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Graphic input tablet

Shintron Co., of Concord, MA, manufactured a computer graphic input tablet called Ecricon. This product was developed in 1967, and a U.S. patent was granted in 1971 [Patent 3,591,718 by S. Asano and L.K. Baxter, assigned to Shintron Company, Inc.]. The Ecricon tablet measured the x, y, and z movements of a small capacitively coupled pickup stylus relative to a square-wave-driven resistive sheet which generates an electrostatic field over an 11 in square tablet. Two different methods of producing the orthogonal field lines were investigated, and a novel phase-locked-loop demodulator was used with ratiometric response and good performance at large stylus-to-tablet separation.

19.1 SPECIFICATIONS

Resolution	1024 × 1024
Accuracy	1%
Sample rate	100 xy samples/s
Output format	10 bit parallel digital
Maximum paper thickness	1/2 in

19.2 GENERATING THE ELECTRIC FIELD

19.2.1 One dimension

Driving a resistive sheet to measure a *single* axis is simple (Figure 19.1). If metallic electrodes A and B are fed with a 5 V square wave, the resistive sheet will generate a linear AC voltage field just over its surface. A stylus using a small electrode will pick up a signal proportional to the y displacement when moved near the surface of the sheet. With circuits which measure signal amplitude, the z position can also be measured, although not linearly.

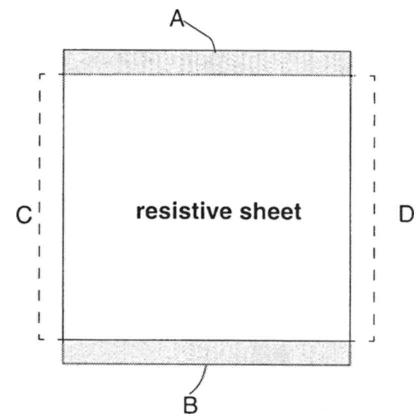

Figure 19.1 Driving a resistive sheet

19.2.2 Two dimensions, resistive sheet

Extending this method to two dimensions is not as simple. If metallic electrodes *C* and *D* are added at the dotted lines, the original electrodes *A* and *B* will be shorted at the corners, or at minimum a very nonlinear field will be produced. One way around this trap is to use a large number of current generators in parallel to drive the edges of the resistive sheet, and in fact a computer graphics input tablet was built this way by Sylvania, Inc. A simpler method is to drive the corners instead of the edges, and to use a medium resistivity and a high resistivity material to produce an orthogonal, linear field (Figure 19.2).

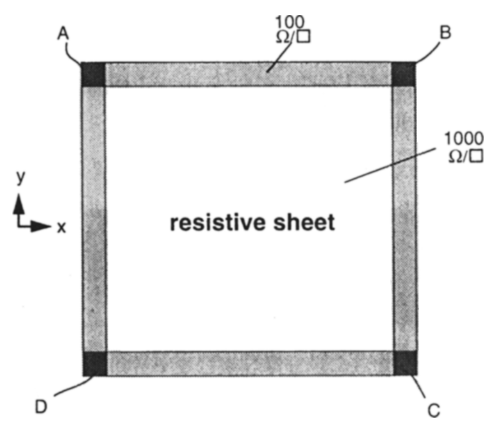

Figure 19.2 Resistive tablet with x and y outputs

To measure position in the y axis, electrodes *A* and *B* are connected together and driven with 100 kHz 0° and electrodes *C* and *D* are connected together and driven with 100 kHz at 180°. Then as the stylus is moved in the y axis, the electrical angle will change from 0 to 180°, but displacement in x will not affect the signal. Position in the x axis is then determined by driving electrodes *A* and *D* together, and *B* and *C* together.

Nonlinearity correction

The field produced by this tablet will be linear and orthogonal, excluding small fringe effects, if the ratio of the resistivities is large. In practice, resistivities may be difficult to obtain with high ratios, and a geometric compensation is needed to correct the resulting nonlinearity (Figure 19.3). The curvature is 10% of the tablet size for the 10:1 resistivity ratio shown.

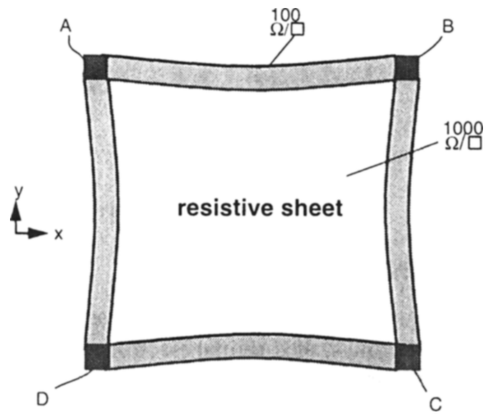

Figure 19.3 Resistive tablet with linearity corrected

With a stored linearity correction table, extreme nonlinearity can be handled; the low resistance strips can be dispensed with, for example, and the resulting over-50% nonlinearity compensated by a table lookup operation.

An intermediate approach to generating a linear orthogonal field is to deposit stripes of conductor on 1000 Ω/□ resistivity material to form the 100 Ω/□ areas with only one resistive ink printing step (Figure 19.4).

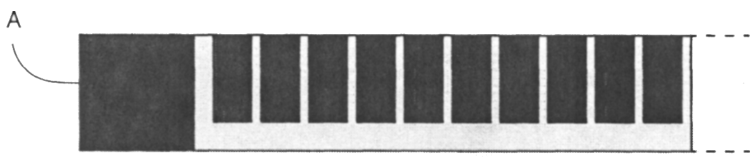

Figure 19.4 Electrodes to reduce 1000 Ω/□ to 100 Ω/□

The stripes are about 10× wider than the gap, and a small strip of unstriped area is left so that the field loses its lumpy character by the time it reaches the active area.

Resistive film

Some materials which can be used for resistive films are shown in Table 8.2. Vacuum-deposited thin films are expensive for large substrates, so screened thick film layers are preferred. Pyrolytic deposition of SnO_2, tin oxide, or $InSnO_2$, indium tin oxide, is used when a transparent conductor is needed.

19.2.3 Potentiometer wire

Due to variation of resistivity, the accuracy which can be obtained with the use of resistive film in large sizes may be inadequate, perhaps 5–15% nonlinearity and 50% absolute accuracy. The absolute accuracy is not important in this application, but the nonlinearity can be excessive for many uses. One fix is to store a table of correction values. Another method is to use potentiometer wire rather than film, as fine nichrome wire with excellent resistance accuracy is available for wirewound resistors and potentiometers. A prototype tablet was built (Figure 19.5) with crossed noncontacting grids of 0.005 in diameter nichrome wire, and demonstrated excellent accuracy in the range of 0.1–0.2%.

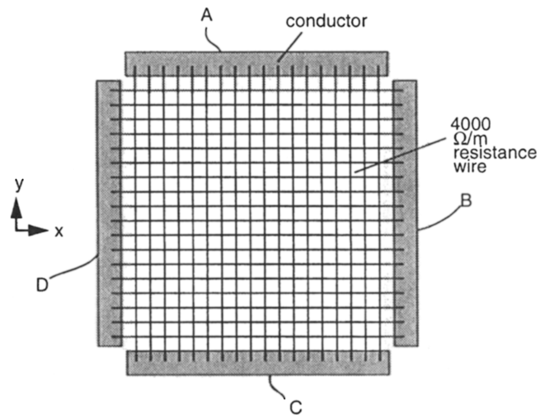

Figure 19.5 Potentiometer wire tablet

Two isolated sheet resistors are formed, one by conductors *A* and *C* and the interconnecting resistance wire, and the other by conductors *B* and *D*. In operation, first a square wave is impressed across *A* and *C* while *B* and *D* are grounded, and then *B* and *D* are driven while *A* and *C* are grounded. The grounded mesh will act as a shield to the driven mesh and reduce the total available field slightly, but as a ratiometric detection scheme is used, the effect is insignificant.

19.3 PICKUP

Stylus

The stylus pickup is a guarded, coaxial construction (Figure 19.6). The stylus used for Ecricon is a standard ballpoint pen with 2 mm of its point exposed for writing and for sensing. Its performance is good up to 10 cm stylus-to-tablet spacing, at which distance its capacitance to the resistive sheet is approximately 0.05 pF and its signal amplitude is reduced to 10% of the amplitude at the surface due to fringe effects and unguarded stray capacitance. This level of performance requires amplifier input capacitance to be less than 0.1 pF; with this low value of amplifier input capacitance the signal is attenuated by 3×, but the ratiometric detection method makes this less important.

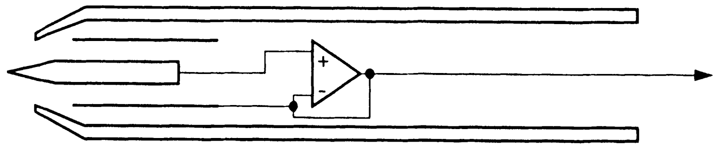

Figure 19.6 Stylus

Pickup circuit

The pickup uses discrete transistors, and both guarding and neutralization to minimize input capacitance (Figure 19.7).

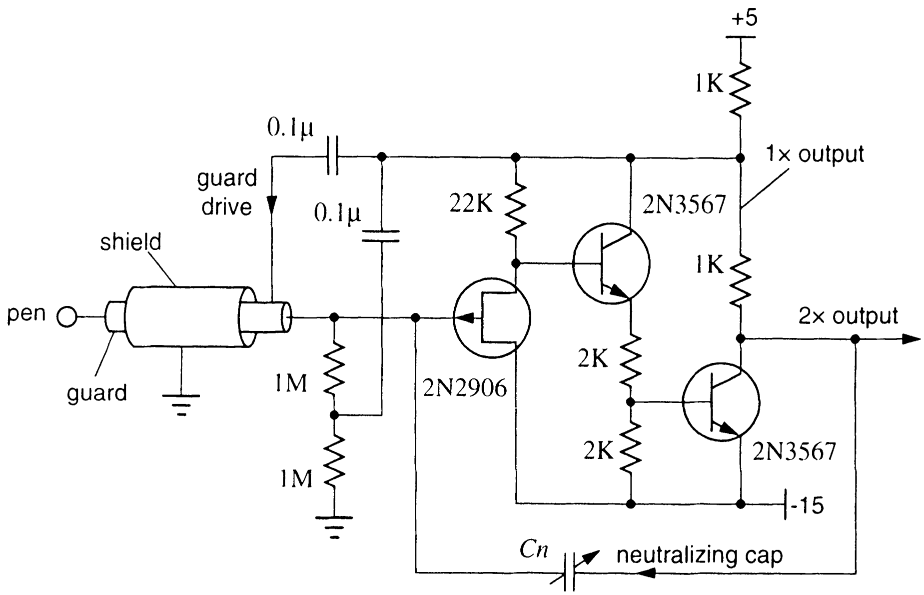

Figure 19.7 Pickup schematic

With this circuit, the guard handles most of the input capacitance cancellation, with a small residue caused by the finite amplifier gain and the gate-to-drain capacitance of the FET. The neutralizing capacitor, with a value of 0–0.1 pF, is adjusted to null out these factors and produce a nominal input capacitance of zero. If *Cn* is adjusted for a slightly negative input capacitance the circuit is stable with high signal level, but with decreasing signal level, as the stylus is moved away from the tablet, the circuit becomes unstable and oscillates at a few kHz. Luckily, parasitic capacitance is reasonably repetitive and stable, so the neutralizing adjustment is not sensitive to environmental factors once adjusted.

19.3.1 Reverse sensing

If the tablet is floated and touched with a grounded stylus or a fingertip, the signal can be picked off the tablet rather than the stylus. As a large parasitic capacitance is typical with this connection, a virtual ground or feedback-type amplifier is used. This technique is used for CRT touchscreens, with a transparent conductor providing the resistive sheet; for large tablet sizes, a tracking algorithm is more resistant to noise as only the field near the touch is of concern.

19.4 EXCITATION

The signal strength varies over a large range as the stylus is moved away from the tablet, so an amplitude-independent ratiometric demodulator must be used, and the design of the drive voltages must include a reference signal. The 90° drive shown previously (Figure 1.36) is used. One additional modulation is performed, however: the 0 and 90° signals are exclusive-OR'd with 102 kHz to provide a higher frequency carrier which is easier to couple to the pickup and provides greater immunity to power-frequency noise coupling.

19.5 DEMODULATION

The demodulator is a novel phase-locked-loop circuit which handles three tasks:

- Amplitude-independent ratiometric demodulation
- Variable bandwidth reduction
- Analog-to-digital conversion

The demodulator circuit is unusual (Figure 19.8).

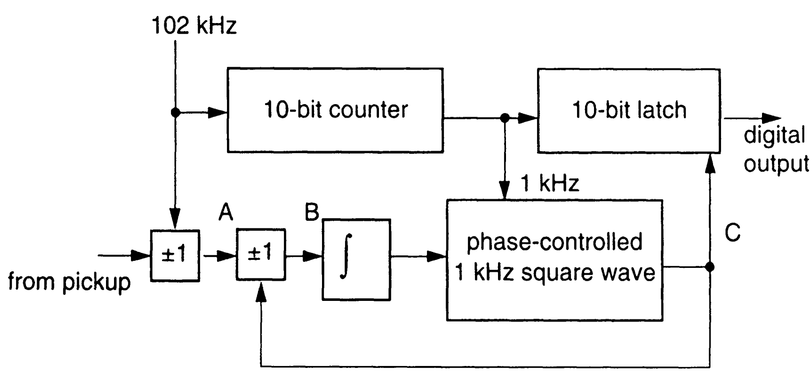

Figure 19.8 Demodulator block diagram

The 102 kHz modulation is demodulated by the first ±1 block, and the signal output of this block is similar to the bottom trace of Figure 1.36. This is then multiplied by the variable-phase square wave output in the second ±1 block and integrated. The integrator time constant is set so that the peak-to-peak AC at its output is small, say 1 V, to avoid saturation effects. The integrator then feeds a voltage-variable phase shift circuit, and the loop is closed back to the second multiplier. This circuit phase locks the square wave so that its phase shift is directly proportional to the ratio of the variable signal to the peak signal.

The operation is explained by the waveform with the 102 kHz carrier subtracted (Figure 19.9). The output at point *A* is the 500 Hz signal, the linear combination of 0° and 90° square waves after demodulating the 102 kHz carrier with the first ±1 stage. As the stylus moves full range, the variable sector moves linearly from the negative reference voltage to the positive reference voltage. This produces a DC offset at the integrator output which changes the phase of the square wave in a direction to null the offset, so that the three areas shown for point *B* have the relationship $S = R1 - R2$. As the input signal changes through full scale, the output phase changes linearly through 90°. The feedback will create an undamped second-order response which will overshoot unless the integrator is lossy. The loss can be adjusted for an appropriate damped response.

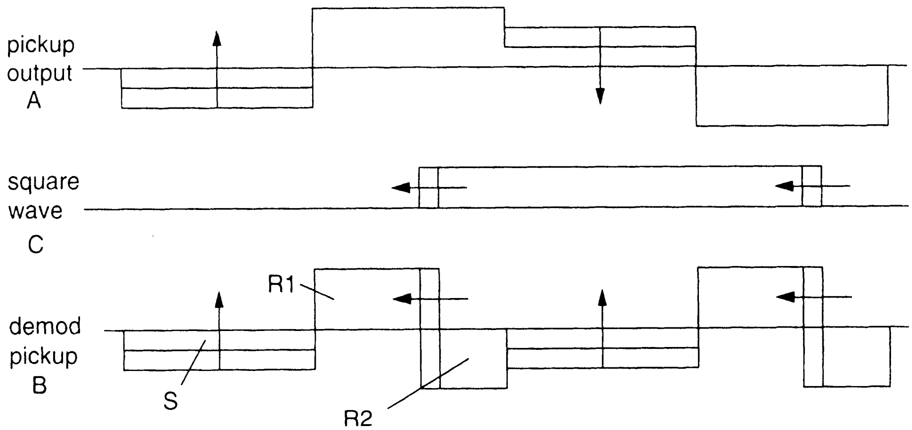

Figure 19.9 Phase-lock waveforms

This demodulator is amplitude-insensitive; it integrates a full cycle so impulse noise is rejected, and it has a variable bandwidth to reject noise. The signal bandwidth is a function of the integrator gain times the input amplitude times the phase-angle-per-volt response of the phase-controlled square wave generator, so as amplitude decreases with increasing stylus height, the gain and bandwidth automatically decrease to reject noise. Another advantage is the precision and simplicity of the digital output.

Although implementation is shown for clarity with two successive ±1 stages, the demodulator can be simplified by combining the two stages into a single ±1 stage with the control signal created by the exclusive-OR of the 102 kHz clock and the phase-modulated square wave.