NumaTac® Product Manual

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1 Introduction to Technology

This manual describes the performance and function of SynTouch’s NumaTac® tactile sensor. The biomimetic design consists of a rigid core surrounded by a sealed open-cell foam, providing compliance similar to the human fingertip (Figure 1). The curved, deformable nature of both the NumaTac and biological fingertips provides mechanical features that are desirable for the manipulation of objects.

Figure 1 – The NumaTac.

The NumaTac is designed to be a robust, compliant tactile sensor for applications where contact detection is prioritized. Contrary to alternative high-resolution tactile arrays, the NumaTac is sensitive to impact over its entire surface, and can be molded into complex 3-dimensional geometries. With customization, NumaTacs can be designed to cover robotic fingertips, hands, arms, or even an entire robot. In addition to high contact sensitivity permitting for dexterity and intelligent grasp control, the biomimetic compliance of the sensors also provides a cushion to protect the robot during a collision, sparing the robot, and anything or anyone it may bump into from serious damage.

The NumaTac sensor is a feature-reduced version of the multimodal BioTac sensor, providing compliance and contact sensitivity that is designed to be low-cost in mass production. Raw data collected from the NumaTac is equivalent to the dynamic fluid pressure (AC Pressure) as measured in the BioTac. Signal processing of this data enables the NumaTac to sense initial contact, with a high sensitivity for controlling collisions and enabling dexterous interactions.
2 Engineering Support

SynTouch provides engineering support for troubleshooting and installation assistance for various platforms. Additional technical support can be purchased to aid with implementing new communication protocols, design and production of mechanical or electrical adapters, or generation of novel signal processing tools. Contact SynTouch at info@syntouchinc.com for additional details.
3 Available Software

SynTouch provides various software and programming libraries to help with the development of custom applications using the NumaTac. As the BioTac and NumaTac use the same SPI communication protocol, all software libraries are mutually compatible. Software is provided free of charge to all customers as a development tool. The latest versions of all software and documentation are provided on our website at www.syntouchinc.com/en/software/

Software provided by SynTouch includes various graphical user interfaces to visualize and record data (Windows) as well as software libraries for LabVIEW, and C-Libraries to support various hardware interfaces. As of the writing of this document, supported hardware includes the Cheetah SPI USB Host Adapter (LabVIEW: Windows, C-Libraries: Linux, Windows, OS X) and PEAK-System Technik’s PCAN-PCI Card (C-Libraries: Real Time Linux).
4 Care and Handling

Special care should be taken when using the NumaTac to ensure its long life and stable performance.

- Maximum Force: The maximum recommended force is 100N. Signals may be saturated below this force level.
- Skin Abrasion: Abrading or puncturing the sealed foam of the NumaTac, as could happen if sliding across a rough surface or contacting very sharp objects, may cause leaks in the skin of the device, decreasing its sensitivity.
- Storage: Store the NumaTac in dry conditions. The NumaTac foam is sealed and water resistant, but the circuit board and electronics are not. Additionally, if water enters the sensor through small leaks in the foam the mechanical properties of the sensor could be altered. The NumaTac skin can be lightly cleaned with water if it is dried before use; however, care should be taken to keep the electronics dry. The sensor should never be used while wet.
- The mounting screws may be removed in order to affix the NumaTac to an adapter or surface. Always unplug the NumaTac cable from the sensor before removing the screws, and replace them before reattaching the cable.
- Do not attempt to disassemble the NumaTac. No user-serviceable parts are inside, and disassembly may degrade the pressure sensor seals.
5 Sensor Electronics

The integrated electronics of the NumaTac contains all sensory transducers, signal conditioning, and analog-to-digital conversion electronics to enable digital transmission of the sensor data (Figure 2).

![Electrical schematic of the NumaTac](image_url)

Figure 2 - Electrical schematic of the NumaTac

5.1 Sensor Output

The NumaTac contains one sensor measuring static and dynamic fluid pressure. Details of the acquisition and summary of performance of the sensor are provided below:

<table>
<thead>
<tr>
<th>Sensory Modality</th>
<th>Symbol</th>
<th>Range</th>
<th>Resolution</th>
<th>Frequency Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Pressure</td>
<td>$P_{DC}$</td>
<td>0 – 6.89 kPa</td>
<td>12.94 Pa</td>
<td>0 - 1750 Hz</td>
</tr>
<tr>
<td>Microvibration</td>
<td>$P_{AC}$</td>
<td>+/-0.27 kPa</td>
<td>0.13 Pa</td>
<td>10 - 1060 Hz</td>
</tr>
</tbody>
</table>

Table 1 – NumaTac Sensory Transducer Sampling Details

- Air pressure is measured with a piezo-resistive pressure transducer with a range of 0-6.89kPa (0-1psi) with reference to atmospheric pressure. The transducer output is biased in the positive direction to prevent negative saturation and amplified with a gain of 20 and a low-pass anti-aliasing filter at 1750Hz to produce the DC pressure signal ($P_{DC}$). A second stage includes a band-pass filter of 10-1060Hz and an additional gain of 100 to produce the high-resolution AC pressure vibration signal ($P_{AC}$). Both are sampled with 12-bit resolution for the range of 0-4.5V. Both AC and DC pressure can be estimated with the following equations (see Application Notes below):

$$\text{fluid pressure} = (P_{DC} - \text{offset}) \times 12.94\, \text{Pa/\text{bit}}$$
$$\text{dynamic pressure} = (P_{AC} - \text{offset}) \times 0.13 \text{Pa/bit}$$

- The pressure transducer used in the NumaTac is not thermally compensated and can drift slightly in response to changes in temperature. Due to the fabrication of the NumaTac, mechanical strains applied to the core are coupled to the pressure transducer and can cause small fluctuations in sensor output.
6 Sensor Performance Considerations

6.1 Permeability
The NumaTac sensor is designed to detect transient contact events, not to act as a steady-state indicator of force. The skin of the sensor is permeable to air, so when pressure is applied to the sensor, the air inside will leak out over a short period of time, returning the pressure signal to a normalized value. This prevents sensor drift that could occur over long periods of contact. The rate at which air leaks through the NumaTac skin during a contact event depends on the particular geometry of the sensor in question; typical values for the rate of decay range from $\tau = 0.1$ sec to $\tau = 1$ sec.

6.2 Maximum Loading

- The maximum force applied to the NumaTac should not exceed 100N.

This assumes a 100N force applied uniformly to the back of the NumaTac while while loading against a relatively large flat surface. Lower forces with sharper objects will result in higher local pressures that could result in skin puncture and should also be avoided.

As a general rule of thumb, the NumaTac has a similar resistance to damage as the human finger. Large forces, heavy impacts, and sharp objects that would cause harm to the biological finger may also damage the skin or core of the NumaTac. Common sense should be used to avoid these situations.

6.3 Wear Rate
The sensor's wear rate will depend upon usage and environmental conditions. In an effort to retain human-like compliance for grip, the hardness of the foam sensor was kept low and near human skin. SynTouch has worked with a leading foam fabricator to select materials optimized for sensitivity and wear resistance. In normal conditions, sensors have been tested to as many as 50,000 grasps without signal degradation. However, care should be taken to avoid sliding the NumaTac over abrasive materials that could wear through the foam skin, which is sealed with a fluroelastomer coating. Degrading the skin will cause the leak rate to increase and the sensitivity of the sensor to fall.

6.4 Accounting for Signal Drift
Similar to human fingertips, the NumaTac is better at providing information about changes than absolute values. The recommended use of the sensor output, is to use the raw data for various signal-processing algorithms. Further, absolute signal levels will drift slightly with changes in temperature. In developing
algorithms utilizing NumaTac data, we suggest that users incorporate a function to account for signal drift that will occur in their particular application and/or conditions of use. In general, these effects are not dramatic, but it is important that users are aware of the potential for these changes to occur. When the NumaTac is not in contact with external objects, it is recommended the sensor be tared to account for any offset.
7 Electrical Connections

- Do not supply the NumaTac 5V input with greater than 5.5V of voltage. This can cause damage to the electrical components, which could make the NumaTac unusable.

NumaTac can be connected with a 6-pin connector (see below) that supplies 5V power and ground as well as the 4 SPI communication lines.

1.1.0 Connector

The NumaTac electronics board has been designed to mate with the following connector:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>JST Sales America Inc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer Part Number</td>
<td>SHR-06V-S-B</td>
</tr>
<tr>
<td>Digi-Key Part Number</td>
<td>455-1381-ND</td>
</tr>
<tr>
<td>Family</td>
<td>Rectangular Connectors - Housings</td>
</tr>
<tr>
<td>Connectors</td>
<td>Interconnects</td>
</tr>
<tr>
<td>Series</td>
<td>SH</td>
</tr>
<tr>
<td>Connector Type</td>
<td>Receptacle</td>
</tr>
<tr>
<td>Number of Positions</td>
<td>6</td>
</tr>
<tr>
<td>Pitch</td>
<td>0.039&quot; (1.00mm)</td>
</tr>
<tr>
<td>Mounting Type</td>
<td>Free Hanging (In-Line)</td>
</tr>
<tr>
<td>Termination</td>
<td>Crimp</td>
</tr>
</tbody>
</table>

Table 3 – 6-Pin Matting Connector Information
8  Power Requirements

The NumaTac requires a 5V power supply for SPI communication. For optimal sensitivity, the noise of these power supplies should be less than 20mV. As an alternative, if clean power is not available, the NumaTac can be supplied with an adapter board that only requires the four SPI lines, 5V power and ground. Power signals are conditioned with this board to provide appropriate output and are designed to work sufficiently with USB power supplies.

- Do not supply the NumaTac 5V input with greater than 5.5V of voltage. This can cause damage to the electrical components, which could make the NumaTac unusable.
9 SPI Communication Protocol

9.1 Overview
During regular data acquisition the master sends a 2-byte request for a particular sensor channel measurement and then pauses the clock while each sensor on the bus simultaneously acquires a 2-byte (12 bit) datum. The master then selects each sensor in sequence and drives the SPI clock so that each slave transmits its datum to the master when its chip select is activated.

9.2 SPI Configuration

**Table 6 - Timing of SPI signal update and sample**

<table>
<thead>
<tr>
<th>Signal update</th>
<th>Signal sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISO</td>
<td>MOSI</td>
</tr>
<tr>
<td>-ve clock edge</td>
<td>-ve clock edge</td>
</tr>
<tr>
<td>+ve clock edge</td>
<td>+ve clock edge</td>
</tr>
</tbody>
</table>
9.3 Command Types
There are four types of basic commands between the host controller and individual BioTac sensor or NumaTac sensor:

- Sampling command
- Resend command
- Parameter Set/Write command
- Parameter Read command

<table>
<thead>
<tr>
<th>First Byte</th>
<th>Second Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit#</td>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Sampling</td>
<td>0b 1 S S S S S S P</td>
</tr>
<tr>
<td>Resend</td>
<td>0b 0 1 0 1 0 0 0 0</td>
</tr>
<tr>
<td>Set/Write</td>
<td>0b 0 1 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Read</td>
<td>0b 0 1 1 0 0 0 0 1</td>
</tr>
</tbody>
</table>

0b: indicating the command is sent as binary code
0/1: command type
SSSSSS: sampling channels number (0~63)
NNNN: subset number (0~15)
VVV: variable number (0~7)
P: parity check (odd parity)
X: ignored

Figure 13 – SPI Communication Protocol Command Types and Structure

While listening to the responses from the NumaTac the host should write 0x0001 to the MOSI lines to avoid errors.
1.1.0 Sampling command

9.3.1 Description
The sampling command is a 2-byte command from the host. Only the first byte is processed and the second byte is ignored. Upon receiving the 2-byte command from the host, all BioTacs or NumaTacs with an active slave select during the command simultaneously and independently sample the requested channel specified by the 6-bit command SSSSSS (63 possible channels) and load the value into a 2-byte buffer.

- NOTE: A minimum of 50µs delay is required between the sampling command and response from the BioTacs or NumaTacs. During this time the CS lines should be disabled.

After the minimum delay of 50µs individual BioTacs or NumaTacs can be queried for this 2-byte buffer by enabling the CS and CLK line to each BioTac or NumaTac for two bytes. This buffer must be read before sending a new sampling request. A sample of the recommended communication structure is outlined below:

![Figure 14 - Recommended Sampling Sequence for 3 NumaTacs](image)

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9.3..2 Detailed Sampling Commands

<table>
<thead>
<tr>
<th>Description</th>
<th>Index</th>
<th>1st Byte Command</th>
<th>Return (bytes)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pac</td>
<td>0</td>
<td>0b10000000</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pdc</td>
<td>1</td>
<td>0b10000011</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 – Sampling Commands

9.3..3 Response Format:
Signals from sensors are digitized as 12 bits of data; and split into two bytes (low byte and high byte) in the following format.

<table>
<thead>
<tr>
<th>MSB</th>
<th>Data&lt;11:5&gt;</th>
<th>Parity</th>
<th>Data&lt;4:0&gt;</th>
<th>0</th>
<th>0</th>
<th>Parity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bit 15</td>
<td>bit 14</td>
<td>bit 13</td>
<td>bit 12</td>
<td>bit 11</td>
<td>bit 10</td>
</tr>
<tr>
<td></td>
<td>bit 9</td>
<td>bit 8</td>
<td>bit 7</td>
<td>bit 6</td>
<td>bit 5</td>
<td>bit 4</td>
</tr>
<tr>
<td></td>
<td>bit 3</td>
<td>bit 2</td>
<td>bit 1</td>
<td>bit 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 15 – Sampling Command Response Format

9.3..4 Error Handling

<table>
<thead>
<tr>
<th>Sampling Errors</th>
<th>NumaTac Response</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient Sampling Delay (-)</td>
<td>0b1010010100101101</td>
<td>There has been insufficient delay between the sampling command and response time (minimum delay is 50µs)</td>
</tr>
<tr>
<td>Channel Not Recognized (X)</td>
<td>0b101001010101000</td>
<td>The channel is not recognized by the BioTac or NumaTac firmware or unavailable</td>
</tr>
</tbody>
</table>

Table 8 – Sampling Error Responses

1.1.0 Data Resend command
The data resend command is a 2-byte command from the host. Only the first byte is processed and the second byte is ignored. Upon receipt of the data resend command, the BioTac or NumaTac responds with the previous 2 bytes of sampled data (this should be used in case of a parity error).

Chip select can be used to request a data resend from an individual BioTac or NumaTac. If the data resend command is sent before the BioTac or NumaTac has been sent a sampling command the BioTac will ignore the resend request.

1.1.0 Set/Write and read command
The set/write and read commands are a 2-byte commands from the host (with additional bytes in the case of set/write. Upon receiving the command the BioTac or NumaTac responds with 2x bytes.

<table>
<thead>
<tr>
<th>Group index</th>
<th>Subset name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NNNN=0001</td>
<td>Information NumaTac general parameters</td>
</tr>
</tbody>
</table>

Table 9 – Read/Write Function Subset Groups
<table>
<thead>
<tr>
<th>Description</th>
<th>2nd byte Command</th>
<th>Return Bytes</th>
<th>rw</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNNN = 0001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General information subset</td>
<td>0b0001VVVP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flex version</td>
<td>0b00010000</td>
<td>4 r-</td>
<td></td>
<td>Format MMNN - ASCII (no parity)</td>
</tr>
<tr>
<td>Software version</td>
<td>0b00010011</td>
<td>4 r-</td>
<td></td>
<td>Format MMNN - ASCII (no parity)</td>
</tr>
<tr>
<td>Serial number</td>
<td>0b00010101</td>
<td>9 r-</td>
<td></td>
<td>Format ASCII (no parity)</td>
</tr>
</tbody>
</table>

Table 10 - Read/Write Function Details

9.3.1 Error Handling

<table>
<thead>
<tr>
<th>Set/Write Errors</th>
<th>NumaTac Response</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter is read-only (R)</td>
<td>0b10100101 01010010</td>
<td>Trying to write to a read-only parameter</td>
</tr>
</tbody>
</table>

Table 11 - Read/Write Error Codes
### Appendix A. Materials

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Weight</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>Delrin - acetal homopolymer</td>
<td>0.8g</td>
<td>Strong</td>
</tr>
<tr>
<td>Foam</td>
<td>Polyurethane</td>
<td>1.1g</td>
<td>Good Compliance and Wear Properties</td>
</tr>
<tr>
<td>Screws</td>
<td>18-8 Stainless Steel</td>
<td>0.1g ea</td>
<td>(2)</td>
</tr>
<tr>
<td>Threaded Inserts</td>
<td>18-8 Stainless Steel</td>
<td>-</td>
<td>(2)</td>
</tr>
<tr>
<td>Electronics Board</td>
<td>Various</td>
<td>1.0g</td>
<td></td>
</tr>
<tr>
<td>Gasket</td>
<td>Silicone</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Glue</td>
<td>Silicone</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B. Legal

1.1.0 SynTouch Standard Warranty

1. All SynTouch sensors come with a standard 1-year warranty from the date of shipment.
2. The Standard Warranty covers the repair or replacement of defective components including sensors, electronics, cables, or adapters.
3. The Standard Warranty includes firmware and software upgrades at no cost as long as the warranty is active.
4. The Standard Warranty excludes the repair or replacement of skins (if applicable), which are designed for periodic replacement through normal use.
5. The Standard Warranty excludes repairs or replacements resulting from damage deemed as misuse as outlined in the highlighted notes and warnings of the BioTac/NumaTac manual.
6. SynTouch reserves the right to amend the BioTac/NumaTac manual to include additional application notes and warnings, which then become part of this Standard Warranty policy.
7. In the event of damage to any product from misuse or damage outside of the Standard Warranty term, costs for repair of the BioTac/NumaTac sensor will be evaluated and quoted before any repairs are made. If the BioTac/NumaTac cannot be adequately repaired, the alternative of a replacement may be offered at 20% off of the current list price.
8. All shipping costs to SynTouch, independent of warranty standing, will be the responsibility of the customer.
9. All repairs and replacements are subject to a 90-day lead-time.
Customer Service and Health and Safety Acknowledgements

1.1.1 Purpose
This document is intended as a written confirmation of the terms and conditions under which SynTouch Inc will provide Customer Service for our products to our customers. This agreement defines the services SynTouch Inc will provide to customer in conjunction with license of or purchase of SynTouch Inc products as well as Customer's notice and acknowledgement of any potential hazards, restrictions or limitations with regards to SynTouch Inc's products.

1.1.2 Custom Support and Services
Under this agreement, Customer seeks to receive, and SynTouch Inc agrees to provide customer service, in some cases for a fee, for Customer's purchased SynTouch Inc products.

Customer agrees and understands that some service options may be limited to normal business hours and days of the week. Customer agrees and understands that this agreement only covers their SynTouch Inc products and not any third-party product or modification. Customer understands that if it is determined that support and service are being used to support a third-party product or any modification or alteration to a SynTouch Inc product not authorized or approved in SynTouch Inc documentation, Customer may be charged and Customer agrees to pay for such service, at SynTouch Inc's sole discretion.

1.1.3 Custom Feedback
Under this agreement, SynTouch Inc seeks to receive, and Customer agrees to provide, certain levels of customer feedback regarding Customer's purchased SynTouch Inc products.

1.1.4 Taxes and Tariffs
Customer shall be responsible for payment and satisfaction of all taxes applicable and/or tariffs, costs of import or costs of export related to purchasing, shipping or transporting materials for providing services under this agreement.

1.1.5 Safety and Health Acknowledgements
SynTouch Inc is concerned for your safety has communicated to Customer, and Customer understands, the following potential safety and health issues associated with SynTouch Inc Products:

1. **SHARPS WARNING** Many SynTouch Inc products use a standard insulin syringe with a 25 gauge needle in the operation of said products. Customer acknowledges
a. that he or she has consulted with a SynTouch sales, marketing or development professional regarding whether his or her purchase uses such needles and therefore whether proper operation of that product involves a sharps hazard;

b. that Customer is wholly responsible for communicating such a hazard to any parties using his or her SynTouch Inc product, whether or not such use is under his or her supervision; and

c. that Customer is wholly responsible for proper storage and disposal of sharps and biomedical waste in conjunction with operation of his or her SynTouch Inc product and in compliance with applicable law.

2. CHEMICAL WARNING    Many SynTouch Inc products use certain chemicals in their operations. Customer acknowledges:

a. that Customer has been provided with the Material Safety Data Sheets (MSDS) for all SynTouch Inc products he or she has purchased, either with said purchase or through a request to a SynTouch Inc sales, marketing or development professional;

b. that Customer has read all MSDS for chemicals used in the appropriate SynTouch Inc products and understands the potential safety and health risks associated with such chemicals;

c. that Customer is wholly responsible for communicating such a safety and health risks to any parties using his or her SynTouch Inc product, whether or not such use is under his or her supervision;

d. that Customer will provide copies of the MSDS for chemicals used in the appropriate SynTouch Inc products to any parties who request them in conjunction with the Customer’s SynTouch Inc products; and

e. that Customer is wholly responsible for proper storage and disposal of chemicals in conjunction with operation of his or her SynTouch Inc product and in compliance with applicable law.
Indemnification

Customer shall indemnify and hold harmless SynTouch Inc for all legal claims resulting from Customer’s failure to reasonably communicate information in this agreement to parties using Customer’s SynTouch Inc products, reasonably communicate information listed under above section Health & Safety Acknowledgements to parties using Customer’s SynTouch Inc products or failure to take steps to account for responsibilities listed under above section Health & Safety Acknowledgements. SynTouch Inc shall indemnify and hold harmless Customer for all legal claims resulting from failure to respond in a reasonable time to requests made by Customer under above section Health & Safety Acknowledgements or for failure to provide full information requested in response to requests made by Customer under above section Health & Safety Acknowledgements. Procedure. In case any Claim is at any time brought against Syntouch Inc or Customer, the party obligated to provide such indemnification (the "Indemnifying Party") will defend such Claim, at the sole expense of the Indemnifying Party, using counsel selected by the Indemnifying Party but subject to the Indemnified Party's reasonable approval. If the Indemnifying Party fails to take timely action to defend such a Claim after having received written notice from the Indemnified Party of such failure, the Indemnified Party may defend such a Claim at the Indemnifying Party's expense. The Indemnifying Party will keep the Indemnified Party fully advised with respect to such Claims and the progress of any suits, and the Indemnified Party shall have the right to participate, at the Indemnified Party's expense, in any suit instituted against it and to select attorneys to defend it, which attorneys will be independent of any attorneys chosen by the Indemnifying Party relating to such Claim or related claim. The Indemnifying Party will not settle, compromise or otherwise enter into any agreement regarding the disposition of any Claim against the Indemnified Party without the prior written consent and approval of the Indemnified Party which shall not be unreasonable withheld.

GOVERNING LAW

This Agreement and the performance hereunder shall be governed by the laws of the State of California without regard to conflicts of law rules. The Parties agree on behalf of themselves and any person claiming by or through them that the sole and exclusive jurisdiction and venue for any litigation which may arise hereunder shall be an appropriate federal or state court located in the County of Los Angeles and the Parties hereby consent to the personal jurisdiction of such courts.

DISCLAIMERS AND LIMITATIONS

DISCLAIMER OF WARRANTIES. EXCEPT AS OTHERWISE PROVIDED IN THIS AGREEMENT, NEITHER PARTY MAKES, AND EACH PARTY HEREBY WAIVES AND DISCLAIMS, ANY REPRESENTATIONS OR WARRANTIES
REGARDING THIS AGREEMENT OR THE TRANSACTIONS CONTEMPLATED HEREBY, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OR IMPLIED WARRANTIES ARISING OUT OF COURSE OF DEALING, COURSE OF PERFORMANCE OR USAGE OF TRADE.

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