

The intention of this document is to highlight the considerations that went into the technical, spatial, temporal, and aesthetic composition of the piece. Therefore, this text can be considered as a form of notation that serves to document the realization of this installation.

push-pole can be installed in two modes of presentation: fixed-frequency mode and compositional mode

*fixed-frequency* mode uses a custom-designed all-analog circuit to convert magnetic fields into sound with the frequencies of oscillation being set manually by the user. - 16 audio channels at 1 W

*compositional mode* uses computer processing to apply realtime frequency contours to the oscillators and as such, the frequency content changes over time. - 4 audio channels



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### About *push-pole*

*push-pole* (2014) is a physical system that focuses on the interplay of agonistic forces involved in the transduction of energy into movement, movement into sound. Sound and movement are produced from the interplay of 16 high powered magnets. This installation reveals the system behavior of coupled oscillators in both sound and motion while exposing the emergent, non-linear phenomena of its response.

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*push-pole* explores the perception of momentum as a restoring force: as energy is transferred into the system (via motors), the response of the system is made visible/audible as it envelops over time and space. As each hanging magnet is coupled to the others in the same structure, their behavior is governed by the dynamics of coupled oscillations in both kinetic motion and sound. Oscillations are at once the most basic and critical part of our physical world. They account for both the motional behavior governing the swinging magnets (e.g. pendula) and for the waveform that accounts for each independent oscillator (sine and triangle waves). The magnetic field of each hanging magnet is picked up by a hall effect sensor affixed to a structure on the floor. This sensor's signal forms a voltage controlled amplifier (VCA) with a host circuit that controls the 'volume' (amplitude) and frequency of the oscillation and how it changes with respect to time. A separate timing circuit controls when the motors kick energy into the hanging structures.



## material specifications

structural rods (4): 60" steel pipes of 0.5" diameter

 $clip \ lights \ (4) \ use \ 15 \ W \ incandescent \ bulbs$ 

The *motor circuit* is controlled by *arduino Uno*<sup>®</sup> microcontroller and a custom built motor driver (see electronic circuit sections).

The compositional mode uses an arduino MEGA® microcontroller for 16 input Analog

#### power specifications

All analog circuits (fixed-frequency mode) draw a nominal 30 mA and at peak output power draw approximately 0.5 A.

The DC motor circuit requires a separate +12 V supply. Each motor pulls  $\approx 400$  mA at 12 V but they can spike to nearly 1 A during impulse triggers. For optimal operating conditions, use a +12 V source capable of delivering 4 A.

# Hanging Magnet + Sensor Rod Lengths

ceiling



#### installation layout\*\*: compositional mode



notes:

DC Motor\* wiring is across the ceiling Structure [1] audio --> monitor 1 Structure [2] audio --> monitor 2 Structure [3] audio --> monitor 3 Structure [4] audio --> monitor 4

\*\**installation orientations*: the modularity of the structures would allow for a multitude of possible layout orientations depending on the site-specific parameters of the installation space

## installation layout: *fixed-frequency mode*



#### Compositional Mode Overview

In compositional mode, sensor data from each of the hall sensors is sent to the A0-A15 analog inputs on an *Arduino Mega* microcontroller. Arduino processes the data with 10-bit integer precision (0-1023) with the input voltage range of 0-5 V. This data is sent to Max/MSP programming environment where it is parsed, low pass filtered, and sent to 'VCAs' within the GUI.

The Max/MSP program utilizes a basic machine-learning algorithm to set the VCAs sensitivity parameter. The sensor reading when no magnetic field is present (when the magnet is away from the sensor) is used as a baseline (reference point) from which to gauge positional deviation. From this point, the maximum and minimum values the arduino's analog input detects is updated to reflect the max/min value of the magnet when it is as close as possible to the sensor. In effect, it *learns* the range of the input sensor values. This allows for each magnet+sensor's voltage controlled amplitude to be normalized despite slight differences in magnet+sensor position (e.g. some magnets and sensors will be slightly closer/further away from one another in an actual space). The frequency values from frequency contour plots that illustrate how the oscillators change with respect to time. Please see next page.



*Max/MSP* compositional mode interface

For arduino and Max/MSP code: please visit www.nolanlem.com/installations/pushpole

In compositional mode, the frequencies of each magnet oscillator change with respect to time. This is denoted by sequential static, ramping, and concurrent frequency-motor sections.

The frequency content of the piece was determined by considering several perceptual characteristics. The static region sees the frequencies distributed over its entire range (100 --> 5 kHz) and as the piece proceeds, the oscillation frequencies narrow in spectral range to approach a frequency region that was chosen for its *otoacoustic characteristics* (2kHz-3.5kHz).

About the *Otoacoustic Frequency Region*: Distortion Product Otoacoustic Emissions (DPOAEs) are created by the simultaneous detection of two closely spaced sinusoidal frequencies. These frequencies are spaced such that they activate the cochlea in the same region of the basilar membrane. Referring to the figures below, the otoacoustic region shows a narrowing of the oscillators' frequency ranges with (quadratic) difference tones between 20Hz - 1kHz. The intended effect is an interiorized auditory "sparkling" as the amplitudes of each frequency throb in concert with the magnets' oscillatory motion. A two minute downward ramp return the oscillators to their original frequency. The next section sees frequency changes instantaneously with each motor kick (approximately 4 minutes).







### fixed frequency circuit overview

This circuit consists of three stages: a hall sensor + voltage buffer, sine wave oscillator + voltage buffer and a voltage controlled amplfier (VCA) with variable signal power gain. See Figure 2 in block diagram form below.





Figure 2: Circuit Schematic for Magnet Structure in push-pole shown in EAGLE PCB layout. note: EAGLE PCB Layout files for this circuit are available at www.nolanlem.com/installations/pushpole



Figure 3: Fabricated PCBs

#### circuit description

referring to Figure 2 on previous page:

*hall sensor* + *buffer*: A hall effect sensor (A1301/1302 Allegro Microsystems) is used to create a control voltage from (0 - 5 Vpp) to control the amplification of a variable frequency sine wave oscillator. The A1301 outputs a constant voltage of 2.5 V when no magnetic field is present. When it senses the presence of a magnetic field of a south (+B) polarity, it increases its voltage linearly with respect to the perceived magnetic field (up to Vs at 5V). A 5 V voltage regulator is used to provide power to the A1301 and draws its power from the  $\pm 12\,\mathrm{V}$ supply (Vcc). A voltage follower (unity-gain op amp, TL072) is used to separate input and output voltages. The control voltage from the A1301 is sent to an optocoupler (FOD814) where it is used as a voltage controlled resistor (VCR) to change the input resistance to pin 4 on the TDA7052A VCA IC. The nonlinear V-I curve of the FOD814 accounts for the saturation of the optocoupler diode current and results in a maximum output gain within the VCA (TDA7052A IC). Essentially, this means at some magnetic field threshold (this was found to be at a distance of about 1 square inch with respect to the magnet and the sensor position), the TDA7052A's output gain is maximized at 30 dB (normally, this pin sees resistance values between 0 an 1 M $\Omega$ ). The TDA7052A is capable of providing 1W of output power. 1W, 3" diameter speakers were used at the output to sound the oscillations.

Oscillator + VCA: The oscillation block of the circuit is centered around the Intersil ICL8038 Precision Waveform Generator (VCO). The sine wave output (pin 2) is sent to a voltage buffer before it is sent as the input signal to the TDA7052A VCA. More specifically, this portion of the circuit allows the user to set the gain floor (volume of the sound when no magnetic field is sensed, R7), the frequency (of the sine wave oscillation, R10) and the waveform adjustment (R6, to calibrate sine wave shape).

All the circuits were fabricated using EAGLE PCB Layout (http://www.cadsoftusa.com/download-eagle/freeware/) and fabricated through OSH Park (www.oshpark.com).

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#### Motor and Driver Circuit Overview



motor mechanism



2 motors mounted onto structure rod



This simple motor driver circuit uses 4 of the pwm output pins from an *Arduino UNO*. The duty cycle of the pwm outputs are integrated by the motors themselves such that the duty cycle is a function of the motors' output RPM. The arduino code employs a scheduled routine to trigger the motors 'ON' for periods of 0.75 seconds. These impulses incite motion into the hanging structures and magnet rods. The motors 'kick' randomly every 45 - 90 seconds. On average, this is the amount of time needed for the magnet rods to settle into equilibrium.