occurs in stopping the haptic device, which can be perceived, in some circumstances, by a user. Such a delay may be undesirable in certain applications.

[0129] **FIG. 20B** is a plot showing an example of a signal **802***b* used to drive a haptic device, according to an embodiment of the invention. The brake-pulse drive signal **802***b* used in **FIG. 20B** includes a portion having a negative pulse prior to a potion of the drive signal **802***b* having zero power. This negative pulse (also referred to as a brake or braking pulse) results in the improved velocity **804***b* shown in **FIG. 20B**, which has improved stopping characteristics compared to devices using a regular-step drive signal **802***a* (shown in **FIG. 20A**). Specifically, the brake-pulse drive signal **802***b* stops a rotating mass or other haptic device more quickly than with a regular step drive signal **802***a*. As with the lead-in-step drive signal **702***b* (shown in **FIG. 19B**), the brake-pulse drive signal **802***b* can be produced, for example, by discharging a previously charged capacitor.

[0130] Drive signals implementing the lead-in pulse and of the lead-in-pulse drive signal **702***b*, and the negative pulse of the brake-pulse drive signal **802***b* can be combined to provide haptic feedback having a reduced lag time (i.e., a reduced response time) at both the beginning and end of the feedback. The drive signals described above in connection with **FIGS. 19B and 20B** can be created via computer programming code that can be programmed in software, firmware, or hardware, according to the desired performance and/or design constraints of the system.

[0131] The effects described above in connection with **FIGS. 19B and 20B** can be implemented in any of the operational modes (e.g., unidirectional, harmonic, transitional, etc.) associated with the invention. Additionally, these effects can be implemented within all of the frequency ranges shown in **FIG. 10** to provide quicker response within each of these ranges.

[0132] From the foregoing, it can be seen that systems and methods for controlling multi-mode haptic devices are discussed. Specific embodiments have been described above in connection with a multi-mode haptic device that has multiple operational modes (e.g., unidirectional, harmonic, etc.), and which operates within multiple frequency ranges including: a low-frequency range, a low-high transition range, and a high-frequency range. Additionally, specific embodiments have been described in the context of haptic devices using rotating masses to produce haptic feedback.

[0133] It will be appreciated, however, that embodiments of the invention can be in other specific forms without departing from the spirit or essential characteristics thereof. For example, while some embodiments have been described in the context of a multi-mode haptic device operating within three frequency ranges, a multi-mode haptic device can have multiple operational modes that span multiple frequency ranges in excess of the three discussed above. For example, such a haptic device could operate within multiple frequency ranges corresponding to multiple harmonics of the device. These multiple frequency ranges can have multiple transition frequency ranges therebetween. Additionally, other types of actuators, spring-mass systems, and feedback devices can be used to provide haptic device according to the principles of the invention disclosed above. The presently disclosed embodiments are, therefore, considered in all respects to be illustrative and not restrictive.

What is claimed is:

1. An apparatus, comprising:

a haptic device having a plurality of operational modes including a first operational mode and a second operational mode, the first operational mode being associated with a frequency range, the second operational mode being associated with a frequency range being different from the frequency range of the first operational mode; and

a controller coupled to the haptic device, the controller configured to send the haptic device a plurality of control schemes each being uniquely associated with an operational mode from the plurality of operational modes.

2. The apparatus of claim 1, wherein the controller is configured to combine each control scheme from the plurality of control schemes prior to sending the plurality of control schemes to the haptic device.

3. The apparatus of claim 1, wherein the controller is configured to superimpose each control scheme from the plurality of control schemes prior to sending the plurality of control schemes to the haptic device, the plurality of control schemes being superimposed according to a predetermined proportion of operational modes from the plurality of operational modes.

4. The apparatus of claim 1, wherein the controller is configured to provide transitional control schemes associated with at least two operational modes from the plurality of operational modes, the transitional control schemes are configured to combine at least a portion of each control scheme from the plurality of control schemes uniquely associated with each of the at least two operational modes.

5. The apparatus of claim 1, wherein the controller is configured to provide transitional control schemes associated with at least two operational modes from the plurality of operational modes, the transitional control schemes are configured to superimpose at least a portion of each control scheme from the plurality of control schemes uniquely associated with each of the at least two operational modes.

6. The apparatus of claim 1, wherein the haptic device includes a rotating mass.

7. The apparatus of claim 1, wherein the haptic device includes a rotating mass, the rotating mass having at least one harmonic response frequency, each at least one harmonic response frequency uniquely corresponding to an operational mode from the plurality of operational modes.

8. The apparatus of claim 1, wherein the controller is configured to control the haptic device using pulse width modulation (PWM).

9. The apparatus of claim 1, wherein the controller is further configured to cause the at least one haptic device to output a first haptic response associated with the first operational mode and a second haptic response associated with the second operational mode.

10. The apparatus of claim 1, wherein the controller is further configured to cause the at least one haptic device to output a first haptic response associated with the first operational mode, a second haptic response associated with the second operational mode, and a transitional haptic response associated with a combination of the first haptic response and the second haptic response.

11. The apparatus of claim 1, wherein the haptic device has at least one of a variable moment and a variable