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(54) Force monitoring system

(57) A force monitoring system, particularly for use in signature verification apparatus, comprises a pad assembly having a base member (1) and a flexible pad member (5) on which forces are applied in use. A pair of superposed arrays of substantially parallel conductors are positioned between the base member (1) and the flexible pad member (5) with the conductors of one array transverse to the conductors of the other, the arrays being normally biased apart and one array being movable towards the other in response to forces applied on the pad member (5). A contact detection system detects changes in potential between conductors of the arrays when a force is applied to the electrical pad member (5) to determine the position of the applied force. The upper array is provided on a piezoelectric member (4) so that the applied force can be monitored by monitoring potentials generated by the piezoelectric member (4) in use.

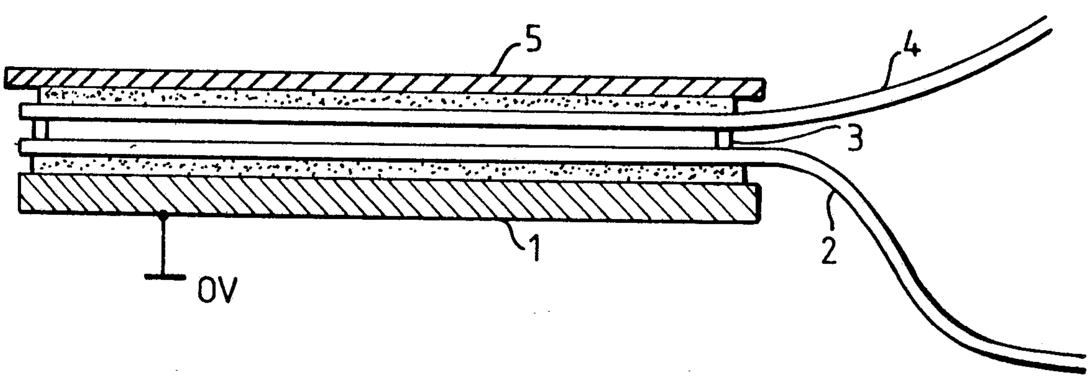


Fig.1

GB 2 196 164 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

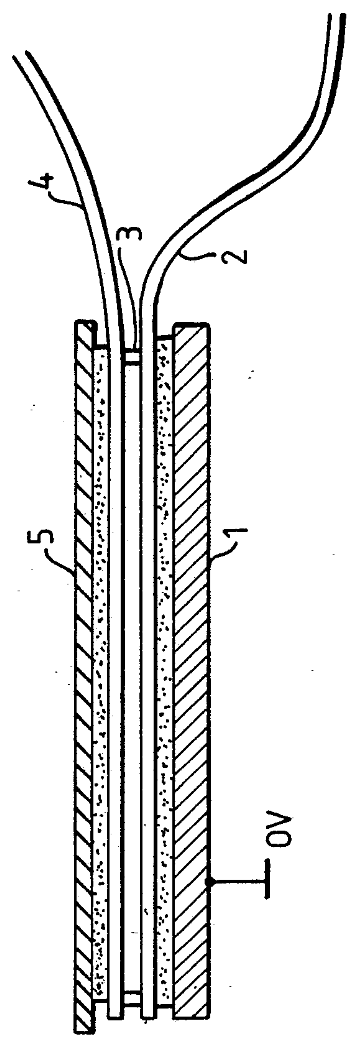


Fig.1

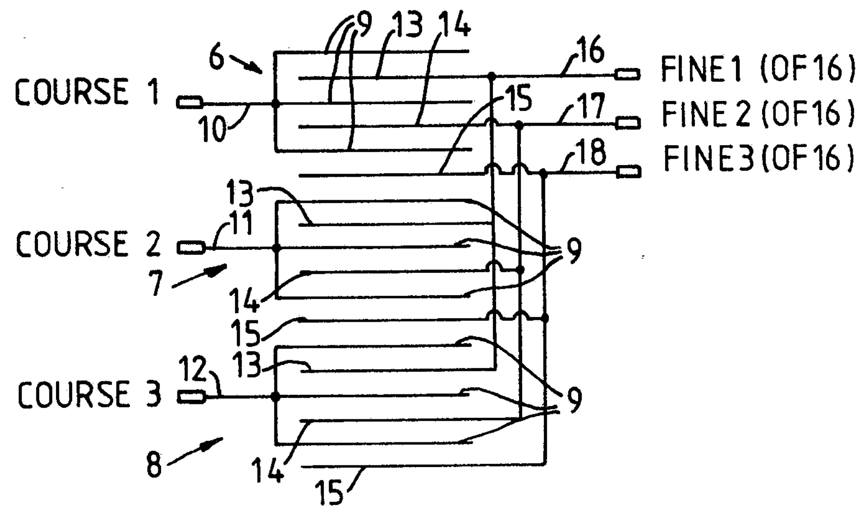

COURSE 1
COURSE 2
COURSE 3
FINE 1 (OF 16)
FINE 2 (OF 16)
FINE 3 (OF 16)
6
7
8
9
10
11
12
13
14
15
16
17
18

Fig. 2

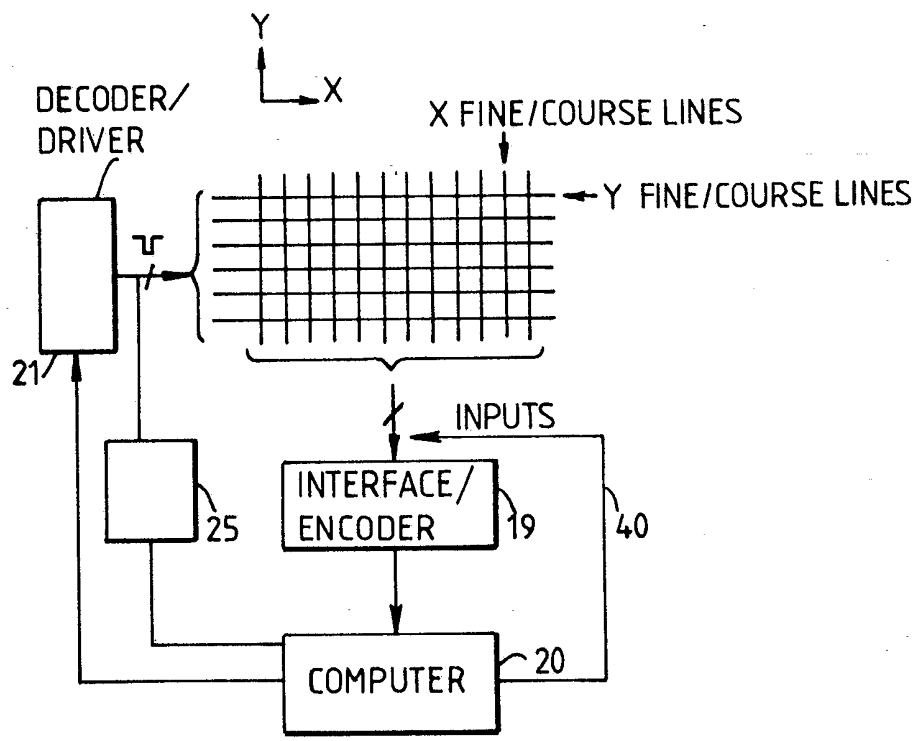

Y
X
DECODER/ DRIVER
X FINE/COURSE LINES
Y FINE/COURSE LINES
21
25
INPUTS
INTERFACE/ ENCODER
19
40
COMPUTER
20

Fig. 3

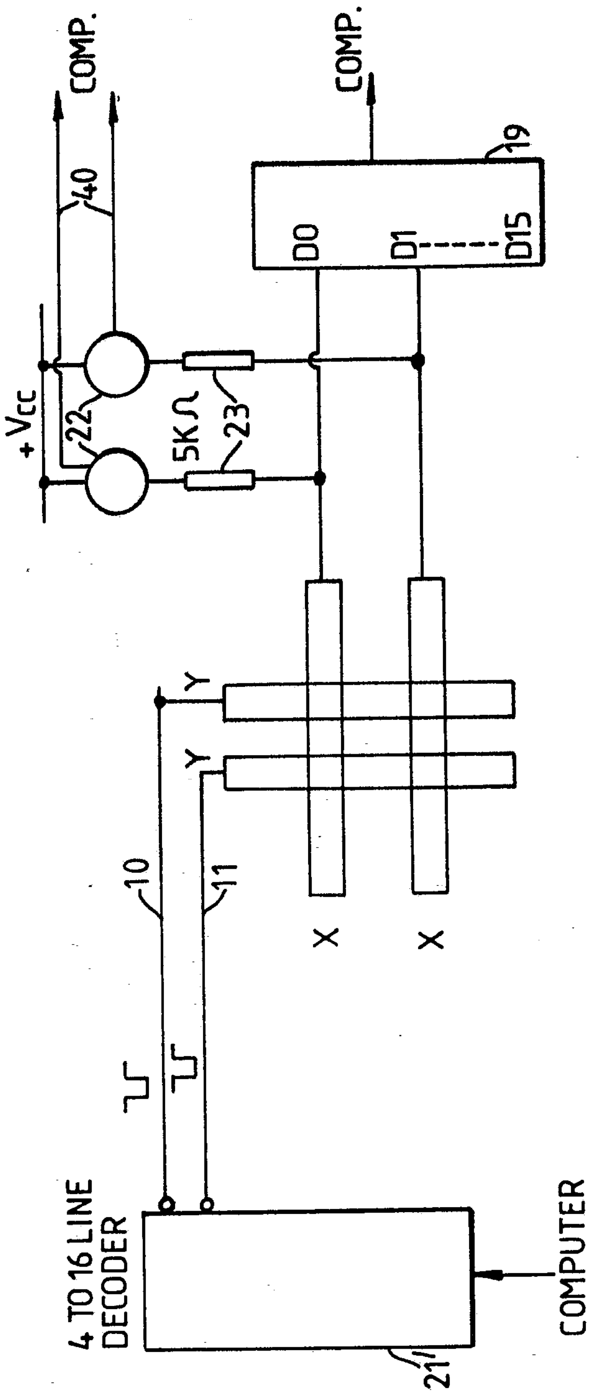
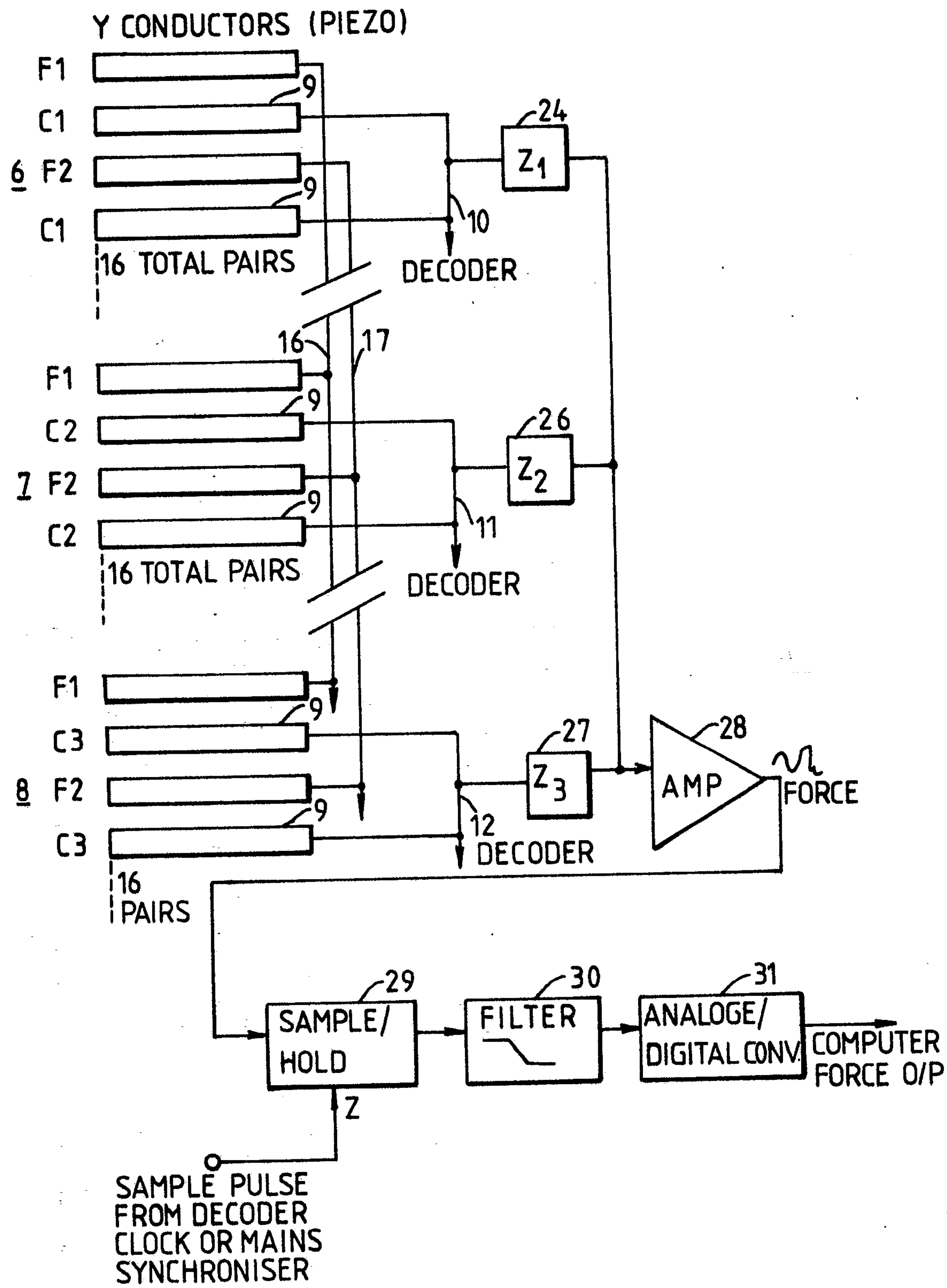
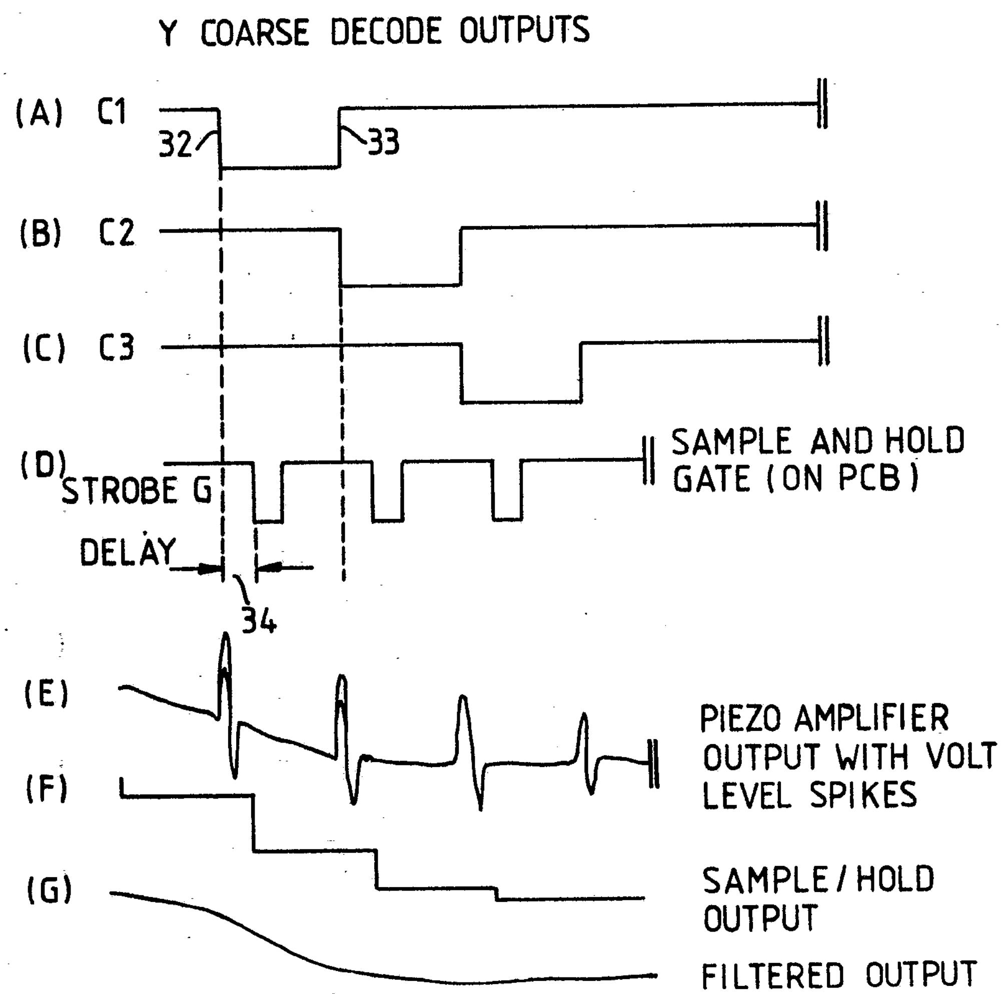

COMP.
COMP.
40
19
D0
D1
D15
+ Vcc
22
5K Ω
23
Y
Y
X
X
10
11
4 TO 16 LINE DECODER
COMPUTER
21

Fig.4



Y CONDUCTORS (PIEZO)
F1
C1
6 F2
C1
9
9
24
Z_1
10
DECODER
16 TOTAL PAIRS
16
17
F1
C2
7 F2
C2
9
9
26
Z_2
11
DECODER
16 TOTAL PAIRS
F1
C3
8 F2
C3
9
9
27
Z_3
12
DECODER
28
AMP
FORCE
16 PAIRS
29
SAMPLE/ HOLD
30
FILTER
31
ANALOGE/ DIGITAL CONV.
COMPUTER FORCE O/P
Z
SAMPLE PULSE FROM DECODER CLOCK OR MAINS SYNCHRONISER

Fig.5



Y COARSE DECODE OUTPUTS
(A) C1
32
33
(B) C2
(C) C3
(D) STROBE G
SAMPLE AND HOLD GATE (ON PCB)
DELAY
34
(E)
PIEZO AMPLIFIER OUTPUT WITH VOLT LEVEL SPIKES
(F)
SAMPLE / HOLD OUTPUT
(G)
FILTERED OUTPUT

Fig.6

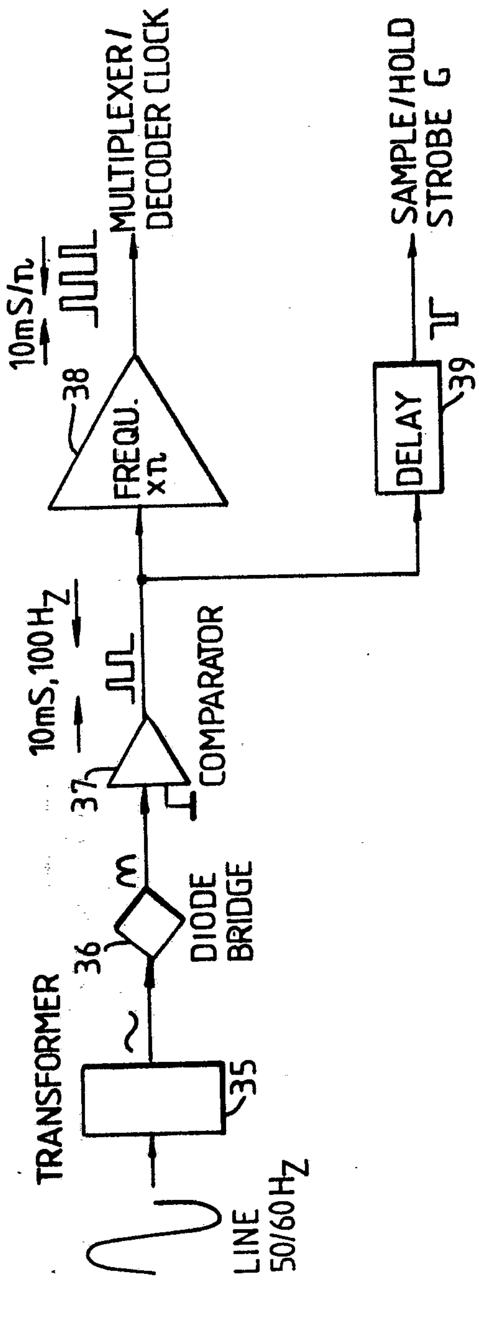

LINE
50/60Hz
TRANSFORMER
35
36
DIODE
BRIDGE
37
COMPARATOR
10mS, 100Hz
38
FREQU.
xn
10mS/n
MULTIPLEXER/
DECODER CLOCK
DELAY
39
SAMPLE/HOLD
STROBE G

Fig. 7

SPECIFICATION

Force monitoring system

The invention relates to a force monitoring system, for example for use in the field of signature verification.

We have described in our copending British Patent Application No.8526113 a special type of pressure pad which accurately measures the position of a writing instrument relatively to the surface of the pad.

An additional characteristic which it is often desirable to determine for a signature is the variation in force with which a writing instrument is urged against the pad while the signature is written. An example of a known system for monitoring force is described in US Patent Specification No.4,513,437 which illustrates the use of a special writing instrument in which is housed a piezoelectric transducer. The special writing instrument is attached via an umbilical cord to the signing tablet. This system is not particularly advantageous due to the requirement of the special pen and due to the connection between the pen and the tablet which can effect hand movements.

In accordance with one aspect of the present invention, a force monitoring system comprises a pad assembly onto which forces are applied in use, position detection means partly positioned on or in the pad assembly for detecting the position on the pad assembly of an applied force, force monitoring means including a piezoelectric member of the pad assembly responsive to an applied force to generate signals related to the variation in magnitude of an applied force with time, and sampling means for sampling at intervals the positions of applied forces determined by the position detection means and signals generated by the piezoelectric member.

The force monitoring system according to the invention provides a number of significant advantages over the known systems described above. In particular, the force monitoring system allows not only the variation in magnitude of the applied force to be monitored but also the position of the applied force so providing considerable detail on the signature or other information being written. In addition, no special writing instrument or connection between the writing instrument and the pad assembly is required. The ability to use a conventional writing instrument permits a more accurate response from the writer because there is no cord to effect hand movements. Furthermore, a normal pen or pencil does not have the problem of potential damage as does a special pen. Thus, the force monitoring system is completely self-contained.

The pad assembly and position detection means may be provided by any conventional system based for example on monitoring the flexure of a flexible pad member at different positions around the pad member but preferably the pad assembly comprises a base member, and a flexible pad member overlying the base member and on which forces are applied in use, and the position detection means comprises a pair of superposed arrays of substantially parallel conductors positioned between the base member and the flexible pad member with the conductors of one array transverse to the conductors of the other, the arrays being normally biased apart, and one array being movable towards the other in response to the application of forces on the pad member, and contact detection means for detecting changes in potential between conductors of the arrays when a force is applied to the flexible pad member to determine the position of contact of the applied force on the pad assembly.

Preferably, one of the arrays is provided on the piezoelectric member of the pad assembly, the force monitoring means being responsive to potentials generated by the piezoelectric member when a force is applied to the pad assembly to provide an indication of the variation in magnitude of the applied force with time.

The use of a piezoelectric member is particularly advantageous since this automatically generates electrical potentials in response to applied forces without the need for an external voltage supply. The piezoelectric member may be attached (bonded) to the flexible pad member or may constitute the flexible pad member.

In some cases, the force monitoring means may include a number of electrical conductors additional to the conductors of the position detection means. Preferably, however, the force monitoring means comprises a number of the conductors of the array of the position detection means provided on the piezoelectric member.

This provides a particularly simple arrangement since the conductors of the force monitoring means do not interfere with the conductors of the position detection means leading to very accurate position detection.

Conveniently, the sampling means, which typically comprises processing means such as a microcomputer, is adapted to strobe the conductors of one array in turn singly or in groups and to monitor the voltage on all the conductors of the other array, the sampling means being adapted to isolate the said number of conductors on the piezoelectric member from the contact detection means in order to detect potentials due to compression of the piezoelectric member. To this end, the sampling means may include one or more switches which are closed to connect a voltage source with the conductors to enable operation of the position detection means and are opened to enable operation of the force monitoring means.

The arrays of conductors may be arranged in any conventional manner but conveniently, at least the array of conductors on the piezoelectric member comprises a number of blocks of substantially parallel first conductors, the conductors of each block being electrically connected to respective coarse common conductors, with second conductors being positioned between each pair of first conductors of each block, corresponding conductors from each block being electrically connected to respective common fine conductors. Preferably, the said conductors of the force monitoring means comprise the coarse common conductors of the array provided on the piezoelectric member. This is the preferred arrangement, because, if the fine conductors were also monitored for force profiles, this would require more complex electronics.

Typically, the coarse common conductors are connected to a summing amplifier to provide an output signal related to the variation in force applied to the flexible pad member.

In accordance with a second aspect of the present invention, a pad assembly for use with a force monitoring system comprises a base member; a flexible pad member overlying the base member and on which forces are applied in use; and a pair of superposed arrays of substantially parallel conductors positioned between the base member and the flexible pad member with the conductors of one array transverse to the conductors of the other, the arrays being normally biased apart, and one array being movable towards the other in response to the application of forces the pad member, wherein one of the arrays is provided on a piezoelectric member of the pad assembly.

The main application for this invention is in the field of signature verification but the force monitoring system could be used in a wide variety of other fields where the variation in applied force is to be determined.

In order that the invention may be better understood, an embodiment of a force monitoring system according to the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a cross-section through the pad assembly of the system;

Figure 2 illustrates a simplified conductor array;

Figure 3 illustrates in block diagram form the position detection arrangement;

Figure 4 illustrates in block diagram form the position detection arrangement in more detail;

Figure 5 illustrates in block diagram form the force monitoring system;

Figure 6 illustrates a number of pulse sequences; and,

Figure 7 is a circuit diagram of the sample/-hold strobe and decoder clock generator.

The force monitoring system to be described is for use in a signature verification application and includes a pressure pad assembly shown in Figure 1. The pad assembly has an earthed aluminium base plate 1 onto which is bonded a flexi-circuit 2 which has an array of gold plated copper conductors on a Kapton base. A spacer member 3 extends around the edge of the flexi-circuit 2 and supports a second flexi-circuit 4. This second flexi-circuit is composed of a piezoelectric material which is photo-etched in a similar manner to the flexi-circuit 2 into a similar array of electrical conductors. The electrical conductors of the circuit 4 are orthogonal to those of the circuit 2, each array of conductors being arranged in blocks to be described below. A suitable material for the flexi-circuit 4 is polyvinylidene fluoride with a metalisation of either aluminium, nickel, or both. An example of a commercial material which is suitable is a film manufactured by the Pennwalt Corporation and sold under the registered trade name of Kynar.

The flexi-circuit 4 is surmounted by a stainless steel diaphragm 5 to which it is bonded to provide a flexible pad member.

In use, a writing material such as paper is placed onto the diaphragm 5 and the user signs his name on the paper. The signing action, using a conventional pen, causes the diaphragm 5 to flex at the position at which the pen is applied thus causing the flexi-circuit 4 to flex. This flexure causes the conductors on the flexi-circuit 4 adjacent the position of applied pressure to be brought close to or into contact with the adjacent conductors on the flexi-circuit 2. In addition, flexure of the material of the flexi-circuit 4 causes a local potential difference to be generated due the piezoelectric effect.

The arrangement of the conductors in each array is of the form shown in Figure 2. This illustrates in simplified form the conductors of the array on the flexi-circuit 4 which are spaced in the Y direction. The conductors on the flexi-circuit 2 are similarly arranged but are orthogonal to those on the flexi-circuit 4 being spaced in the X direction and typically comprise eleven blocks of coarse and fine conductors.

The array shown in Figure 2 is divided into three blocks 6-8 which, in this simplified arrangement, each have three coarse conductors 8 linked to common, respective coarse conductors 10-12. Interleaved between each pair of coarse conductors 8 is a respective fine conductor 13-15 corresponding fine conductors being connected with respective common fine conductors 16-18.

In other arrangements (not shown), more than one fine conductor could be interleaved between coarse conductors, or some interleaved conductors could be omitted.

In principle, the position of a writing instrument is determined initially by locating the block 6-8 of coarse conductors 8 in which the writing instrument is located and then by determining the position within that block from the information derived from the fine conductors 16-18.

In a practical application, each block of conductors 6-8 will comprise sixteen coarse conductors and sixteen fine conductors.

The conductors of the X array are connected to an interface/encoder 19 (figure 3) which in turn is connected to a microcomputer 20. The microcomputer 20 is connected with a decoder/driver 21 which is connected in turn to the Y array conductors.

The system is shown in more detail in Figure 4. The decoder/driver 21 comprises two four to sixteen line decoders one of which 21′ is shown. Each of the sixteen output ports of the decoder 21′ is connected to a respective fine conductor similar to the fine conductors 16-18 shown in Figure 2, while three of the output ports of the other decoder are connected to respective coarse conductors 10-12. Each coarse conductor of the X array is coupled via a respective line to the encoder 18 and is also coupled to a potential V_{cc} via respective switches 22 and resistors 23.

The encoder 19 comprises a number of sixteen to four line encoders, for instance a microcomputer controlled peripheral interface adaptor with parallel inputs and parallel outputs.

In operation, the switches 22 are closed to connect the V_{cc} line with the resistors 23 and a high potential is applied to each of the Y conductors via the decoder 21. The microcomputer 20 then outputs an address for each of the three Y coarse conductors in sequence causing a zero voltage strobe pulse to be applied to the addressed coarse Y conductors. Thereafter each of the fine Y conductors, which normally carry a high voltage, are also strobed in sequence. The encoder 19 effectively scans each of the X lines and when a pulse is detected on one of the X lines the address of the line is fed to the microcomputer 20. The presence of a pulse on one or more of the X lines results from the movement of one or more of the Y conductors towards the X conductors in response to an applied force and will occur when the Y conductor or conductors concerned is strobed. At the least pulses will be detected on one of the common coarse K conductors indicating the block and on one of the common fine x conductors indicating the position within the block. In this way, all the Y lines are strobed and the X lines monitored to determine the position of an applied force at spaced intervals in time.

To obtain information on the force with which a writing instrument is pressed onto the pad member 5, use is made of the piezoelectric property of the member 5 on which the Y array conductors are mounted. Figure 5 shows the three blocks 6-8 of Y conductors. Each block, as previously described, has sixteen coarse conductors 9 (labelled C1, C2, and C3 in Figure 5) and sixteen interleaved fine conductors two of which are shown for each block labelled F1, F2. Again, as previously described, each of the coarse conductors is connected via a respective common conductor 10-12 to the decoder 21. Bach set of fine conductors is connected via a respective common conductor, two of which are shown in Figure 5, labelled 16, 17, to the decoder 21.

In addition to their connection to the decoder 21, all the coarse conductors are coupled via respective impedances 24, 26, 27 to a common summing amplifier 28. The output from the summing amplifier 28 which is an analogue signal is fed to a sample/hold circuit 29. The output from the sample/hold circuit 29 is filtered in a filter circuit 30 and converted to digital form in an analogue/digital converter 31 to produce an eight bit digital code which is fed to the microcomputer 20. The elements 24, 26-31 shown in Figure 5 are indicated by a single box 25 in Figure 3.

It should be noted that the fine conductors are not used for monitoring force profiles because this would require an extra sixteen resistors 23 and switches 22. In practice, when the fine conductors are traversed by a writing instrument, there will always be one or more coarse conductors activated by the applied force. The force profile is not lost although the amplitude is reduced by about 50%. This is compensated for by the amplifier 28.

It is necessary to isolate the signals generated in the conductors 9 due to the piezoelectric effect from the signals produced by the decoder/driver 21 while strobing the conductors. The pulse diagrams labelled A-C in Figure 6 illustrate the strobe zero voltage pulse applied to each of the sets of coarse conductors 9 during a single strobe of all the Y conductors. Thus, pulse diagram 6A indicates at 32 the start of a zero voltage pulse and at 33 the end of the pulse. As soon as the zero voltage pulse to the coarse conductors C1 ends, a similar pulse is applied to the coarse conductors C2 and then to the coarse conductors C3 (see figures 6B,6C). Subsequently all the fine conductors F1-F16 are pulsed in a similar manner. During the pulsing of the fine conductors, the switches 22 are closed.

During each strobe pulse of the coarse conductors C1-C3, a strobe signal G (pulse diagram 6D) is generated for a relatively short period. This signal is fed to the sample/hold circuit 29. During the existence of this strobe pulse, the switches 22 are opened by feeding the strobe pulse along lines 40 (Figures 3 and 4) thus breaking the connection with the V_{cc} line and isolating the Y array conductors from the potential applied from the decoder/driver 21. During this period, the output from the amplifier 28, which is substantially solely due to the potential relative to the earthed base plate 1 generated by the piezoelectric effect in response to the applied force, is sampled by the sample/hold circuit 29. This provides an indication of the force applied either in absolute or relative terms. The piezoelectric output does not provide an absolute force measurement. Being a capacitive device it provides an output proportional to dF/dt ie. the differential of force with respect to time. This signal does, however, provide all of the dynamic frequency content of a true (absolute) force profile. For instance signing time, number of pen lift-offs, frequency of hand movements are all readily measurable, together with a force waveform which is virtually unique for a particular signer.

After filtering and conversion to digital form, a "force" value is fed to the microcomputer 20. Pulse diagrams 6E-6G indicate the signals output from the amplifier 28, sample/hold circuit 29 and the filter 30 respectively.

As soon as the signal from the amplifier 28 has been sampled the strobe signal G ceases and the switches 22 close.

The interference caused by the multiplexed signals on the conductors is significantly reduced by sampling the analogue signal from the amplifier 28 after a delay from the start of a voltage strobe pulse on the corresponding coarse conductors. The delay is indicated at 34 in Figure 6D. Further attenuation is provided by the earthed base plate 1 and the conductive cover (stainless steel or rubber) 5.

Further interference in high impedance circuits is caused by electromagnetic mains radiation at 50 or 60 Hz. This can occur for a variety of reasons. To reduce this, a circuit has been devised (Figure 7) for generating the strobe clock signal for the driver/decoder 21 and the sample/hold strobe signal G. This circuit includes a transformer 35 coupled to a mains supply, the output of the transformer being fed to a diode bridge 36 which generates full wave rectified sine signals which are fed to a zero-crossing comparator 37. This generates a clock signal at 10ms intervals each time the input mains passes through a null point. This signal is fed in parallel to a frequency multiplier 38 and a delay circuit 39. The output from the frequency multiplier 38 provides a multiplexer/decoder clock control signal at a higher frequency than the rectified mains (100Hz) to operate the decoder/driver 21 while the output from the delay circuit 39 constitutes the strobe signal G used to control the sample/hold circuit 29. As previously mentioned, the sample/hold strobe signal must be synchronised and delayed from the waveforms on the X and Y circuits to prevent excessive radiation pick up.

Frequency multiplication can be achieved with a single chip phase-locked-loop or by using the microcomputer to monitor the mains period (10ms) with its dedicated internal counter, and generating the clock as before. The monitoring would be necessary only at fairly long intervals since there is no rapid change in line frequency. Using this technique, individual Y conductors could be strobed at for example 0.1 ms, the complete pad scanned in 5 ms and the force profile monitored in 10 ms, therefore providing low noise, mains synchronised data in XY position and force.

CLAIMS

1. A force monitoring system comprising a pad assembly onto which forces are applied in use, position detection means partly positioned on or in the pad assembly for detecting the position on the pad assembly of an applied force, force monitoring means including a piezoelectric member of the pad assembly responsive to an applied force to generate signals related to the variation in magnitude of an applied force with time, and sampling means for sampling at intervals the positions of applied forces determined by the position detection means and signals generated by the piezoelectric member.

2. A force monitoring system according to claim 1, wherein the pad assembly comprises a base member, and a flexible pad member overlying the base member and on which forces are applied in use, and the position detection means comprises a pair of superposed arrays of substantially parallel conductors positioned between the base member and the flexible pad member with the conductors of one array transverse to the conductors of the other, the arrays being normally biased apart, and one array being movable towards the other in response to the application of forces on the pad member, and contact detection means for detecting changes in potential between conductors of the arrays when a force is applied to the flexible pad member to determine the position of contact of the applied force on the pad assembly.

3. A system according to claim 2, wherein one of the arrays is provided on the piezoelectric member of the pad assembly, the force monitoring means being responsive to potentials generated by the piezoelectric member when a force is applied to the pad assembly to provide an indication of the variation in magnitude of the applied force with time.

4. A system according to claim 3, wherein the force monitoring means comprises a number of the conductors of the array of the position detection means provided on the piezoelectric member.

5. A system according to claim 4, wherein the sampling means is adapted to strobe the conductors of one array in turn singly or in groups and to monitor the voltage on all the conductors of the other array, the sampling means being adapted to isolate the said number of conductors on the piezoelectric member from the contact detection means in order to detect potentials due to compression of the

piezoelectric member.

6. A system according to any of claim 2 to 5, wherein at least the array of conductors on the piezoelectric member comprises a number of blocks of substantially parallel first conductors, the conductors of each block being electrically connected to respective coarse common conductors, with second conductors being positioned between corresponding pairs of the first conductors of each block, corresponding second conductors from each block being electrically connected to respective common fine conductors.

7. A system according to claim 6, when dependent on claim 4 or claim 5, wherein the said conductors of the force monitoring means comprise the first conductors of the array provided on the piezoelectric member.

8. A system according to claim 7, wherein the coarse common conductors are connected to a summing amplifier to provide an output signal related to the variation in force applied to the flexible pad member.

9. A force monitoring system substantially as hereinbefore described with reference to the accompanying drawings.

10. A signature verification system including a force monitoring system according to any of the preceding claims; and processing means responsive to output signals from the position detection means and the force monitoring means to generate a representation of a signature written on the pad assembly.

11. A pad assembly for use with a force monitoring system, the pad assembly comprising a base member; a flexible pad member overlying the base member and on which forces are applied in use; and a pair of superposed arrays of substantially parallel conductors positioned between the base member and the flexible pad member with the conductors of one array transverse to the conductors of the other, the arrays being normally biased apart, and one array being movable towards the other in response to the application of forces the pad member, wherein one of the arrays is provided on a piezoelectric member of the pad assembly.

12. A pad assembly substantially as hereinbefore described with reference to the accompanying drawings.

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