A cordless digitizer system (10) is disclosed which comprises a digitizer tablet (11) and a cordless pointing device (12) which cooperate to provide to the tablet information relating not only to the position of the pointing device relative to the tablet, but also relative to the status of any switches (37, 38) on the pointing device. The pointing device (12) generates and radiates to the tablet (11) first and second signals (23, 24) of different frequencies. The first and second signals are radiated from the pointing device (12) at a third frequency (30) which contains information of the status of the switch. For example, one of the signals may be radiated relatively continuously or both of the signals may be alternatingly radiated at the third frequency in dependence upon the status of the switches. The first and second signals induce corresponding signals in the tablet which are processed to provide respective signals at the third frequency. These signals are then processed to obtain the status of the pointing device switches. Switch status information can also be binary encoded as a particular sequence of alternations of the first and second signals.
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BACKGROUND OF THE INVENTION

This invention relates to position determining systems, such as digitizer tablets, and to pointing devices of such tablets, and in particular to so-called cordless digitizer tablets in which the pointing device typically in the form of a stylus or cursor is free of any cable, cord, wire or other direct connection to the tablet.

Digitizer tablets employing a pointing device, e.g. a stylus or cursor, without a direct connection to the tablet are known in the art. A pointing device without such a direct connection to the tablet will be referred to as a cordless pointing device, and a system or tablet employing such a cordless pointing device will be referred to as a cordless system or tablet. The major advantage of cordless tablets is that the absence of a cable, cord or wire direct connection between the pointing device and the tablet facilitates use. One way of providing information from a cordless pointing device to the tablet is by transmitting signals from the pointing device to the tablet which induce signals in the tablet which can be processed and interpreted by the tablet. Such information transmitted from the cordless pointing device to the tablet may include the status of any switches within or on the pointing device.

A digitizer tablet is typically connected to a host computer such as a PC which includes a monitor. The monitors of such computers radiate signals that may interfere with the operation of the digitizer tablet, particularly a digitizer tablet that uses electromagnetic
or electrostatic coupling of the pointing device to the tablet.

U.S. Patent No. 4,672,154 discloses a cordless stylus which utilizes a signal of a different frequency to convey different switch statuses, e.g., n different frequency signals to indicate n switch statuses. A problem with a cordless digitizer system utilizing such a cordless stylus is that it requires a tablet signal processor having a sufficiently wide bandwidth to accommodate the range of the n different frequencies, which makes the tablet more prone to noise and electromagnetic interference.

**SUMMARY OF THE INVENTION**

An object of the invention is to provide an improved cordless pointing device for a position-determining system.

A further object of the invention is to provide a cordless digitizer tablet employing a cordless pointing device which is less subject to noise and/or electromagnetic interference.

Another object of the invention is to provide a cordless digitizer tablet employing a cordless pointing device which determine status information of one or more switches on the pointing device to the tablet while providing good noise immunity.

Another object of the invention is to provide a cordless digitizer tablet employing a cordless pointing device in which the pointing device is capable of transmitting to the tablet position information and switch status information using signals having frequencies within a relatively narrow bandwidth.

Another object of the invention is to provide a cordless tablet capable of processing such signals within a narrow band-width to provide increased noise immunity.

Still another object of the invention is a switch
status information transmittal scheme for use with digitizer tablets employing digital techniques.

In accordance with the invention, the pointing device generates signals of as few as two different frequencies which are radiated to the tablet to indicate switch status. In other words, as few as two different frequency radiated signals may impart a multitude of switch status conditions. These different frequency signals induce corresponding signals of different frequencies in the tablet, one at a time, as a function of pointing device switch status. The different frequency signals induced in the tablet are processed to decode switch status. For example, the relative strength, presence or absence, or other parameter of the induced signals may contain switch status information. In the preferred embodiment, the relative duration or order (including relative continuous presence or absence) of the two induced different frequency signals contains the switch status information.

In accordance with an aspect of the invention, the tablet may be made extremely noise immune by utilizing narrow bandwidth processing closely tuned to the induced different frequency signals.

In the preferred embodiment, the pointing device includes one or more oscillators which generate the two different frequency signals. These signals are supplied to structure in the pointing device which radiates or couples the signals from the pointing device, e.g., from the pointing device tip which functions as a capacitive or electrostatic coupling electrode for electrostatic voltage signals or an antenna or coil for electromagnetic current signals, to the tablet. The tablet includes a structure, for example a conductor array or system, in which corresponding signals are induced by the coupled or radiated different frequency signals. The tablet
includes a narrow bandwidth filter coupled to process the induced signals closely tuned to the frequency of the particular signal being processed. For signals induced at two different frequencies, preferably two narrow bandwidth filters are employed each closely tuned to the frequency of the signal it processes. The output from each of these filters can be further processed to provide the switch status information contained in the signals. As indicated above, switch status information is preferably contained in the relative duration or order of the induced signals. The signal amplitudes are combined to provide a composite amplitude signal from which position determination is made.

In the preferred embodiment, the statuses of the pointing device switches set the times during which each of the different frequency signals are radiated from the pointing device and the sequence of the radiated signals. For example, in a two signal frequency embodiment, the signals at the two different frequencies are alternatingly radiated (or one or the other is relatively continuously radiated), and the frequency at which the two radiated signals alternate (or the relative continuous presence or absence of a particular signal) contains the switch status information. In other words, the switch status information is not determined by the frequencies of the two different frequency signals, but rather by the frequency of a third signal which in a sense modulates the two different frequency signals similar to frequency shift keying.

For a first switch status, only one of the signals may be relatively continuously radiated, i.e., continuously radiated during the time that a particular set of switch conditions are present. For a second switch status, both signals may be radiated alternatingly at a first frequency. For a third switch status, both
signals may be radiated alternatingly at a second frequency, etc.

In accordance with still another aspect of the invention, multiple switch status may be encoded as a particular sequence of alternations between the two transmit frequencies, and means can be incorporated to synchronize the reception of these sequences for proper decoding. For example, the status of multiple switches may be encoded into an 8 bit binary word, allowing for up to 256 different combinations of switch status (suitable for the transmission, for example, of 256 different levels of switch pressure from a pressure sensitive stylus). This 8 bit binary word would be transmitted as alternations between the two frequencies; for example, a binary 0 would result in the transmission of frequency $f_0$ for a fixed time duration, and a binary 1 would result in the transmission of frequency $f_1$ for a fixed time duration. Or, the 0 or 1 combination may determine the time duration of the transmission of each frequency. These packets of sequences of alternations between frequencies would typically be appended by a unique sequence to allow for synchronous decoding at the receiving digitizer.

Preferably, the pointing device utilizes digital circuitry to provide the different frequency signals which are radiated by the pointing device. Among other reasons, such circuitry facilitates providing radiated signals of substantially equal amplitude which then induce signals of substantially equal amplitude in the tablet. This facilitates signal processing in the tablet. For example, each induced signal may be rectified to provide an analog DC signal representative of the amplitude of the respective induced signal. The analog DC signal may be converted to a digital signal and digitally processed by a microprocessor or microcomputer.
to obtain the pointing device switch status.

The pointing device may be battery powered and include a relatively simple power-down circuit which operates to switch off power at least to the oscillator(s) if a switch has not been activated within a preset interval.

The invention is further described with respect to preferred embodiments in connection with the accompanying drawings, but it is to be understood that the invention is not to be limited to the details of the preferred embodiments described herein.

SUMMARY OF DRAWINGS

The invention is illustrated by way of example in the figures of the accompanying drawings in which like references refer to like or corresponding elements, and in which:

Fig. 1 is a schematic diagram of a cordless digitizer system according to the invention comprising a cordless stylus and a cordless digitizer tablet according to the invention, in which the digitizer tablet is shown coupled to a host computer;

Fig. 2 is a cross-sectional view of the cordless stylus of Fig. 1;

Fig. 3 is a block diagram of circuitry in the cordless stylus and cordless tablet of the cordless system of Fig. 1;

Fig. 4 is a schematic circuit diagram of a preferred embodiment of circuitry in the cordless stylus of Fig. 1 for generating signals of different frequency and the sequence duration in which the different frequency signals are radiated from the stylus;

Figs. 5A-5H show signal waveforms radiated from the stylus as a function of switch status;

Figs. 6A-6H show induced and processed waveforms and logic information for a particular switch status;
Fig. 7 is a flow chart of a routine for determining switch status from the digital signals obtained from the signals induced in the tablet;

Fig. 8 is a circuit schematic and block diagram of a power-down circuit in accordance with the invention connected in the cordless stylus of Fig. 1;

Figs. 9 and 10 illustrate signal sequences of additional embodiments of the invention in which the switch status is binary encoded;

Fig. 11 shows block diagrams of suitable circuitry for implementing the binary encoding of Figs. 9 and 10;

Fig. 12 shows an example of a protocol for synchronizing the decoding of binary encoded transmissions.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Fig. 1, cordless digitizer tablet or system 10 comprises a generally flat rectangular member 11 constituting the tablet itself within which but not shown in Fig. 1 are contained an X-Y conductor grid system, and a cordless pointing device 12 in the form of a stylus. The stylus 12 interacts with the tablet 11 in a known manner to induce signals in the tablet from which the position of the stylus 12 relative to the tablet 11 may be determined. The structure in stylus 12 and in tablet 11 and the processing method for interactively determining the position of the stylus may be conventional and preferably employs electrostatic or electromagnetic coupling between the stylus and the conductor grid system. The tablet 11 is typical connected to a host computer 13 for displaying the patterns or other icons representing the location of stylus 12 with respect to the tablet 11.

The digitizer system 10 and the conductor system contained in tablet 11 are of the electrostatic type. However, the invention is not limited to such digitizer
systems and such conductor systems, and the invention is applicable to other types, for example, an electromagnetic system. Also, while digitizer system 10 is shown and described to include a stylus 12, the invention is applicable to systems which include other types of pointing devices, for example, cursors having a flat portion which interacts with a conductor system in the tablet.

In a conventional electrostatic digitizer system, the conductors of the grid conductor systems within the tablet are electrically scanned in a desired scanned sequence while the stylus generates an RF signal which is supplied to the tip of the stylus. The stylus tip acts as a capacitor electrode and electrostatically or capacitively couples the RF voltage signal to the tablet conductor system. This coupling induces voltage signals in the conductors of the grid conductor system when the pointing device is held over the grid conductors. The intensity of the induced voltage signals in a particular conductor are a function of the position of the pointing device with respect to the particular conductor being scanned. Processing of the induced voltage signals in the conductors produces the position of the stylus relative to the grid conductor system. A detailed description of such processing and the circuitry for performing the processing will not be made herein since the same may be conventional and are known to those of skill in the art.

The stylus illustrated in Fig. 2 comprises a housing 15 similar to that of a ball point pen with a metal tip 16 projecting from the bottom end thereof. Tip 16 functions as a capacitor electrode for electrostatically or capacitively coupling voltage signals to the grid conductor assembly in tablet 11. At the upper end of stylus 12 within housing 15 is located one or more
batteries 17 used to power circuitry within stylus 12 mounted on a PCB 18. As shown in the upper part of Fig. 3 which represents stylus circuitry, the circuitry in stylus 12 includes oscillators 20, 21, and 22 each of which provides an output signal of a different frequency from that of the other oscillators.

The particular frequencies are not critical. The frequency of oscillator 22 is substantially different from that of oscillators 20 and 21 due to the different functions performed by the oscillator outputs. The outputs of oscillators 20 and 21 may be viewed as carrier signals while the output of oscillator 22 may be viewed as a switch status information carrying signal that frequency shift keys the carrier signals. Thus, only two signals of different frequency may carry a large number of switch status conditions contained in the particular frequency of the third signal. Typical and presently preferred values are 100 kHz for oscillator 20, 50 kHz for oscillator 21 and 3 kHz for oscillator 22. Oscillators 20-22 may be conventional and preferably are of the crystal-controlled type.

The outputs 23, 24 of oscillators 20 and 21, respectively, are connected to different input terminals 25, 26 of a switch 27. The output terminal 28 of switch 27 is connected to the tip 16 of stylus 12. Input terminal 29 of switch 27 is a control input and the signal on this input controls switching of switch 27 between input terminals 25 and 26. Switch 27 may be conventional analog or digital (logic) single pole, double throw switch controlled by the signal present on control input terminal 29, which is the output 30 of oscillator 22. The signals generated by oscillators 20 and 21 at outputs 23 and 24 thereof are alternatingly coupled one at a time to switch output terminal 28 and conducted to stylus tip 16, from which the signals are
radiated or transmitted to a grid conductor system 35 in the lower part of Fig. 3 which represents tablet 11.

In use stylus tip 16 is positioned sufficiently close to the top of tablet 11, typically within one half inch, to electrostatically (capacitively) couple the radiated signals to the conductors of the grid conductor system 35 in tablet 11 to electrostatically induce voltage signals in the conductors. These induced voltage signals are then processed to obtain the position of stylus 12 relative to conductor system 35. A plurality of switches 37, 38 may be coupled to oscillator 22 for changing the frequency of the signal output (30) from oscillator 22. Switches 37 and 38 may, for example, be a button switch typically provided on the body of a stylus, and a switch located within the body of a stylus which is activated by pressing the stylus tip onto the tablet surface.

The signals induced in the conductors of grid conductor system 35 are fed to preamplifier 40 through scanning circuitry 39. At that point, in a conventional tablet, the signal from preamplifier 40 would be filtered and then typically full-wave rectified to provide a DC value which can be used to indicate the distance of the stylus from the particular grid conductor being scanned at that time.

However, in the present invention, two bandpass filters 41, 42 are coupled to preamplifier 40. Each bandpass filter 41, 42 has a relatively narrow bandpass, one bandpass being selected to pass the signal induced by the signal generated by oscillator 20 and the other bandpass being selected to pass the signal induced by the signal generated by oscillator 21. For an oscillator frequency of 50 kHz, a typical bandpass Characteristic of filter 41 would be 47-53 kHz, and for an oscillator frequency of 100kHz, a typical bandpass characteristic
for filter 42 would be 96-104 kHz, each typically having less than a 10 kHz bandpass. However, the invention is not limited to these particular values. Such a narrow bandwidth provides for the improved noise immunity referred to above.

Filters 41 and 42 effectively separate the different frequency signals induced by the signals generated by oscillators 20 and 21, which after conversion to digital form may be processed conventionally for position determination. Thus, for example the induced, filtered signals are each full-wave rectified by AC to DC circuits 43, 44 to provide respective analog DC values representative of the respective amplitudes of the induced signals. The analog DC values are converted in respective conventional A/D converters 50 and 52 to digital values representative of the voltage amplitudes of the signals. These digital values are then fed to a microprocessor 53 for digital processing to determine stylus position more or less the same as if a single digital signal were fed to microprocessor 53. For example, the digital signals obtain position information. Microprocessor 53 also controls conventional scanning circuitry 39 for scanning the grid conductors and coupling them to preamplifier 40.

With respect to determining stylus switch status, with two stylus switches 37, 38, four different switch status conditions or states are possible as set forth in Table I below.
TABLE I

<table>
<thead>
<tr>
<th>Switch Status</th>
<th>Condition</th>
<th>Switch 37</th>
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<tr>
<td>0</td>
<td>open</td>
<td>open</td>
<td>open</td>
</tr>
<tr>
<td>1</td>
<td>open</td>
<td></td>
<td>closed</td>
</tr>
<tr>
<td>2</td>
<td>closed</td>
<td></td>
<td>open</td>
</tr>
<tr>
<td>3</td>
<td>closed</td>
<td></td>
<td>closed</td>
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Three switches (two button switches 38 on the body of the stylus 12 and a tip switch 37) have 8 possible switch status conditions. For a cursor, which is conventionally provided with four or more buttons, a total of 16 or more switch status conditions is possible. All such switch statuses may be carried by two different frequency "carrier" signals, as "modulation by the third signal", although for a large number of switch statuses, a third different frequency "carrier" signal may be preferred or in practice required.

Switch status information is contained in the frequency at which switch 27 switches the outputs of oscillators 20 and 21 to tip 16. As mentioned above, oscillator 22 provides the control signal for switch 27 on output 30 and is similar to the information signal in a frequency shift keying system. Stylus switches 37 and 38 determine the frequency output of the oscillator 22 to the switch 27 which alternatingly connects the oscillator outputs 23, 24 to tip 16 at a rate equal to the frequency of oscillator 22. Software controlling the microprocessor 53 measures the durations of the signals of different frequency induced in grid conductor system 35, which can be mapped to switch status.

The embodiment shown in block diagram form in Fig. 3 utilizes three oscillators. However, as shown in Fig. 4, a single conventional crystal-controlled oscillator 70 may be utilized and its output signal on output 71 and signals counted down from that output signal by a conventional binary counter 72 used to provide the three signals of different frequency provided by oscillators.
20-22 in Fig. 3. The oscillator output signal at output 71 is input to binary counter 72 whose outputs Q_0...Q_6 each halve the input or previous stage frequency. For a 100 kHz clock signal output by oscillator 70 and output 71, each successive stage output of binary counter 72 halves the frequency. Thus, the first stage Q_0 output is a 50 kHz clock signal, the Q_4 output is at 3.125 kHz and the Q_5 output is at 1.5625 kHz. Both the 100 kHz input to counter 72 and the 50 kHz Q_0 output are connected to switch 27. The 3.125 and 1.5625 kHz Q_4 and Q_5 outputs are each connected by a stylus switch 37, 38 and an OR circuit 74 as the control signal (output 76) for the switch 27.

Figs. 5A-5D show the carrier signal outputs at tip 16, and Figs. 5E-5H show on a shorter time scale base the control signal waveforms at output 76 supplied to switch 27. With both switches 37 and 38 open (Fig. 5A, switch status 0 in Table I), the signal on tip 16 is a continuous 100 kHz signal. At different conditions of the two switches 37, 38, the signal on tip 16 alternates between 100 kHz and 50 kHz for durations determined by frequency of the control signal output by OR circuit 74 on output 76. The frequency of the signal at tip 16 alternates at the frequency of the control signal at output 76 as illustrated by the waveforms of Figs. 5E-5H. Detecting and processing this switch frequency yields switch status. The intensity of the signals on tip 16 remains constant independent of frequency and stylus switch position, and therefore does not affect determination of stylus location.

Figs. 6 and 7 and Table II illustrate a method of mapping the detected waveforms to switch status. The method is illustrated in Fig. 6 for the case of switch 37 closed (pressed) and switch 38 open, i.e., switch status 2 in Table I. The radiated signal is illustrated in
Figs. 5B and 6A, and the control signal on output 76 is illustrated in Fig. 5F. A time scale is shown at Fig. 6B, for Figs. 6A, C and D. The outputs at the two A/Ds 50, 52 (Fig. 3) are shown at Figs. 6C and 6D, respectively.

Referring to the flow chart in Fig. 7, the outputs of A/Ds 50 and 52 (Fig. 3) are obtained in step 90 and sampled at 50 µs intervals, sequentially or at the same time, in step 91. The samples are numbered 1..14 in Figs. 6C and 6D. The number of samples should be high enough to accurately reflect the waveforms. Each of the logically high values are assigned a "1", and each of the logically low values a "0". Figs. 6E and 6F show the resultant 1s and 0s is counted in step 92 and the number of 1s and 0s is counted in step 93 for each of the received signals. The results are shown in Figs. 6G and 6H.

The collected information is used with a look-up switch table in step 94 to determine switch status. A typical look-up switch table is illustrated in Table II below and is a matrix of the number of counted 1s (or 0s) (vertically at left) against the number of transitions (horizontally at top).
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<th>Number Of Ones</th>
<th>Number Of Transitions</th>
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<td>5</td>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15</td>
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<td>10</td>
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<tr>
<td>15</td>
<td>-1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1</td>
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As shown in the above switch table, for 6 and 8 transitions (read down from "6" and "8" columns) and with either 6 or 8 1s (read right from "6" and "8" rows), the table indicates switch status condition 2, represented by the circled 2s, which is switch 37 closed and switch 38 open. In the switch table, 0, 1, 2 and 3 represent the switch status condition given in Table I above, i.e., a "0" represents no switch closings, a "1" represents switch 38 closed, a "2" represents switch 37 closed, and a "3" represents both switch 37 and switch 38 closed. The negative "1" represents an invalid condition.

Other ways of mapping the received signal waveforms to the switch status conditions will be evident to those skilled in this art. The mapping is straightforward where the signals are symmetrical, for example, as shown in Figs. 5F and 5G. For asymmetric signals, as shown in Fig. 5H, signal inversion or other processing may be necessary to avoid incorrect results.

Since stylus 12 is powered by a battery, it is desirable to minimize battery drain when the stylus is
not being used. Fig. 3 shows a power-down circuit 80 connected between the battery 17 and the oscillators 20, 21 and 22. Fig. 8 illustrates a preferred embodiment of power-down circuit 80 which is relatively inexpensive to implement. Switches 37 and 38 are coupled to a source of power 17" in the circuit, which may be binary counter 72 in Fig. 4, and are connected in parallel with each other (illustrated schematically in Fig. 8), for example through OR circuit 74 in Fig. 4. Diode 82 is connected in series with the parallel connection of switches 37, 38 and in series with a charging circuit 83 comprising a parallel of capacitor 84 and bleed-off register 86. The charging circuit 83 is connected to a voltage-sensitive circuit 88 whose output drives a logic circuit 90.

Operation of the power-down circuit 80 is as follows. Anytime a switch 37, 38 is closed, the capacitor 84 is charged to the source voltage, which turns on circuit 88. The logic circuit in turn supplies the battery power 17 to oscillators 20-22. When the depressed switch is released, capacitor 84 slowly discharges through resistor 86. In a given time dependent upon the values of capacitor 84 and resistor 86, for example 15 minutes, the capacitor voltage drops below the threshold of circuit 88, which turns off (or on) logic circuit 90 thereby isolating the battery 17 from the oscillators. The drain on the battery is effectively reduced by a factor of about 100, and its lifetime correspondingly increased. The power down circuit can also be added to the Fig. 4 embodiment. Means are provided to provide power to source 17" when power is cut to the oscillators.

In the description given so far, the transmissions radiated by the stylus, illustrated in Fig. 5 and Fig. 6A, can be viewed as analog signal transmissions. Analog encoding of multiple switch status is somewhat limiting
in the number of different switch combinations that can be represented. There are, however, circumstances in which many more combinations are desired. An example is a stylus provided with a pressure-responsive transducer coupled to the tip. In this case, the user, by pressing the stylus tip against the tablet surface, desires to transmit to the tablet, say, one of 256 different levels of switch pressure. This information can be interpreted by the tablet—usually determined by application software—for example, as representing line width or color.

In accordance with this aspect of the invention, the transmitted signal alternations is encoded as a unique sequence representing multiple switch status. Preferably, the status of multiple switches is encoded into a binary code. For example, an 8-bit binary word would allow for up to 256 different combinations of switch status. This would be suitable for the transmission, for example, of 256 different levels of switch pressure from a pressure sensitive stylus. This 8 bit binary word would be transmitted as alternations between the two frequencies generated by OSC 1 20 and OSC 2 27 (Fig. 3). This can be implemented in a number of different ways. Examples of these different ways includes, but are not limited to, the following. For example, a binary "0" would result in the transmission of frequency \( f_0 \) (from OSC 1) for a fixed time duration, and a binary "1" would result in the transmission of frequency \( f_1 \) (from OSC 2) for a fixed time duration. Or, the 0 or 1 combination may determine the time duration of the transmission of each frequency.

While an 8-bit binary word has the advantage that it can represent up to 256 different combinations, the invention is not so limited. A 3-bit binary code could represent any one of four switch conditions for a stylus.
having four switches. An example is:

- 000 - No switch
- 001 - Switch 1
- 010 - Switch 2
- 011 - Switch 3
- 100 - Switch 4

To implement the above by the preferred frequency encoding, an example is the following: with a binary "0" represented by a low frequency \( f_0 \), and a binary "1" represented by a higher frequency \( f_1 \). Fig. 9A shows the two signal representations. Fig. 9B illustrates a unique sequence of signal alternations representing activation of switch 2. Fig. 9C illustrates a different unique sequence of signal alternations representing activation of switch 4.

Instead of digitally representing switch status by a frequency, a unique sequence of frequency durations can be employed to represent a binary "0" and "1". For example, a binary "0" can be represented by frequency \( f_0 \) for 2/3 of a cycle, and frequency \( f_1 \) for 1/3 of a cycle, whereas the "1" is represented by the same frequencies but with inverted durations. Fig. 10A shows this encoding scheme. Fig. 10B shows this encoding scheme encoding "101", and Fig. 10C encoding "111".

Suitable electronics to implement the above would be evident to those skilled in this art. A block diagram of an example of one suitable system is illustrated in Fig. 11. Fig. 11A shows an encoder 70 to which inputs including \( f_0 \), \( f_1 \), and the desired code are supplied. The output—which could be, for example, Fig. 9B, Fig. 9C, Fig. 10B, or Fig. 10C—is supplied to the stylus transmitter 71, and the resultant transmission passed on to the stylus tip. At the tablet, the induced signal is received and processed 72, and then decoded 73, to reconstitute the original code. Standard software can now process the resultant binary code to represent
particular switch status.

It will be appreciated by those skilled in this art that the specific encoding does not matter; the fact that the button information can be encoded once you have a stylus which can switch between two frequencies is the important factor.

In processing the signals received from the grid, it is important to synchronize the reception of these unique sequences for proper decoding. This is represented in Fig. 11B by incorporation of a conventional sync circuit 74.

A preferred scheme for implementing the synchronous decoding feature of this invention is by generating signal packets comprising unique signal alternations to which has been appended an additional unique sequence representing sync information.

The concept is based on the following. In order to tell where one encoding begins, and another ends, a "protocol" is required to mark the beginning and end of each packet of information. Any desired protocol can be employed. As one example, which is not meant to be limiting, one can declare that all packets will start with a "0", and end with two or more "1"s. This is how RS-232 delineates bytes—with a start bit (0) and two stop bits (11). Then the previous coding in this protocol would be:

000011 - No Switch
000111 - Switch 1
001011 - Switch 2
001111 - Switch 3
010011 - Switch 4

The system receiver 72,74 would "sync" to these packets by waiting for a series of 2 or more "1"s, then know that the next packet starts when it sees the next "0".

Fig. 12 illustrates the operation. The transmitted
and received signal is illustrated at 75. The packet boundaries under the protocol is indicated by the arrows 76. The binary code represented by this particular signal sequence is 2204. The appropriate software can interpret this as follows: switch 2 closed, switch 2 closed, no switch closed, switch 4 closed. This interpretation is easily implemented with a look-up table.

While the preferred embodiment employs two signal frequencies for the radiated signals from tip 16, the invention can be implemented with three or more radiated signal frequencies.

While the invention has been described and illustrated in connection with preferred embodiments, many variations and modifications as will be evident to those skilled in this art may be made therein without departing from the spirit of the invention. The invention as set forth in the appended claims is thus not to be limited to the precise details of constructions set forth above as such variations and modifications are intended to be included within the scope of the appended claims.
What is claimed is:

1. A cordless pointing device for use with a position determining system, comprising:
   a manually operable switch;
   means for generating first and second signals each at a frequency different from that of the other of said signals;
   means for selectively radiating from said pointing device signals alternatingly in dependence upon the status of said switch.

2. The cordless pointing device of claim 1 wherein said radiating means selectively radiates either one of said signals relatively continuously or both said signals alternatingly in dependence upon the status of said switch.

3. The cordless pointing device of claim 1, wherein said radiating means for a first given switch status alternatingly radiates said first and said second signals at a first frequency and for a second given switch status alternatingly radiates said first and said second signals at a second frequency.

4. The cordless pointing device of claim 1 wherein said radiating means comprises means for generating a third signal having a frequency substantially different from that of said first and said second signals in dependence upon the status of said switch, said third signal controlling selective radiation of said first and said second signals from said pointing device.

5. The cordless pointing device of claim 1, wherein said radiating means radiates said signals at substantially constant amplitude.

6. The cordless pointing device of claim 1, wherein said generating means comprises means for generating said first and second signals as digital clock signals and said radiating means includes a radiating element and
means for selectively coupling said clock signals to said radiating element.

7. The cordless pointing device of claim 6 wherein said generating means comprises an oscillator and a binary counting circuit coupled thereto, first and second outputs of said oscillator and binary counting circuit providing said first and said second signals as digital clock signals.

8. The cordless pointing device of claim 4, wherein said generating means comprises means for generating said first, second and third signals as digital clock signals and said radiating means includes a radiating element and means for selectively coupling said first and second clock signals to said radiating element, and wherein said generating means comprises an oscillator and a binary counting circuit coupled thereto, first, second and third outputs of said oscillator and binary counting circuit providing said first, second and third signals as digital clock signals.

9. The cordless pointing device of claim 8, wherein said radiating means comprises a switch having a first input coupled to receive said first signal, a second input coupled to receive said second signal, an output coupled to said radiating element and another input for receiving said third signal and coupling said first and said second signals to said switch output in dependence upon said third signal.

10. The cordless pointing device of claim 1, further comprising a battery in the pointing device for powering at least said signal generating means.

11. The cordless pointing device of claim 6, further comprising a power-down circuit which selectively disconnects said battery from at least said signal generating means.

12. The cordless pointing device of claim 11,
wherein said power-down circuit includes a capacitor connected to be charged whenever said switch is activated, and means responsive to the voltage on said capacitor for selectively connecting said battery to the signal generating means.

13. A cordless digitizer system comprising:
   a tablet including comprising a conductor system and means for processing signals, said conductor system under control of said signal processing means interacting with a cordless pointing device to generate signals representing the position of the pointing device relative to the tablet,
   a said cordless pointing device comprising a switch and means for radiating to said tablet signals having information representative of the position of said pointing device relative to said tablet and the status of said switch, said radiating means comprising:
   means for generating first and second signals each at a frequency different from that of the other of said signals;
   means for selectively radiating from said pointing device both said signals alternatingly in dependence upon the status of said switch;
   said signal processing means including means processing said radiated signals to determine said switch status and the position of said pointing device relative to said tablet.

14. The digitizer system of claim 13, wherein said radiating means selectively radiates either one of said signals relatively continuously or both said signals alternatingly in dependence upon the status of said switch.

15. The digitizer system of claim 13, wherein said radiating means of said pointing device comprises means for generating a third signal having a frequency
substantially different from that of said first and said second signals in dependence upon the status of said switch, said third signal controlling selective radiation of said first and said second signals from said pointing device; and wherein said signal processing means of said tablet comprises means for detecting said third signal and for processing said detected third signal to obtain said switch status.

16. The digitizer system of claim 15, wherein said signal processing means includes a narrow bandwidth bandpass filter coupled to process the signals generated in said conductor system and closely tuned to the frequency of the particular signal being processed.

17. The digitizer system of claim 16 comprising first and second bandpass filters each coupled to process a different one of the signals generated by said conductor system and each closely tuned to the frequency of the signal that the particular filter is to process.

18. The digitizer system of claim 17 comprising means for rectifying and peak detecting signals output from said filters to provide respective pulsed signals, means for converting said respective pulsed signals to digital signals and means for digitally processing said digital signals to obtain said switch status.

19. A method of deriving switch status information from a cordless pointing device cooperating with a digitizer tablet, comprising:
   
   alternatingly radiating first and second signals of first and second different frequencies from said pointing device at a third frequency different from the first and second frequencies which represents the status of at least one switch in the pointing device;

   generating a first signals in the tablet in response to the first radiated signal at the third frequency and generating in the tablet a second signal in response to
the second radiated signal also at the third frequency, each of tablet generated first and second signals changing between first and second levels in accordance with the third frequency;

sampling the tablet generated first and second signals a preselected number of times in a preselected time interval;

detecting from said sampling the number of first and second levels and the number of transitions between the first and second levels in each of the first and second tablet generated signals during the preselected time interval;

counting the number of first or second levels occurring during the preselected time interval for one of the first and second tablet generated signals;

counting the number of transitions between first and second levels occurring during the preselected time interval for the one of the first and second signals; and

determining the switch status from the number of levels counted and the number of transitions counted.

20. The method of claim 19, wherein the determining step employs a look-up table.

21. A cordless pointing device for use with a position determining system, comprising:

a manually operable switch;

means for generating first and second signals each at a frequency different from that of the other of said signals;

means for selectively transmitting from said pointing device a sequence of signal frequency alternations in dependence upon the status of said switch, said sequence uniquely identifying the status of said switch.

22. The cordless pointing device of claim 1, wherein said sequence of signal frequency alternations is binary
encoded.

23. The cordless pointing device of claim 2, wherein said sequence of signal frequency alternations is encoded as a 3-bit byte or as an 8-bit binary word.

24. The cordless pointing device of claim 21, further comprising means for generating additional signals to serve as synchronizing means, said sequence of signal frequency alternations incorporating said additional signals.

25. The cordless pointing device of claim 21, further comprising means for creating signal packets for transmission by said pointing device, said signal packets including said sequence of signal frequency alternations and a unique sequence for synchronous decoding.

26. The cordless pointing device of claim 21, wherein said transmitting means radiates said signals at substantially constant amplitude.

27. The cordless pointing device of claim 26, wherein said generating means comprises means for generating said first and second signals at respective frequencies of $f_0$ and $f_1$.

28. A cordless digitizer system comprising:

- a tablet comprising a conductor system and means for processing signals, said conductor system under control of said signal processing means interacting with a cordless pointing device to generate signals representing the position of the pointing device relative to the tablet,

- said cordless pointing device comprising a switch and transmission means for radiating to said tablet signals having information representative of the position of said pointing device relative to said tablet and the status of said switch, said transmission means comprising:

  - means for generating first and second signals each
at a frequency different from that of the other of said signals;

means for selectively transmitting from said pointing device a sequence of signal frequency alternations in dependence upon the status of said switch, said sequence uniquely identifying the status of said switch;

said signal processing means including means receiving and processing said radiated signals to determine said switch status and the position of said pointing device relative to said tablet.

29. The digitizer system of claim 28, wherein said signal processing means includes a narrow bandwidth bandpass filter coupled to process the signals generated in said conductor system and closely tuned to the frequency of the particular signal being processed.

30. The digitizer system of claim 28, wherein the sequence of said signal frequency alternations is binary encoded.

31. The digitizer system of claim 30, wherein the sequence includes synchronizing information.

32. The digitizer system of claim 31, further comprising said receiving means including means to use the synchronizing information to identify the binary code.

33. The system of claim 22, wherein the last-named means employs a look-up table.
FIG. 4.
FIG. 6

A SIGNAL GENERATED BY STYLUS WITH BUTTON 2 PRESSED

B TIME IN μS

RECEIVED SIGNALS:

C OUTPUT OF A/D 1

D OUTPUT OF A/D 2

E 100 KHz SAMPLES

F 50 KHz SAMPLES

G 100 KHz: 14 SAMPLES → 8 ONES AND 6 TRANSITIONS

H 50 KHz: 14 SAMPLES → 6 ONES AND 8 TRANSITIONS
FIG. 7

90. GET OUTPUTS OF BOTH A/D's

91. SAMPLE EACH OUTPUT AT FIXED INTERVALS

92. COUNT THE NUMBER OF HIGH/LOW TRANSITIONS

93. COUNT THE NUMBER OF HIGHS OR LOWS

94. GO TO LOOK-UP TABLE FOR SWITCH STATUS
FIG. 9A

"0" = f₀

"1" = f₁

FIG. 9B

- Switch 2

"0" "1" "0"

FIG. 9C

- Switch 4

"1" "0" "0"

FIG. 10A

"0" = f₀ for 2/3 of cycle, f₁ for 1/3 of cycle

"1" = f₀ for 1/3 of cycle, f₁ for 2/3 of cycle

FIG. 10B

"1" "0" "0"

FIG. 10C

"1" "1" "1"
FIG. 11A

Input Code → Encoder → Stylus Transmitter

f₀ → 70
f₁

FIG. 11B

From Grid → Receiver → Decoder

Sync. → 72

74

Output Code

FIG. 12

...0110010110010110000110100110...

75

Packet Boundaries

"2" "2" "0" "4"
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) : G06C 21/00
US Cl. : 178/19
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 178/19 178/18; 340/706,709

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO APS: (Cordless, Wireless, Pointing Device, Pen, Mouse, Digitizer, Tablet, Digitizing System, Status, Switch#).

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US, A, 4,672,154 (Rodgers et al.) 09 June 1987 See Col. 3, lines 6-10; Col. 5, lines 4-13; Col. 5, lines 57-60; Col. 7, lines 12-24.</td>
<td>1,13,21-22, 28,30, 2-12,14-20, 23-27,29, 31-33</td>
</tr>
<tr>
<td>Y</td>
<td>US, A, 5,049,862 (Dao et al.) 17 September 1991 See Col. 8, lines 24-28.</td>
<td>1,13,19,21, 28</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

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