and computer **14** and may also, in some embodiments, provide power to the device **12**. In other embodiments, signals can be sent between device **12** and computer **14** by wireless transmission/reception. In some embodiments, the power for the actuator can be supplemented or solely supplied by a power storage device provided on the device, such as a capacitor or one or more batteries. The bus **20** is preferably bi-directional to send signals in either direction between host **14** and device **12**. Bus **20** can be a serial interface bus, such as an RS232 serial interface, RS-422, Universal Serial Bus (USB), MIDI, or other protocols well known to those skilled in the art; or a parallel bus or wireless link.

[**0065**] Device **12** may be a separate device from host **14** with its own housing, or may be integrated with the host computer housing, as in the laptop computer of **FIG. 1**. Device **12** can include or be associated with a dedicated local microprocessor **110**. Processor **110** is considered local to device **12**, where "local" herein refers to processor **110** being a separate microprocessor from any host processors in host computer system **14**. "Local" also may refer to processor **110** being dedicated to haptic feedback and sensor I/O of device **12**. Microprocessor **110** can be provided with software instructions (e.g., firmware) to wait for commands or requests from computer host **14**, decode the command or request, and handle/control input and output signals according to the command or request. In addition, processor **110** can operate independently of host computer **14** by reading sensor signals and calculating appropriate forces from those sensor signals, time signals, and stored or relayed instructions selected in accordance with a host command. Suitable microprocessors for use as local microprocessor **110** include lower-end microprocessors as well as more sophisticated force feedback processors such as the Immersion Touchsense Processor. Microprocessor **110** can include one microprocessor chip, multiple processors and/or co-processor chips, and/or digital signal processor (DSP) capability.

[**0066**] Microprocessor **110** can receive signals from sensor **112** and provide signals to actuator **18** in accordance with instructions provided by host computer **14** over bus **20**. For example, in a local control embodiment, host computer **14** provides high level supervisory commands to microprocessor **110** over bus **20** (such as a command identifier and one or more parameters characterizing the tactile sensation), and microprocessor **110** decodes the commands and manages low level force control loops to sensors and the actuator in accordance with the high level commands and independently of the host computer **14**. This operation is described in greater detail in U.S. Pat. Nos. 5,739,811 and 5,743,373, both incorporated herein by reference in their entirety. In the host control loop, force commands are output from the host computer to microprocessor **110** and instruct the microprocessor to output a force or force sensation having specified characteristics. The local microprocessor **110** reports data to the host computer, such as locative data that describes the position of the device in one or more provided degrees of freedom. The data can also describe the states of buttons, switches, etc. The host computer uses the locative data to update executed programs. In the local control loop, actuator signals are provided from the microprocessor **110** to an actuator **18** and sensor signals are provided from the sensor **112** and other input devices **118** to the microprocessor **110**. Herein, the term "tactile sensation" refers to either a single force or a sequence of forces output by the actuator **18** which provide a sensation to the user. For example, vibrations, a single jolt, or a texture sensation are all considered tactile sensations. The microprocessor **110** can process inputted sensor signals to determine appropriate output actuator signals by following stored instructions. The microprocessor may use sensor signals in the local determination of forces to be output on the user object, as well as reporting locative data derived from the sensor signals to the host computer.

[**0067**] In yet other embodiments, other hardware instead of microprocessor **110** can be provided locally to device **12** to provide functionality similar to microprocessor **110**. For example, a hardware state machine incorporating fixed logic can be used to provide signals to the actuator **18** and receive sensor signals from sensors **112**, and to output tactile signals.

[**0068**] In a different, host-controlled embodiment, host computer **14** can provide low-level force commands over bus **20**, which are directly transmitted to the actuator **18** via microprocessor **110** or other circuitry if there is no microprocessor **110**. Host computer **14** thus directly controls and processes all signals to and from the device **12**, e.g. the host computer directly controls the forces output by actuator **18** and directly receives sensor signals from sensor **112** and input devices **118**. Other embodiments may employ a "hybrid" organization where some types of forces (e.g. closed loop effects) are controlled purely by the local microprocessor, while other types of effects (e.g., open loop effects) may be controlled by the host.

[**0069**] Local memory **122**, such as RAM and/or ROM, is preferably coupled to microprocessor **110** in device **12** to store instructions for microprocessor **110** and store temporary and other data. In addition, a local clock **124** can be coupled to the microprocessor **110** to provide timing data.

[**0070**] Sensors **112** sense the position or motion (e.g. an object on a touchpad) in desired degrees of freedom and provides signals to microprocessor **110** (or host **14**) including information representative of the position or motion. Sensors suitable for detecting motion include capacitive or resistive sensors in a touchpad, contact sensors in a touchscreen, etc. Other types of sensors can also be used. Optional sensor interface **114** can be used to convert sensor signals to signals that can be interpreted by the microprocessor **110** and/or host computer system **14**.

[**0071**] Actuator(s) **18** transmits forces to the housing, manipulandum, buttons, or other portion of the device **12** in response to signals received from microprocessor **110** and/or host computer **14**. Device **12** preferably includes one or more actuators which are operative to produce forces on the device **12** (or a component thereof) and haptic sensations to the user. The actuator(s) are "computer-controlled", e.g., the force output from the actuators is ultimately controlled by signals originating from a controller such as a microprocessor, ASIC, etc. Many types of actuators can be used, including rotary DC motors, voice coil actuators, moving magnet actuators, E core actuators, pneumatic/hydraulic actuators, solenoids, speaker voice coils, piezoelectric actuators, passive actuators (brakes), etc. Some preferred actuator types are described below. Actuator interface **116** can be optionally connected between actuator **18** and microprocessor **110** to convert signals from microprocessor **110** into signals appropriate to drive actuator **18**. Interface **116** can include power amplifiers, switches, digital to analog con-