# SONIK SPRING

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## ABSTRACT
The Sonik Spring is a portable and wireless digital instrument, created for real-time synthesis and control of sound. It brings together different types of sensory input, linking gestural motion and kinesthetic feedback to the production of sound.

The interface consists of a 15-inch spring with unique flexibility, which allows multiple degrees of variation in its shape and length. The design of the instrument is described and its features discussed. Three performance modes are detailed highlighting the instrument's expressive potential and wide range of functionality.

## Keywords
Interface for sound and music, Gestural control of sound, Kinesthetic and visual feedback

## 1. INTRODUCTION
A spring is a universal symbol for oscillatory motion and vibration. Its power stems from being an object whose shape, length, motion, and vibrating kinetic energy, can be easily felt and modified. The popular Slinky® is an example of such an object. As an interface, the Sonic Spring departs from the simplicity of the slinky. It too can be compressed, expanded, twisted or bent in any direction, allowing the user to combine different types of intricate manipulation.

The novelty of the Sonik Spring lies within the unique malleability of its coils. They provide well-balanced resistance, triggering a muscle feedback response that lends a strong sense of connectedness with the person who plays it. This rapport mimics a key quality found in acoustic instruments that enables the interface to become a responsive musical device [1], [2], [3].

Holding and playing the Sonik Spring is meant to feel as if one is sculpting sound in real time. The continuous change in the interface's physicality, induced by arm/hand/wrist motions, overall gestures, and visual cues, are all directly translated into a strongly grounded sonic narrative [4], [5].

## 2. RELATED WORK
Research in kinesthetic perception reveals force feedback as a stimulus deeply rooted into the human cognitive system [6], [7]. An example of an early interface that explored force feedback is the Harmonic Driving [8]. It used a spring attached to a bike's handle bar to drive musical events. When bent, capacitive sensors placed on adjacent coils of the spring measured their displacement. Torsion was read as a function of the varying angle between the top and bottom of the spring, using a potentiometer attached to its base.



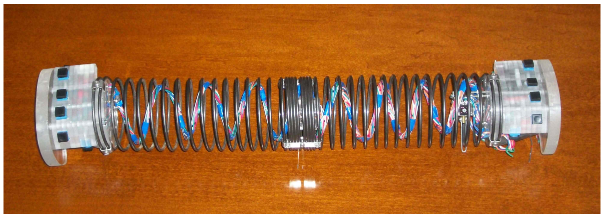

**Figure 1.** Sonik Spring

More recent experiments with force feedback include controllers such as the Sonic Banana [9] and the G-Spring [10] The Sonic Banana uses four bend sensors linearly attached to a 2-foot long flexible rubber tube. When bent it maps the data from the sensors to sound synthesis parameters. The G-Spring, features a heavy 25-inch close-coil expansion spring, and uses light-dependent resistors to measure the amount of light that slips through the coils when they are bent.

The Accordiatron is a controller based on the paradigm of a conventional squeezebox [11], featuring a collapsible linkage mechanism and edges that can rotate to capture motion in two perpendicular axes, using potentiometers as sensing elements.

**Figure 2.** Extending the Sonik Spring

The Sonik Spring takes accelerometers and gyroscopes to measure complex spatial motion. The interface offers great physical flexibility, since the spring can be easily manipulated to vary its length, shape, and orientation. The Sonik Spring is portable, wireless, and comfortably played using both hands. All of the above characteristics make it a friendly, performable, "human-scaled" instrument.

# 3. DESIGN

## 3.1 The Interface

Choosing a spring with the right force feedback resistance was paramount to this project. The goal was to get a spring that could be *both compressed and extended* and that could provide an ideal amount of force feedback pressure when changing its length.

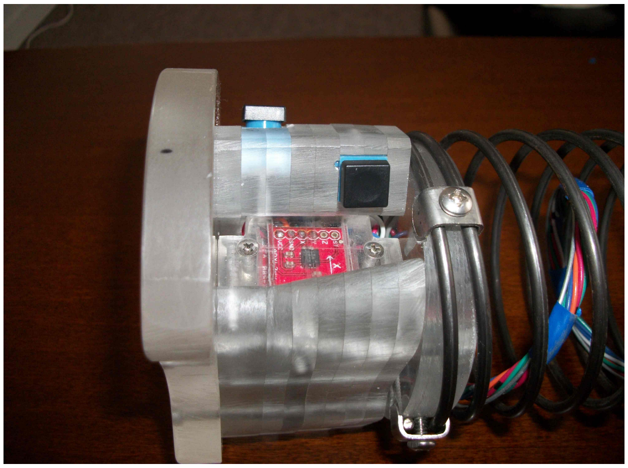

**Figure 3.** LH Controller: Accelerometer and thumb button

The Sonik Spring features a coil with an unstrained length of 15-inches and a diameter of 3-inches. The spring extends to a length of 30-inches, and when fully compressed shrinks down to 7-inches. It therefore allows a length variation from roughly half its size to exactly twice the length. These proportions cover a 4:1 ratio and prove to be uniquely intuitive when applying mappings of the spring's varying length to simple linear changes in musical parameters. The spring attaches at both ends to hand controller units made of plexiglass. Each unit houses the orientation sensors and five multi-purpose push buttons.

## 3.2 Sensing Motion

The Sonik Spring has three groups of orientation sensors: one in each of the hand units, and one at its middle. Each group consists of a 2-axis accelerometer to detect pitch and roll, and a 1-axis gyroscope to detect yaw.

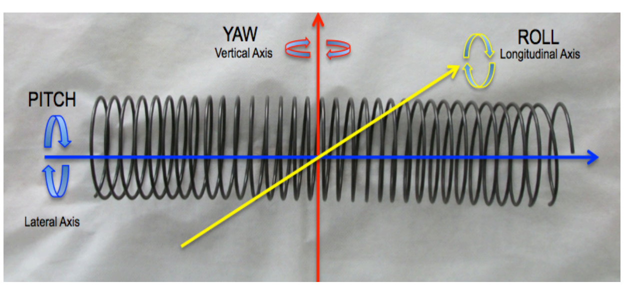


**Figure 4.** Spring's three axes of rotation

The amount of expansion or compression of the spring is measured using a small joystick built into the right-hand controller unit. The joystick's shaft was lengthened to allow it to reach and sit tightly against one of the spring's coils. Changing the spring's length forces the shaft of the joystick to move accordingly, giving an accurate and virtually latency free measure of the overall length variation.

The five push buttons are symmetrically placed in each hand controller unit. The buttons perform multiple tasks, from tape-like transport functions, to routing the data from the sensors to be processed.

## 3.3 Sonik Spring: A two-spring mass system

Since a group of sensors were placed in the center of the spring they make up for a small weight, behaving as a mass in a classic spring-mass system. This arrangement offers the possibility to generate oscillatory motion of this center mass by shaking the spring either longitudinally or transversely, with different force amounts. In the Sonik Spring, the center weight acts upon both halves of the spring, turning the interface into a two-spring mass system, with both halves having similar spring constants.

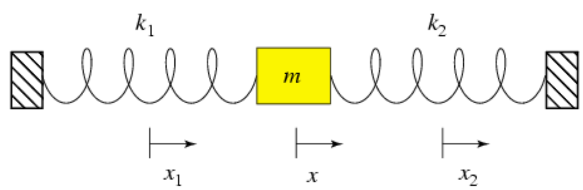


**Figure 5.** Two-spring mass system

When the mass *m* is displaced the distance *x,* it extends the 'first' spring the distance x1, pulling it with a force in the –x direction. As a result, the 'second' spring is compressed the distance x2, pushing with the same force, also in –x direction. Because the two halves of the Sonik Spring have the same spring constant, (k1=k2), the amount of extension x1 equals the compression x2. The equation of motion and the frequency of the mass oscillation is then calculated as follows:

$$ma = F \qquad ma = -kx$$

$$ma = -k1x - k2x = -(k1 + k2)x$$

$$k1 = k2$$

$$ma = -2kx$$

$$a = -(2kx)/m$$

$$\omega = \sqrt{2k/m}$$

$$T = 2\pi\sqrt{m/2k} \Rightarrow f = 1/2\pi\sqrt{m/2k}$$

**Figure 6.** Two-spring mass system equation

The accelerometer and gyroscope placed in the center of the spring are used to measure the rate of oscillation of the mass of the system. The displacement of this mass and the cyclic way the rings compress and extend is visually very apparent. This quality suits the interface to being used rhythmically, in a very tangible way.

## 3.4 Gathering the Sensor Data

A MIDItron™ wireless transmitter placed within the right hand controller collects the information from the ten analog sensors and ten digital buttons [12]. The analog sensor data is formatted as MIDI continuous controller messages, and the on-off states of the buttons, as MIDI note-on and note-off messages. All the information is sent to a computer running the MaxMSP software, which does all the data processing.

# 4. PLAYING THE SONIK SPRING

The Sonik Spring can be used in different ways. Three relevant 'performance modes' have been identified. These are: Instrument mode, Sound Processing Mode and Cognitive Mode.

## 4.1 Instrument Mode

In *"Instrument mode"* the Sonik-Spring is played as a virtual concertina. In its current implementation the instrument can either use a MaxMSP patch that controls the generation of sounds based on a physical model of an air-driven vibrating reed [13] [14] [15], or it can process the sensor data sending it via MIDI to commercial hardware and software synthesizers.

To play the Sonik Spring the performer holds it horizontally, with both hands, comfortably grabbing the instrument. The sensors of the left hand unit trigger the generation of chords while those of the right hand generate melodic material.

The motion of pulling and pushing the spring emulates the presses and draws of virtual bellows using the tone generation technique of an English concertina. The amplitude of those gestures is mapped to the loudness of the sound.

**Figure 7.** Complex manipulation of the spring: S-shape

The accelerometer and the five push buttons of the right hand unit are combined to generate the melodic material. This is accomplished using fingers index through pinky, to access 4 buttons that borrow the pitch generating method of a 4-valve brass instrument, allowing the production of the 12 chromatic tones within an octave. Changing the springs' 'pitch' by rotating it in the lateral plane maps the accelerometer data to select the desired pitch-octave, triggered by pushing the button assigned to the right hand thumb. A total of 6 octaves can be comfortably selected. Melodically, the Sonik Spring can thus simulate an instrument with 72 air-blown free reeds.

Pitch bend and glissandi effects are done by mapping changes in roll and yaw using the right hand's accelerometer and gyroscope, respectively.

Chords are generated using the five push buttons, the accelerometer and the gyroscope of the left hand controller. The software that generates the chords is based on the author's work implemented in the wind controller META-EVI [16].

**Figure 8.** Spring bent downwards: Inverted U-shape

Changes in the timbre of the sound produced by the physical model are obtained by mapping a series of gestural motions into synthesis and control parameters. A vocabulary of a small group of such gestures has been implemented and it has proven to be a simple and effective way to correlate visual to auditory information [17] [18].

a) Twisting the hand units symmetrically in opposite directions and with the same force to map changes to Filter Cutoff frequency
b) Twisting the hand units symmetrically in opposite directions while bending the spring down to map both Filter Cutoff *and* Resonance
c) Bending the spring so that it defines a "U" shape mapping that shape to LFO rate, acting on the pitch being played
d) Bending the spring so that it defines an inverted "U" shape, mapping it to LFO amplitude
e) Bending the spring so that it defines an "S" shape, mapping it to Amplitude Modulation

## 4.2 Sound Processing Mode

The Sonik-Spring works as a controller for real-time sound processing too. It uses a granular synthesis engine to playback and process sounds stored in memory [19].

The most immediate use of the spring's ability to change sound is to simply vary its length. Mapping length to classic pitch transposition, where both pitch and tempo are simultaneously altered, is very engaging. Other powerful mappings of the spring's length include changes in loudness, and freezing sound playback to explore scrubbing effects. Mappings of the accelerometer data in the right hand unit include the independent control of a sound's pitch and playback speed, by respectively varying the spring's 'pitch' and tilt. Also in the right hand unit, the gyroscope detects the spring's yaw and performs panning changes.

The five buttons serve to trigger sounds, forward or backwards, as well as stop, pause, mute, and loop audio playback, with the option of selecting variable loop start and end points.

The sensors of the left hand perform additional functions, such as controlling grain duration and randomization of sample playback. They are also used to affect parameters that perform amplitude modulation and filtering.

### 4.3 Cognitive Mode

An interesting and useful use of the Sonik Spring is as a tool to test different sensorial stimuli. At an immediate and simple level, it can be used to gauge an individual's upper limbs muscle and force responsiveness by directly linking variations in a sound's parameter such as pitch or loudness, to variations of the spring's length.

A more complex approach to study an individual's level of cognitive perception can be done by simultaneously linking auditory, visual, spatial and force feedback. This last scenario is especially promising to medically assess individuals with neurological challenges [20].

## 5. CONCLUSIONS AND FUTURE WORK

The Sonik Spring is a versatile instrument and an interface that is *fun* to play with. Interactive demos show that the *Sample Processing Mode* is the most popular performance mode.

Using the instrument as a virtual concertina is also musically rewarding. The interface is agile, responsive and highly expressive allowing the user to develop performance skills that could reach virtuosity.

A growing interest in the use of the interface in Cognitive Mode is also evident. Collaborations with researchers in the medical field are planned.

Future work will focus on combining the data from all sensors so as to apply "many-to-one" mapping strategies. This will be useful for the control of synthesis parameters when the instrument is being played with a physical model, increasing the high level of feedback that it already conveys. More research is also planned to continue exploring the two-spring mass system. Of relevant interest is the inclusion of user generated oscillatory motion to affect synthesis parameters of the physical model being used to generate sound.

## 6. ACKNOWLEDGEMENTS

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