potential is determined via stray capacitances. Prior art implementations ignore control and processing of the distribution of capacitances and voltages, and some embodiments of the present invention aim at alleviating this separate problem.

[0026] For example, the invention differs from prior art solutions in that no touching or mechanical movement or vibration is required to generate the stimulus. Accordingly, the invention provides advantages over solutions which are based on, say, stroking the finger over the electrodes and on locally varying friction caused by the electric field. Furthermore, the various embodiments of the invention support solutions which are based not only on alternating current but also on direct current. Yet further, the inventive solution can be provided with a functionality to detect proximity and touch, whereby the same component can be used for input and output functions. In addition, various embodiments of the invention may utilize thick insulators, for example, which are mechanically stronger than thin insulators. Moreover, it has been discovered in connection with several embodiments of the invention that it is beneficial to use particular variation frequencies for the electric field, as they will enable smaller energy consumption in the generation of the stimulus.

[0027] In one embodiment the electrical input also comprises a high-frequency component having a frequency which is higher than the frequency of the low-frequency component and lower than 500 kHz. This embodiment may also comprise a modulator or other means for modulating the high-frequency component by the low-frequency component.

[0028] The electrical input to the one or more conducting electrodes has a peak-to-peak voltage of 750 to 100,000 Volts and the insulator should be dimensioned accordingly. In practical implementations with currently available materials the insulator thickness is typically between 0.1 mm and 50 mm.

[0029] In order to convey time-variant information, as opposed to a steady-state sensation, the apparatus may comprise means for modulating the electrical input according to the time-variant information.

[0030] A simple but effective implementation of the invention comprises precisely one conducting electrode for each spatially distinct area of the body member. There may be more than one conducting electrode such that each conducting electrode stimulates a spatially distinct area of one or more body members. The apparatus may comprise an enclosure which contains the high-voltage source which is common to all the several conducting electrodes and wherein the enclosure also contains means for conveying the electrical input to zero or more of the several conducting electrodes simultaneously. The inventive apparatus and/or the one or more conducting electrodes may be positioned such that that the body member most likely to be affected is part of a human hand. For example, five conducting electrodes under control of a common controller, may stimulate, at different times, zero to five fingertips in parallel. The five conducting electrodes thus convey five bits of information in parallel. The apparatus may be implemented as part of an input/output peripheral device connectable to a data processing equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] In the following the invention will be described in greater detail by means of specific embodiments with reference to the attached drawings, in which

[0032] FIG. **1** illustrates the operating principle of a capacitive electrosensory interface (“CEI”);

[0033] FIG. **2** illustrates an embodiment of the CEI;

[0034] FIG. **3** shows an enhanced embodiment with multiple independently-controllable electrodes;

[0035] FIG. **4** shows a specific implementation of the embodiment shown in FIG. **3**;

[0036] FIG. **5** is a graph which schematically illustrates the sensitivity of a test subject to sensations produced by the inventive capacitive electrosensory interface at various frequencies;

[0037] FIG. **6** is a graph which further clarifies the operating principle of the CEI;

[0038] FIGS. **7**A and **7**B show an implementation of the CEI wherein the strength of the capacitive coupling is adjusted by electrode movement;

[0039] FIG. **8** shows an implementation of the CEI wherein the charges of different electrodes have opposite signs;

[0040] FIG. **9** shows an implementation of the CEI wherein a group of electrodes are organized in the form of a matrix;

[0041] FIG. **10** illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is grounded;

[0042] FIG. **11** illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is floating (not grounded);

[0043] FIG. **12** illustrates distribution of an electric field-generating potential in capacitive couplings when the apparatus is floating and the user is sufficiently close to the apparatus and capacitively grounded to the ground (reference) potential of the apparatus;

[0044] FIG. **13** shows an arrangement wherein capacitive couplings are utilized to detect touching; and

[0045] FIGS. **14** and **15** illustrate embodiments in which a single electrode and temporal variations in the intensity of the electrosensory stimulus can be used to create illusions of a textured touch screen surface.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0046] FIGS. **1** through **15** relate to the operation and implementation of a capacitive electrosensory interface (“CEI”) which can be employed in the inventive touch screen interface.

[0047] FIG. **1** illustrates the operating principle of the CEI. Reference numeral **100** denotes a high-voltage amplifier. The output of the high-voltage amplifier **100**, denoted OUT, is coupled to an electrode **106** which is insulated against galvanic contact by an insulator **108** which comprises at least one insulation layer or member. Reference numeral **120** generally denotes a body member to be stimulated, such as a human finger. Human skin, which is denoted by reference numeral **121**, is a relatively good insulator when dry, but the CEI provides a relatively good capacitive coupling between the electrode **106** and the body member **120**. The capacitive coupling is virtually independent from skin conditions, such as moisture. The inventors' hypothesis is that the capacitive coupling between the electrode **106** and the body member **120** generates a pulsating Coulomb force. The pulsating Coulomb force stimulates vibration-sensitive receptors, mainly those called Pacinian corpuscles which reside under the outermost layer of skin in the ipodermis **121**. The Pacinian corpuscles are denoted by reference numeral **122**. They are shown schematically and greatly magnified.

[0048] The high-voltage amplifier **100** is driven by an input signal IN which results in a substantial portion of the energy