

## Evaluating the AD7150 Capacitance-to-Digital Converter

### GENERAL DESCRIPTION

This document describes the [AD7150](#) evaluation board and PC software.

Additional details about the AD7150—an ultralow power, 2-channel capacitance-to-digital converter (CDC)—are available in the AD7150 data sheet, which should be consulted in conjunction with this document when using the EVAL-AD7150EBZ.

More information about the Analog Devices, Inc., family of CDC products can be found at [www.analog.com/CDC](http://www.analog.com/CDC).

### EVALUATION BOARD DESCRIPTION

The AD7150 evaluation kit is a powerful tool for exploring and evaluating the AD7150 features at many different levels.

The board is connected to a PC via a standard USB interface. The PC software allows the graphical display of real-time data, modification of the AD7150 internal settings, and generally assists in understanding the part features and performance.

The flexible interface structure of the evaluation board allows it to be connected in several useful configurations. For example, the digital section of the evaluation board can be used independently as a convenient digital interface for a user's own sensor design PCB or as a module containing the AD7150. Alternatively, an external microcontroller can be interfaced to the AD7150. Therefore, the evaluation board can act as a complete analog front end for creating and debugging software on the user's own digital platform.

### DIGITAL PICTURE OF EVALUATION BOARD

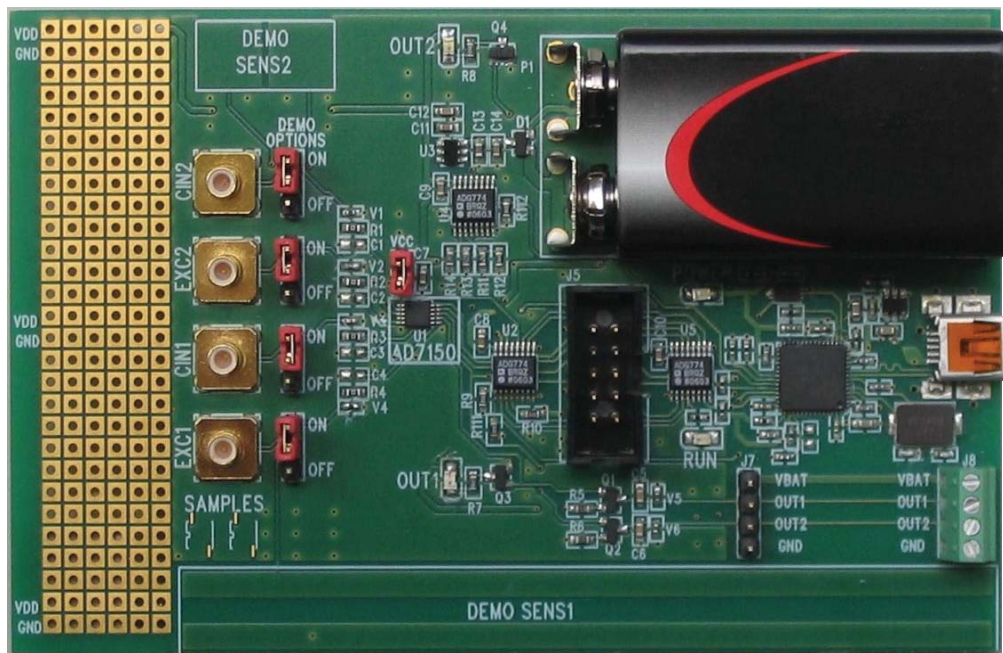


Figure 1.

08796-001

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**REVISION HISTORY**

5/10—Revision 0: Initial Version

## EVALUATION SOFTWARE INSTALLATION

Install the **AD7150** evaluation board software before connecting the AD7150 evaluation board to the PC. To do so, complete the following steps:

1. Insert the AD7150 evaluation kit CD into the CD-ROM drive of your PC. The evaluation software installation wizard should start automatically. If the wizard does not start, run **Setup.exe** from the AD7150 evaluation kit CD.

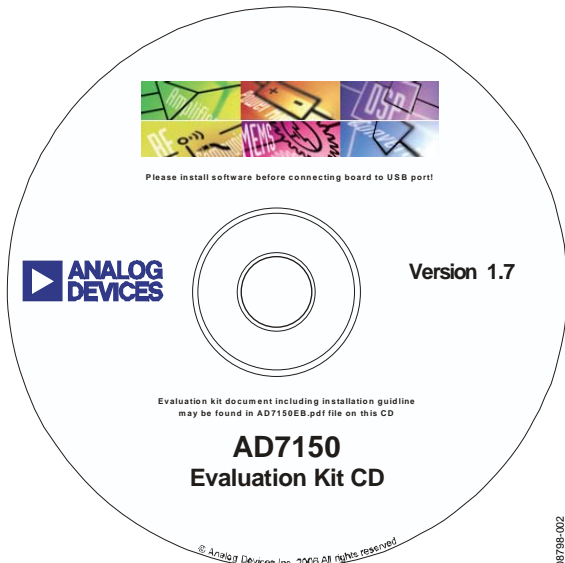


Figure 2. AD7150 Evaluation Kit CD

2. Follow the steps in the evaluation software installation wizard until the installation is completed.



Figure 3. AD7150 Evaluation Software Installation

3. Connect the AD7150 evaluation board to your PC USB connector using the USB cable included in the evaluation kit. The **POWER LED** on the evaluation board turns on and the **Found New Hardware Wizard** starts automatically on the PC.



Figure 4. Found New Hardware Wizard

4. Follow the steps in the **Found New Hardware Wizard** window. If a message that the software has not passed Windows® Logo testing appears, click **Continue Anyway**.

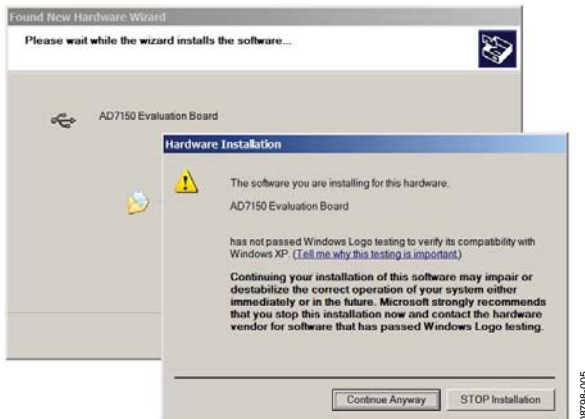


Figure 5. Windows Logo Warning

5. Follow the steps in the **Found New Hardware Wizard** window until the installation is completed.

## EVALUATION BOARD HARDWARE

### POWER SUPPLY

The AD7150 evaluation board is supplied by the USB interface, and the LED labeled **POWER** on the board should turn on when the board is connected.

To use the AD7150 evaluation board, make sure that the link on the supply header (J6) is in place.

### I<sup>2</sup>C INTERFACE CONFIGURATION OPTIONS

The AD7150 evaluation board uses the circuitry shown in Figure 6, which allows different digital interface configurations by redirecting the I<sup>2</sup>C signals—SDA and SCL—among the USB microcontroller, the on-board AD7150, and external components connected via J5.

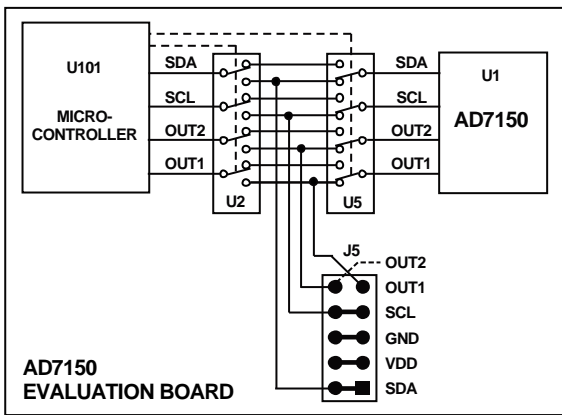


Figure 6. AD7150 Evaluation Board I<sup>2</sup>C Configuration

### Default

By default, the I<sup>2</sup>C interface signals SDA and SCL connect the USB microcontroller as the I<sup>2</sup>C bus master to the on-board AD7150, bypassing the J5 connector, shown in Figure 7. This allows easy use of the evaluation board and the PC software.

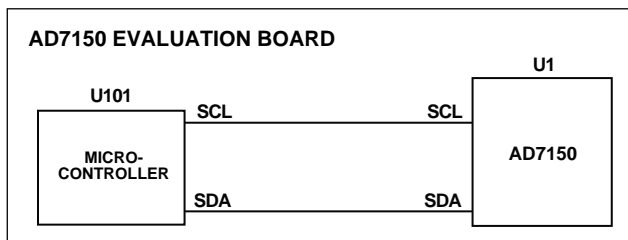


Figure 7. AD7150 Evaluation Board in Default Configuration

### USB—External Connection

The AD7150 evaluation board allows you to connect your own specific AD7150 application board to the evaluation board via Connector J5. This enables the PC evaluation software to evaluate your application hardware using the AD7150 evaluation board as only a USB-to-I<sup>2</sup>C digital interface, as shown in Figure 8

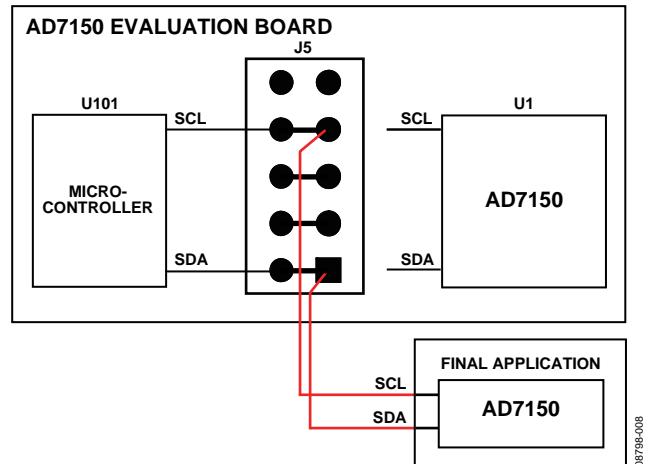


Figure 8. AD7150 Evaluation Board as USB-to-I<sup>2</sup>C interface

### External Connection—AD7150

The AD7150 evaluation board can be used for software development by connecting a customer-specific external microcontroller board to the AD7150 on the evaluation board via Connector J5, as shown in Figure 9. In this configuration, the AD7150 CDC on the evaluation board is used as the sensing device.

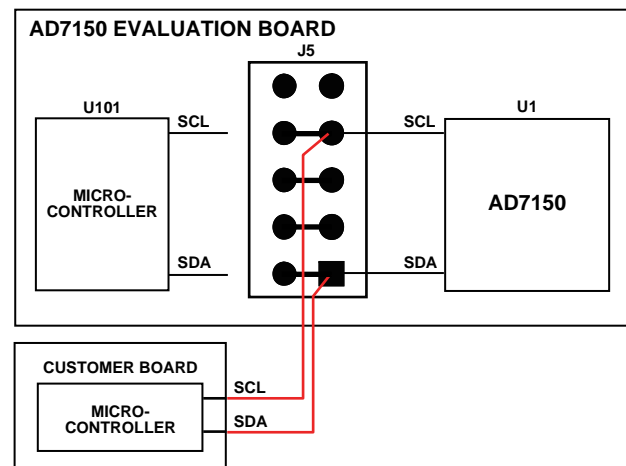


Figure 9. AD7150 Evaluation Board Software Development Platform

## EVALUATION BOARD SOFTWARE

### STARTING THE EVALUATION SOFTWARE

To run the evaluation software,

1. Start the **AD7150** evaluation software on the PC.
2. Click the **Start** button, located at the bottom left-hand corner of your desktop. Select **Programs**, then **Analog Devices**, then **AD7150 Evaluation Software**, and then **AD7150EB** to run the software.

If a connection between the software and the evaluation board is correctly established, the window shown in Figure 10 appears. The USB indicator in the top right corner of the software window turns on green, and the LED labeled **RUN** on the AD7150 evaluation board flashes in approximately 1 sec intervals.

### DATA ACQUISITION WINDOW

#### Reset AD7150

When **Reset AD7150** is clicked, the software accesses AD7150 Register Address 0xBF to reset the part. See the AD7150 data sheet for details on the serial interface.

#### Demo Setup

Clicking on **Demo Setup** configures the AD7150 to its default settings, as shown in Figure 11.

#### Setup AD7150

Click **Setup AD7150** to open the AD7150 setup window (see Figure 11), which provides access to the AD7150 settings.

#### Log Data to File

When **Log data to file** is clicked, the software allows you to log the acquisition data into a text file with the ASCII tab character as the delimiter to allow easy import to a data processing tool, such as Microsoft® Excel.

#### Start Acquisition

Clicking the green **Start Acquisition** button in the AD7150 evaluation software window starts the data acquisition. The LED labeled **RUN** on the evaluation board turns on, the **RUN** indicator in the top right corner of the software window turns on red, and graphs in the software start displaying the measured data.

The data displays and the traces in the graphs represent real-time data read from the AD7150.

#### Graphs

The graphs show the history of data of up to 65,536 samples. You can modify the graph appearance. For example, the scale can be modified by typing minimum and maximum numbers when the autoscale is turned off. Place the cursor on the graph and right-click the mouse to open the graph submenu, which allows different individual graph settings.

When **Clear Graphs** is clicked, the graph and the graph history are cleared.

#### Data Format and Units

Both displays show the data as hexadecimal codes read from the AD7150 and translated to picofarads (pF). The graphs can show the data in either hexadecimal codes or translated in picofarads. To switch between these two modes, click **Display pF**. The **Display pF** button switches to **Display Code** when clicked.



Figure 10. AD7150 Evaluation Software Data Acquisition Window

## SETUP WINDOW

### Register Field

The register section of the setup window (left portion of the window) indicates the address, register name, and the current content in hexadecimal form for each [AD7150](#) register.

### Reset AD7150

When **Reset AD7150** is clicked, the software accesses AD7150 Register Address 0xBF to reset the part. See the AD7150 data sheet for details on the serial interface.

### Demo Setup

Clicking **Demo Setup** configures the AD7150 to its default settings as shown in Figure 11.

### Read AD7150

When **Read AD7150** is clicked, the evaluation software reads the current register content of the AD7150 registers and the updates are shown in the setup window.

### Read from File

When **Read from File** is clicked, a window opens to allow you to read back previously saved settings from a text file.

### Write AD7150

When **Write AD7150** is clicked, the evaluation software writes the current settings shown in the setup window into the AD7150 registers.

### Save to File

When **Save to File** is clicked, a window opens to allow the current settings to be saved to a text file.

## AD7150EB Interface Configuration

The AD7150 evaluation board digital interface can be configured to several different modes. The following modes can be selected from the **AD7150EB Interface Configuration** box in the AD7150 setup window:

- Selecting **USB -> AD7150** connects the USB microcontroller as the I<sup>2</sup>C bus master to the on-board AD7150. This option is the default when running the evaluation software on a PC and allows easy use of the evaluation board and the PC software.
- Selecting **USB -> ext.con** connects the USB microcontroller as the I<sup>2</sup>C master to the I<sup>2</sup>C/outputs connector. This option allows using a customer-specific board with the AD7150 and PC evaluation software, where the AD7150 evaluation board acts only as a USB/I<sup>2</sup>C digital interface.
- Selecting **Ext -> AD7150** connects an external microcontroller to control the AD7150 on the evaluation board. This option is the default for the board after power-up. Therefore, the AD7150 on the evaluation board can be accessed through the I<sup>2</sup>C/outputs connector without using the USB microcontroller and PC software at all.
- Selecting **All connected** connects the on-board AD7150 with both the on-board USB microcontroller and the I<sup>2</sup>C/outputs connector. This mode is meant mainly for debug purposes. The practical use of this option is limited, however, because the USB microcontroller firmware does not implement multimaster protocol on the I<sup>2</sup>C bus.

### OK

When **OK** is clicked, the evaluation software writes the current settings into the [AD7150](#) registers, the setup window closes, and the software returns to the data acquisition window.

### Cancel

When **Cancel** is clicked, the evaluation software writes the register settings that were buffered from the time the setup window was opened to the AD7150 registers. The setup window then closes, and the software returns to the data acquisition window.



Figure 11. AD7150 Evaluation Software Setup Window

**MODE OF OPERATION**

**Mode**

The **Mode** box allows you to put the AD7150 into the following operating modes:

- Standby mode (idle): The part is fully powered up, but not performing any conversion.
- Continuous conversion: The part is repeatedly performing conversions on the enabled channel(s). If two channels are enabled, the part is sequentially switching between them.
- Single conversion: The part performs a single conversion on the enabled channel. If two channels are enabled, two conversions are performed, one on each channel. After finishing the conversions, the part goes to standby mode (idle).
- Power-down: Powers down the on-chip circuits, except the digital interface.

**Threshold Modes**

The upper **Threshold** box allows you to set the AD7150 threshold to either adaptive or to fixed (see Figure 12).

When the upper mode box is set to adaptive mode, the lower **Threshold** box allows you to define the threshold level to be negative, positive, in-window, or out-window (see Figure 12).

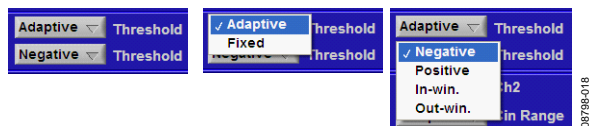


Figure 12. Threshold Mode Select Options

**Adaptive Mode**

In adaptive mode, the thresholds are dynamically adjusted, ensuring indication of fast changes (for example, an object moving close to a capacitive proximity sensor) while eliminating slow changes in the input (sensor) capacitance that are usually caused by environment changes such as humidity or temperature.

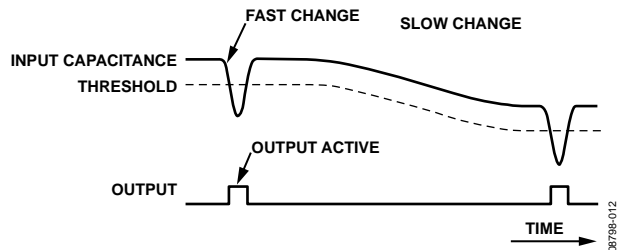


Figure 13. Adaptive Threshold Indicates Fast Changes and Eliminates Slow Changes in Input Capacitance

**Fixed Mode**

In fixed mode, the threshold is fixed to a defined value, and changes in the input capacitance are indicated when the input data crosses the fixed threshold.

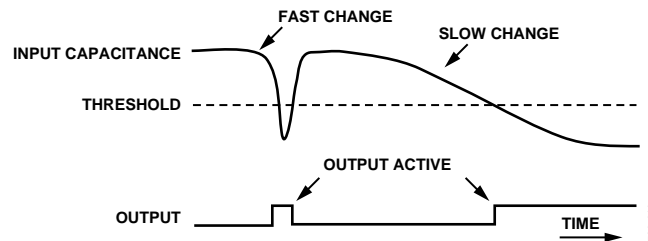


Figure 14. AD7150 in Fixed Mode

**Negative Threshold**

The negative threshold is set below the average and is used when a negative change on the capacitive input is expected. The change in the input is indicated when the input data goes below the threshold.

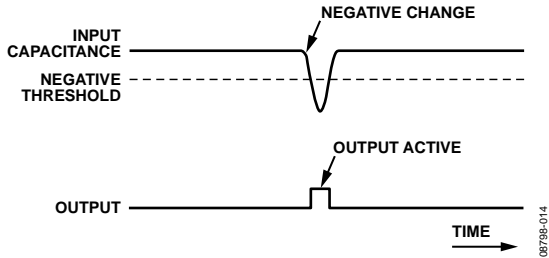


Figure 15. Negative Threshold Mode Indicates Negative Change in Input Capacitance

**Positive Threshold**

The positive threshold is set above the average and is used when a positive change on the capacitive input is expected. The change in the input is indicated when the input data goes above the threshold.

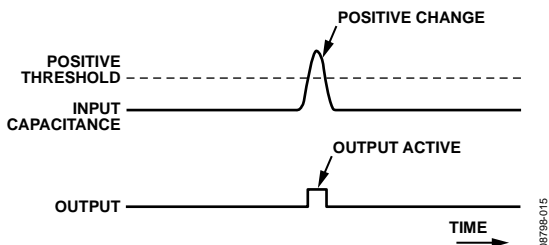


Figure 16. Positive Threshold Mode Indicates Positive Change in Input Capacitance

**In-Window Threshold**

The in-window threshold has two thresholds: one above and one below the average. The output stays high as long as the input data stays within the threshold window. A change in the input is indicated by a low on the output when the input data goes either above the positive threshold or below the negative threshold.

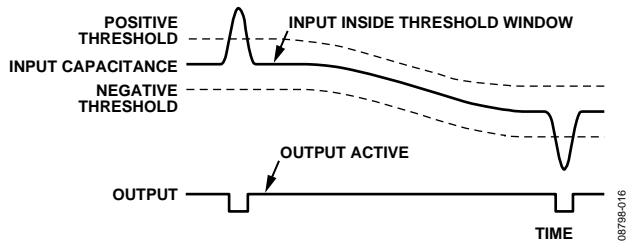


Figure 17. In-Window (Adaptive) Threshold Mode

**Out-Window Threshold**

The out-window threshold has two thresholds: one above and one below the average. A change in the input is indicated when the input data goes either above the positive threshold or below the negative threshold.

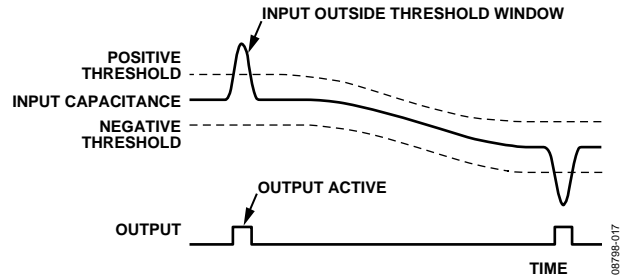


Figure 18. Out-Window (Adaptive) Threshold Mode

**CAPACITIVE INPUT SETTINGS**

The AD7150 has two capacitive input channels that can be set up independently via the I<sup>2</sup>C-compatible interface. These AD7150 settings are described in this section and are valid for both channels.

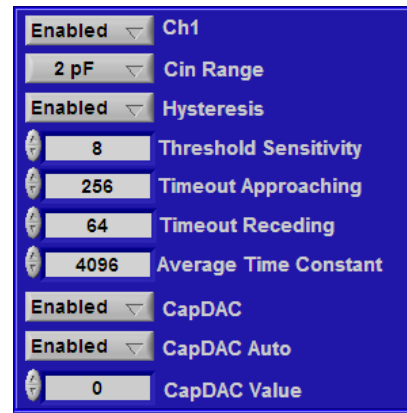


Figure 19. AD7150 Capacitive Input Setup

**Ch1, Ch2**

The Ch1 and Ch2 boxes allow you to enable or disable the capacitive input channels individually.

**Cin Range**

The Cin Range box allows you to select one of the following capacitive input ranges for each channel: 4 pF, 2 pF, 1 pF, or 0.5 pF.

**Hysteresis**

The Hysteresis box allows you to enable or disable threshold hysteresis when operating in adaptive mode. The hysteresis is fixed to  $\pm 1/4$  of the threshold sensitivity and can be programmed to be enabled or disabled.

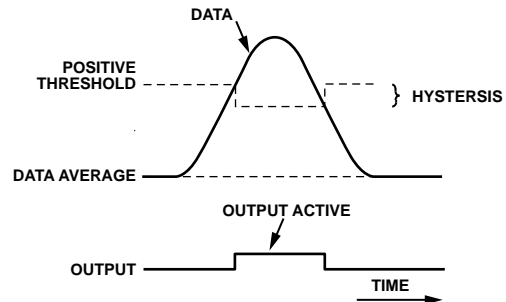


Figure 20. Threshold Hysteresis



**Threshold Sensitivity**

The **Threshold Sensitivity** box allows you to set a defined sensitivity. This is defined as the distance between the data average and the threshold in codes and is a fixed portion in the range of the lower eight bits of the 12-bit CDC full-scale range of 0xA000 codes (d40944). Therefore, it represents a different capacitive input value for each capacitive input range.

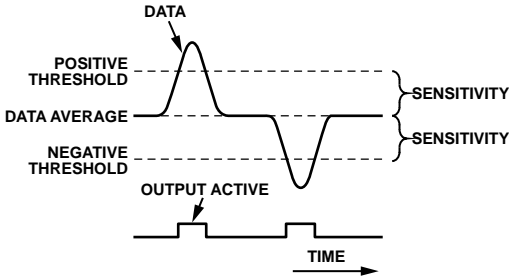


Figure 21. Threshold Sensitivity

**Timeout Approaching, Timeout Receding**

The **Timeout Approaching** box and **Timeout Receding** box allow you to set a time after which the adaptive average and the threshold adapt to a fast and seemingly permanent change in input capacitance to ensure normal operation after the event.

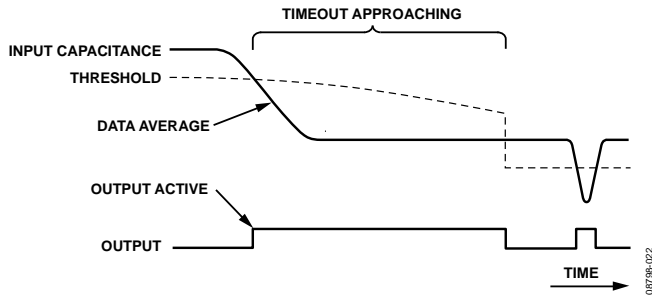


Figure 22. Approaching Timeout in Negative Threshold Mode Shortens False Output Trigger

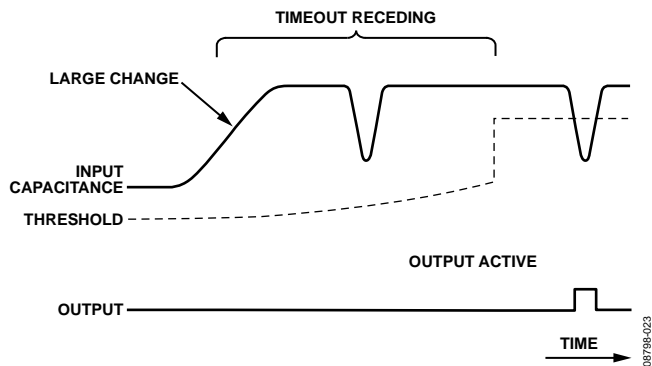


Figure 23. Receding Timeout in Negative Threshold Mode Shortens Period of Missing Output Trigger

The number of conversion cycles,  $N_C$ , required for the timeouts to elapse can be calculated using the following equation:

$$N_C = Roundup\left(\frac{2^{16} - 1}{2^{15-P+1} - 1}\right)$$

where  $P$  is the value of the register nibble.

**Average Time Constant**

The **Average Time Constant** box allows you to determine how fast the moving average adjusts to changes in the capacitive input data. The adaptive threshold algorithm is based on an average calculated from the previous CDC output data using the following equation:

$$Average(N) = Average(N - 1) + \frac{Data(N) - Average(N - 1)}{2^{ThrSettling + 1}}$$

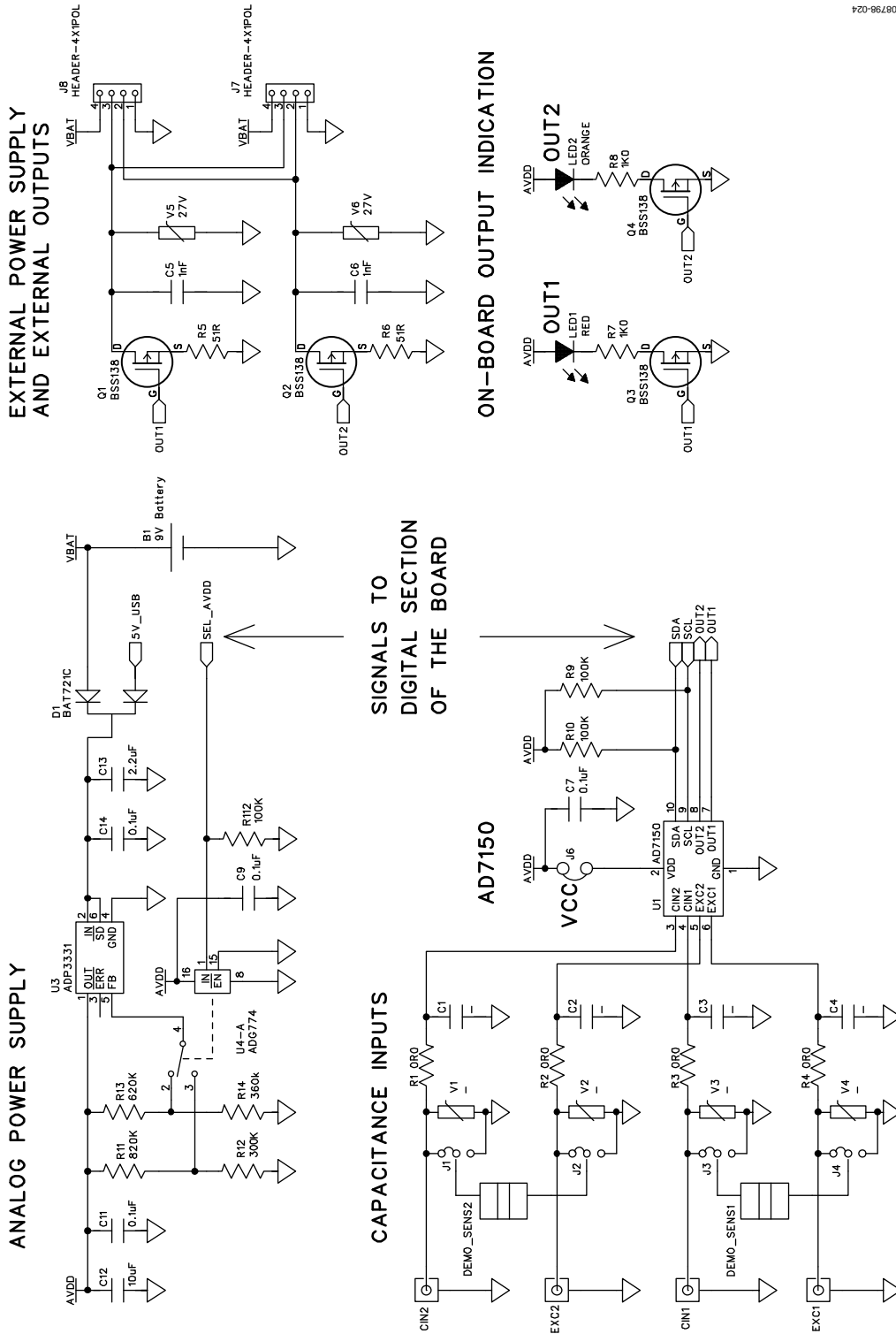
**CapDAC**

The **CapDAC** box allows you to enable the CapDACs that compensate for capacitive offsets in the input (nonchanging).

The **CapDAC Auto** box enables the auto-DAC function, which ensures that the data input stays within 25% to 75% of the selected capacitive input range.

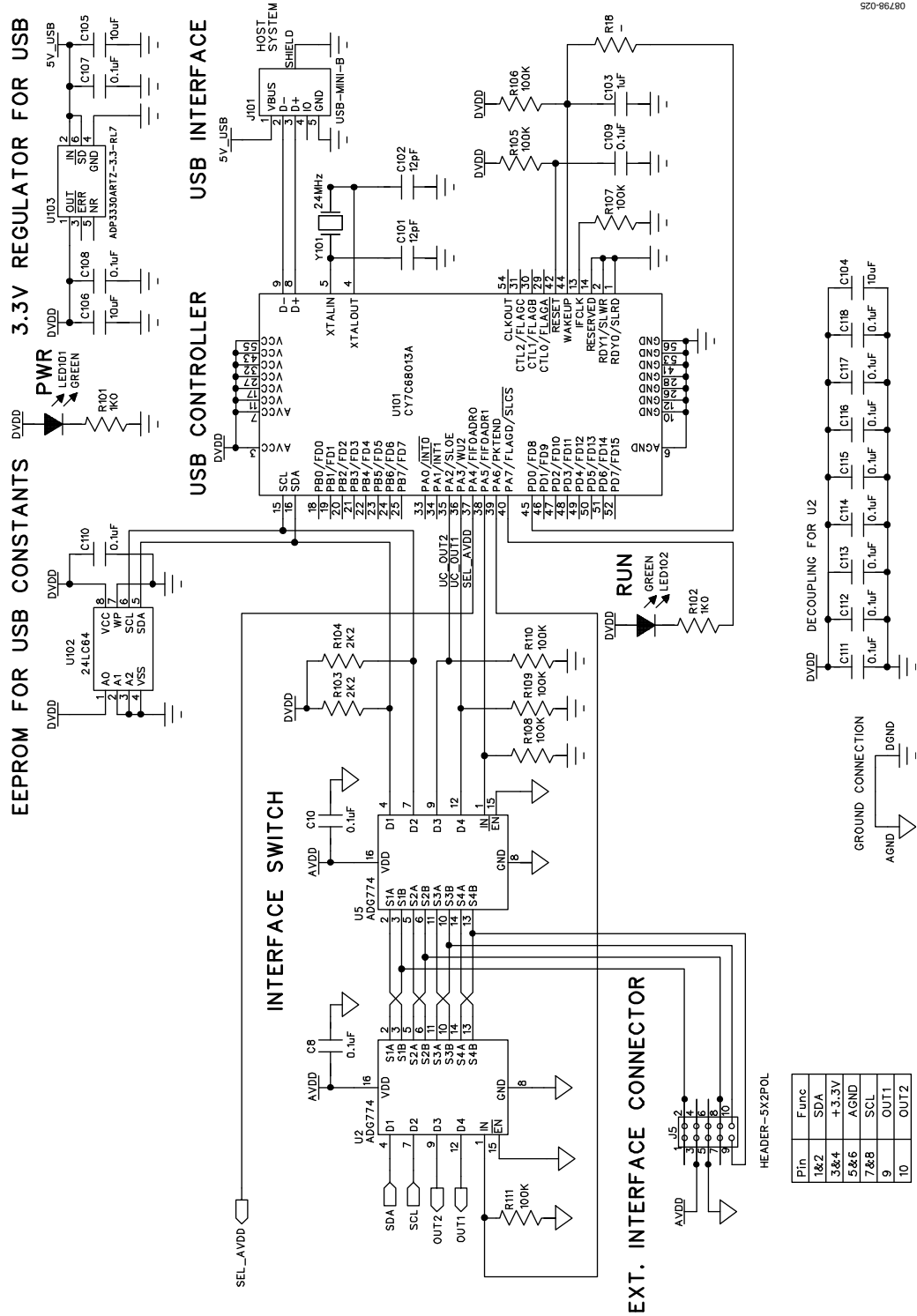
The **CapDAC Value** box contains the current CapDAC value set by the auto-DAC. This box also allows you to set the value when the auto-DAC function is disabled.

EVALUATION BOARD SCHEMATIC AND ARTWORK  
SCHEMATICS



08798-024

Figure 24. AD7150 Evaluation Board Schematic—Analog Part



S20-96L80

Figure 25. AD7150 Evaluation Board Schematic—Digital Part

COMPONENT ID

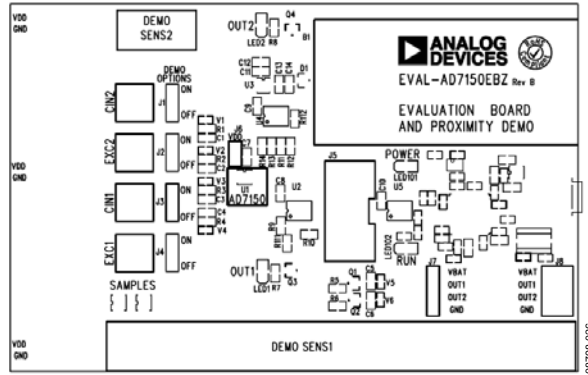


Figure 26. AD7150 Evaluation Board Layout—Silkscreen

LAYOUT

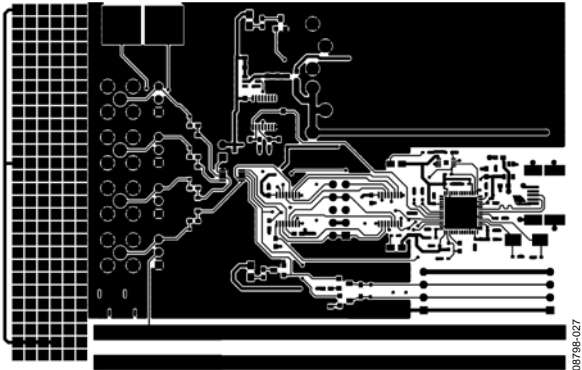


Figure 27. AD7150 Evaluation Board Layout—Component Side

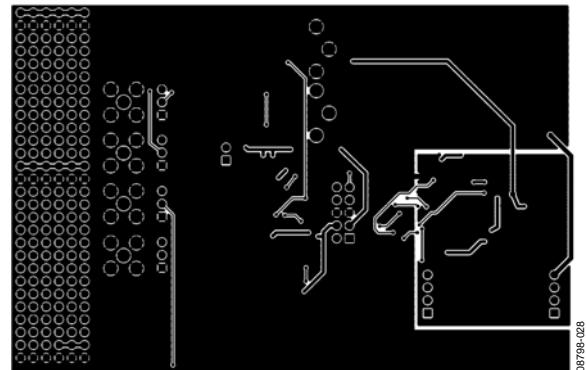


Figure 28. AD7150 Evaluation Board Layout—Bottom Side

## ORDERING INFORMATION

### BILL OF MATERIALS

Table 1. Bill of Materials

Designator	Qty.	Description	Manufacturer	Order No.
PCB	1	2-layer FR4 PCB, 1.6 mm × 75 mm × 115 mm		EVAL-AD7150EB Rev. B
U1	1	CDC for proximity sensing, 10-lead MSOP	Analog Devices	AD7150BRMZ
U2, U4, U5	3	Multiplexer, quad 2:1, 16-lead QSOP	Analog Devices	ADG774BRQZ
U3	1	Volt regulator, adjustable Voltage, low I <sub>Q</sub> 6-lead SOT-23	Analog Devices	ADP3331ARTZ
U103	1	Volt regulator, 3.3 V, low I <sub>Q</sub> , 6-lead SOT-23	Analog Devices	ADP3330ARTZ3.3-RL7
U101	1	Microcontroller, EZ-USB FX2LP, 56-lead QFN	Cypress	CY7C68013A-56LFXC
U102	1	EEPROM, I <sup>2</sup> C, 64k, 8-DFN	Microchip	24LC64T-I/MC
D1	1	Diode, 2× Schottky common cathode, 40V 0.2 A, SOT-23	NXP	BAT721C
Q1 to Q4	4	Transistor, N-MOSFET, 60 V, 0.23 A, SOT-23	Infineon	BSS138N
LED1	1	LED, red, high intensity (>100 mCd), 0805	Kingbright	KP-2012SURC
LED2	1	LED, orange, high intensity (>100 mCd), 0805	Kingbright	KP-2012SEC
LED101, LED102	2	LED, green, high intensity (>50 mCd), 0805	Kingbright	KP-2012MGC
Y101	1	Crystal, 24 MHz, 12 pF, CSM-8 series	ECS	ECS-240-12-20A-TR
V1 to V6	6	Protection component, 0402, not inserted	N/A	N/A
C1 to C4	4	Capacitor ceramic, not inserted	N/A	N/A
C5, C6	2	Capacitor ceramic, 1 nF, 50 V, X7R, 0603	Murata	GRM188R71H102K
C7 to C11, C14	6	Capacitor ceramic, 0.1 μF, 16V, X7R, 0603	Murata	GRM188R71C104K
C12, C104 to C106	4	Capacitor ceramic, 10 μF, 6.3 V, X5R, 0603	Murata	GRM188R60J106M
C13	1	Capacitor ceramic, 2.2 μF, 16 V, X5R, 0603	Murata	GRM188R61C225K
C101, C102	2	Capacitor ceramic, 12 pF, 50 V, COG, 0402	Murata	GRM1555C1H120J
C103	1	Capacitor ceramic, 1 μF, 6.3 V, X5R, 0402	Murata	GRM155R60J105K
C107 to C118	12	Capacitor ceramic, 0.1 μF, 16 V, X7R, 0402	Murata	GRM155R71C104K
R1 to R4	4	Resistor, 0.0 Ω, 0603	Phycomp	232270296001
R5, R6	2	Resistor, 51 Ω, 1%, 0603	Phycomp	232270465109
R7, R8	2	Resistor, 1.0 kΩ, 1%, 0603	Phycomp	232270461002
R9, R10, R111, R112	4	Resistor, 100 kΩ, 1%, 0603	Phycomp	232270461004
R11	1	Resistor, 820 kΩ, 1%, 0603	Vishay	CRCW0603 820k 1% 100 ET1
R12	1	Resistor, 300 kΩ, 1%, 0603	Vishay	CRCW0603 300k 1% 100 ET1
R13	1	Resistor, 620 kΩ, 1%, 0603	Vishay	CRCW0603 620k 1% 100 ET1
R14	1	Resistor, 360 kΩ, 1%, 0603	Vishay	CRCW0603 360k 1% 100 ET1
R101, R102	2	Resistor, 1.0 kΩ, 1%, 0402	Phycomp	232270671002
R103, R104	2	Resistor, 2.2 kΩ, 1%, 0402	Phycomp	232270672202
R105 to R110	6	Resistor, 100 kΩ, 1%, 0402	Phycomp	232270671004
J1 to J4	4	Jumper, 2-way, pitch 2.54 mm	FCI	68786-202LF
J1 to J4	4	Header, straight, pitch 2.54 mm, 1 × 3-pin	Harwin	M20-9990346
J5	1	Header straight, pitch 2.54 mm, 2 × 5-pin	Multicomp	MC9A12-1034
J6	1	Header, straight, pitch 2.54 mm, 1 × 2-pin	Harwin	M20-9990246
J7	1	Header, straight, pitch 2.54 mm, 1 × 4-pin	Harwin	M20-9990446
J8	1	Connector, screws, pitch 2.54 mm, 4-way	Phoenix Contact	1725672
J101	1	Connector, USB mini-B, SMD	Molex	54819-0578
CIN1, CIN2, EXC1, EXC2	4	Connector, SMB 50 Ω, PCB straight	Amphenol	SMB1251B1-3GT30G-50
B1	1	Clip for 9V battery, PCB mounting	Keystone	593+594
	4	Feet, stick-on, diameter = 9.5 mm, height = 3.8 mm	3M	SJ5306TRANS

**NOTES**

**NOTES**

## NOTES

Purchase of licensed I<sup>2</sup>C components of Analog Devices or one of its sublicensed Associated Companies conveys a license for the purchaser under the Philips I<sup>2</sup>C Patent Rights to use these components in an I<sup>2</sup>C system, provided that the system conforms to the I<sup>2</sup>C Standard Specification as defined by Philips.

**ESD Caution**

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

**Legal Terms and Conditions**

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.