*, 5(3):3838–3845, 2020.