

INASTOMER[®]

Force Sensor Interface Guide



The Sony[®] Aibo robot was one of the first products which employed the Inaba sensor material

Table of Contents

Technology Overview	2
Sensor Configuration	2
Temperature Considerations	2
Response	3
Durability	3
Applications	3
Specifications	3
Evaluation Models	4
Typical Interface Circuits	4,5

INASTOMER[®] Technology Overview

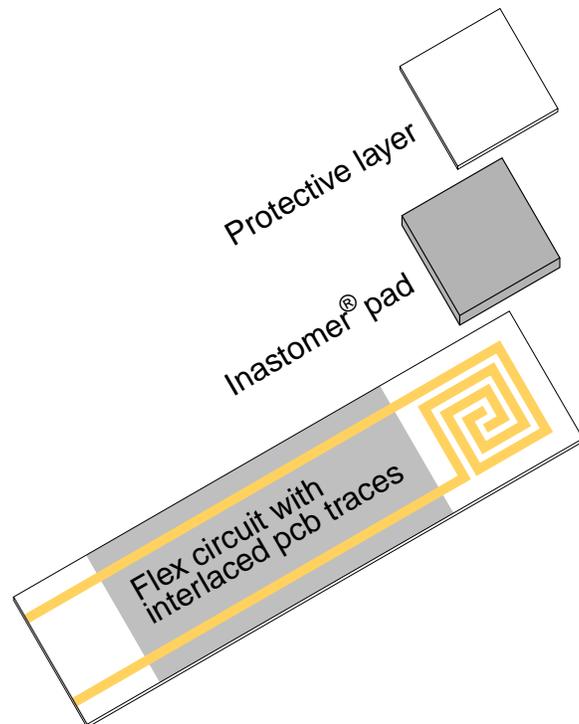
The patented Inastomer[®] material at the heart of the sensor is a flexible, conductive, elastomer-based composite excellent in reliability, linearity and mechanical characteristics. The composite contains spherical carbon molecules which, when altered in proximity to each other by forces such as compression, torsion, elongation or bending, cause the conductivity of the material to increase in proportion to the magnitude of the applied force. Unlike competitive force-sensing materials available, the response of the Inastomer[®] sensor is almost instantaneous, and the material is flexible so that it may be applied to curved or uneven surfaces. A proprietary mixing process and the use of alumina nano-particles provide the means to enhance the force/resistance response and durability of the material.

Fig. 1 shows the the number of particles per unit area to the distance between particles most proximate to each other in three variations. The variation in the particle distribution results in the conductive response as shown in Fig. 2, 3 & 4. Fig. 2 corresponds to Example 1 in Fig. 1, Fig. 3 corresponds to Comparative example 1 in Fig. 1, and Fig. 4 corresponds to Comparative example 2 in Fig. 1.

Formulation of the sensor material can be varied to suit specific application parameters such as force sensitivity, repeatability, durability, durometer, etc. A specific formulation can be construed for your application.

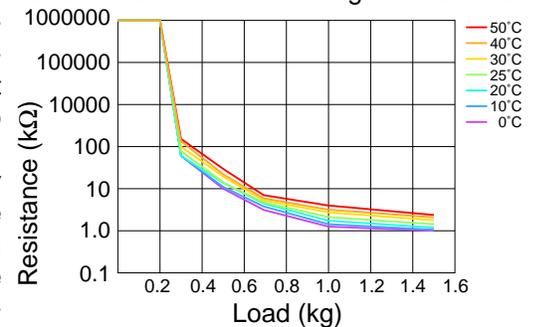
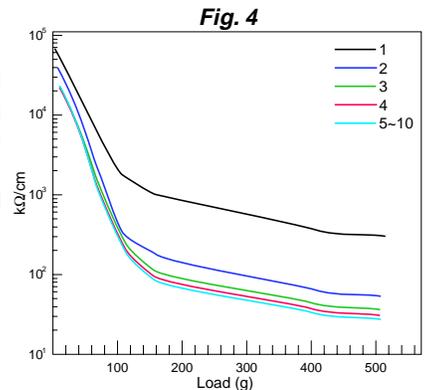
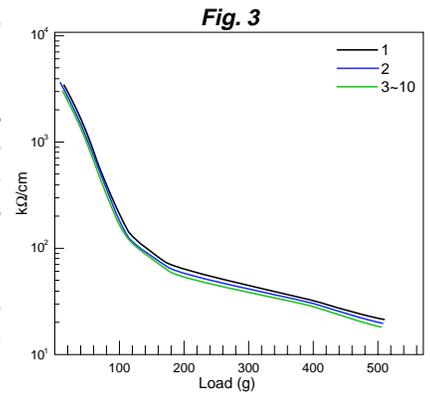
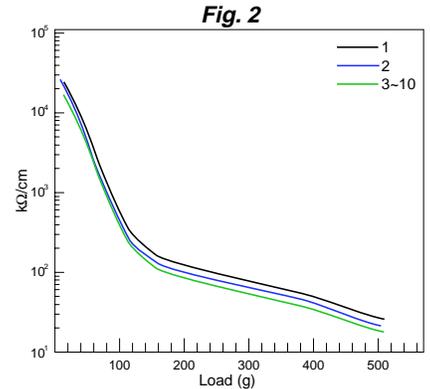
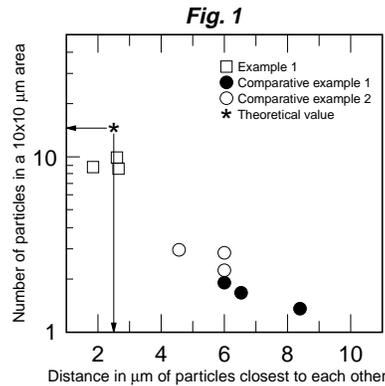
Sensor Configuration

A typical sensor assembly, shown below, consists of a layer of Inastomer[®] material bonded to a flex circuit with a protective polymer layer atop the sensor material. In many applications it is more effective to bond the Inastomer[®] material directly to a pc board trace. The size and shape of the sensor pad can be configured to satisfy the application requirement. The example in Fig.5 and the evaluation models on page 4 are generic and designed to demonstrate the basic sensor assembly construction.



Temperature

The proximity of conductive molecules in the sensor matrix is affected by temperature, thus the response of the sensor is affected. This 'drift' from changes in ambient temperature between 15°~35°C is insignificant. When the sensor is used in applications where the temperature varies beyond that range, or if it is critical to maintain highest resolution, drift can be compensated by using an IC such as the LM35DZ (see pg. 6). Even when compensated, the maximum operating temperature is -10~+70°C.

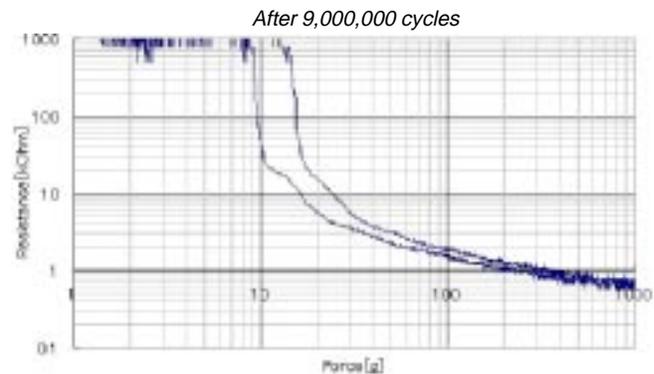
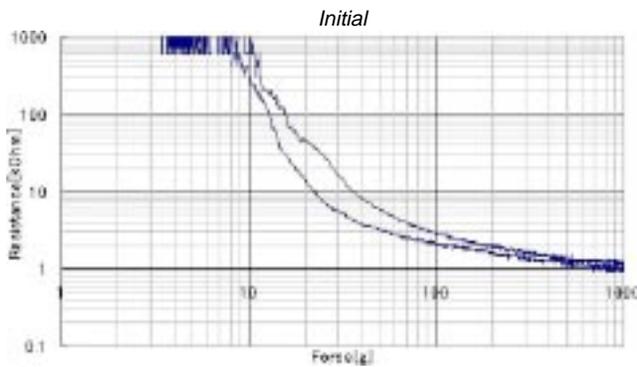
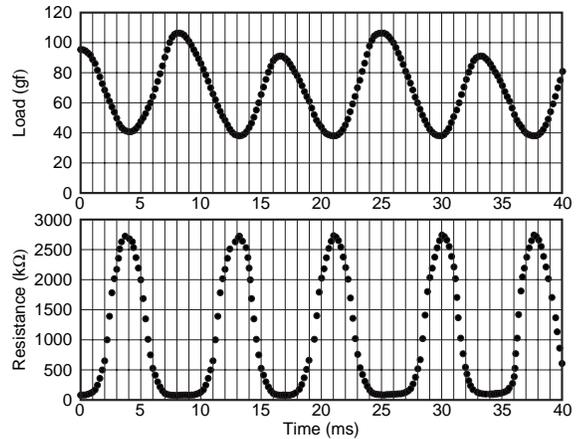


Response

Similar sensors can take up to 1 ms or more to respond to force. The nearly instantaneous response of the Inastomer® material make it highly desirable for real-time force feedback. In some applications such as variable switches for power tools or force feedback in graphic interface devices an instantaneous response is critical. The graph at the right illustrates the sensor's response time which is typically $\leq 6\mu\text{s}$.

Durability

The data in the graphs below were derived using a 2mm x 2mm x 0.74mm sensor @ 25°C. Basic sensor characteristics such as force-resistance response, durometer and durability can be obtained by modifying the type and amount of nano-particles present in the composite material. Initial response data are shown in the graph on the left. The data in the graph on the right were taken after 9,000,000 cycles were applied to the sensor material. Each cycle consisted of 100g applied for one second and no load for 1 second.



Applications

Inastomer®-based sensors are used in controls, prosthetic equipment, sports equipment, robotics, ballistics, amusement devices, material handling, security systems, toys, electric tools, automotive devices, prototype development, medical devices, computer interface devices, and many other applications too numerous to mention here.

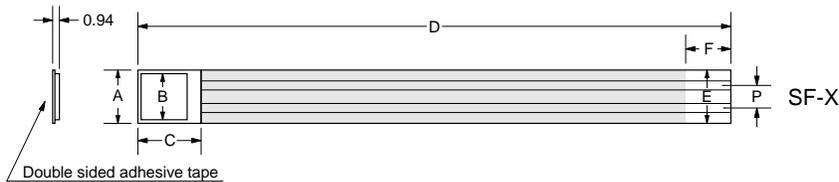
Typical Specifications

1. Supply voltage: 3~6VDC
2. Maximum allowable voltage: 30VDC
3. Current: 5mA
4. Maximum allowable current: 20mA
5. Resistance @ no load: $\geq 10000\text{M}\Omega$
6. Resistance @ full load: $\leq 15\Omega$
7. Response: $\leq 6\mu\text{s}$
8. Recommended load: 1.0kgf (~360PSI)
9. Maximum load: 3.0kgf (~1065PSI)
10. Life: $\geq 10,000,000$ cycles @ 100gf
(1 second ON/3 seconds OFF)
11. Operating Temp: -10° to $+40^\circ$ C
12. Storage Temp: -40° to $+70^\circ$ C
13. Humidity: 85% RH, no condensation

Evaluation Models

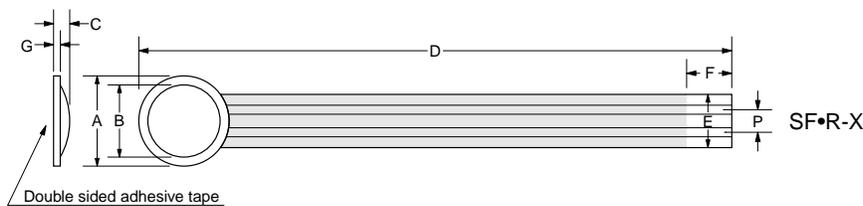
The evaluation models shown below are available from stock. In some instances they may be useful 'as is' but their primary purpose is to allow experimentation with and analysis of the Inastomer® sensor with regard to its suitability for an application. The sensor configuration can be easily modified to suit a specific application requirement.

SF Series



Model Item	SF-2	SF-3	SF-4	SF-5
A	2.9	3.9	4.9	5.9
B	2.1	3.1	4.1	5.1
C	4.0	5.0	5.8	7.0
D	40.0	50.0	50.0	65.0
E	2.9	3.9	4.9	5.9
F	5.5	5.5	5.5	5.5
G	12.0	12.0	13.0	13.0
P	1.0	1.5	2.0	2.5

SF•R Series



Model Item	SF•R-3	SF•R-4	SF•R-5
A	Ø7.2	Ø8.8	Ø10.0
B	Ø6.2	Ø7.2	Ø8.0
C	1.63	1.73	1.74
D	51.3±1	51.6±1	66.7±1
E	3.9	4.9	5.9
F	5.0	5.5	5.0
G	0.73	0.73	0.74
P	1.5	2.0	2.5

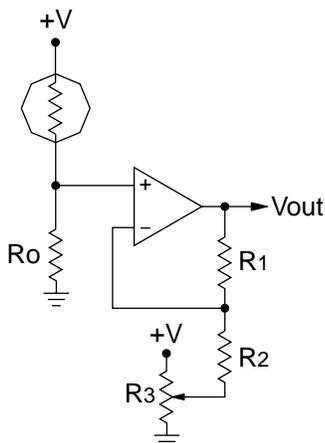
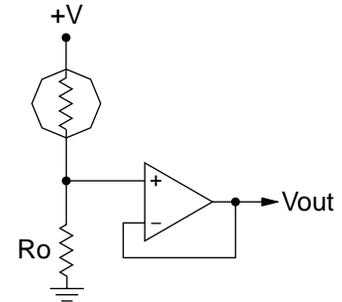
Interface Circuits

Voltage Divider

This basic interface provides a simple force input > voltage output conversion. The value of R_o drives the voltage output response. The output voltage is proportionate to the value of R_o , i.e., as the value of R_o increases, the voltage output increases.

In the schematic shown the output voltage (V_o) increases as the force applied to the sensor is increased. A value between 2.7kΩ~100kΩ is recommended for R_o depending upon the desired force sensitivity and current limiting considerations.

Recommended op-amps for the interface are LM324 or LM358. Their low bias currents tend to reduce the possible error due to the source impedance of the voltage divider.



Isolated Output

The voltage divider circuit can be modified by adding a buffer to isolate the output from the high source impedance of the sensor. This alternative allows adjustment of the output offset and gain.

In the schematic shown the gain of the output is determined by the ratio of the value of R_1 and R_2 . Bias currents or offsets resultant from the zero-force resistance value of the sensor can be trimmed with the R_3 pot.

Recommended value of R_3 is about 5% of the value of R_1 or R_2 . Using a pot for R_2 allows easy adjustment of the gain; for a broader gain adjustment range a single pot can be used in place of R_1 and R_2 .

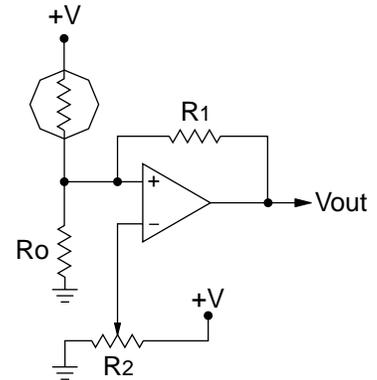
Interface Circuits

Force-Specific Switch

In some applications it is desirable to have on-off switching at a specific force. The first interface example (voltage divider) is the basis for this circuit but in this case the op-amp is used as a comparator for the switching function.

The output of the op-amp will be either high or low depending on the output of the voltage divider and reference voltage from R1. When the voltage from the divider meets or exceeds the reference voltage, the op-amp will flop high. Care should be taken in selecting the values for R₀ and R₂ so the optimal force sensitivity and current limitation can be obtained.

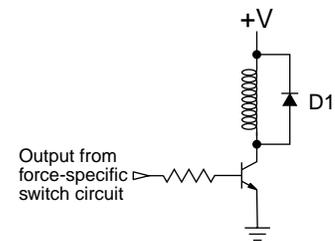
Recommended op-amps for the circuit are LM324 or LM358. Their low bias currents tend to reduce the possible error due to the source impedance of the voltage divider.



Relay Drive Circuit

To drive a higher current device the force-specific switch interface can be enhanced by connecting the base of a transistor to the output through a current-limiting resistor. A typical value for the current-limiting resistor (R₃) is 47k Ω . Selection of the transistor is based on the current requirement of the relay coil. R₂ is recommended to address hysteresis and dampen any tendency toward spurious triggering of the op-amp.

The diode prevents reverse EMF which could damage the relay and/or the circuit. The same basic considerations in the force-specific switch example should be adhered to in this example.



Temperature Compensation

When the sensor is applied to a device used where the environment is not controlled it will be necessary to compensate for the drift in response associated with temperature fluctuations. In this example a temperature-sensing IC is used with an op-amp to compensate the output of the Inastomer[®] sensor as the temperature fluctuates. The LM35DZ used in this example outputs 10mV/ $^{\circ}$ C of temperature rise. The Inastomer[®] material becomes less conductive as the temperature rises and the output voltage from the Inastomer[®] sensor diminishes accordingly. The LM35DZ supplements the diminished output. The op-amp, LM2904, further amplifies the LM35DZ output to the necessary compensatory level.

