optimizing the location, shape or number of piezoelectric patches. The disadvantage of this technique is that the final configuration of the piezoelectric material distribution is defined prior to manufacturing and thus may not be suitable for different vibration conditions during operation.

[006] Another technique used to control the vibrations on a host structure includes optimizing the location and shape of electrodes covering the piezoelectric layer, instead of the piezoelectric materials. For example, a numerical topology optimization can be used to find the best pattern, or variable porosity distributed electrodes can be used. The disadvantage of this technique is that the electrode configuration is also static.

[007] Further, controlling the vibrations on a host structure can be performed by designing shaped piezoelectric transducers or shaped electrodes with a spatial distribution based on the output response in different vibration modes, using numerical methods prior to manufacturing. However, the shapes of the piezoelectric transducers or electrodes are fixed during the design phase.

[008] Another technique to control the vibrations on a host structure makes use of a multi-channel noise or vibration control system, including those used for the active noise cancellation. The multi-channel noise or vibration control system comprises multiple piezoelectric devices, each connected to a separate vibration controlling signal, thereby achieving noise or vibration reduction over a large spatial distribution. Due to the one-to-one coupling between the actuators and vibration controlling signals, an *n*-channel vibration control system with an *n* number of actuators would require an *n* number of signal channels for vibration control. Such a technique, therefore, cannot be effectively scaled up into a highly distributed system with vastly numerous actuators since an equivalent number of signal channels may not be realistically implementable.

[009] A need therefore exists to provide a vibration control system that seeks to address at least some of the above problems.

SUMMARY

[0010] An aspect of the present invention provides a vibration control system comprising:

a plurality of spatially distributed piezoelectric transducer elements;

a switching circuit connected to each of the transducer elements;

one or more vibration control circuits configured to perform vibration control, each of the one or more vibration control circuits being connected to the switching circuit; and

a controller circuit configured to control the one or more vibration control circuits and the switching circuit,

wherein the switching circuit is configured to interconnect selected ones of the transducer elements based on a switching signal provided by the controller circuit, the switching signal being in response to a vibration condition, to adaptively form a group of interconnected transducer elements; and

wherein the switching circuit is further configured to connect the group of interconnected transducer elements to a selected at least one of the one or more vibration control circuits for receiving a single vibration control signal or electrical impedance source corresponding to the vibration condition.

[0011] The vibration control system may further comprise a sensing circuit configured to detect the vibration condition, the sensing circuit being connected to the controller circuit.

[0012] The sensing circuit may be connected to the transducer elements for receiving outputs from the transducer elements as inputs.

[0013] The sensing circuit may comprise a Boolean switch configured to be controlled by the controller circuit to connect the sensing circuit to the transducer elements only during a sensing operation.

[0014] The sensing circuit may be connected to one or more vibration sensing elements disposed on a host structure.

[0015] The sensing circuit may be connected to a sensing layer disposed on a host structure and configured to detect the vibration condition.

[0016] The piezoelectric transducer elements may comprise discrete piezoelectric devices.

[0017] The piezoelectric transducer elements may comprise a piezoelectric layer and an electrode layer, and the electrode layer may comprise a plurality of electrode segments electrically isolated from each other.

[0018] The one or more vibration control circuits may be configured to perform vibration control based on dissipation, absorption or cancellation of vibration energy.

[0019] The one or more vibration control circuits may comprise a shunt circuit and/or an active control circuit.

[0020] At least a parameter of the one or more vibration control circuits may be configurable.

[0021] The system may be encapsulated in a unitary package, and the package may comprise a flexible material.

[0022] Another aspect of the present invention provides a vibration control method comprising:

spatially distributing a plurality of piezoelectric transducer elements;

interconnecting, by a switching circuit, selected ones of the transducer elements based on a switching signal provided by a controller circuit, the switching signal being in response to a vibration condition of a host structure, to adaptively form a group of interconnected transducer elements;

connecting, by the switching circuit, the group of interconnected transducer elements to at least one vibration control circuit; and

providing a single vibration control signal or electrical impedance source corresponding to the vibration condition to the group of interconnected transducer elements.

[0023] The vibration control method may further comprise determining the vibration condition of the host structure by a sensing circuit before interconnecting selected ones of the transducer elements.

[0024] The sensing circuit may be connected to the transducer elements, and inputs of the sensing circuit may comprise outputs from the transducer elements.

[0025] Determining the vibration condition of the host structure may further comprise controlling, by the controller circuit, a Boolean switch of the sensing circuit to connect the sensing circuit to the transducer elements only during a sensing operation.

[0026] The sensing circuit may be connected to one or more vibration sensing elements disposed on the host structure.

[0027] The sensing circuit may be connected to a sensing layer disposed on the host structure and configured to detect the vibration condition.

[0028] The piezoelectric transducer elements may comprise discrete piezoelectric devices.

[0029] The piezoelectric transducer elements may comprise a piezoelectric layer and an electrode layer, and the electrode layer may comprise a plurality of electrode segments electrically isolated from each other.

[0030] The vibration control method may further comprise dissipating, absorbing or cancelling vibration energy based on the single vibration control signal or electrical impedance source provided to the group of interconnected transducer elements.

[0031] The one or more vibration control circuits may comprise a shunt circuit and/or an active control circuit.

[0032] The vibration control method may further comprise configuring a parameter of the at least one vibration control circuit.

[0033] Another aspect of the present invention provides a method of fabricating a vibration control system, the method comprising:

providing a plurality of spatially distributed piezoelectric transducer elements;

connecting a switching circuit to each of the transducer elements;

connecting each of one or more vibration control circuits to the switching circuit;

connecting the one or more vibration control circuits and the switching circuit to a controller circuit,

programming the controller circuit to control the switching circuit to interconnect selected ones of the transducer elements based on a switching signal provided by the controller circuit, the switching signal being in response to a vibration condition, to adaptively form a group of interconnected transducer elements; and

programming the controller circuit to control the switching circuit to connect the group of interconnected transducer elements to a selected at least one of the one or more vibration control circuits for receiving a single vibration control signal or electrical impedance source corresponding to the vibration condition.

[0034] The method may further comprise connecting a sensing circuit to the controller circuit, and the sensing circuit may be configured to detect the vibration condition.

CLAIMS

1. A vibration control system comprising:

a plurality of spatially distributed piezoelectric transducer elements;

a switching circuit connected to each of the transducer elements;

one or more vibration control circuits configured to perform vibration control, each of the one or more vibration control circuits being connected to the switching circuit; and

a controller circuit configured to control the one or more vibration control circuits and the switching circuit,

wherein the switching circuit is configured to interconnect selected ones of the transducer elements based on a switching signal provided by the controller circuit, the switching signal being in response to a vibration condition, to adaptively form a group of interconnected transducer elements; and

wherein the switching circuit is further configured to connect the group of interconnected transducer elements to a selected at least one of the one or more vibration control circuits for receiving a single vibration control signal or electrical impedance source corresponding to the vibration condition.

2. The vibration control system according to claim 1, further comprising a sensing circuit configured to detect the vibration condition, the sensing circuit being connected to the controller circuit.

3. The vibration control system according to claim 2, wherein the sensing circuit is connected to the transducer elements for receiving outputs from the transducer elements as inputs, and wherein the sensing circuit comprises a Boolean switch configured to be controlled by the controller circuit to connect the sensing circuit to the transducer elements only during a sensing operation.

4. The vibration control system according to claim 2, wherein the sensing circuit is connected to one or more vibration sensing elements disposed on a host structure.

5. The vibration control system according to claim 2, wherein the sensing circuit is connected to a sensing layer disposed on a host structure and configured to detect the vibration condition.

6. The vibration control system according to any one of claims 1 to 5, wherein the piezoelectric transducer elements comprise discrete piezoelectric devices.

7. The vibration control system according to any one of claims 1 to 5, wherein the piezoelectric transducer elements comprise a piezoelectric layer and an electrode layer, and wherein the electrode layer comprises a plurality of electrode segments electrically isolated from each other.

8. The vibration control system according to any one of claims 1 to 7, wherein the one or more vibration control circuits are configured to perform vibration control based on dissipation, absorption or cancellation of vibration energy.

9. The vibration control system according to any one of claims 1 to 8, wherein at least a parameter of the one or more vibration control circuits is configurable.

10. The vibration control system according to any one of claims 1 to 9, wherein the system is encapsulated in a unitary package, and wherein the package comprises a flexible material.

11. A vibration control method comprising:

spatially distributing a plurality of piezoelectric transducer elements;

interconnecting, by a switching circuit, selected ones of the transducer elements based on a switching signal provided by a controller circuit, the switching signal being in response to a vibration condition of a host structure, to adaptively form a group of interconnected transducer elements;

connecting, by the switching circuit, the group of interconnected transducer elements to at least one vibration control circuit; and

providing a single vibration control signal or electrical impedance source corresponding to the vibration condition to the group of interconnected transducer elements.

12. The vibration control method according to claim 11, further comprising determining the vibration condition of the host structure by a sensing circuit before interconnecting selected ones of the transducer elements.

13. The vibration control method according to claim 12, wherein the sensing circuit is connected to the transducer elements, and wherein inputs of the sensing circuit comprise outputs from the transducer elements; and wherein determining the vibration condition of the host structure further comprises controlling, by the controller circuit, a Boolean switch of the sensing circuit to connect the sensing circuit to the transducer elements only during a sensing operation.

14. The vibration control method according to claim 12, wherein the sensing circuit is connected to one or more vibration sensing elements disposed on the host structure.

15. The vibration control method according to claim 12, wherein the sensing circuit is connected to a sensing layer disposed on the host structure and configured to detect the vibration condition.

16. The vibration control method according to any one of claims 11 to 15, wherein the piezoelectric transducer elements comprise discrete piezoelectric devices.

17. The vibration control method according to any one of claims 11 to 15, wherein the piezoelectric transducer elements comprise a piezoelectric layer and an electrode layer, and wherein the electrode layer comprises a plurality of electrode segments electrically isolated from each other.

18. The vibration control method according to any one of claims 11 to 17, further comprising dissipating, absorbing or cancelling vibration energy based on the single vibration control signal or electrical impedance source provided to the group of interconnected transducer elements.

19. The vibration control method according to any one of claims 11 to 18, further comprising configuring a parameter of the at least one vibration control circuit.

20. A method of fabricating a vibration control system, the method comprising the steps of:

providing a plurality of spatially distributed piezoelectric transducer elements;

connecting a switching circuit to each of the transducer elements;

connecting each of one or more vibration control circuits to the switching circuit;

connecting the one or more vibration control circuits and the switching circuit to a controller circuit,

programming the controller circuit to control the switching circuit to interconnect selected ones of the transducer elements based on a switching signal provided by the controller circuit, the switching signal being in response to a vibration condition, to adaptively form a group of interconnected transducer elements; and

programming the controller circuit to control the switching circuit to connect the group of interconnected transducer elements to a selected at least one of the one or more vibration

control circuits for receiving a single vibration control signal or electrical impedance source corresponding to the vibration condition.