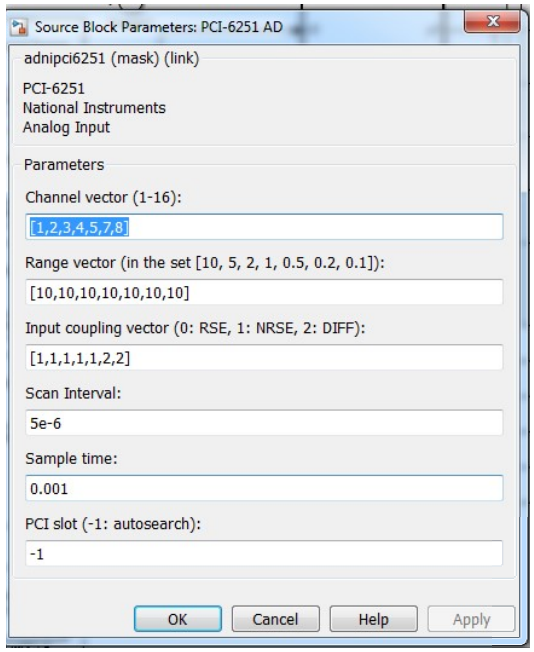

Figure 76: Parameters for Inputting Analog Signal to DAQ from Potentiometers.

The analog input block will provide a dialog box like the one shown in Figure 76 that allows the appropriate channels, voltage range, and type of signal (differential, referenced to ground) to be set. In this case, voltage range was set to max at 10V as each potentiometer is powered by a 12V source, and potentiometers were all referenced to a common ground separate from the internal ground provided in the DAQ card. The last two channels correspond to analog signals from the button load cells used for passive evaluation, and were set as a differential signal. Separate blocks were given for each digital input, where input channel and sample time were specified.

2.2. Low Pass Filter:

This block handles filtering of the analog signals by applying a minimum-order FIR filter with a cutoff frequency of 2 Hz. Normal limb movements should not exceed 2 Hz, so applying the cutoff this low is reasonable in order to attenuate as much noise as possible. Stopband frequency was set at 5 Hz, with an attenuation of -60 dB. Though this may seem excessive, it was experimentally found that these settings provided the best signal to noise ratio without degrading the signal of interest.

2.3. Volt to Degree Conversion:

This block houses a function script that performs a mathematical unit conversion from the raw signal input to a usable angular measurement. This relationship was found experimentally, and was integrated as part of the calibration of sensors prior to testing. During calibration, the robot is placed in an orientation that has been predetermined as the “zero” position for each potentiometer, and the corresponding voltages are noted in the script as the relative zero for each joint. The relationship between voltage and angle is created by the voltage difference observed along two lines creating a 25° angle. A volts/degree factor is created and is used as the divisor for the difference between the read voltage and relative zero for each joint. The calculation for the elevation joint requires an extra step, as "zero" position places this joint as a slight angle. This angle was calculated mathematically as 5.6932°, and the relative zero for this joint is set relative to this. Performing the conversion for the linear string potentiometer used a simpler process, as the fully retracted position is the relative zero, while a volts/distance factor is determined based on the voltage difference over the known distance between the fully extended and fully retracted states.

2.4. Forward Kinematics:
This block provides the conversion that takes the angular position of each potentiometer and mathematically calculates the Cartesian position using the Denavit-Hartenberg convention. This convention represents each joint using a set of four basic transformations that feature a pair of rotations and a pair of translations in order to move to the next joint. Each homogenous transformation is multiplied with the other transformations in order to express the end effector position. Refer to section 3.6.3 to see the generation of expressions used for the orthosis.

2.5. Filtered Derivatives / Velocity Out:
The filtered derivatives take the angular orientation determined by the motor encoders for the actuated joints of the orthosis, and extract the instantaneous velocity for these joints. This information is utilized within the mapping subsystem. A discrete IIR filter is applied first, configured using the *fdatool* command in Matlab, with a cutoff frequency of 10 Hz. The discrete derivative blocks apply the derivative following the filter to create the final velocity output.

2.6. Real Time Displays:
This subsystem simply acts to display the real-time position and orientation values while running the model. This is most useful during the calibration steps to make sure the displayed position is in line with the position of the orthosis. These displays can also be useful in diagnosing faulty sensor readings, or monitoring whether or not proper compensation is being applied at the actuated joints.