signal, for instance in the form of a logic bit, both of which preferably are sent to a driver circuit **714**. The driver circuit **714**, in turn, sends electrical power to the actuator **716**.

[0246] Digital control circuitry can be used to control a complete vibration device in synchronized vibration. In synchronized vibration the frequency and phase of two or more actuators are the same. Accordingly, a single square wave can be used to control the direction of the vibration actuators that are in synchronized vibration. The amplitude of vibration can be controlled independently for each actuator, with separate PWM signals.

[0247] **FIG. 42** shows an embodiment **720** where a vibration device controller **722** generates one directional signal ("dir")), which may be in the form of a square wave. The dir signal is preferably provided to a pair of drive circuits **724***a* and **724***b*. The vibration device controller **722** desirably generates separate amplitude signals, $A_1$ and $A_2$, in PWM form to the drive circuits **724***a,b* for a pair of actuators **726***a* and **726***b*. The vibration device controller **722** preferably includes a direction and amplitude controller **728**, a frequency controller **730** and a vibration controller **732** as in the embodiment described above with regard to **FIG. 35**. The direction and amplitude controller **728**, the frequency controller **730** and the vibration controller **732** may be configured in hardware, software, firmware or a combination thereof, and may be implemented either as separate components or processes, or may be implemented as a single component or process.

[0248] The embodiment **720** of **FIG. 42** may be used to control in synchronous vibration the vibration devices with two actuators, for instance as described above with regard to **FIGS. 10-20**. Embodiment **720** can also be used to vibrate two or more actuators completely out of phase, which occurs during synchronized vibration when equation 25 provides results with the sign of $A_1$ being different than the sign of $A_2$. To vibrate two actuators completely out of phase, the binary direction signal dir can be inverted for one of the actuators. The inversion of the directional signal dir can occur at a driver circuit **724***a* or **724***b*, or the vibration controller **732** can output two directional signals, with one being the inverse of the other. The case where two actuators are being driven completely out of phase is shown in **FIG. 13**.

[0249] Electric actuators in accordance with the present invention can be driven with unipolor or bipolor drivers. A uniplor driver will generate current in an actuator in a single direction. A unipolor driver is well suited for actuators where the moving mass is ferromagnetic and an electromagnetic coil only generates attractive magnetic forces, such as the actuator **150** shown in **FIG. 9**. One example of a unipolar driver circuit is a Darlington array, such as the ULN2803A DARLINGTON TRANSISTOR ARRAY manufactured by Texas Instruments.

[0250] A bipolar driver can generate current in two directions. Bipolar drivers are well suited for actuators where the moving mass is magnetic and where reversing the direction of current in an electromagnetic coil can reverse the direction of force on the moving mass. Examples of such actuators are presented in FIGS. **5**A-B through **8**A-B. One example for a bipolar driver circuit is an H bridge, such as the L298 manufactured by ST Microelectronics. Alternative H bridges are the 3958 and 3959 drivers manufactured by Allegro Microsystems.

[0251] In vibrating circuits it can be advantageous to increase power output of the driver circuits through use of a charge pump capacitor as used in 3958 and 3959 drivers manufactured by Allegro Microsystems. It can also be advantageous to incorporate a capacitor in series with a linear motion vibrating actuator to benefit from resonance effect and temporary storage of energy in the capacitor, as described in the aforementioned U.S. patent application entitled "Vibration Devices."

[0252] As detailed herein, vibration actuators can be used in a variety of methods to create haptic effects. Vibration actuators can be operated continuously throughout the duration of a specified haptic effect, or can be pulsed on and off during the haptic effect. By pulsing vibration actuators on and off the user feels only a small number of vibrations, then feels a pause, and then the vibration resumes. In this fashion it is possible to generate secondary sensations associated with the frequency of pulsing the actuators on and off. Examples of how such pulse effects can be used are described in U.S. Pat. Nos. 6,275,213 and 6,424,333.

[0253] Any of the actuators described herein may be used in accordance with the present invention to produce a wide variety of haptic effects. While some actuators such as linear actuators and rocking mass actuators may be particularly suited for low frequency operation, all actuators herein may provide synchronized feedback. Such feedback may be employed in games, virtual reality equipment, real-world equipment such as surgical tools and construction equipment, as well as portable electronic devices such as cellular phones and pagers. By way of example only, cellular phones and pagers may implement different vibration effects to identify different callers or different actions. Synchronized vibration may provide directional feedback, for instance, with the impact or recoil of a gun in a game, or to distinguish between frontal and side impacts in driving games. Synchronized vibration may also provide a continual rotation of a vibration force vector in a game to simulate a car spinning out of control. Synchronized vibration may also be used in endless other applications and situations to provide a rich haptic experience to a user.

[0254] Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention as defined by the appended claims. By way of example only, it is possible to vary aspects of the embodiments herein to some degree while achieving synchronous vibration and other benefits of the invention. For instance, the frequency of vibration, amplitude of vibration, profile or waveform of vibration, phase of vibration, timing of vibration, alignment of actuators, rigidity of the vibration device, rigidity of the attachment between the actuators and the vibration device, and design and control parameters may all be adjusted, either independently or in any combination thereof.