Computer Peripherals

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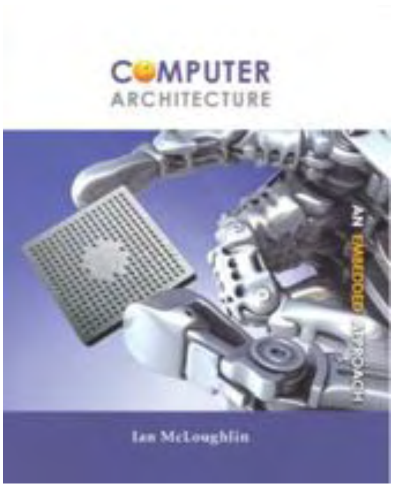
These notes are part of a 3rd year undergraduate course called "Computer Peripherals", taught at Nanyang Technological University School of Computer Engineering in Singapore, and developed by Associate Professor Kwoh Chee Keong. The course covered various topics relevant to modern computers (at that 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 13. Impact Printers

The early proponents of electronic mail and office automation forecasted the demise of printers in the early 80's. With each user having a video display terminal capable of sending and receiving messages and documents over the telephone and local area networks, it was predicted that printers, which were noisy, slow, and produced low quality output would be relegated to the computer room. The personal workstation would not include a printer. This was to be the era of the paperless office.

A decade later, the paperless office is still a pipe-dream, and inspite of the *green revolution* printed reports are still being generated in ever increasing volumes. A contributing factor to the increase in printed output is the development of low cost, relatively quiet laser and inkjet printers which are capable of high quality text and graphics.

Besides, people are still more confident working with the printed document. It is something they can hold in their hands, and can put their signature on. In addition , there times and places where computer display devices are not available or are inconvenient to use. Today, a book or report is still much easier to carry around, read and as needed, annotated. In most commercial and legal transactions, paper documentation are required. In addition to paper, printers can also produce output on other media like film and transparencies.

Printers were the earliest output devices to be attached to computers and it will not be obsolete for a long time. The first printers were in fact typewriters interfaced to the CPU's. Today there are a wide range of hard copy output devices which are used to produce permanent records. Most of these come under the class of printers although the strictly graphics output devices are classified as plotters.

13.1 Classification

All printers have three main components: the printing mechanism itself, paper feed mechanism, and the control and interface electronics.

Printers are divided into the two broad categories of impact and non-impact printers. Figure 1 A classification of impact printers. shows the various categories of impact printers. With impact printers, the image is formed by the pressure applied by the printing mechanism on the paper. The image itself is formed by pressing an inked ribbon against it, or by the use of pressure sensitive paper. The print character may be fully formed as in a daisy wheel or drum printer, or it might be created as a matrix of dots.

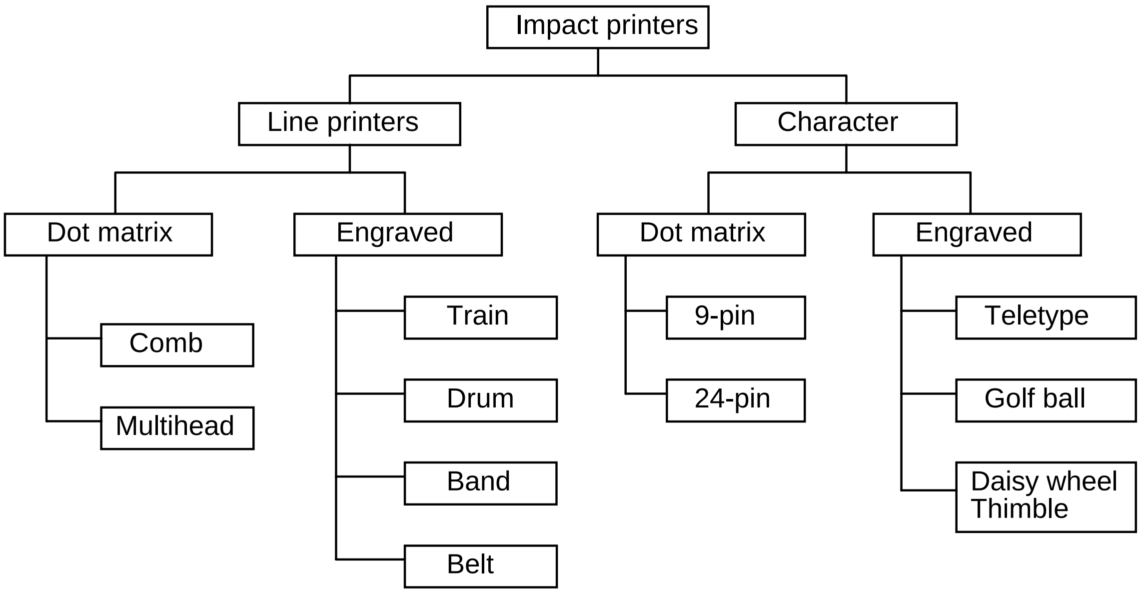


Figure 1 A classification of impact printers.

In non-impact printing there is no direct contact between the printhead and the paper. The many technologies available in non-impact printing are shown in Figure 2 Classification of non-impact printing technologies. Ink-jet printers, for example fire small electrostatically charged droplets of ink at the paper in dot matrix patterns. Electrostatic discharge printers develop a small arc (spark) to burn a spot on sensitized paper. Similarly sensitized paper is placed in contact with a thermal head which heats up to create the dot matrix image on it. Laser printers, using a technology similar to photocopiers, from the bulk of non-impact printers now in use.

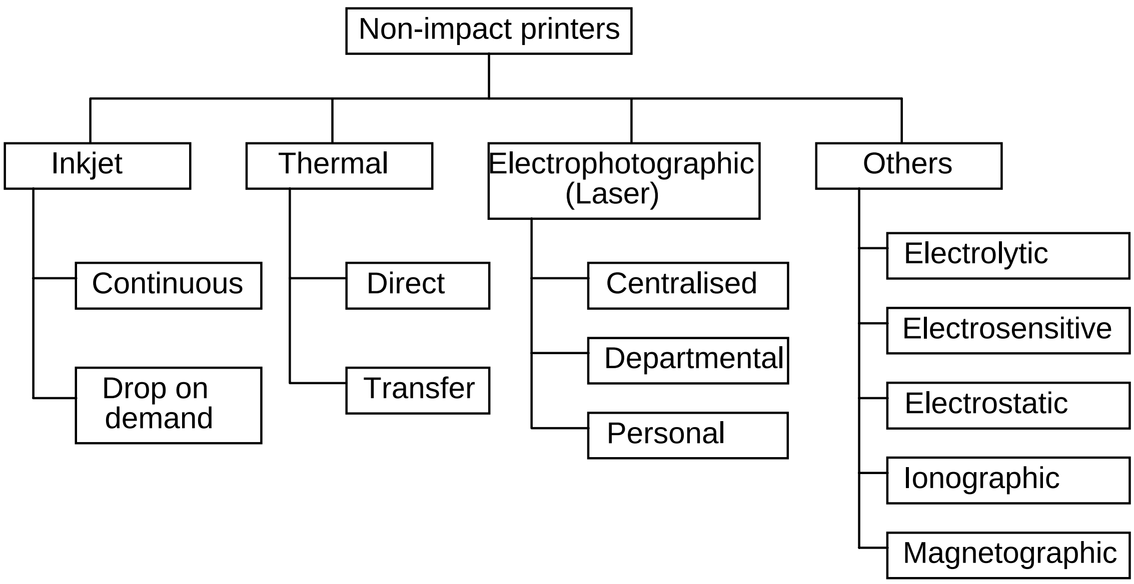


Figure 2 Classification of non-impact printing technologies

Laser printer prices are dropping to the extent that even small offices can afford them. With the superior print quality, they are replacing lower cost impact printers in many applications. One major disadvantage all non-impact printers suffer is that they cannot provide multicopy printouts.

13.2 Impact Printers

Under impact printers, the sub-classifications are line printers where a whole line of characters is printed almost instantaneously, and serial character printers.

13.2.1 Line Printers

Line printers are the work horses in the large computer installations, with print speeds ranging from 300 lpm to well in excess of 2000 lpm. In a serial printers in that the characters of a printed line are printed serially, one at a time. In line printing the characters in a line are printed in a somewhat random manner and to some extent in parallel with one another. Mentioned has already been made of the dot matrix line printer. Attention here is given to the fully formed or engraved character line printer.

An engraved character line printer consists of *four electromechanical subassemblies*, and the power, logic and control to drive these subassemblies. The four electromechanical subassemblies are the hammer unit, the paper incrementing system, the ribbon system and the type element system. The hammer unit typically consists of a bank of individual hammers, one for each print position, which when actuated, effects the printing by pressing the ribbon on the paper against the type element. The type element consists of arrays of fully formed characters moving past the stationary hammers at relatively high speeds. The print element itself could be a band, a chain, a train, a drum, etc. Any character on the print element can be impacted by an individual hammer in a direction perpendicular to the motion of the print element.

The paper incrementing system consists of motors, tractors and other paper handling devices to move the paper line by line, and page by page as required through the printer. The ribbon systems moves the ribbon so that the impact is not localized on a portion of the ribbon. Ribbons are loaded in spools or cartridges and can be as wide as the the paper forms width. Low cost stepper motors are used to increment the paper, move the type element and the ribbon. The hammer unit is solenoid activated, and the whole system controlled by microprocessor-based logic.

One of the main differences between serial printing and line printing technologies is the speed at which the respective type element traverses the stationary paper or media during printing. For serial printers, the print element is either stationary or nearly stationary during the printing of the character, thus producing a very sharp edge definition. However with the line printer, the type element does not stop and the hammer is synchronized to strike at the instant the desired character is in position. This enables the high print speeds to be achieve at the expense of degraded print quality. Since printing takes place while the print element is moving relative to the paper at relatively high speeds, a blurring of the edges of the type results. However, with the use of electronic sensing circuits, the print element in every print position is monitored and the hammers are actuated asynchronously to accurately strike the character to be printed, so that print quality degradation is not significant even as the throughput is increased.

Figure 3 illustrates the basic mechanisms of the various types of engraved printer: *drum* and *band* printers; *Chain* and *train* printers are conceptually similar to the band except that the type elements are small pieces linked together like a chain or train. It will be seen that registration (alignment) errors on the drum printer will result in the line being uneven vertically, whereas the misregistrations on the band printers are horizontal, producing uneven spacing between characters, which is much less offensive visually. The printer band is usually a strip of steel with the character arrays electrochemically etched onto it and welded into a continuos band. This relative simplicity and low cost enables typefaces to be changed by changing the bands and band printing is currently the most prevalent technology used in impact line printers.

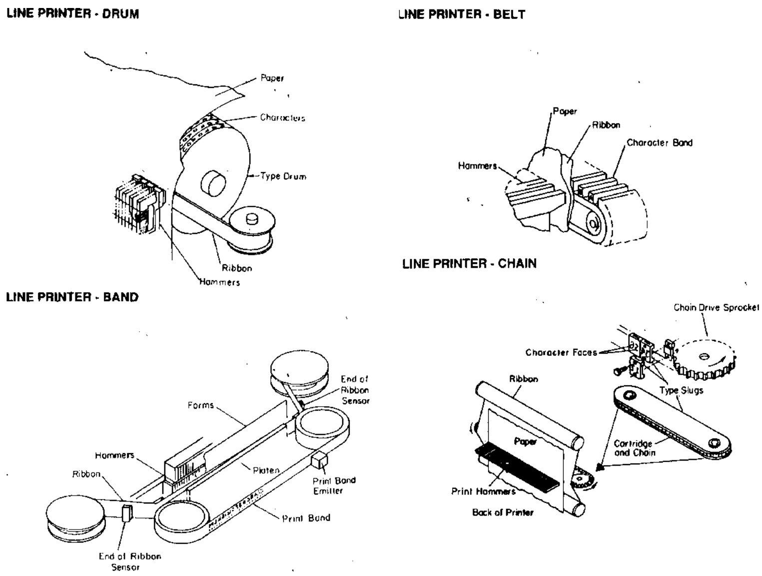


Figure 3 Various types of engraved printer

The total time, T_{total} taken to print one line is

$$T_{total} = T_{incr} + P \cdot N / v$$

where T_{incr} is the time taken to increment the paper by one line spacing, P is the character pitch, N is the number of characters in the array (48, 64 or 96), and v is the band velocity. Thus the throughput is the inverse of T_{total} in lines per unit time.

In terms of price/performance, impact line printers have the advantage over other printing technologies at the medium and high speed ranges. In terms of print quality, graphics and flexibility it loses out to laser and other non-impact printers but it has its own advantages of being about to print multipart forms and print-though envelopes. Print-through envelopes are a new application that is pervading the industry in the form of pay-slips, tax returns and other confidential reports.

13.2.2 Character printers

The other group of impact printers have fully formed fonts which produce a complete character when used to impact the ribbon against the paper. The low speed units are essentially typewriters with either a set of keys, a "golf-ball", or a daisy wheel. The first two types were very complex mechanically and requires maintenance and adjustments, especially when operated at the maximum speeds of 10- to 15- cps.

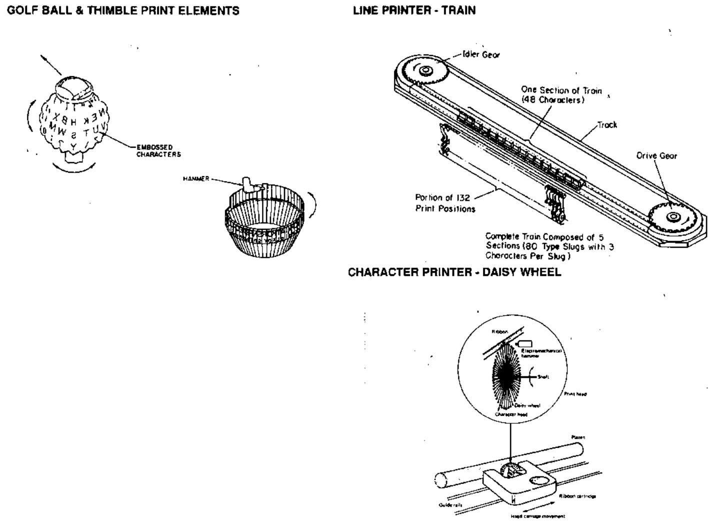


Figure 4 Character printes

Daisy wheel printers use a daisy wheel on which the letters are formed on the ends of the spokes of a wheel. The wheel is mounted on a carriage to move it across the page. the desired character is rotated into the print position where a hammer presses the character against the paper. Most modern electric / electronic typewriters also use the same technique. The main advantage of this printer is that the type fonts (letter styles and sizes) can be changed by changing the print wheel, and the fonts are "letter quality". Low speed and noise are its disadvantages. The typical speeds are 20- to 30- cps although the more expensive heavy duty ones can achieve up to 90 cps. Many users of the higher speed units have replaced them with laser printers as their prices are in the same range.

13.2.3 Dot Matrix Printers

Dot matrix printers are so named because the printed characters are formed by a matrix of dots (Figure 5: 7 by 5 matrix with 2 additional dots for descender). Each dot is produced by a moving wire striking a ribbon against paper. Dot matrix printers are perhaps the most widely used hard copy output devices. The small basic units are quite inexpensive. On the high end, they can be quite fast, and the be capable of producing limited graphics.

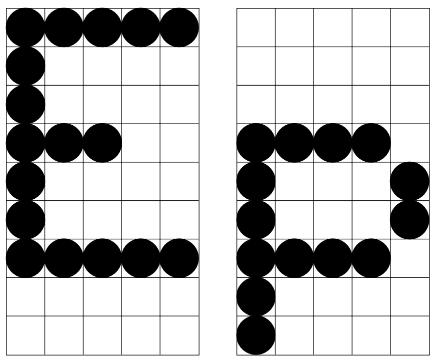


Figure 5: 7 by 5 matrix with 2 additional dots for descender

The dot matrix printer skyrocketed to popularity for the following reasons:

- It was faster than daisy wheel printers.
- It could print multi-part forms.
- It was reliable.

- It could print graphics as well as text.
- It could print color.
- Its consumable were of low cost.
- Printer designs were miniaturized to fit on a desk.
- Printer cost dropped as sales volumes rose and more mass production techniques and plastic tooling were used.

Today, dot matrix printer is still popular in the following markets:

- Home
- Personal Computer
- Demand Document
- Ticket
- Cash Register
- Business Computer

13.2.3.1 Theory of Operation

A dot matrix printer has the following major sub-systems:

- Print Head
- Carriage and Platen
- Ribbon System
- Paper Handling System
- Power Supply
- Electronic Control System

13.2.3.1.1 Print Head

The wire is activated many techniques. However it usually consist of different configuration with work magnets. For illustration, we will look at the solenoid configuration. The solenoid type print head attaches a print wire to the plunger of the solenoid. In this design, the wire strikes the ribbon and prints before the plunger bottoms on the pole. A portion of the kinetic energy of the plunger and wire is used to print. The remainder of the kinetic energy is used to create the return velocity of the plunger and wire.

The print wire can be used in a free-flight mode or crunch mode. Free-flight mode means that all the print energy is delivered by the kinetic energy of the wire. At the time of printing, the armature has reached the pole and its velocity has dropped to zero. The wire is in free-flight before it strikes the ribbon and paper. In crunch print mode, some of the kinetic energy of the armature is used to print. It should be realized that the armature could contact the pole before the ribbon/paper stack height has been fully compressed.

Ink does not transfer from the ribbon to the paper until the pin has compressed the ribbon and paper about fifty percent of its uncompressed stack height. With a stack height of 0.004 inch ribbon and 0.004 inch paper, ink transfers when the pin penetrates the stack approximately 0.004 inches.

13.2.3.1.2 Print Wire.

Print wires are typically 0.008, 0.010, 0.012, 0.014 or 0.016 inches in diameter. The minimum size is usually determined by the ribbon. A wire whose diameter is too small will snag the ribbon. On the other hand, too large a diameter will reduce print quality.

The material of the print wire should be hard so that it resists wear. It is usually made of steel or tungsten. Wear of the wire is determined by the abrasiveness of the ribbon and ink formulation. Therefore, ribbons using dye-based ink yield the longest wire life

A spring is used to return the wire to the initial position. Much of the return velocity is rebound velocity caused by the wire hitting the ribbon and paper against the platen.

13.2.3.1.3 Print Wire Jewels.

Print wire jewels guide the wires in the matrix pattern (Figure 6 Print jewel).

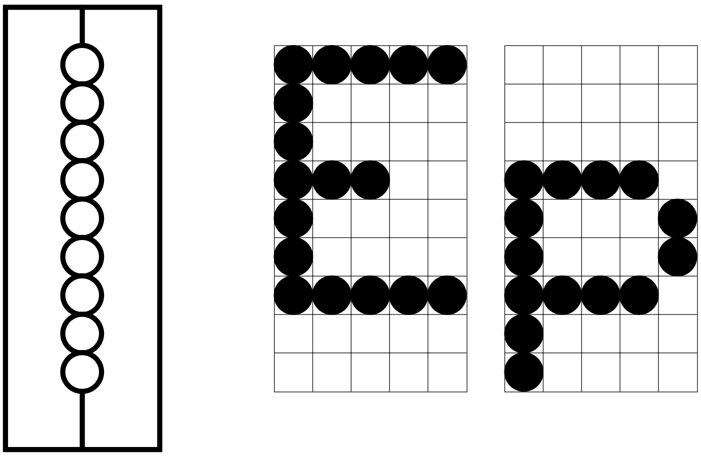
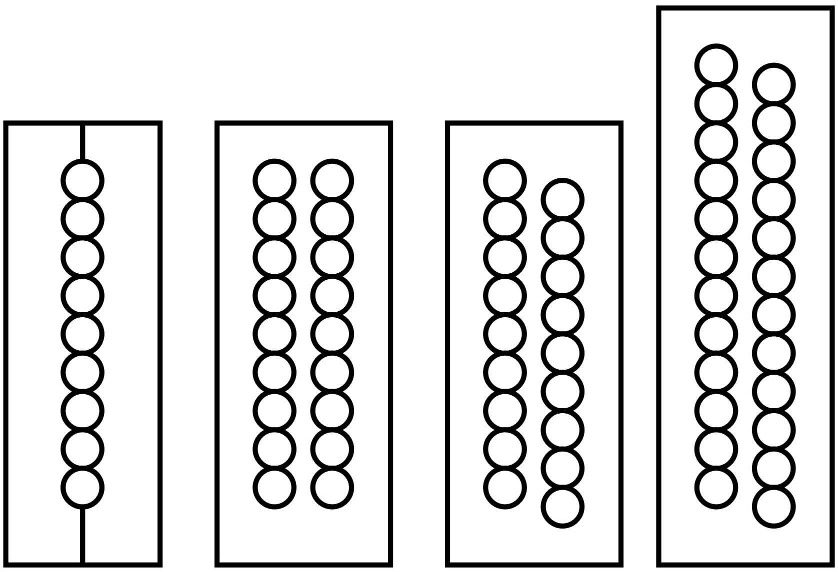


Figure 6 Print jewel

These jewels are usually made of ruby or ceramic materials. The wire pattern is tailored for the application. Modern printers typically use 9, 18, or 24 wire guides (Figure 7 Various configuration for wire guides).



Single row 18 pins, in-line 18 pins, staggered 24 pins

Figure 7 Various configuration for wire guides

Single-row jewels are used when the wire size is smaller than the wire pitch. The in-line jewel is used when the wire is smaller than the vertical pitch. The placing of wires in two adjacent rows allows printing a horizontal row by using the pins in both rows. Dot 1 of a horizontal row can be printed by pin 1 of row 1, while dot 2 of a horizontal row can be printed by pin 1 of row 2. The cycle is repeated. Repeating the sequence allows printing at twice the carriage speed.

Two rows of staggered wires are used to print a closer pitch than can be achieved by placing wires in a single row or in two in-line rows. This configuration is used to print letter-quality characters with a single pass.

13.2.3.1.4 Frequency Response.

The frequency response of early matrix print heads was approximately 1000 to 2000 Hertz. Frequency response means the number of times a print wire can print per second. Dividing this value by the number of column in a dot matrix character, inclusive of inter-character gaps, you can easily work out the rating of a dot matrix printer.

13.2.3.1.5 Print Energy.

Commercial-grade printers use powerful actuators that can successfully print on six-part forms. The energy level of many low-cost printers limit printing to three-part forms.

13.2.3.2 All-Points-Addressable (APA).

The dot matrix printer can be configured for graphics printing. One of the mode of graphics printing is all-points-addressable (APA). APA refers to data sent to the printer to tell it how to actuate each pin as it moves across the print line. An escape code is sent to tell the printer that the following data will be APA data. Another escape code must also be sent to return the printer to its normal data print mode.

Several graphics densities can be printed horizontally. The speed of the carriage can be regulated so that print densities can be varied (e.g., from 72 dpi to 360 dpi). However the vertical density is a function of the print wire jewel size and the smallest step available from the paper handling system. Typical stepper motor increments are 72 steps per inch, 144 steps per inch, and 216 steps per inch. Using a print head with wire spaced at 72 wires per inch and a stepper motor with 72 steps per inch, a vertical resolution of 72 dpi can be achieved. With a 144-steps-per-inch stepper motor, the 72-wireperinch head will provide a vertical resolution of 72 or 144 dots per inch vertically. However, this requires two passes.

If the allowable data speed for APA using a 1000-hertz head is 8000 bits per second (note that the 9th pin is usually not used). Therefore, if the printer is connected to a conventional 1200 bits-per second serial line, it will be waiting for data. In APA mode, most printers artificially slow down the print speed to avoid overheating the head. In normal text mode, the wires use only 20% of the potential print positions; whereas in APA, all black printing could cause 100% of the print positions to be used.

Current print heads typically overheat at a 40% utilization factor. This means that at peak operating frequency, only 40% of the wires should be used at a time.

13.2.3.3 Electrical Components of a Dot Matrix Printer

A character-based dot matrix printhead is shown in Figure 8 Character generator schematic circuit.[TC1] Typically there are nine solenoids arranged in a circle each linked to a wire in the print- head. The nine wire are aligned vertically although some designs stagger them slightly in an effort to close the gap between the print wires. As the head moves across the page, electrical impulses are sent to the solenoids, which propel the print wire against the inked ribbon and the paper. Which solenoids are activated at any particular time depends on the the dot pattern to be created on that column.

With a 9-pin head, a 7-column x 9-row dot matrix character cell is normally used. The character proper is formed using a 5 x 7 matrix, with the additional columns used for spacing between characters. Lower case descenders or underline uses the additional rows. To improve the appearance of the font, overlapping of the dots is used. Between each of the five columns an extra column of dot is printed, and the character is now formed by a 9 x 7 matrix.

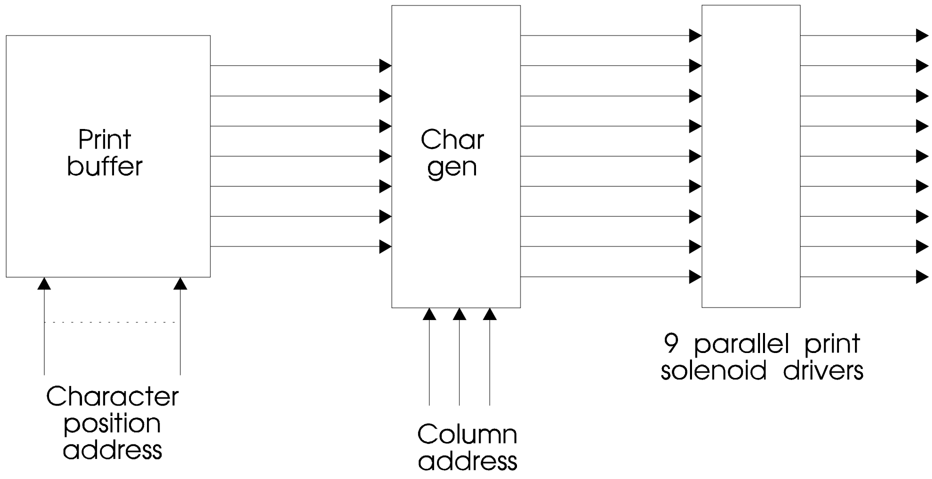


Figure 8 Character generator schematic circuit.

In addition, the printhead can make several passes over the same line, creating a denser matirx of dots. In this way, it is possible to support additional fonts, italics and other print attributes. By using a colour ribbon consisting of black, yellow, blue and red, colour printing can be achieve. Having the printhead make several passes over the same line will of course reduce the throughput. 18-pin and 24-pin printheads are used in the near-letter quality (NLQ) printers, which with control of the paperfeed mechanism, can achieve resolutions of up to 360 dpi (dots per inch).

The speed of dot matrix printers are usually rated in characters per second (cps). Low cost units generally have speeds in the 80-120 cps range. Often, most text output do not use the whole width of the printer of either 80 or 132 character columns. Most printers now incorporate bidirectional printing, i.e. the printing can take from left-to-right as well as right -to-left. In additional, some intelligence is incorporated which looks forward at the next line and determines the shortest head movement needed and the direction to use to print that next line.

High speed units can go up to 1000 cps. To achieve these speeds, two or even three heads are used with each head printing a portion of the line. It must be remembered that the quality of the output (draft, NLQ, LQ) significantly changes the print rate and decisions on printer selection should take in account the normal print quality required, the typical length of documents, and the total volume to be printed. Other factors affecting throughput are the line feed and form feed times.

A high speed variation of the dot matrix is the dot matrix line printer. Instead of a printhead with wires aligned vertically. the line printer uses a comb with 132 pins for a 132-column printer (80 pins for 80 columns). Again each pin have its own solenoid. The comb is mounted so it can move horizontally in 5 steps, corresponding to the five cell columns of the 5 x 7 character matrix. To print one cell row, the comb starts at the left printing the first column, shifts right by 1 cell column position and prints that column. This is repeated for all the five columns in the character after which the comb moves back to the left position. As there are 132 pins, the cell row of all 132 characters are printed at the same time. The paper is moved up by one cell row and the next cell line is printed. After all 9 cell rows are printed in this way, we have one complete character line. A line printer cannot take advantage of short lines as the process takes just as long to print a line with one character as with all 132 character positions filled. Line printers are rated in lines per minute (lpm) and are commonly available in the range of from 200 lpm to 1000 lpm.

13.2.3.4 PAPER HANDLING

The simplest paper feed mechanism provides a line feed at the receipt of the linefeed or carriage return code. The paper is held between two rubber rollers and the main roller, sometimes called the platen, is rotated to move the paper up by 1/6-inch, typically for printing at 6 lines per inch. This is the basic friction feed mechanism used in typewriters and on low cost printers. With faster printers where the motion of the printhead is high and correspondingly the paper movement speeded up, there is a likelihood that the paper will become misaligned. To improve the registration of the paper movement, pins or sprockets are used and the paper forms have perforations at the edges to match them.[TC2] Pins are usually fixed in the roller and handle fixed standard width forms. To cope with varying width forms, adjustable tractors with sprockets on it are used. Normally these were mounted in the paper path after the printing and are called "pull" tractors. The means that the first line printed have to be several inches from the top, and when pre-printed forms are used, the first set of forms is wasted. Many new printers move the position of the tractors before the print head and use them to "push" the paper through.

At the present, hard copy printers still use the imperial units of measurement and standard paper feed parameters are in lines per inch and forms lengths are usually 11 inches. Sprocket forms have trouble conforming to international paper sizes like A4 or B4.

13.2.3.5 RIBBON SYSTEM

The image on the paper is made by using a pin to impact the inked ribbon onto the paper. Ribbons are normally made of cloth or nylon impregnated with ink. One-time ribbons have a film of carbon on a thin plastic material. Originally two spools were used and the ribbon mechanism advanced the ribbon slowly in front of the print head. When the whole length has moved over to the take spool, the direction is reversed. Most printers use a cartridge system to simplify their replacement. Cartridges are made of light plastic casing into which a continuous loop of ribbon is packed. Various ways are employed to efficiently use the whole width of the ribbon which is usually wider than the depth of the head. Some use a single twist at one point to ensure the upper and lower half are used equally, the full width cartridges mount the ribbon slightly askew so that the printhead prints on the top edge of the ribbon at one end, gradually moving down to print at the bottom at the other end.

13.2.3.6 PRINT HEAD

There are many techniques in realising a dot matrix print head design. Namely, Solenoid print head; Ballistic print head; Stored energy print head and Print comb. For details, please refer to Chapter 7 of Durbeck and Sherr, “Output Hardcopy Devices.” In this section, we will look at the electrical aspect of the print head design.

Figure 9 Dot matrix print head drive circuit. illustrates the print head and the drivers used to power each pin solenoid. With a nine-pin print head, fairly good dot matrix quality is attainable because lower-case letters can have descenders. A descender is the part of a character that descends below the base line, such as the lower part of the letters q or p. The drivers are simple transistor switches that amplify the current at the output of a TTL I/O port connected to the microprocessor. In addition to the drivers, a 555 timer is used to fire the print heads for 200 µs each time the 555 timer receives a trigger pulse.

The output of the standard TTL circuits do not provide sufficient power to drive the solenoids of the print head. The signal is used to switch driver transistors (sometimes darlington pairs). Typically a 24V or 48 VDC supply is used, and drive currents are in the range of 100 mA to 1 A with peak currents much greater than that. Note the use of the free-wheeling diode is to prevent the build up of reverse e.m.f. when the current is the coil is switched off suddenly.

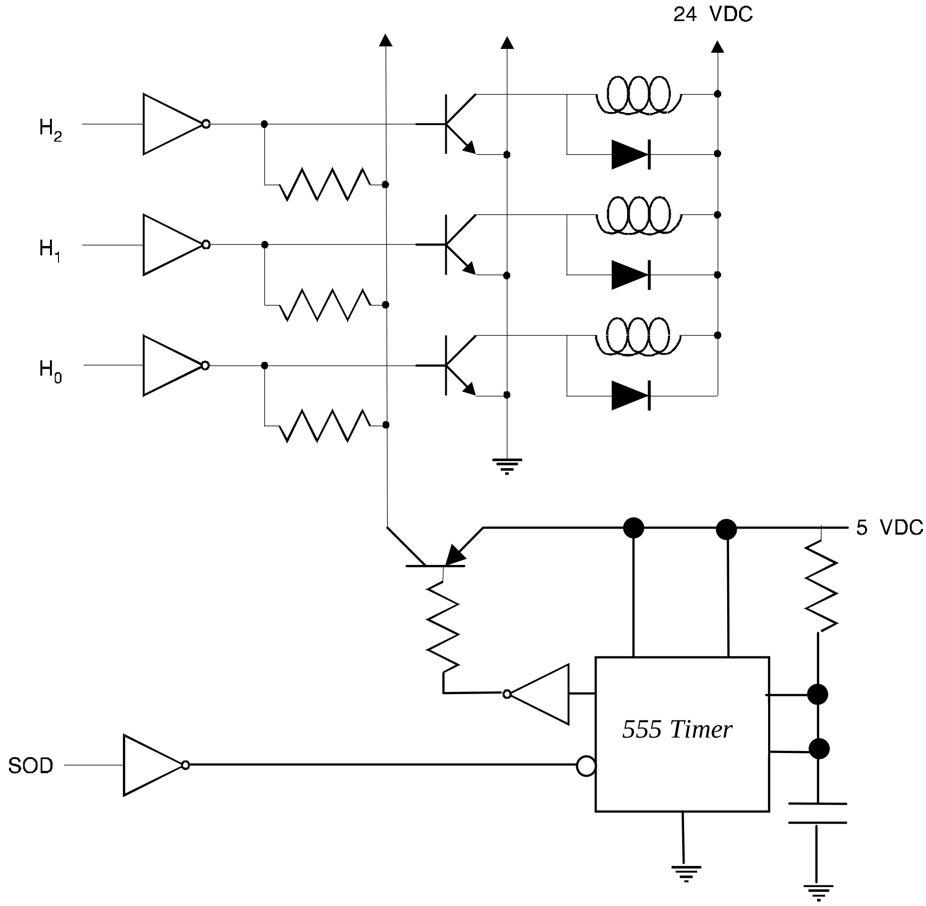


Figure 9 Dot matrix print head drive circuit.

13.2.3.7 MICROPROCESSOR CONTROL

Figure 10 Circuit for a dot matrix printer illustrates a circuit of the printer controller for a dot matrix printer. Each pin in the 9-pin print head is actuated by a solenoid powered by simple transistor switches that amplify the current at the output of a TTL I/O port (8155), connected to the 8085 microprocessor.

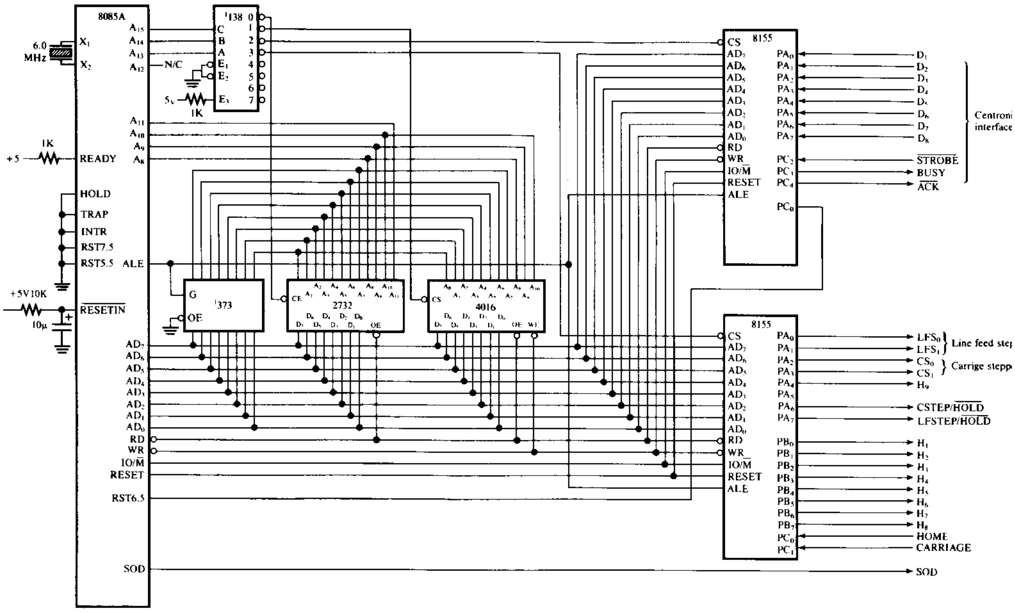


Figure 10 Circuit for a dot matrix printer

The print head is mounted on a carriage assembly together with the ribbon cartridge. A stepper motor positions the print head by way of a belt drive. In order to align the cell rows correctly, the position of the stepper motor and printhead must always be known. To determine this position, an optical timing disk which is a wheel with accurate timing slots cut in it is connected to the stepper motor. A optical detector is mounted to sense the timing slots and produce a pulse for each slot. By keeping track of the pulses counted, up or down depending on the direction of movement, the position of the carriage can be determined. The timing pulses are also used to time the firing of the pins ensuring even spacing for the printed characters (Figure 11 Carriage stepper motor assembly).

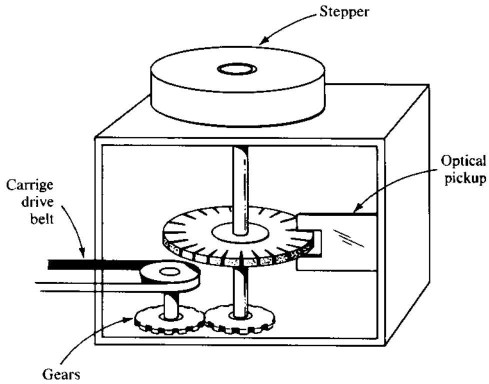


Figure 11 Carriage stepper motor assembly

A second stepper motor, connected to the friction roller or the tractors, is used to move the paper past the printed head after printing each line. Basic printers will advance the paper 1/48-inch per step so that 6- or 8- lines per inch formats may be chosen. Graphics printers have a smaller step size and may have bidirectional movement capability.

13.2.3.8 STEPPER MOTOR

Stepper motors are used for positioning applications in digital circuits and are found in many computer peripherals such as printers, plotters, diskette drives etc. Quartz clocks and watches use them, accounting for the step-wise movement of the hands. Generally the number angular positions is equal to the number of poles in the motor. It is possible to double this resolution by using half-steps. Current flowing through coils generate a magnetic field in the stator. The permanent magnet rotor aligns itself with this field. Figure 12 Internal representation of a stepper motor.

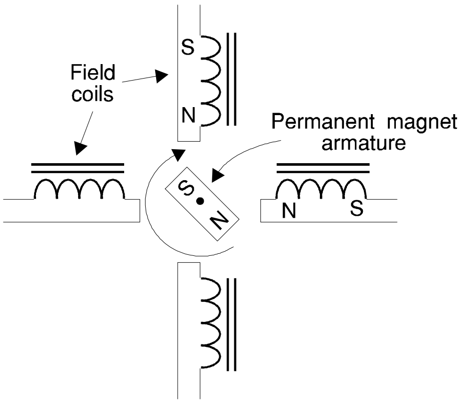


Figure 12 Internal representation of a stepper motor

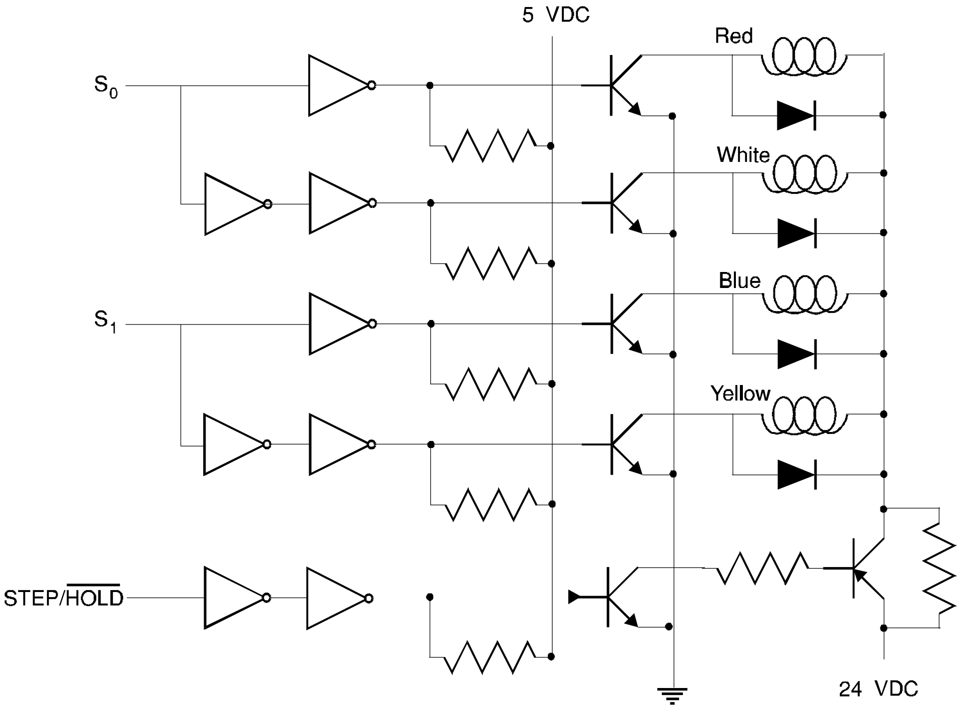


Figure 13 Driver circuit for stepper motor.

Figure 13 shows the stepper motor drive circuit used for both the paper feed stepper motor and the print head position stepper motor. Four separate current drivers and a step control signal is used to control this motor. Normal current holds the rotor stationary while the STEP signal increases the current and causes the rotor to turn. Bit patterns to control the current drivers:

CCW				CW			
0	0	1	1	1	1	0	0
0	1	1	0	0	1	1	0

1	1	0	0	0	0	1	1
1	0	1	0	1	0	0	1

The driver circuit in Figure 13 uses only two signals, S_0 and S_1 to energize the four coils in the stepper motor. The third signal is used to hold or step the motor. A small amount of current flows through the coils of the stepper motor to hold them in position when the motor's armature is not being moved.

13.2.3.9 INTERFACE

The most common interface on the stepper is the parallel or Centronics interface. In addition, some printers also have a standard RS-232 serial port.

In our example, the Centronics interface is connected to the 8085 via an 8155. A second 8155 is used to interface the print head, stepper motors, and both the home and carriage sensors. The EPROM holds the printer control program as well as the character generator. The character generator has a function very similar to the that used in the CRT controller. In this case, a 81-character buffer stores the contents of the characters in ASCII code. As the head moves across the page, the desired character is used to address the character generator. In addition a three-bit counter is used to address each of the five cell columns. The output of the character generator is sent to the 8155 to drive the solenoid amplifiers. Data arriving at the Centronics port is buffered by the 2K x 8 RAM.

The Centronics interface was developed by Centronics Data Corporation, Inc., once the leading manufacturer of dot matrix printers. It uses standard TTL logic levels and 8-bit parallel data lines for high speeds and low cost. However this limits the practical length of the cable between the printer and the CPU to about 15 feet. The cable is a 36-conductor cable, preferably with twisted pairs terminating at the printer end with an Amphenol 36-way male ribbon connector.

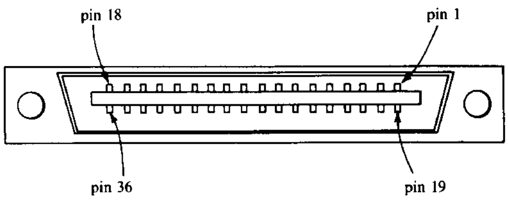


Figure 14 36-pin Centronics-type interface connector

Table 1 Centronics parallel interface signal description

Pin	Name	Function
1	STROBE/	The STROBE signal is an input to the printer that enters (strobes) the character placed on the data connections (Dl-D8) into the printer for printing.
2	D1	Data connection 1 (least significant data line).
3	D2	Data connection 2.
4	D3	Data connection 3.
5	D4	Data connection 4.
6	D5	Data connection 5.
7	D6	Data connection 6.
8	D7	Data connection 7.
9	D8	Data connection 8 (most significant data line).
10	ACK/	A signal back to the computer that indicates the printer has received the data sent to it via the STROBE signal.
11	BUSY	Indicates that the printer is busy printing data when it is

		a logic one level.
12	PE	A signal that is a logic one level whenever the printer is out of paper or whenever the ribbon is out.
13	SLCT	A logic one whenever the printer is selected or on line.
14	GND	Ground.
15		No connection.
16	GND	Ground.
17	CHS	Chassis ground.
18	VCC	+5.0 at 20 mA maximum from the printer.
19-30	GND	Ground.
31	RESET/	This pin is used to reset the printer to its initial state when a logic zero is applied to this pin.
32	ERROR/	The ERROR pin indicates to the computer that a printer error has occurred.
33-36		No connection.

Table 1 Centronics parallel interface signal description lists the signals of the Centronics interface. The data lines are labeled D1 - D8, and provision is made to pair each of them with a ground wire. The control lines are BUSY/, STROBE/, and ACK/. The Busy line indicates the printer is busy and the CPU should not send any data to the printer unless this line is high. Each character is placed on lines D1 - D8 and clocked-in by the STROBE pulse. The data must be at least 0.5 ms before and after the STROBE signal, and the STROBE pulse width must be at least 0.5 ms as shown in the timing diagram in Figure 15 Centronics printer interface timing signals.[TC3] On successfully receiving each character, the printer responds with ACK, indicating that it is ready for the next character.

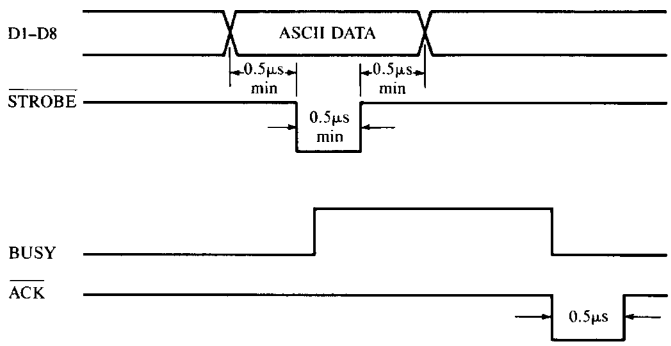


Figure 15 Centronics printer interface timing signals

13.3 Non-Impact Printing Technologies

Electrolytic: Current through a metal stylus that slides on the surface of specially treated paper initiates a chemical reaction that darkens the paper locally.

Electrophotographic: A corona source charges a photo-conductive surface. A laser or other light source then scans this surface to selectively discharge it. The charge pattern remaining on the photo-conductor is the latent image. It is developed with toner to make it visible and the toned image is transferred from the photoconductor to plain paper. Fusing permanently bonds the toner to the paper.

Electrosensitive: Current through a metal stylus that slides on the surface of specially prepared paper either vaporizes a light top coating to reveal a darker sub-layer, or with a different type of paper, locally reduces an oxide coating to elemental metal.

Electrostatic: An array of metal styli contact a moving web of dielectric-coated paper. The styli are selectively pulsed to a high potential to create a charged latent image on the paper, which is then toned to make the latent image visible.

Ink Jet, Continuous: A continuous stream of charged ink drops is projected from the nozzle of a jet. As the jet is scanned over the surface of a sheet of paper, only those drops that are required for generating dots in the image are allowed to reach the paper. All others are deflected into a gutter.

Ink Jet, Impulse: As an impulse (drop-on-demand or DOD) ink jet is scanned over the surface of a sheet of paper, it jets a drop of ink whenever a dot is required in the image.

Ionographic: An array of ion sources projects beams of ions onto a rotating, dielectric-coated cylinder to create a charged latent image. After developing with toner, the toned image is transferred from the cylinder and fused to plain paper.

Magnetographic: An array of magnetic styli contact a moving ferromagnetic surface. These styli are selectively pulsed to create a magnetic latent image in the ferromagnetic material. This image is developed with toner and the toned image is electrostatically transferred and fused to plain paper.

Thermal, Direct: The thermal printhead slides on the surface of specially treated paper. Small resistors on the surface of the printhead are briefly heated whenever they pass a location on the paper that requires a printed dot. This heating initiates a chemical reaction that causes the paper to change color locally.

Thermal, Transfer: A donor film coated with pigmented waxes or sublimable dyes is sandwiched between the printhead and the receiver sheet. As the printhead slides over the donor film, resistors on it are pulsed whenever a dot of wax or dye is to be transferred to the receiver sheet.

Colour Printers: Many of the above technologies can produce colour graphics hard copy.