Typographical Effects by Cathode Ray Tube Typesetting Systems

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Until recently the history of typesetting has been a simple one. Printers who needed typesetting did it themselves, using the machinery or the type made for them by a relatively small number of specialist firms. An understanding existed between the printers and these specialists, and they spoke each other's language. This led to the use of peculiar jargon and special standards such as the pica em, etc. A few years ago typesetting machinery was made in substance by only three major manufacturers.

Suddenly electronic engineering and a trend towards printing methods requiring filmed typography to prepare the printing surfaces has produced some dramatic changes. Cast metal type has ceased to be the sole source of typography and is being partially replaced by systems that project light onto sensitive film, which, when developed, have the appearance of the familiar and historical paper proof but with one important difference. The film can be immediately used to prepare printing surfaces capable of very high speed printing production. As soon as this trend got under way the fertile minds of a number of development engineers fostered yet another idea, "Why not utilize the fullest speed obtainable from modern electronics and do away with all the moving mechanical parts necessary to systems projecting light through master character negatives?"

The answer to this question is the cathode ray tube (CRT) image generator. And now several manufacturers are working to develop high speed typesetting systems intended to operate as slave units under the control of computers. Such systems can be extremely fast and versatile, and provide the high quality typography needed by the printing trade. The success of this development will have great value to the graphic arts.

Such development contains dangers. The dialogue mentioned earlier between printers and the typesetting machine manufacturers appears to be breaking up. Newcomers, specialists in electronic engineering, are busy making machinery to project type images, and they may not be paying enough attention to the long established art of typography.

The form of the typesetting machine is a detail of lesser importance than the end product—the typography. Many printers feel the same way. The machine should never be considered as an end in itself; if this is accepted, then it becomes of importance to understand the weaknesses as well as the strengths of any new and little tried devices.

An indication of the divergence of understanding between the graphic arts and the new electronic manufacturing potential aimed at the printing trade is a recently advertised system offered by a major world name in electronics.

This system is claimed to be able to italicize Roman type. What is obviously meant by this claim is that Roman type can be electronically inclined from vertical or slanted—a very different thing from italics having the traditional forms of *a, f, j, w,* etc., as well as the reduced width of the individual characters usual to this style.

This play of words is a small thing in itself, but supposing in like manner we find that what the electronics engineer believes is acceptable quality to himself is in fact considerably different from what is really needed. Obviously, not only does the electronics engineer need to know about typography when he is making typesetting machinery, but the printer also needs to know about such things as CRT character generation. We both need to know these things at the beginning of the development rather than later when it may be too late to avoid losses and disappointments.

My paper seeks to cast some light on a not very well illuminated subject. To begin with, it is well to run through some of the basic principles of how CRT typesetting devices work. Of the several variations possible there are two kinds of systems. Both have similar output or projector stages, so that the particular variation that determines the difference has to do with the input.

The Direct System

This consists of a means to scan original master negative character images with something akin to a television camera. The essence of this process is the conversion of a visible and physical image into a series of electrical signals. These signals can derive from scanning the master images with a spot of light travelling at high speed across the face of a CRT in a series of adjacent sweeps. This spot of light can be focussed by conventional optics to reflect from, or be transmitted through the master type patterns, depending whether they are opaque prints or transparent film negatives. In either case the differential reflection or transmission of the flying spot of light can be detected by light-sensitive cells, and electrical signals are generated.

Once the master images have been scanned into a sequential train of electrical signals, these signals can then be used to drive another CRT, which can project from its face a reproduction of the original master onto light-sensitive film. Thus the selection, regeneration, and projection of a type image can be done at high speed with no physically moving parts. By directing the scanner camera or CRT sequentially to one of many character images held in an array, characters may be selected according to a programme to cause the normal typesetting on film of words, sentences, paragraphs.

The Indirect System

Having scanned the character images to produce electrical signals, it is possible to commit these signals to be retained in various memory systems used with electronic data processors. In this way, once the scanning process has been done it need not be repeated. A typesetting machine could get its input signals direct from a memory store instead of its own scanner.

The relative merits of these two systems are not important to my theme, but I want it understood that all CRT typesetting devices, whether "direct" or "indirect," finally create and project their typographic images by means of a flying spot of light. This requires that each character image is reduced to, and later built up from, a number of small elements, rather as a half-tone illustration is composed of dots.

Obviously the size of the picture elements (or the flying spot) relative to the size of the actual character is a prime factor in resolving quality. If an infinitely small spot of light is chosen, pure facsimile reproduction is possible; if a large spot is chosen, the reverse is true and reproduction tends to be increasingly impure.

Unfortunately the flying spot in a CRT is made small only with considerable difficulty, and reduction below .001 in. is very difficult. Steering the spot in straight lines over the whole arc of the tube face and keeping the spot identical in size and shape during the movement is also difficult.

The size of the spot used in a given system is directly related to the cost of the equipment, the speed at which it runs, and the size of the fount or array of master images used. The relation promotes low quality if speed and versatility are to be given priority. Quality, speed, and versatility will have to be traded—the one against the other—in a particularly troublesome way. For instance, in theory, to raise the quality of reproduction by 2 to 1 means cost goes up by 4 to 1, or the available array of characters (fount) must be reduced by 4 to 1. Speed will be reduced by 4 to 1 in either event.

The most important thing in this new technique, for both user and maker of the equipment, is to agree on what is the *lowest* number of picture elements per character (or per inch of final projection area) that will produce tolerable typographic standards in the final printed result.

Manufacturers' View of CRT Image Generation

The first decision is the allocation of a particular number of flying spot sweeps to a character image. Arising out of this decision is the actual size of the character presented for scanning, since the number of raster sweeps has a fixed maximum for a given CRT. Typographical characters have almost random shapes, and the printer's alphabet is much larger than one would suppose.

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Figure 1. Typical characters in a common type face. The serifs limiting the apparent height of the characters are approximately .003" thick in the 12-point size, which means the ratio of serif thickness to body height is about 50 to 1. One might assume from this that the picture element, or size of flying spot, could not resolve such a narrow area of the image unless it was at least smaller itself. This predicates a flying spot size of substantially less than 1/50" or 2% of the body depth, just to reproduce in a degenerated way.

Figure 2. The same characters as Figure 1 broken into 72 horizontal elements with a thickness of 1-1/2% of the body depth. The scan direction is exactly parallel to the width of the characters, and it can be seen how some of the picture elements contain areas where only portions of the element are true image. When such areas are scanned by a flying spot, some decision is necessary to arrange which portions will be acceptable and which will be rejected. An arbitrary decision might be to accept only areas more than 50% true image. If one did this, the scanning system would only register elements in each track where the signal strength exceeds 50%.

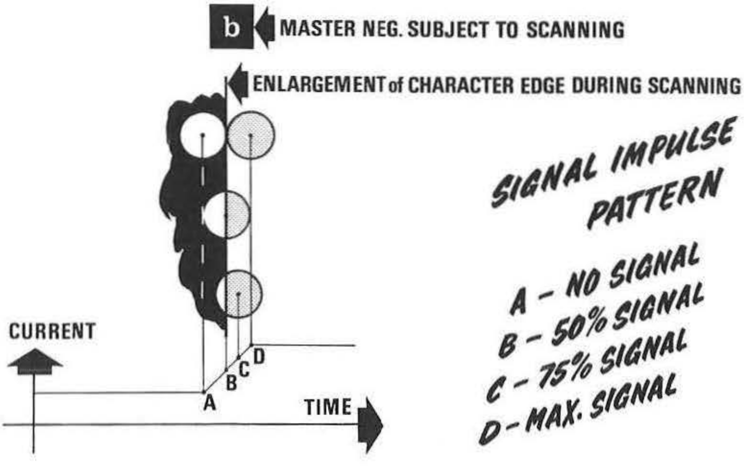

Figure 3. Relationship of input signal to output. The electrical current rises on the output side of the primary scan device as the flying spot approaches (A), crosses into the image area (B & C), and finally passes into the "dead" area of the character form (D). The 50% or 75% signal acceptance can be seen.

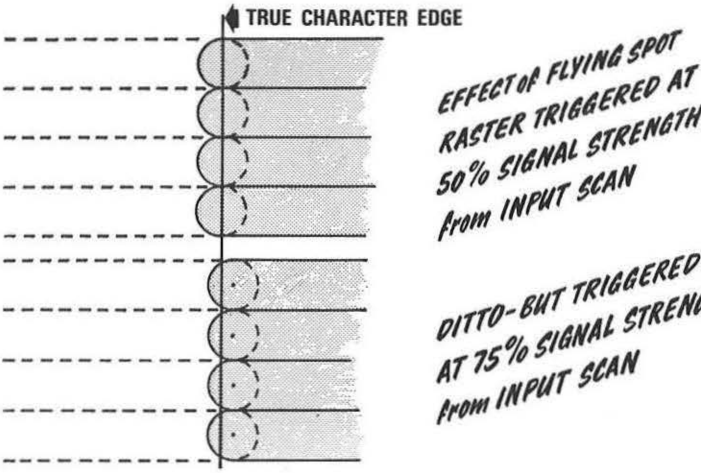

Figure 4. Relationship of input signal to output. By triggering the system to accept at 50% or 75%, different effects would be achieved at the final output projection. 50% acceptance will produce an enlargement of the final image by one-half flying spot dimension at each image edge at right angles to the direction of the scan sweep. The 75% acceptance only adds one-fourth flying spot size to the real image.

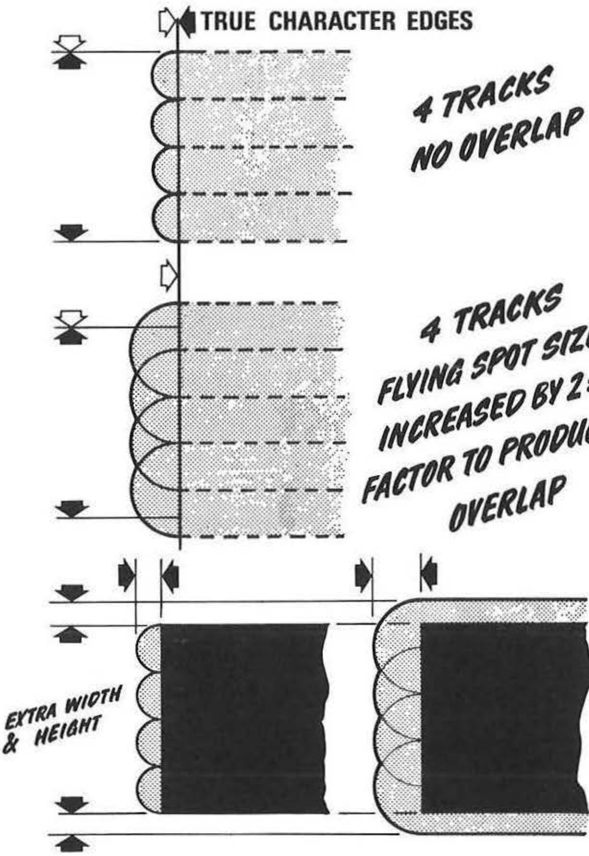

Figure 5.
Effect of flying spot track. This attempts to show how the flying spot movement can be deliberately overlapped on successive sweeps. This will then add not only to the character edges at 90° to the direction of scan, but will also add to the edges parallel to the scan movement.

OVERLEAF. Characters are shown as they would appear if projected from a CRT with 72 flying spot sweeps used to resolve the image. These are the best results that might be obtained for 72 sweeps, and in practice it would be difficult to avoid conditions where the flying spot movement would not be exactly parallel to the serif and straight-character forms. Where there was a departure from parallelism, the character edges might arbitrarily be given extra flying spot sweeps or, on the other hand, might lose them over part of normal straight edges. This stimulation and all the following ones represent signal acceptance rated at 50%.

Figure 6. Scanning at 72 sweeps of the flying spot, vertically and horizontally.

Figure 7. This shows the projected output overlaid with the actual original type forms, to illustrate the growth of the image due to the flying spot tracks where signals are accepted at 50%.

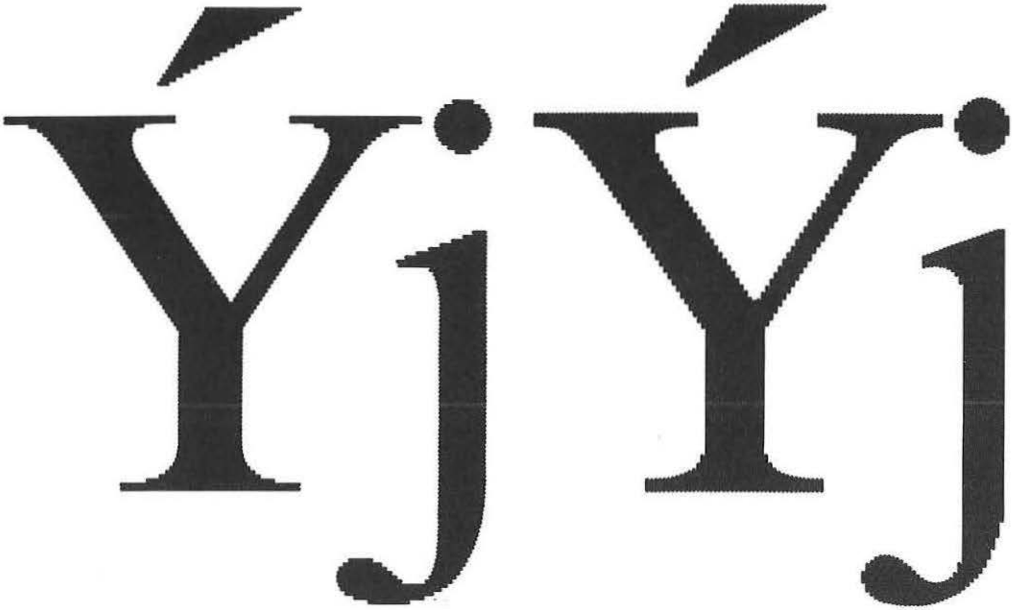

Figure 8. The improved effects obtained by doubling the scan sweeps to 144.

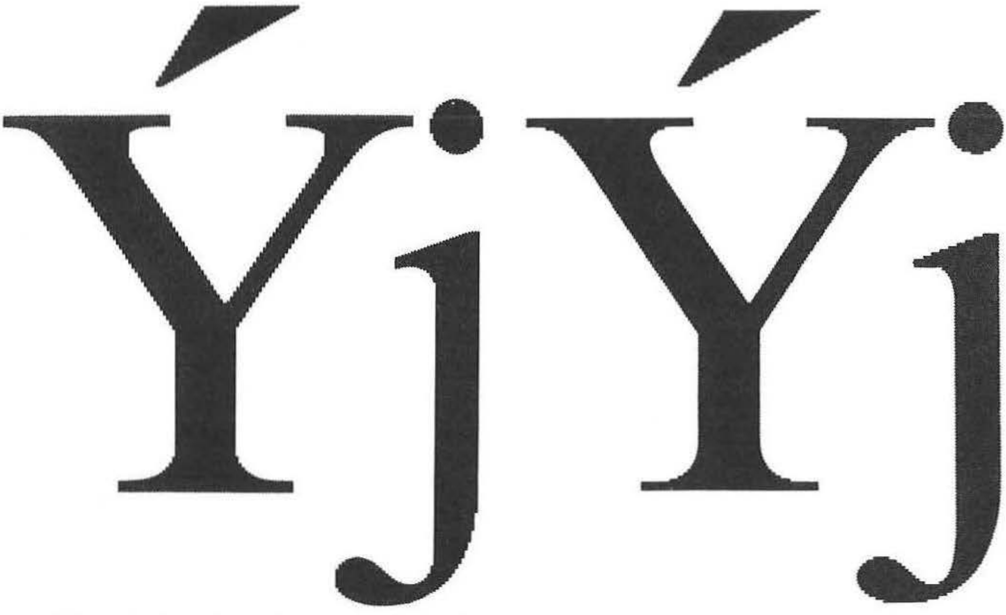

Figure 9. Scanning at 216 sweeps of the flying spot.

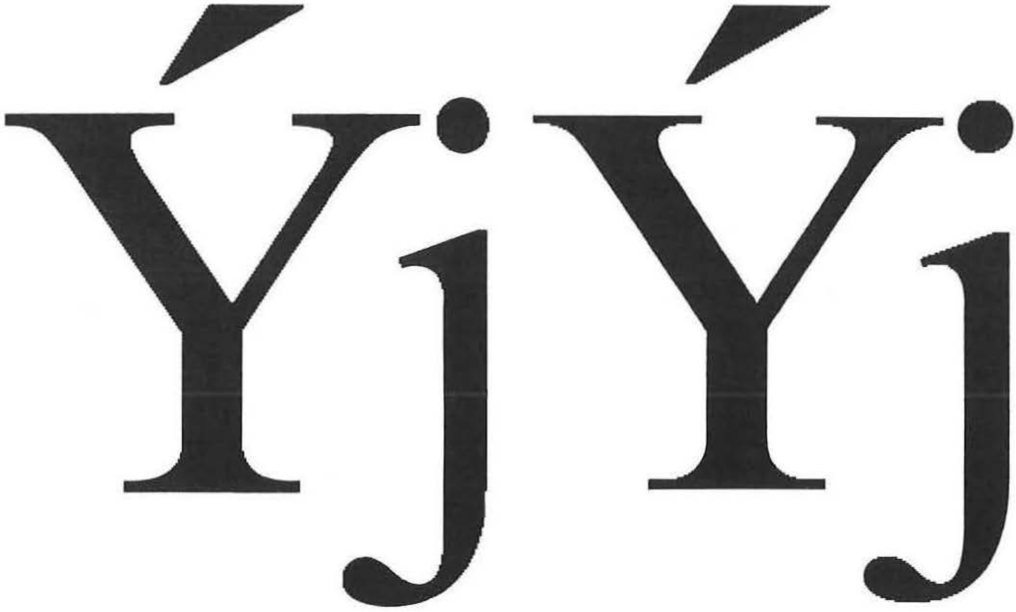

Figure 10. Almost pure resolution by scanning at 288 sweeps of the flying spot.

Figure 11. Some of the effects of scanning "drop out" and "pick up." This image was scanned vertically at approximately 50 sweeps (per body depth). The scanning was not parallel to the main ascenders and the effects of flying spot sweeps being accepted or rejected halfway down a character stroke are very obvious.

Conclusions

The choice of the number of picture elements allotted to a given character size at the output end of a CRT typesetting system is of prime importance. The speed, the cost, the versatility in fount capacity, and the quality of typographic resolution all depend on this.

The above illustrations should be viewed prudently. They do not represent all conditions and, in any case, they are mere theoretical simulations. Generally they represent the picture better than one would achieve in practice, because they do not include the effects of generation from different parts of the CRT face, nor do they suffer the barrel and pin cushion distortions, so difficult entirely to irradicate from CRT.

Somewhere between 100 and 150 lines per character body seem to resolve typography tolerably well. The ultimate threshold of mere identification of alphabet characters should not be deduced from a's and b's. The important and essential conditions are those where differentiation must be made between an inch mark and a double quote mark, between an apostrophe and an acute accent, between an italic and roman comma or full point.

The problem of flying spot "pick up" and "drop out" is objectionable in that certain characters always will have elements not quite parallel to the scan direction—italic and roman mixtures. The flying spot, therefore, must be small enough to allow arbitrary additions and losses to the image areas without their being noticeable, for instance, between one serif and the next.

The terms used in this technique are somewhat misleading. The number of scan tracks or sweeps used is frequently quoted as so many lines per inch. This is meaningless until the type size at the output stage is mentioned, so that the number of lines or picture elements per character body depth can be known. One thousand lines per inch is about 150 lines per character *in 12 point*—it is 75 in 6 point!

The ultimate objective for the manufacturer is to preserve rather than destroy typographic quality in any new equipment. This can be done, but it will require the printer or other potential purchaser to press this need (and the level of quality required) early, rather than later, in development programmes.