A VARIABLE CAPACITANCE TOUCH SENSOR*

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Tactile feedback is useful in performing many robot manipulator tasks. This paper describes the simple touch sensor used on the robot manipulator at the Coordinated Science Laboratory. This sensor has a range of 1 to 80 ounces with a resolution of about 0.2 ounces at the low end of the scale. It is inexpensive, easy to construct, and relatively free of hysteresis, drift and fatigue. Also, the output is inherently digital, which aids in interfacing to a computer controller.

The sensor consists of a variable capacitor which controls the frequency of an oscillator. The output of the oscillator is connected to a simple 8-bit frequency counter which can be read by a computer, or fed into a D/A converter. The variable capacitor consists of two parallel plates constructed from copper clad glass-epoxy printed circuit board stock. The two plates are separated by a 3/32" thickness of plastic foam. One plate is rigidly affixed to the robot manipulator, and the other to a movable finger tip. Applying a force to the finger tip compresses the foam which reduces the distance between the plates increasing the capacitance.

The oscillator circuit is constructed from two TTL monostables and generates a train of fixed 230 nanosecond pulses separated by 300 to 550 nanoseconds, as determined by the variable capacitor. A preloaded down counter is used to count the pulses during a fixed time period. Therefore, a higher pressure (lower frequency) will result in a higher number in the counter.

Sensor readings from 20 to 220, which correspond to from 3 to 90 ounces of force, may be read directly. However, error in the frequency counter causes successive readings to Jitter by plus and minus 4 counts. By reducing this jitter with a simple digital filter, the range is extended downward to one ounce with a resolution of 0.2 ounces. Figure 1 shows a plot of force as a function of touch sensor reading. Plot A was made after the touch sensor had been idle overnight. Plot B was made after several minutes of use. The differences between these plots is due to fatigue in the plastic foam. Figure 2 shows the same data as Figure 1 except that the log of the force is plotted. The relationship between the touch sensor reading and the force applied is approximated by:

$$x = 63 \, (\ln(F) - 1)$$

where F is the force applied and x is the touch sensor reading.

The recent advances in hybrid circuit fabrication would indicate that an array of very small capacitors might be constructed to provide a shape-sensitive touch sensor. Finding a material which acts as a compressible insulator may be a problem, but connections to an LSI oscillator/frequency counter should be straightforward.

The touch sensor is used in a software servo loop to control the closing force of the CSL robot manipulator hand. Using this device, delicate tasks such as handling *eggs* and squeezing and releasing a plastic bottle without dropping it, are possible with very little programming effort.

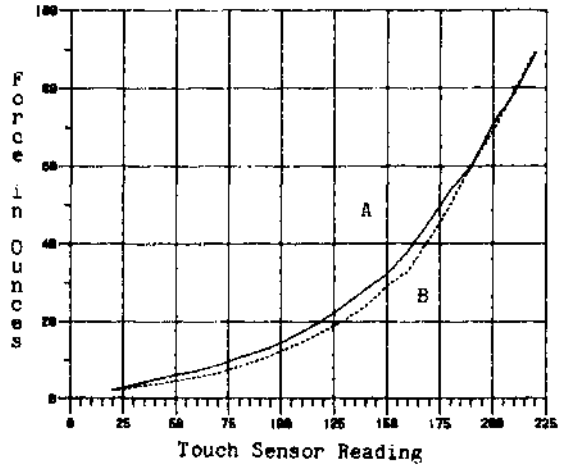

Figure 1. Force vs. Touch Sensor Reading

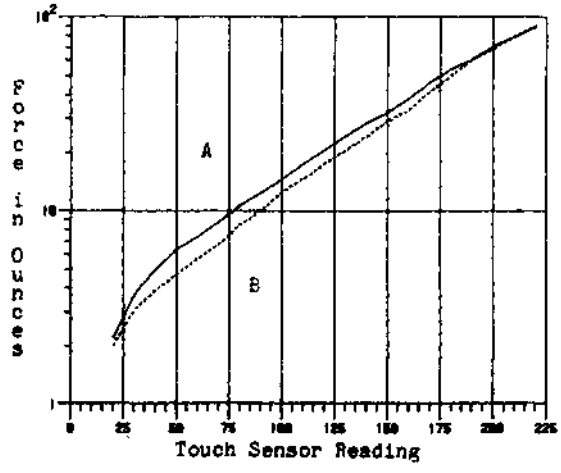

Figure 2. Log of Force vs. Touch Sensor Reading

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