Computer Peripherals

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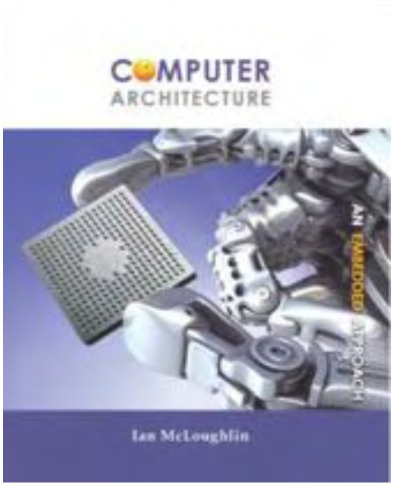
These notes are part of a 3rd year undergraduate course called "Computer Peripherals", taught at Nanyang Technological University School of Computer Engineering in Singapore, and developed by Associate Professor Kwoh Chee Keong. The course covered various topics relevant to modern computers (at that time), such as displays, buses, printers, keyboards, storage devices etc... The course is no longer running, but these notes have been provided courtesy of him although the material has been compiled from various sources and various people. I do not claim any copyright or ownership of this work; third parties downloading the material agree to not assert any copyright on the material. If you use this for any commercial purpose, I hope you would remember where you found it.

Further reading is suggested at the end of each chapter, however you are recommended to consider a much more modern alternative reference text as follows:



Computer Architecture: ***an embedded approach***
Ian McLoughlin
McGraw-Hill 2011

Chapter 16 Thermal Printing

16.1 Introduction

The growth in use of personal computers in the work place and in the home has spurred the development of compact printers capable of printing text and graphics for a variety of applications. A number of competing technologies have emerged, each with its own characteristics, and among these, thermal printing has progressed from providing primarily a utility function confined to special paper for calculators or portable terminals, to a much wider range of applications and capabilities. Today's market offerings range from low cost, quiet, home printers using a transfer ribbon to provide solid black or colour printing on selected smooth bond-like paper, to machines capable of printing several pages a minute at densities of 200 per inch and higher. With the advent of the resistive ribbon technology (see below), the capability extends to high quality correspondence printing on a wide range of papers. The simplicity and reliability of the technology has made thermal printing also of special interest for instrumentation, ticket and label making devices.

The next major development of thermal printing was in the 1970s, when silicon mesa printheads and the thick film were designed as serial printheads to output a complete character at a time. The silicon mesa was the technology employed in the Texas Instruments Silent 700 terminal and the Hewlett Packard computer series, (Lo and Keil, 1980). There was also a flurry of activity in Japan to develop thermal printing for facsimile applications. The demand for printing on plain paper led to the development of thermal transfer printing. The next logical evolution was the capability to print on a wide range of papers, and this led to the introduction in 1984 of resistive ribbon printing technology. The 1980s have seen a full blossoming of the thermal transfer technology, and today there are many dozens of printers in the market place, ranging from basic serial devices to high resolution machines for full colour printing and copying.

16.2 Technology Attributes

Thermal technology provides a simple mechanism for making a compact printer. It is characterised as a quiet, highly reliable, rugged, clean, mechanically simple, relatively low power (as compared to impact) and attractively low cost method of printing that is adaptable to serial or line printhead configurations. The technology is extendible, and it is now also being developed for high quality images in full colour.

There are essentially three different printing methods employing thermal technology. Direct thermal printing on heat sensitive paper was an early method employed that continues to find application due to its simplicity. The introduction of thermal transfer printing, in which a sheet or ribbon of a very thin paper or plastic material carrying a layer of waxy, easily melted ink is interposed between the printhead and the paper, made possible dense black printing on non-chemically coated, but distinctly smooth paper. In a significantly different development known as resistive ribbon, heat is liberated not in the printhead but in a conducting ribbon by injection of current from the printhead. This is the technology employed in the IBM Quietwriter serial printers that provide high quality text and graphics on a wide range of papers.

The basic components of thermal printing are the printhead and the receiving medium, which in the case of direct thermal is a heat sensitive paper, and in thermal transfer is both an intermediate ribbon and the paper. The different printer types can employ either serial or line printheads, with black or Gary scale capability, and today may also provide print in full colour.

In the serial configuration, the printhead contains a vertical column of heater elements covering the height of a character box and printing is carried out by moving the head across the page to output a line of text at a time, as shown in Figure 1 Configuration for serial printing on heat sensitive paper. In another configuration, a line head containing several thousand closely spaced heater elements spans completely across the page as shown in Figure 2 Arrangement for thermal transfer printing using a line printhead, transfer ribbon and plain paper. Now, the paper moves at a fixed rate beneath the stationary printhead, and the printer contains remarkably few moving parts. In either case a thermally sensitive paper or a transfer ribbon may be used. Multicolour is achieved by using a ribbon with multiple colour serial stripes, and producing a Gary scale involves spatial dithering of the printing elements. The recent full colour printers use spatial dithering and also provide optical density modulation by using sublimable dyes as the transfer medium.

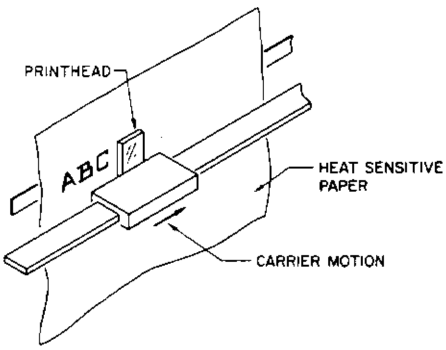


Figure 1 Configuration for serial printing on heat sensitive paper.

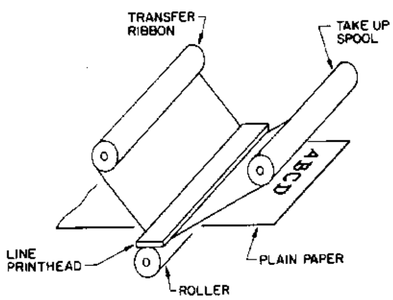


Figure 2 Arrangement for thermal transfer printing using a line printhead, transfer ribbon and plain paper.

A factor that has helped considerably in the steady development of the technology has been that the printhead could be fabricated by thin layer deposition and lithographic techniques familiar to the electronics industry. With logic and drive circuits integrated upon the printhead, a reliable, cost effective printhead technology has emerged to make viable a range of printers which are competitive in the marketplace.

Some basic functional limitations, for example, print speed, or the inability to print on a wide range of surfaces, exist that may be traced to fundamental properties of the thermal process.

16.3 Thermal Printing Technology

Thermal printing is characterised by the utilisation of heat to produce a chemical or physical change so as to give rise to visible marks upon paper or some other substrate material. Although it is appealing to consider generation of the heat pattern optically, for example, by a scanning laser beam, this is an inefficient way to deliver the energy required for printing at useful rates. Printheads for thermal printing use instead the conversion of electrical energy into thermal energy by means of Joule heating within an electrically resistive material. Figure 3 Expanded view of heating element structure, and cross-section of thick film technology serial printhead. shows schematically some structural details of a serial thermal printhead containing an array of electrical resistor heating elements constructed upon a ceramic substrate. The resistors are obtained by making contact to a line of resistive material prepared by so called thick film techniques, in which the resistive line is deposited in the form of a paste which is then fired in a furnace to develop the required characteristics. The resistor elements may be made by either thick film or thin film deposition methods. Thick film elements provide a solid footprint for making contact to the paper; however, thin film technology makes possible the use of lithographic patterning to make high resolution resistor arrays, in which the resistors may be given, if desired, an optimum shape. This is the case for the page wide head where a resolution of 200 printing elements per inch is the norm and where much higher resolution is becoming increasingly prevalent.

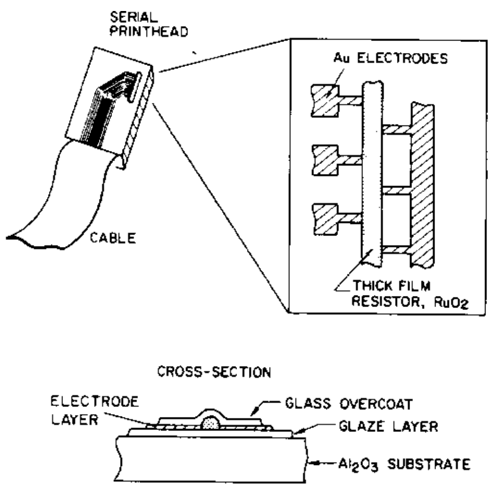


Figure 3 Expanded view of heating element structure, and cross-section of thick film technology serial printhead.

A further distinction is made between heads which have the electrodes placed extremely close to the edge of the printhead for ease of peel of the transfer ribbon. In order to improve the mechanical contact between the head and the paper or ribbon a narrow strip of a glaze material (partial glaze) is placed beneath the thin film resistor heating element. Figure 4 Photolithographically defined heating elements of a thin film technology printhead. shows an example of a thin film heater arrangement where the resistor elements have been given a meandering shape by photolithographic etching. An important aspect is that the printhead is given a protective coating to minimise wear since in use it is brought into close mechanical contact to either a special paper or a thermal transfer ribbon.

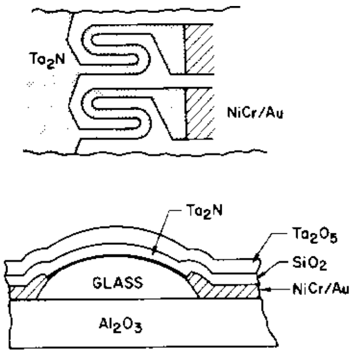


Figure 4 Photolithographically defined heating elements of a thin film technology printhead.

16.3.1 Direct Printing on Thermal Paper.

We consider first the direct thermal printing case as shown schematically in Figure 5 Direct printing on heat sensitive paper., where a printhead is used to supply heat by contact to a heat sensitive paper. A pulse of current is applied to one or more of the heating elements to cause rapid heating of the resistors; heat conducted to the paper via the region of contact produces a significant temperature rise on the surface of the heat sensitive paper. The resistor element must be able to heat the thermally sensitive paper up to the coloration temperature, and its surface must be highly resistant to friction from the paper. The heat sensitive paper contains a coating of dye forming chemicals held within a binder material. At room temperature the dyes are in a leuco (i.e., colourless) form, and the paper has the appearance and feel of smooth paper. The dye precursor agents react at the printing temperature to generate a light absorbing dye resulting in the visual printed image.

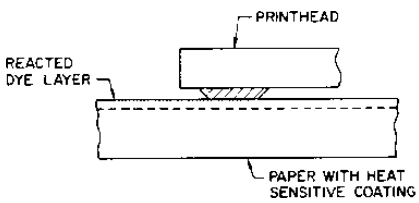


Figure 5 Direct printing on heat sensitive paper.

It is important that the temperature excursion of the heater elements be kept within a reasonable range (typically several hundred degrees Centigrade) in order to ensure long head life and avoid direct thermal damage to the material in contact with the head. The width of the excitation pulse applied to the heating elements is then chosen to be long enough to allow sufficient energy to migrate into the paper to develop the required level of blackness, typically, a few joules/cm2. Following the heating pulse, the resistor heating elements are allowed to cool prior to printing at the next desired location upon the paper. Most of the energy generated flows into the printhead, with only a small amount actually transfers to the paper. Hence, the thermal time constant of the printhead structure is therefore of major importance in determining the rate at which printing may be achieved, typically results in thermal cycle times on the order of a millisecond. This is sufficient to allow printing at several tens of characters per second in a serial printing mode.

Figure 6 Line thermal printhead with integrated electronic packaging. shows an example of a high resolution line printhead with fully integrated electronics.

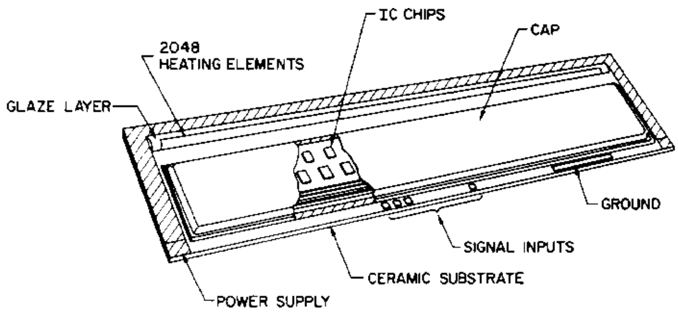


Figure 6 Line thermal printhead with integrated electronic packaging.

The page wide configuration printhead makes possible printing at much higher rates and permits printing of graphic images at a higher than 200 dots per inch. The attractive feature of this arrangement is that the head extends completely across the page and is stationary during printing. Since the printhead contains several thousand resistor elements, printing may be accomplished at high resolution with a throughput of several pages per minute. The data handling and driver circuits are integrated upon the ceramic printhead so that relatively few electrical connections to the head are required. Speed in this case is limited by the energy dissipation capability of the printhead rather than by the thermal cycle time of the print elements.

Thermal printing on heat sensitive paper provides a quiet, compact, reliable printing method that is of importance today for instrumentation applications or where simplicity is a prime requirement. Thermal papers are smooth to ensure good thermal contact to the printhead, and are available for printing in a limited range of colours. Improvements in shelf life, resistance to unwanted coloration due to fingerprints or other contaminating materials, and in appearance, coupled with the availability of inexpensive integrated printheads make direct thermal printing of continuing interest for a number of applications such as most low end facsimile machines.

16.3.2 Thermal Transfer Printing.

The desire to print with high optical density on non-special papers led to the development of the thermal transfer printing process. This represented a major step forward in the ability to create solid black printing on plain paper. Figure 7 shows schematically the arrangement for thermal transfer printing, where a ribbon carrying a layer of low melting point ink is interposed between the printhead and the paper. The ribbon consists of a thin carrier layer of capacitor paper (for greatest economy) or polyester film available in thickness as thin as a few microns. One side of the carrier layer is coated with a layer of hot melt, wax like ink. In this case, heat from the printhead must traverse the several microns of thickness of the ribbon to melt the ink layer. Pressure from the printhead forces the molten ink into the surface of the paper. As the printhead moves, the heated section of the ribbon is peeled from the paper leaving a dense layer of ink. Further, ribbons with different colours are available, with inks suitable for producing very solid colour on paper (typically pigments), or alternatively, with inks containing dyes suitable for printing upon transparency materials. Recently, sublimable dyes have also been developed for high quality colour images where the amount of dye transferred into a special paper can be controlled by the amount of energy supplied to the print elements.

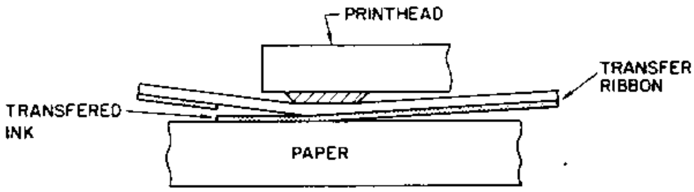


Figure 7 Thermal transfer printing. The printhead applies heat to the ribbon causing the ink layer to melt and transfer to the paper.

A number of processes contribute toward achieving satisfactory thermal transfer printing. First, sufficient heat must be generated within the printhead, typically on the order of several joules/cm2, to allow the solid ink to become sufficiently molten to permit substantial flow of the ink. Secondly, the mechanical loading of the head against the paper influences the rheological conditions governing the manner in which ink bonds into the surface of the paper. Finally, the details of the peeling of the ribbon from the paper affect the extent to which ink is cleanly removed from the parting ribbon. All of these factors must be considered in optimising the thermal transfer printing process.

Since the ink layer is essentially completely removed from the ribbon during the printing process, very striking black or coloured print may be obtained on smooth papers. However, due to the mechanical rigidity of the printhead, print quality degrades rapidly with increasing paper roughness, and good quality output is restricted to smooth paper.

16.3.3 Resistive Ribbon Thermal Transfer Printing.

It is a feature of resistive ribbon thermal transfer printing that high quality printing may be carried out on a wide range of standard papers. This major step forward was made possible by a radical change in the printing technology. The concept was developed to a practical technology by IBM and was introduced in a new family of typewriters and office printers in 1984.

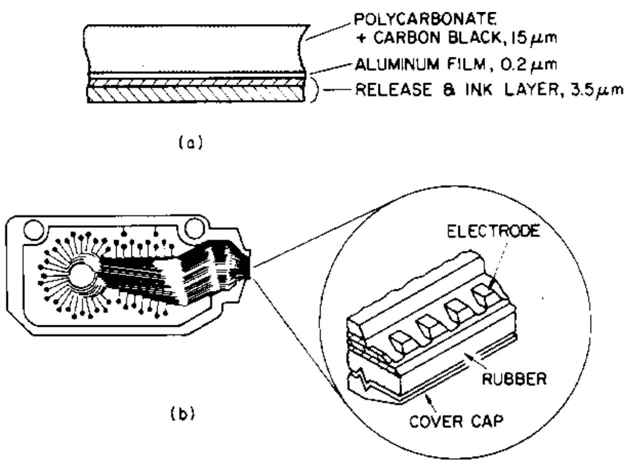


Figure 8 Structure of a resistive ribbon (a) and printhead arrangement (b)

Figure 8 (a) shows a cross section of the resistive ribbon. The major part of the ribbon consists of a layer of polycarbonate polymer containing about 28% carbon black. The polymer provides the strength to the 15 micron thick layer while the addition of carbon black makes the ribbon electrically conducting, with a sheet resistivity of the order of 350 ohms/ square. An aluminium film is vacuum deposited upon the polycarbonate layer to form an electrical ground layer. An ink layer is then coated upon the aluminium film using a solvent deposition process. The ink is formulated from a latex based material and has a tendency to maintain some degree of sheet strength during printing. A very thin release layer beneath the ink layer facilitates the peel process and aids in obtaining true correspondence quality printing. The typewriter utilises the ribbon for both printing and erasure, while in the printer the ribbon is optimised so that the ink is more strongly bound to the paper, and consequently is difficult to erase.

Figure 8(b) shows a schematic view of the printhead. This is a functionally simple structure consisting of a row of thin, metal etched lines designed to provide electrical contact to the surface of the ribbon. The electrodes are formed from a sheet of 25 micron thick tungsten and are finished so that the head contacts the ribbon at 45 degrees. The 40 print electrodes are spaced apart by approximately 100 microns and have a width of about 50 microns. An important feature of the construction of the head is the use of a thin Kapton bonding layer and rubber backing layer allowing some degree of mechanical compliance between the electrodes. This is a key feature in allowing printing to be carried out on a wide variety of papers.

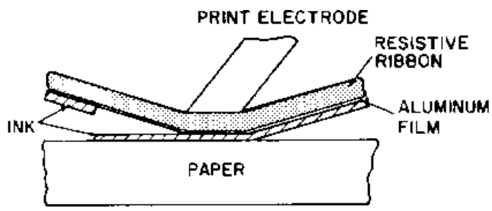


Figure 9 Resistive ribbon, thermal transfer printing.

Figure 9 Resistive ribbon, thermal transfer printing.shows the arrangement for resistive ribbon thermal transfer printing. In order to print, electrical current is passed between one or; several of the electrodes as required, through the ribbon to the aluminium film ground plane. Current flows along the ground plane for a short distance to a current return roller contacting the ribbon. Due to the electrical resistance to current flow existing within the ribbon, the ribbon becomes heated, the ink softens and is transferred to paper with the aid of the head pressure. It can be noted that most of the excess heat is carried; away with the ribbon so that printing is not limited by the thermal recovery of the printhead as with ceramic thermal printheads. This results in the possibility of printing at a significantly higher temporal rate per print electrode than in normal thermal printing. Although in principle, a line printhead arrangement for resistive ribbon is possible, the higher ribbon cost and the presence of a common electrical ground plane makes multiplexing of the electronic driver circuits unfavourable, and thus far only a serial printer is available.

In practice, the thermal compliance of the printhead, the electrical properties of the ribbon, the rheological properties of the ink and the mechanics of the ribbon peel press are all important in making possible office correspondence quality printing on a wide range of papers, almost up to 350 Sheffield number in roughness.