

## THE AT&T SOFT TOUCH-SENSITIVE SCREEN

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**Introduction**

In the past, conventional touch-sensitive screens have not received widespread acceptance due to very structured target placement, video-image and touch-target alignment problems caused by cathode-ray tube drift, and the unfriendly feel of the hard surface. This article describes a touch screen technology that has overcome all of these problems—a unique, optically based soft touch screen developed by members of AT&T. The screen is the primary interface to the broad range of features of the world's most advanced telephone—the AT&T Personal Terminal model 510. With this touch screen, commanding almost any complex feature can be reduced to the simple act of touching. This holds significant promise for drawing the computer-leery into the realm of data bases and computer applications, making access to them easier than dialing a telephone. The applications are limited only by one's imagination and creativity.

The soft touch screen was developed for the AT&T Personal Terminal model 510. The product is designed for managers who typically use voice features intensively and have moderate needs for data access and manipulation. Virtually all of the features of the product are accessible with one touch, including a 100-entry phone directory, a time manager, and a calculator. The 510 terminal is a charac-

ter-mapped system that allows target placement in any of its 2160 character positions (80 columns by 27 rows.) Touch screens are ideal for applications involving menu selection, including: one-touch dialing from shared-access corporate directories, automatic teller machines, airline seat selection, on-board automotive environmental control, and on-line factory process control systems. The versatility of the AT&T optical technology allows great freedom in touch target placement, permitting custom tailoring of menu screens to fit almost any application.

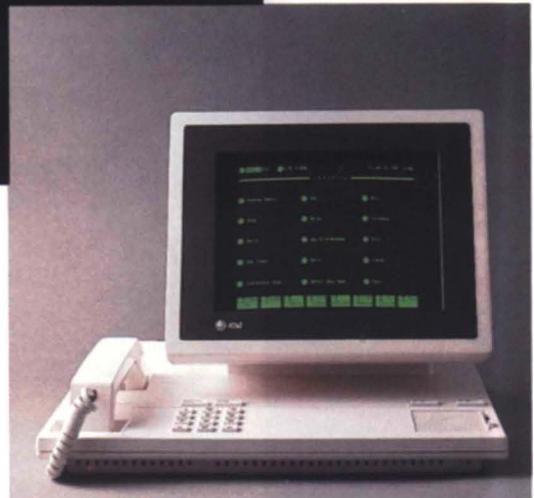
**Touch Screen Optics**

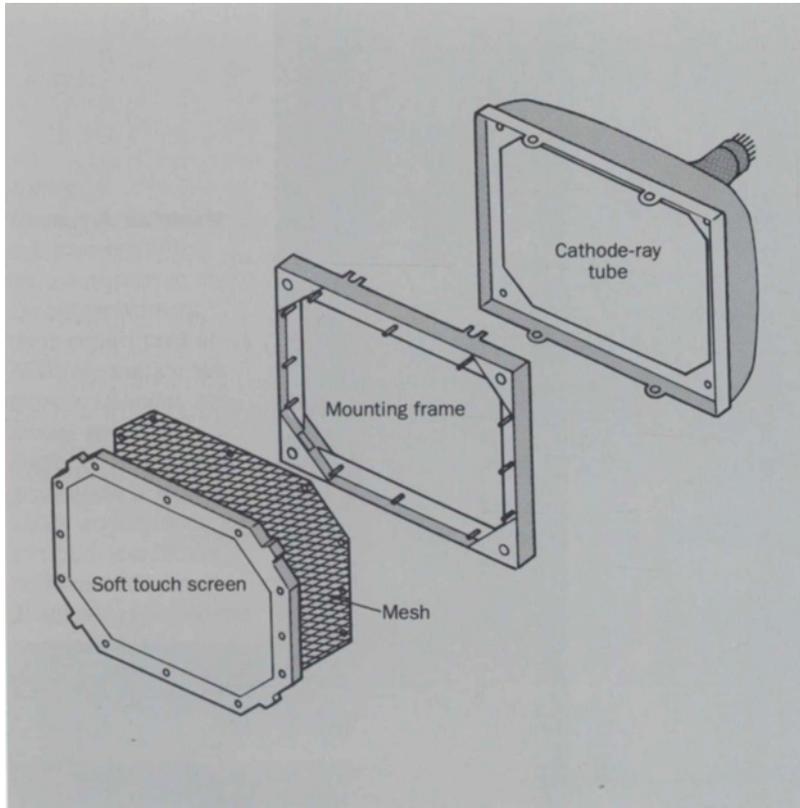
The AT&T optical touch screen consists of a soft, transparent membrane stretched over the faceplate of a cathode-ray tube (CRT) (Figure 1). Light from the CRT becomes trapped in the membrane through total internal reflection when the user deflects the front surface with a finger. The light travels to the edge of the membrane where it is detected by photo-sensors. The position of the touch is determined by correlating the coincidence of the signal generated by the touch with the write address of the CRT controller which governs raster (electron-beam scanning) position. As a result, the system is independent of CRT raster drift and is therefore inherently aligned.

An air gap is required behind the membrane to assure total internal reflection within the membrane. This air gap is maintained by a black monofilament nylon mesh having 139 threads per inch. The threads are not visible to the user. The mesh also enhances the optical contrast of the system. When the screen is deformed by a touch, light is refracted according to Snell's law and becomes



**Soft touch screen is a user-friendly transparent membrane for the AT&T Personal Terminal model 510. It overcomes problems of other touch screen technologies.**





**Figure 1. Structure of the soft touch-sensitive display. The screen consists of a gel within polyurethane sheets, mounted in a frame.**

trapped in the membrane for incident angles greater than the critical angle (Figure 2).

#### **Chemistry of the Membrane**

The soft touch screen is a three-layer composite in cross section (Figure 3). The front and back surfaces (0.020-in-thick thermoplastic polyurethane) are durable, nontacky, scratch-resistant, and puncture-resistant. Polyurethane was chosen for its toughness, ease of cleaning, and history of not causing skin irritation on contact. The layer between is a filler material of a two-part soft, tacky silicone. The system is curable at room temperature. The material had to be custom-developed to obtain the desired softness and durability. The filler material is a gel, rather than a fluid. Deflection of the front surface causes material deformation without flow. As a result, puncture of the front surface does not result in material flowing from the membrane.

An injection-molded polyurethane frame forms the border of the touch screen to provide a semirigid mounting structure (Figure 1). Twelve holes permit alignment to a plastic frame mounted to the CRT which houses the photosensors and preamplifier circuitry. The front and back sheets of the membrane are heat laminated to the polyurethane frame, forming, in essence, a polyurethane pillowcase filled with silicone gel.

#### **Performance Requirements**

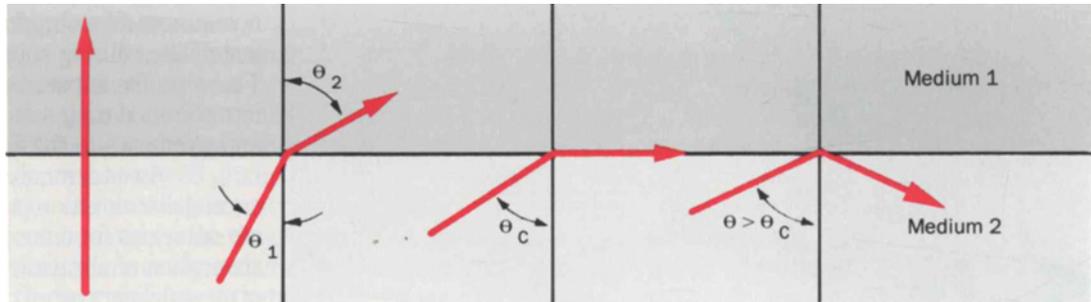
The hardness of the touch screen is dictated by electrical signal-processing capabilities and human factors considerations. Figure 4 is a plot of the design constraints. A 0.090-in deflection is required to provide an ample optical signal to the detection electronics. At this

deflection, a hardness of 200 to 300 grams is judged optimum, according to human factors studies. On the basis of anthropomorphic data and optical measurements, a 0.625-in-diameter shiny steel sphere was chosen as a “standard finger” for optical and hardness measurements of the membrane. The membrane thickness (0.180 in) is determined from image resolution and parallax requirements and the size of the silicon photodiodes. The front surface thickness is optimized for puncture resistance, feel, membrane distortion under deflection, and film manufacturing constraints. For a standard finger geometry, the membrane force/deflection curve of Figure 4 follows a power law relationship with a correlation coefficient of the data generally above 0.98.

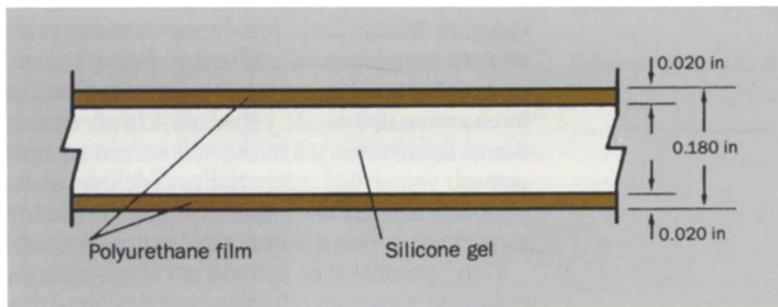
Resilience, the restoring characteristic of the material after a touch, is also very important. Slow restoration causes lingering image distortion and is therefore unacceptable to the user. A minimum acceptable value of 14 on a Shore SR1 resiliometer was obtained empirically.

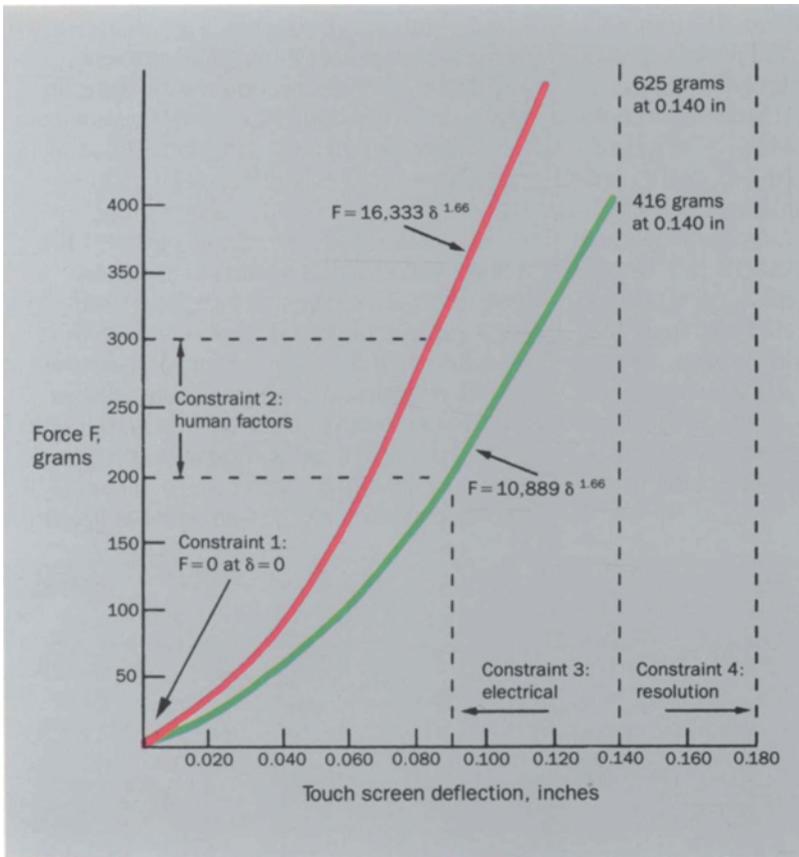
The composite screen can be mathematically modeled as a plate on an elastic foundation. The plate and foundation stiffnesses are a function of both thickness and material modulus of rigidity. These four variables were optimized under the aforementioned design constraints to provide the desired hardness and system durability. Since the stiffness of the polyurethane film is much greater than that of the silicone gel, a thicker film stiffens the sys-

**Figure 2. Light at an angle greater than the critical angle  $\theta_c$  is reflected to photosensors in medium 2. The photosensors are in the frame that holds the soft touch screen.**



**Figure 3. Cross section of the soft touch screen. The gel is formulated expressly for the screen to insure softness and durability.**





**Figure 4. Design constraints superimposed on a plot of touch force versus deflection of the touch screen.**

tem. If the film is too thick, “oilcanning” of the surface (disturbance of the front surface around the finger) occurs during touches—an undesirable attribute. If the film is too thin, rippling of the front surface occurs when a user skims a finger over the front surface while choosing a touch target.

#### Development Hurdles

As with any new technology, the development of the soft touch screen had its share of technical obstacles. Obtaining film of acceptable cosmetic quality proved difficult due to air trapped during take-up of the finished film on rollers, impurities settling on the film during manufacture, and gels lodging in the die during film extrusion. In addition, stretching of the film during roll-up on a take-up roller caused nonuniform film shrinkage and dimensional instabilities during subsequent processing. These problems were solved by cutting the film into sheets during manufacture and general improvements to the film process conditions.

An additional cosmetic problem concerned discoloration over time. Polyurethanes are notorious for color instability because of absorption of ultraviolet (uv) light. The addition of uv stabilizers often complicates subsequent thermal processing steps. Aliphatic polyurethanes possess excellent nonyellowing characteristics, but, in general, are more difficult to process than the aromatic variety used in the soft screen. Accelerated uv aging data on the soft screens coupled with human factors studies concluded that discoloration does not become objectionable for at least 2 years under normal use. Yellowing is a slow and gradual degradation which should not be apparent short of a side-by-side comparison with a new screen.

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A failure mode of the system is the fracture of the silicone gel and/or gel-polyurethane interface due to bottoming out of the screen (i.e., forcing both film surfaces into contact and crushing the gel to zero thickness). Given the design constraints of Figure 4, the force to bottom the screen is approximately 1 lb. As a consequence, any failure or insensitivity of the touch detection circuitry can result in the user easily bottoming out the screen in an attempt to activate a touch target. When the screen is bottomed, the film-gel interface is in shear and the gel directly under the applied load is in biaxial tension and uniaxial compression. The fractured interface or gel is a nucleation site which results in bubble formation.

#### **Future Developments**

Recent improvements in the signal detection electronics have reduced the activation deflection from 0.090 in to approximately 0.040 in, resulting in an activation force of approximately 60 grams. In light of the relaxation of this design constraint, work has commenced on the development of a lower cost, more easily manufacturable membrane. Current plans are to retain a three-material composite (two polyurethane sheets with a firm gel in between) and eliminate the polyurethane frame border. The elimination of the frame border allows the membrane to be punched out from larger sheets, thereby permitting high-volume manufacture of membranes of various shapes and sizes. Hardening the system by firming up the gel will also eliminate the remaining major failure mode of the current system—gel fracture due to bottoming out of the screen. Changes to the mounting procedure

would also be required, since mounting on pins would no longer be feasible due to the relative displacement of the two sheets during stretching of the membrane over the CRT.

#### **Conclusion**

The AT&T soft touch-sensitive screen is the primary user interface to the AT&T Personal Terminal model 510. The soft touch screen overcomes problems of other commercial touch screen technologies: limited target placement, CRT raster drift, and the unfriendliness of the hard surface. Recent advances in the signal detection electronics have relaxed the screen hardness requirement, permitting design of a simpler, more manufacturable, lower-cost soft touch screen which will permit timely incorporation in a variety of products.

#### **Acknowledgments**

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