"personal digital assistant" (PDA), a "pen-based" computer, "web pad,""electronic book", or similar device (collectively known as a "personal digital assistant" (PDA) herein). Those devices which allow a user to input information by touching a display screen or readout in some fashion are relevant to the present invention, as well as devices allowing button input. Such devices can include the Palm Pilot from 3Com Corp. or similar products, pocket-sized computer devices from Casio, Hewlett-Packard, or other manufacturers, E-books, cellular phones or pagers having touch screens, laptop computers with touch screens, etc.

[0055] In one embodiment of a device **50**, a display screen **52** positioned adjacent a housing **54** may cover a large portion of the surface of the computer device **50**. Screen **52** is preferably a flat-panel display as is well known to those skilled in the art and can display text, images, animations, etc.; in some embodiments screen **52** is as functional as any personal computer screen. Display screen **52** can be a "touch screen" that includes sensors which allow the user to input information to the computer device **50** by physically contacting the screen **50** (i.e. it is another form of planar "touch device" similar to the touchpad **16** of **FIG. 1**). For example, a transparent sensor film can be overlaid on the screen **50**, where the film can detect pressure from an object contacting the film. The sensor devices for implementing touch screens are well known to those skilled in the art.

[0056] The user can select graphically-displayed buttons or other graphical objects by pressing a finger or a stylus to the screen **52** at the exact location where the graphical object is displayed. Furthermore, some embodiments allow the user to "draw" or "write" on the screen by displaying graphical "ink" images **56** at locations where the user has pressed a tip of a stylus, such as stylus **57**, or a finger or other object. Handwritten characters can be recognized by software running on the device microprocessor as commands, data, or other input. In other embodiments, the user can provide input additionally or alternatively through voice recognition, where a microphone on the device inputs the user's voice which is translated to appropriate commands or data by software running on the device. Physical buttons **58** can also be included in the housing of the device **50** to provide particular commands to the device **50** when the buttons are pressed. Many PDA's are characterized by the lack of a standard keyboard for character input from the user; rather, an alternative input mode is used, such as using a stylus to draw characters on the screen, voice recognition, etc. However, some PDA's also include a fully-functional keyboard as well as a touch screen, where the keyboard is typically much smaller than a standard-sized keyboard. In yet other embodiments, standard-size laptop computers with standard keyboards may include flat-panel touch-input display screens, and such screens (similar to screen **12** of **FIG. 1**) can be provided with haptic feedback according to the present invention.

[0057] In some embodiments of the present invention, the touch screen **52** may provide haptic feedback to the user similarly to the touchpad **16** described in previous embodiments. One or more actuators can be coupled to the touchscreen, or movable surfaces near the touchscreen, in a manner similar to the embodiments described below. The user can experience the haptic feedback through a finger or a held object such as a stylus **57** that is contacting the screen **52**.

[0058] The touch screen **52** can be coupled to the housing **54** of the device **50** by one or more spring or compliant elements, such as helical springs, leaf springs, flexures, or compliant material (foam, rubber, etc.), to allow motion of the screen approximately along the z-axis, thereby providing haptic feedback. The screen can also be provided with flexures or other couplings allowing side-to-side (x and/or y) motion, similar to the appropriate embodiments described below.

[0059] **FIG. 4** is a block diagram illustrating a haptic feedback system suitable for use with any of the described embodiments of the present invention. The haptic feedback system includes a host computer system **14** and interface device **12**.

[0060] Host computer system **14** preferably includes a host microprocessor **100**, a clock **102**, a display screen **26**, and an audio output device **104**. The host computer also includes other well known components, such as random access memory (RAM), read-only memory (ROM), and input/output (I/O) electronics (not shown).

[0061] As described above, host computer **14** can be a personal computer such as a laptop computer, and may operate under any well-known operating system. Alternatively, host computer system **14** can be one of a variety of home video game console systems commonly connected to a television set or other display, such as systems available from Nintendo, Sega, Sony, or Microsoft. In other embodiments, host computer system **14** can be an appliance, "set top box", or other electronic device to which the user can provide input. Computer **14** can also be a portable, hand-held computer such as a PDA, or can be a vehicle computer, stand-up arcade game, workstation, etc.

[0062] Host computer **14** preferably implements a host application program with which a user is interacting via interface device **12** which includes haptic feedback functionality. For example, the host application program can be a video game, word processor or spreadsheet, Web page or browser that implements HTML or VRML instructions, scientific analysis program, movie player, virtual reality training program or application, or other application program that may utilize input of mouse **12** and which outputs haptic feedback commands to the device **12**. Herein, for simplicity, operating systems such as Windows™, MS-DOS, MacOS, Unix, Palm OS, etc. are also referred to as "application programs." Herein, computer **14** may be referred as providing a "graphical environment," which can be a graphical user interface, game, simulation, or other visual environment and can include graphical objects such as icons, windows, game objects, etc. Suitable software drivers which interface such software with computer input/output (I/O) devices are available from Immersion Corporation of San Jose, Calif.

[0063] Display device **26** can be included in host computer **14** and can be a standard display screen (LCD, CRT, plasma, flat panel, etc.), 3-D goggles, or any other visual output device. Audio output device **104**, such as speakers, is preferably coupled to host microprocessor **100** to provide sound output to user. Other types of peripherals can also be coupled to host processor **100**, such as storage devices (hard disk drive, CD ROM drive, floppy disk drive, etc.) other input and output devices.

[0064] Interface device **12** is coupled to the computer **14** by a bus **20**, which communicates signals between device **12**