Active Control of a Vibrating String

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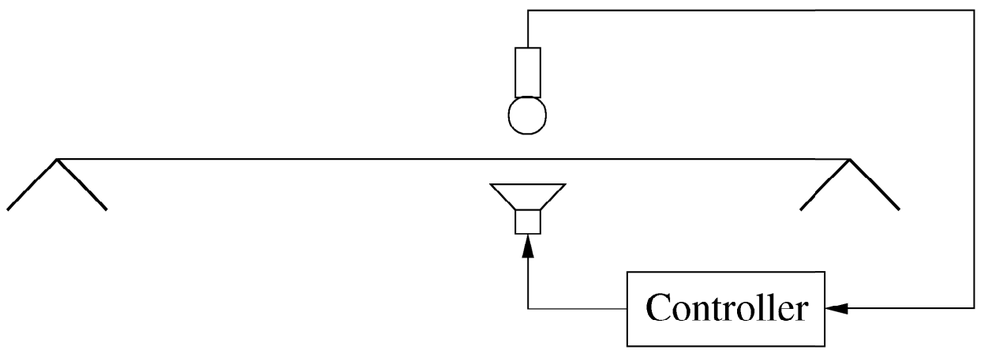
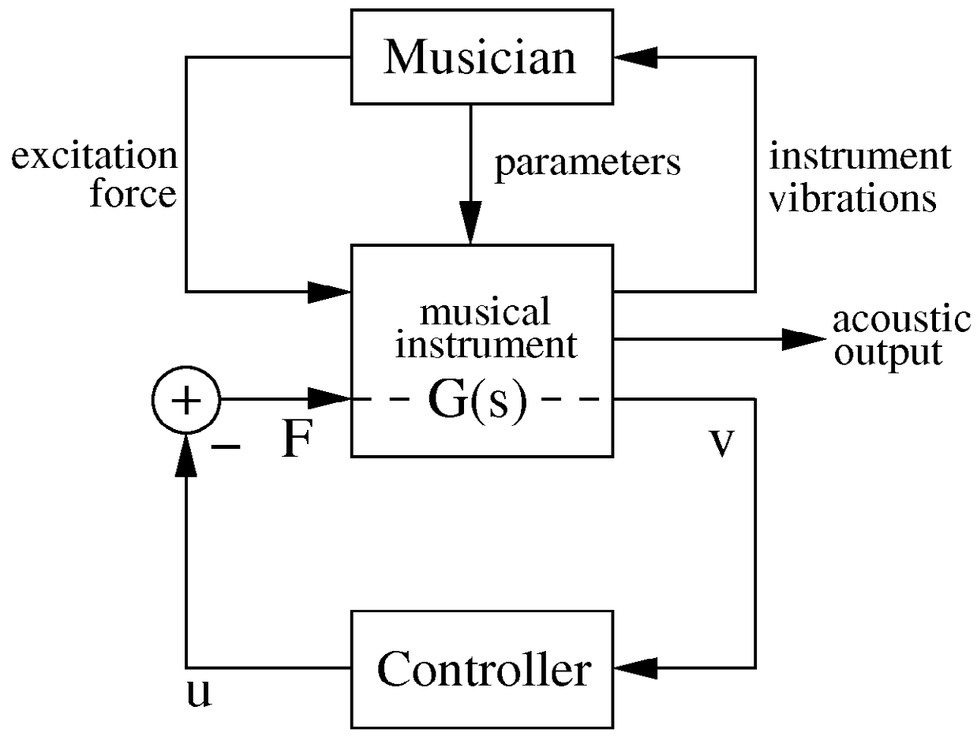
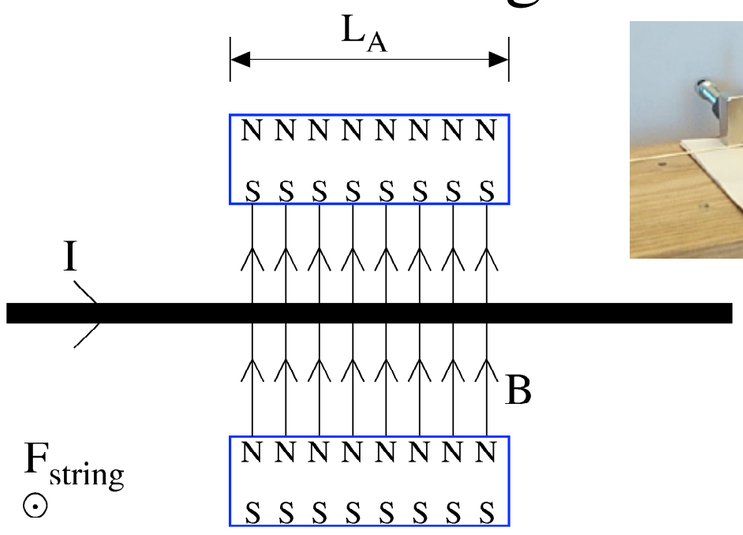
Example sounds available at http://ccrma.stanford.edu/~eberdahl/Projects/PassiveControl

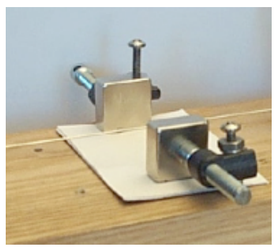
Concept





Lorentz Force String Actuator



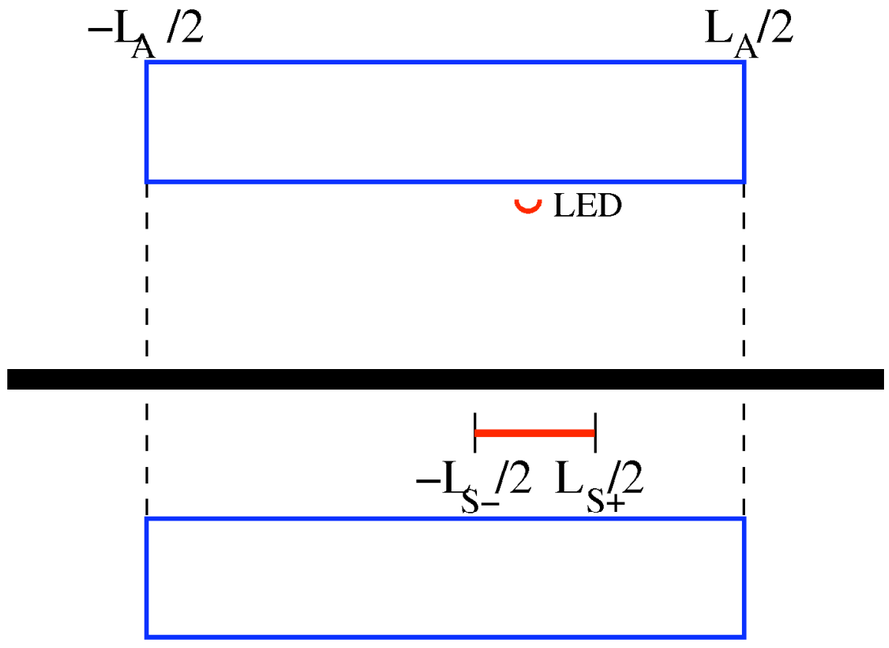


$$\mathbf{F_{string}} = L_A \mathbf{I} \times \mathbf{B}$$

Optical Displacement Sensor

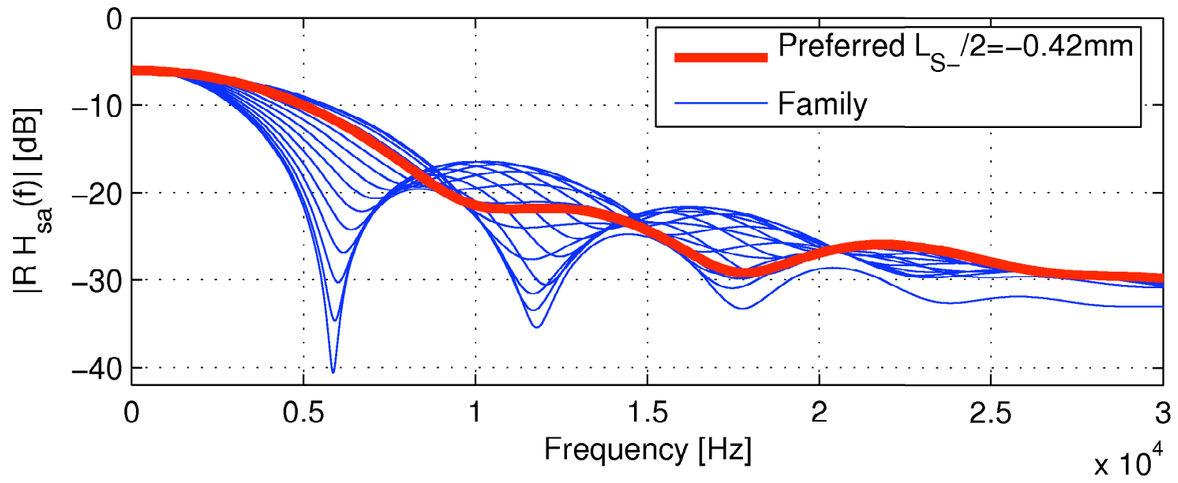
There is an affine relationship between the amount of light occlused by the string and the ***vertical*** string displacement.

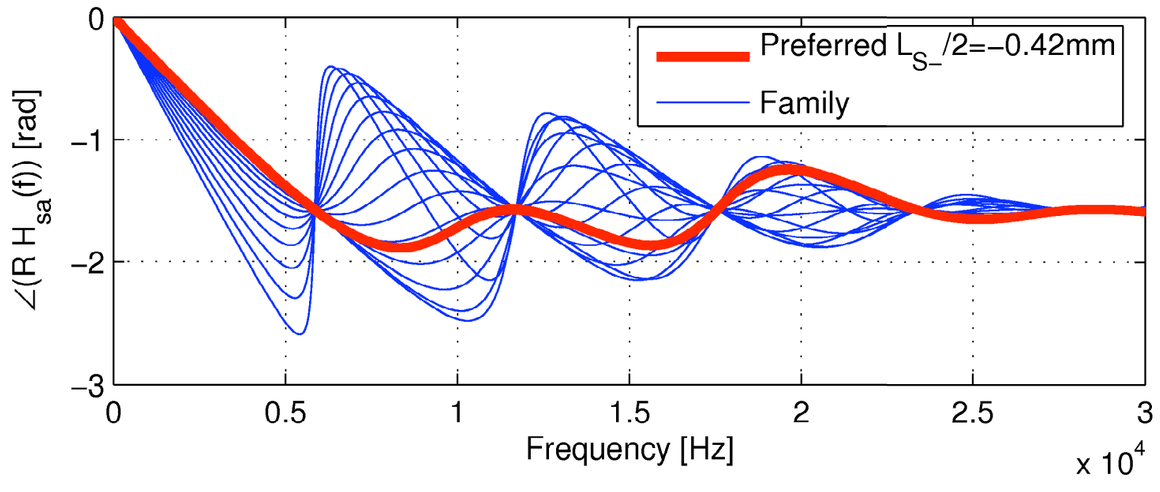
Preferred Sensor Position



$$V_{sens}(f) = \frac{1}{2R_0} \int_{w=-\frac{L_{S-}}{2}}^{\frac{L_{S+}}{2}} \int_{u=-\frac{L_A}{2}}^{\frac{L_A}{2}} \frac{1}{L_A L_S} F(f) e^{-j2\pi f \frac{|w-u|}{c}} du dw$$

To the right, we plot the generalized mobility $R_0 V_{sens}(f)/F(f)$ in blue for L_{S-} in [L_S -3L_A/4] with L_A=19mm and L_S=4mm.



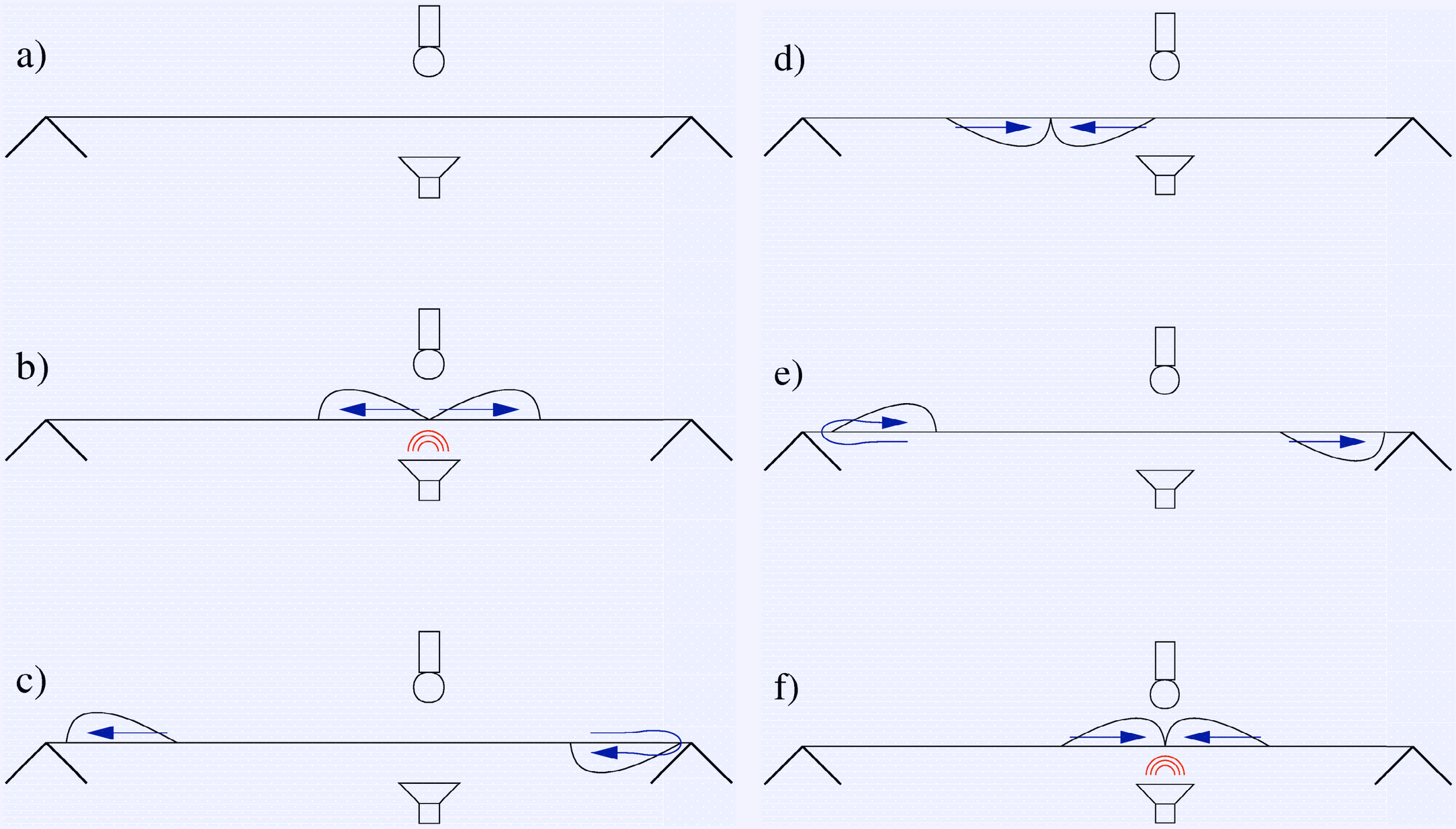


Event-Based Control Algorithm

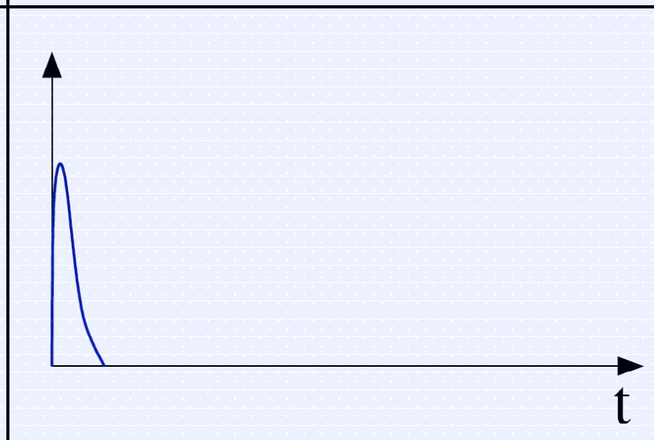
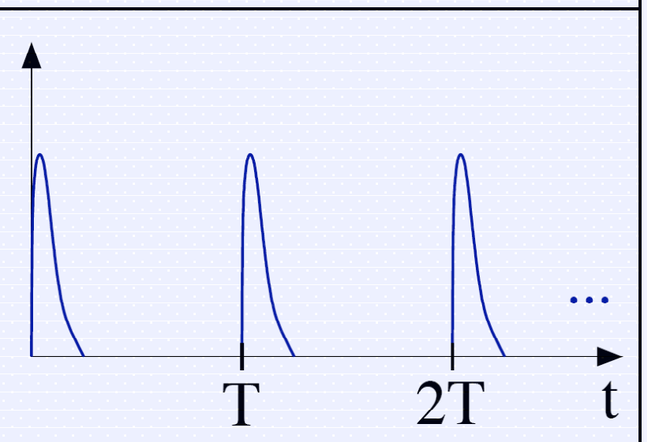
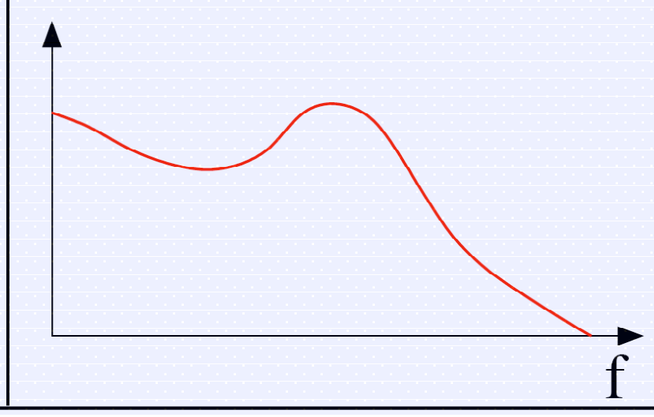
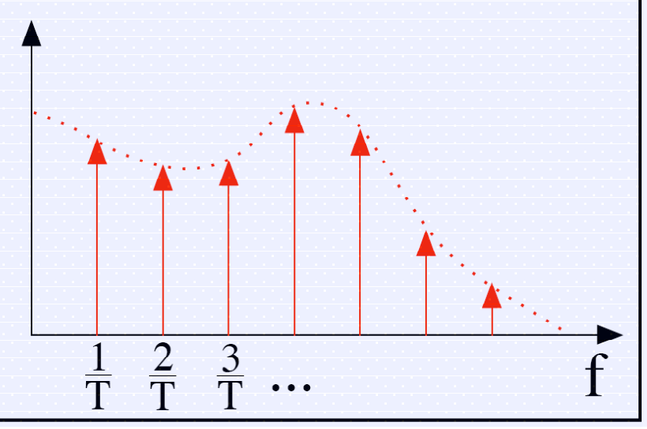
for obtaining generalized bowed string behavior

Repeat the following indefinitely:

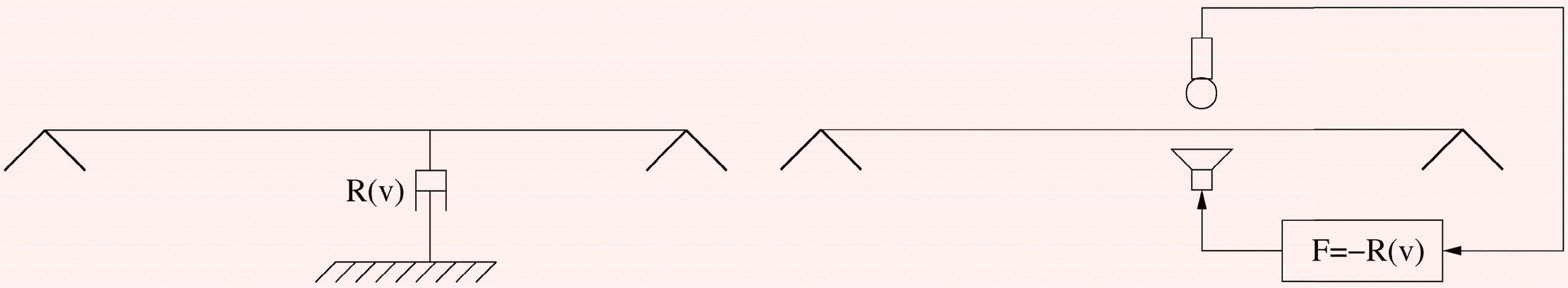
1. Wait until an event is detected (e.g. Helmholtz corner arrives).
2. Actuate the system with a predetermined pulse.

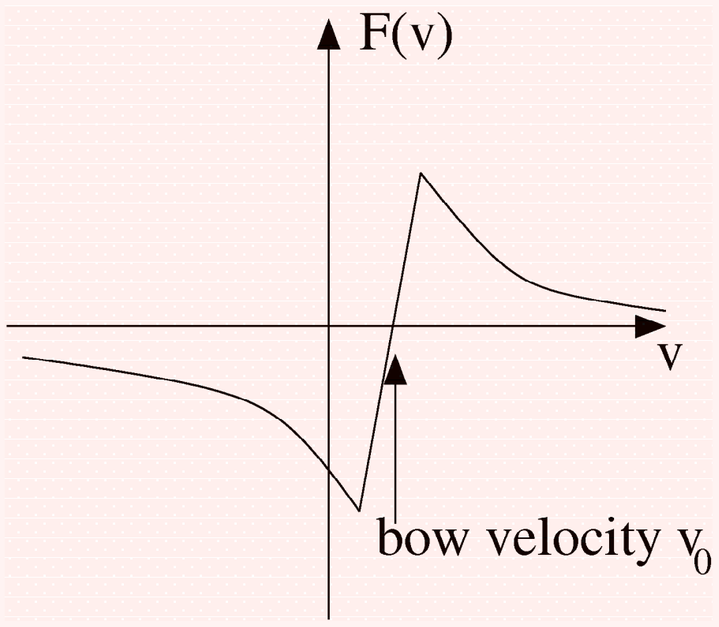


Event-Based Control Allows Control Of Spectral Envelope

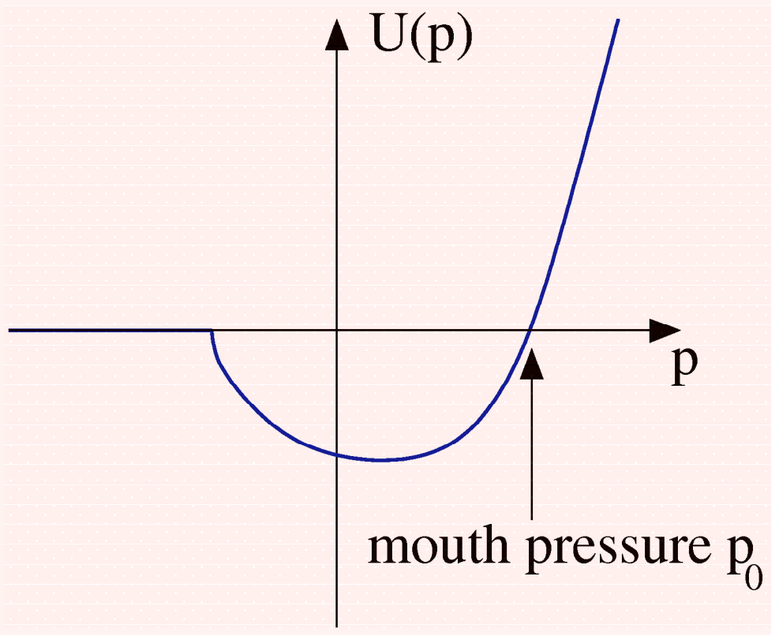
	Single Pulse	**Pulse Train**
Time-domain Representation		
Frequency-domain Representation		

Nonlinear Damper Control

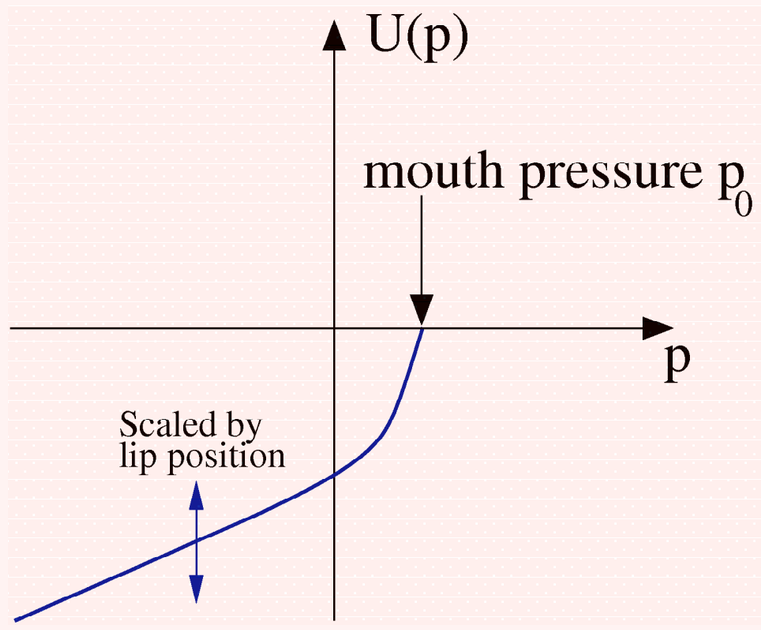




Bowed String Nonlinearity



Clarinet Reed Nonlinearity



Trumpet Player Lips Nonlinearity

Real Musical Instrument Implementation

To mitigate noncollocation effects for the higher modes we apply the bowing function to a low-pass signal approximately in phase with the velocity—a leaky integration of the displacement:

$$-\alpha \int_0^\infty x(t-\tau)e^{-\alpha\tau}d\tau$$

See also: E. Berdahl, N. Lee, G. Niemeyer, J. Smith III, *Practical implementation of low-latency DSP for feedback control of sound in research contexts*, Paper presentation #1842, SA06 - Active Noise Control: New Strategies and Innovative Concepts, Room 253, Friday July 4th 2008, 15:00.