that are detected audibly by a user can be can be added such that the perceived overall experience has a greater frequency range. Because a user is able to sense an increased range of frequencies, more information can be communicated to the user using such combination of haptic effects and audio output.

[0022] When pulse-like control signals are used to generate haptic effects, control signals having a constant average energy can be used to provide a variety of different audio output frequencies. The different audio output frequencies can cause a user to believe that he or she is sensing tactilely a different frequency of a haptic effect, even though tactilely sensing such a difference would not be possible. Thus, according to one or more embodiments of the invention, a variety of overall experiences (each having a haptic component and an audio component) caused by a corresponding variety of control signals, each of which has the same average energy, is able to be sensed by a user via a combination of the haptic effect and the associated audio output, even though the variety of haptic effects alone would be perceived as having the same feel without the audio output. The average energy can be maintained constant by varying the frequency and/or duty cycle of a control signal inversely with the magnitude of a control signal. Thus, as the frequency of the control signal is increased, the magnitude decreases and, conversely, as the frequency of the control signal decreases, the magnitude increases, to maintain a constant average energy of the carrier signal.

[0023] **FIG. 1** is a block diagram of a processor system, according to an embodiment of the invention. The processor system **110** illustrated in **FIG. 1** can be, for example, a commercially available personal computer, portable electronic device, or a less complex computing or processing device (e.g., a device that is dedicated to performing one or more specific tasks). For example, the processor system can be a mobile telephone, a PDA, a portable gaming system, an MP3 player, or the like. Alternatively, the processor system **110** can be a terminal dedicated to providing an interactive virtual reality environment, such as a gaming system, or the like. Although each component of the processor system **110** is shown as being a single component in **FIG. 1**, the processor system **110** can include multiple numbers of any components illustrated in **FIG. 1**. Additionally, multiple components of the processor system **110** can be combined as a single component.

[0024] The processor system **110** includes a processor **112**, which according to one or more embodiments of the invention, can be a commercially available microprocessor capable of performing general processing operations. Alternatively, the processor **112** can be an application-specific integrated circuit (ASIC) or a combination of ASICs, which is designed to achieve one or more specific functions, or enable one or more specific devices or applications. In yet another alternative, the processor **112** can be an analog or digital circuit, or a combination of multiple circuits.

[0025] Alternatively, the processor **112** can optionally include one or more individual sub-processors or coprocessors. For example, the processor can include a graphics coprocessor that is capable of rendering graphics, a math coprocessor that is capable of efficiently performing complex calculations, a controller that is capable of controlling one or more devices, a sensor interface that is capable of receiving sensory input from one or more sensing devices, and so forth.

[0026] The processor system **110** can also include a memory component **114**. As shown in **FIG. 1**, the memory component **114** can include one or more types of memory. For example, the memory component **114** can include a read only memory (ROM) component **114***a* and a random access memory (RAM) component **114***b*. The memory component **114** can also include other types of memory not illustrated in **FIG. 1** that are suitable for storing data in a form retrievable by the processor **112**. For example, electronically programmable read only memory (EPROM), erasable electrically programmable read only memory (EEPROM), flash memory, as well as other suitable forms of memory can be included within the memory component **114**. The processor system **110** can also include a variety of other components, depending upon the desired functionality of the processor system **110**. The processor **112** is in communication with the memory component **114**, and can store data in the memory component **114** or retrieve data previously stored in the memory component **114**.

[0027] The processor system **110** can also include a haptic device **116**, which is capable of providing a variety of haptic output. For example, the haptic device **116** can be configured to output basis haptic effects, such as periodic effects, magnitude-sweep effects, or timeline haptic effects, each of which is described in greater detail below. According to one or more embodiments of the invention, the haptic device **116** can include one or more force-applying mechanisms, which are capable of outputting haptic effects or force, to a user of the processor system **110** (e.g., via the housing of the processor system **110**). These effects or forces can be transmitted, for example, in the form of vibrational movement caused by the haptic device **116** (e.g., caused by a rotating mass, a piezo-electric device, or other vibrating actuator), or in the form of resistive force caused by the haptic device **116**.

[0028] The processor system **110** can also, according to one or more embodiments of the invention, include a sensor **118** that is capable of receiving input from a user, the haptic device **116**, or is otherwise capable of sensing one or more physical parameters. For example, according to one or more embodiments of the invention, a sensor **118** can be configured to measure speed, intensity, acceleration, or other parameters associated with a haptic effect output by the haptic device **116**. Similarly, the sensor **118** can be configured to sense environmental or ambient conditions of the processor system's surroundings. The sensor **118** can interface and communicate with the processor **112** by way of a sensor interface (not shown) within the processor **112**.

[0029] The processor system **110** can also include a controller **120**, which can optionally be internal to the processor **112**, or external thereto, as shown in **FIG. 1**. The controller **120** can be configured to control the haptic device **116** when the processor **112** is not directly controlling the haptic device **116**. Similarly, the controller **120** can control the memory **114** and/or the sensor **118**, as well as devices external to the processor system **110** by way of an input/output (I/O) component **124** (described below).

[0030] The various components of the processor system **110** can communicate with one another via a bus **122**, which