



## **Shadow Dexterous Hand G Series: Shadow Hand Lite (G1M4R, G1M4L)**

**Technical Specification**  
Release: September 2015

## Table of Contents

<b>1 Overview.....</b>	<b>4</b>
<b>2 Mechanical Profile.....</b>	<b>5</b>
2.1 Dimensions.....	5
2.2 Kinematic Diagram.....	6
2.3 Kinematic structure.....	7
2.4 Weight and Payload.....	7
2.5 Speed.....	7
2.6 Material.....	7
<b>3 Communications.....</b>	<b>8</b>
3.1 Hand Features.....	8
3.2 Control.....	8
3.3 Micro-controllers.....	8
<b>4 Sensing.....</b>	<b>9</b>
4.1 Position.....	9
4.2 Tactile Sensing.....	9
4.3 Force.....	9
4.4 Temperature and Current.....	9
4.5 Hand Sensor Node.....	9
<b>5 Actuation.....</b>	<b>10</b>
5.1 Smart Motors.....	10
<b>6 PC and Software.....</b>	<b>10</b>
6.1 Open platform.....	10
6.2 ROS.....	10

<b>7 Power</b> .....	<b>11</b>
7.1 Consumption.....	11
<b>8 Options</b> .....	<b>11</b>
8.1 Left Hand.....	11
8.2 CyberGlove Integration.....	11
8.3 BioTac Integration.....	11
<b>9 Change list</b> .....	<b>13</b>

# 1 Overview

The Shadow Hand Lite takes the full dexterity of the Shadow Hand design into a smaller, lighter, and cheaper package. By removing a finger and the wrist, and shrinking the forearm, Shadow's engineers have produced a compact yet highly capable dexterous manipulator for the wider world. This Hand has been developed to bring dexterity and manipulation to areas where five-fingered motion is not needed, but the flexibility and dexterity of the human hand is desired.

The Shadow Dexterous Hand is a self-contained system - all actuation and sensing is built into the hand and forearm. The Shadow Dexterous Hand development kit includes:

- Control systems
- Software (provided under GNU GPL or BSD as appropriate)
- ROS compliant
- PC
- Power supplies
- Tactile sensing
- Auxiliary equipment (if required)
- Documentation and training

All versions of the Hand use an EtherCAT bus (Ethernet for Control Automation Technology), providing a 100Mbps Ethernet-based communications field-bus, and full integration into ROS (Robot Operating System).

This document describes the core Shadow Dexterous Hand with Motor actuations system. The following table shows the model numbers for Right and Left Hand models.

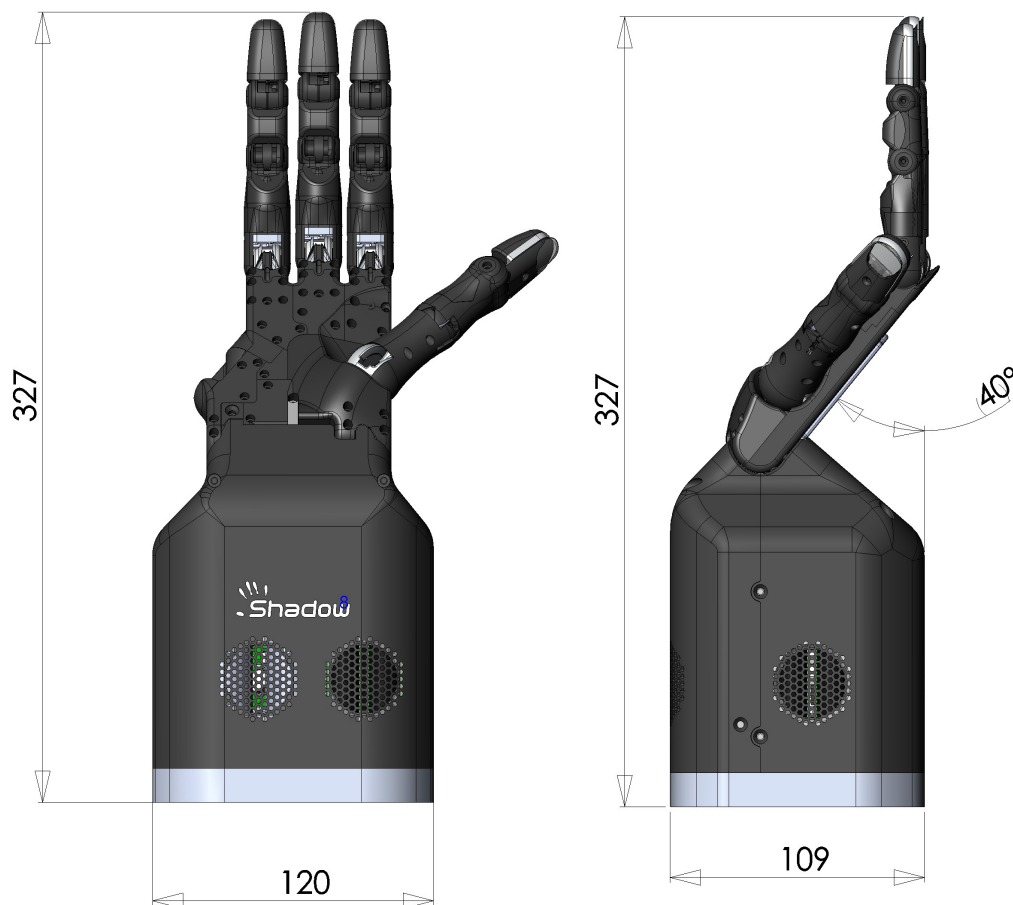
Right Hand	Left Hand
G1M4R	G1M4L

The Shadow Hand Lite series use Shadow's electric "Smart Motor" actuation system, rather than the pneumatic "Air Muscle" actuation system. The "Smart Motor" integrates force and position control electronics, motor drive electronics, motor, gearbox, force sensing and communications into a compact module, 13 of which are packed into the Hand base.

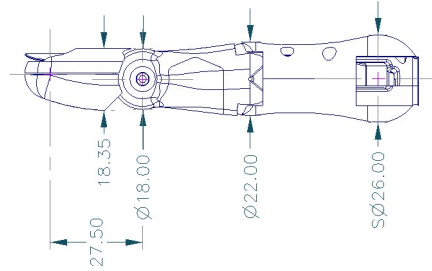
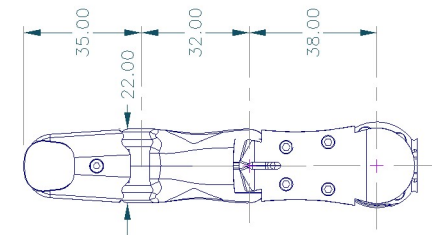
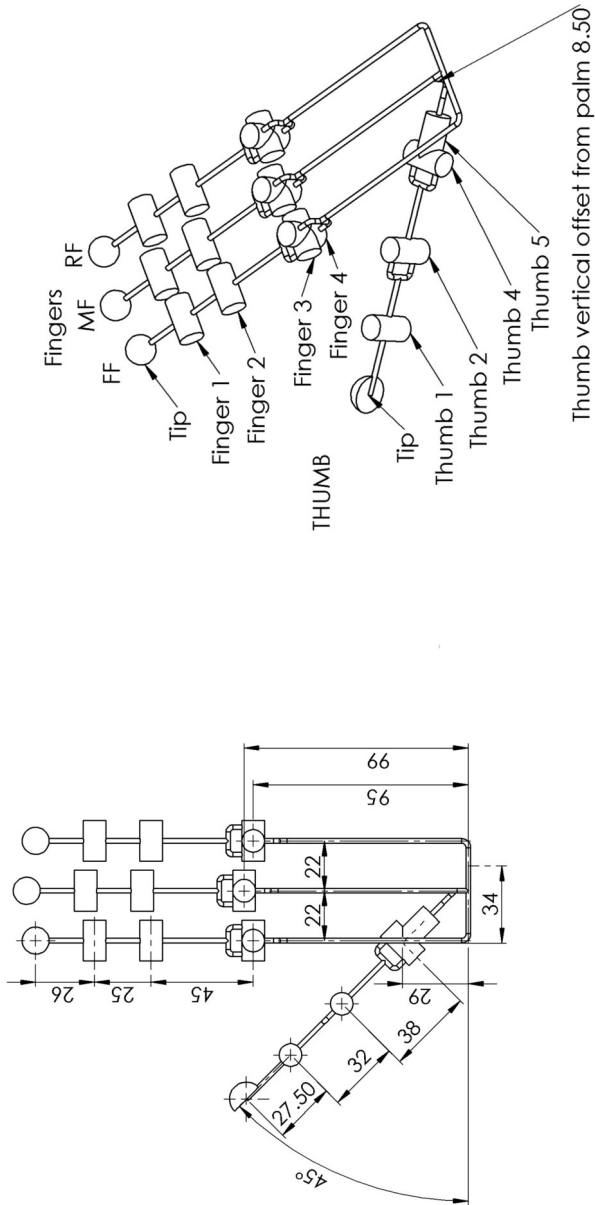
## 2 Mechanical Profile

### 2.1 Dimensions

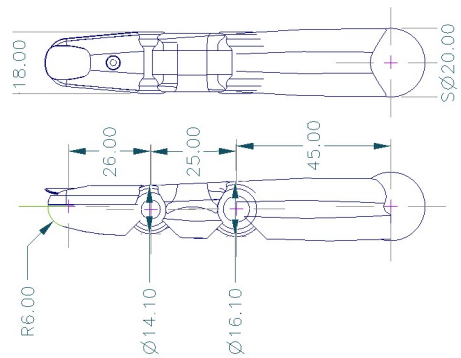
The Shadow Hand Lite maintains the human-like kinematics of its big brother, with the exception of the loss of the little finger and wrist. The size and shape is otherwise the same as a normal male human hand, down to finger lengths and tip positions.



## 2.2 Kinematic Diagram



Thumb



Finger

Positive rotations are anti-clockwise



Doc-KinDimLab-C6,00
Doc-Kin-C6,00
Doc-Labels-C6,00
Doc-FingerMeasure,00
Doc-ThumbMeasure,01b
Hugo Elias
07 Dec 2012

## 2.3 Kinematic structure

The Shadow Hand Lite joints are a subset of the full 5 fingered Shadow Hand, who's kinematics are optimized to be as close as possible (within engineering constraints) to the kinematics of the human hand.

Joint(s)	Degrees		Radians		Notes
	Min	Max	Min	Max	
FF1, MF1, RF1	0	90	0	1.571	Coupled
FF2, MF2, RF2	0	90	0	1.571	
FF3, MF3, RF3	0	90	0	1.571	
FF4, MF4, RF4	-20	20	-0.349	0.349	
TH1	0	90	0	1.571	
TH2	-30	30	-0.524	0.524	
TH4	0	70	0	1.222	
TH5	-60	60	-1.047	1.047	

The thumb has 4 degrees of freedom and 4 joints. Each finger has 3 degrees of freedom and 4 joints.

The distal joints of the fingers are coupled in a manner similar to a human finger, such that the angle of the middle joint is always greater than or equal to the angle of the distal joint. This allows the middle phalange to bend while the distal phalange is straight.

All joints except the finger distal joints are controllable to +/- 1° across the full range of movement.

## 2.4 Weight and Payload

The Hand and forearm have a total weight of 2.4 kg. The Hand, while in a power-grasp, can hold up to 4 Kg.

## 2.5 Speed

Movement speed is dependent on safety settings in the control system. Typical parameters allow a full-range joint movement in free space to operate at a frequency of 1.0 Hz.

## 2.6 Material

The entire system is built with a combination of metals and plastics including aluminium, brass, acetyl, polycarbonate and polyurethane flesh.

## 3 Communications

All versions of the Hand use an EtherCAT bus. EtherCAT (Ethernet for Control Automation Technology) is a 100Mbps ethernet-based fieldbus. It is currently used in a number of systems, such as Willow Garage's PR2 robot, making these versions of the Hand compatible with the PR2, and any other research or industrial control systems that are EtherCAT/ROS compatible. The EtherCAT bus plus ROS requires a powerful multi-core PC (supplied) with a standard Ethernet port. The EtherCAT protocol used by the hand is simple since the position control loop happens in the host (documentation supplied)

### 3.1 Hand Features

- Enable and disable torque control
- Change torque control PID values
- Change operational limits such as force and temperature cut-outs
- Reset motors
- Adjust data transmission rates for motors and tactile sensors
- Track error and status indicators from the components
- Download new firmware into the Smart Motor modules

### 3.2 Control

As standard, the EtherCAT Hand implements a position control strategy in the host PC. Other control algorithms can be used as much more complex control strategies can be implemented, fusing information from joint and tactile sensors and even visual signals via ROS

The torque loop is closed inside the motor unit at 5kHz. The PID settings for this loop can be changed in real time. Alternatively, new firmware can be downloaded into the motor units if you require a different control strategy, or a new version is available from Shadow. All other control loops run at 1kHz through the host.

The PID controllers are set up in the configuration or boot phase of the system, can be changed on the fly, and can be configured to operate from sensor data and from user-supplied values, permitting control of joint position, force, or user-supplied parameters.

### 3.3 Micro-controllers

Microchip PIC18Fxx80 micro-controllers are used for embedded control throughout the robot system, except on the palm, where a PIC32 is used; and on the Pressure Sensor Tactiles (PSTs), where PSoCs are used. The firmware is available upon request by customer under Non-Disclosure Agreement (NDA). All micro-controllers are connected to the internal bus and can be accessed via the EtherCAT interface.



## 4 Sensing

All sensor data are presented to the PC at various rates depending on the rate setting for that sensor. Typical rates are:

	Update Rate	Bits
<b>Position</b>	1000 Hz	12
<b>PST</b>	500 Hz	11
<b>Force</b>	5000 Hz	12
<b>Temperature</b>	100 Hz	12
<b>Current</b>	100 Hz	12
<b>Voltage</b>	100 Hz	12

### 4.1 Position

A Hall effect sensor senses the rotation of each joint locally with typical resolution 0.2 degrees. This data is sampled in the Hand by 12-bit ADCs. Data is provided to the communication bus in raw form, and is calibrated at the host.

### 4.2 Tactile Sensing

All Shadow Hands have Pressure Sensor Tactiles (PSTs) fitted as standard in the fingertips. They are a single region sensor with high sensitivity. The data is sampled by an 11-bit ADC. Raw temperature compensated data is available.

The PSTs can be substituted for other tactile sensors (see section: 8 Options). A protocol in the palm firmware can detect different types of compatible sensors and configure them correctly.

### 4.3 Force

A separate force sensor measures the force in each of the pair of tendons driven by the Smart Motor unit. This data is captured by 12-bit ADCs and used locally for torque control. The data are also transmitted back to the PC. The sensors have a resolution of about 30mN. They are zeroed, but not calibrated. I.e. a reading of zero means zero difference between the tendons.

### 4.4 Temperature and Current

The current flow through the motor unit, and the temperature of the motor unit, are measured internally to the Smart Motor unit, and are used to ensure safety and reliability.

### 4.5 Hand Sensor Node

The Hand Sensor Node, which is made up of a number of PCBs throughout the palm, fingers and thumb, reads joint position data and tactile sensing data, provides this to the communication bus in raw form, and is calibrated at the host. Other sensors can be attached to the Hand sensor node by request and arrangement.

## 5 Actuation

### 5.1 Smart Motors

Each of the thirteen Smart Motor nodes drives a Maxon motor using PWM. The Smart Motor node implements a PID controller, which can be set to do force control on the tendons at the motor end, or position control on the joints.

## 6 PC and Software

All Hands are supplied with a standard multi-core PC running Ubuntu 14.04 with 2 EtherCAT compatible network ports (more optional). The drivers and other useful packages are installed by default on the computer. The software is based on the ROS meta-operating system.

Software in the host PC provides sensor calibration and scaling, mappings from sensor names to hardware, and permits easy access to all robot facilities from Python and/or C++.

### 6.1 Open platform

- All source code for the micro-controllers and schematics for the electronics subsystems are available on request under Non-Disclosure Agreement (NDA).
- Example code along with documentation is provided, along with access to e-mail support from Shadow.
- Solid models (VRML) and kinematic data are supplied via ROS.
- An open software layer supports easy interfacing between this and other systems, as well as quick prototyping of algorithms and tools.

### 6.2 ROS

The Shadow Dexterous Hand is fully compatible with ROS (Robot Operating System [www.ros.org](http://www.ros.org)) providing a full range of capabilities including:

- Control
- Visualisation
- Simulation

The `sr_hand` package provides a simulated model of the Hand running in the Gazebo simulator. It integrates full physics model for grasping and manipulation development. The `shadow_robot_ethercat` stack provides the drivers for the Hand.

All the back-ends (simulated or real) present the same interface to your software - selection is simply made depending on which launch file is used, be it the real Hand or the simulated Hand - making it easy to test software away from the hardware and then run on the real hardware.

## 7 Power

Power supplies are provided with the Hand

### 7.1 Consumption

- 24 V
- Min 20W
- Max 60W

## 8 Options

The following options may be selected at the time of ordering.

### 8.1 Left Hand

The Left Hand is functionally identical to the standard Hand, but mirrored for use in a bi-manual system. Models G1M4L.

### 8.2 CyberGlove Integration

The Dexterous Hand system can be supplied integrated with a 22 sensor CyberGlove for lab or remote use.



### 8.3 BioTac Integration

Produced by Syntouch, the BioTac is a revolutionary tactile sensor capable of detecting the full range of sensory information that human fingers can detect: forces, micro-vibrations, and temperature.

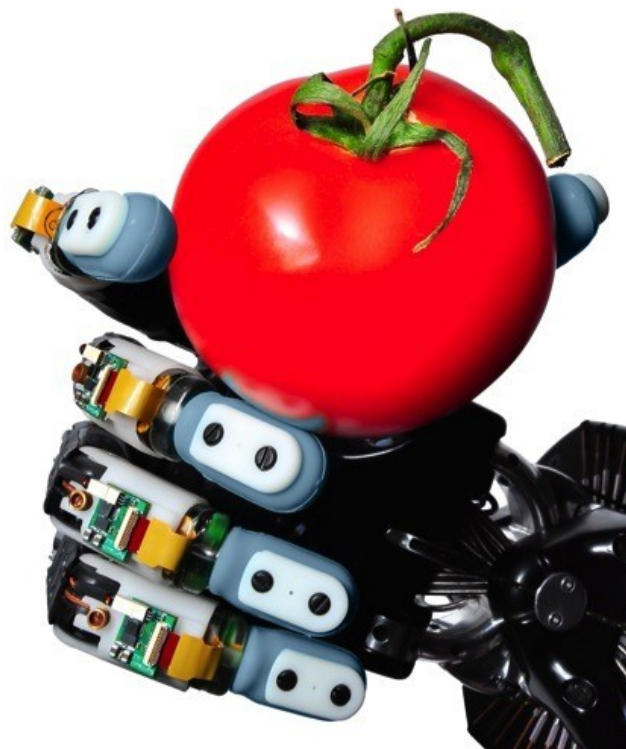
Raw data collected from the BioTac include:

- Voltages on impedance sensing electrodes
- Absolute fluid pressure (DC Pressure)
- Dynamic fluid pressure = vibration (AC Pressure)
- Temperature (DC Temperature)
- Heat flow (AC Temperature)

Signal processing of these data enables the BioTac to do many things that humans can do by touch, such as:

- Determine point of contact
- Estimate tri-axial forces
- Estimate radius of curvature of a contacted object
- Discriminate edges, corners, and flat surfaces
- Sense initial contact, with a remarkably high sensitivity
- Detect slip
- Discriminate objects based on their texture
- Discriminate objects based on their compliance
- Discriminate objects based on their thermal properties

Shadow has partnered with Syntouch and provides a full integration option.



## 9 Change list

Date	Person	Changes
8 Sep 2014		Created document
17 Aug 2015	ART	Adjusted ranges to be coherent with all documents.