ELECTRO-OPTICAL PRINTER WITH VARIABLE SPACING AND WIDTH CONTROL

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UNITED STATES PATENTS
3,273,476 9/1966 Haynes ........................................... 95/4.5

3,553,676 1/1971 Raciti ........................................... 95/4.5

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ABSTRACT

An electro-optical system for printing a line of characters from appropriate matrices of the characters comprises a cathode ray tube for successively scanning the matrices, and means for translating the modulated light signals thus obtained into electrical signals which are transmitted to print-out means comprising a cathode ray tube producing a raster comprising successive parallel trace lines and optical means for projecting the trace lines on a film in spaced parallel relationship. The print-out cathode ray tube comprises means for deflecting the light spot in a first direction to form a trace line and means for deflecting it incrementally in a second direction perpendicular to the first between successive trace lines to adjust the spacing between trace lines. It is thereby possible to control the width and spacing between printed characters and to obtain an overlap of characters when desired.

8 Claims, 11 Drawing Figures
FIG. 5

FIG. 6
FIG. 11
ELECTRO-OPTICAL PRINTER WITH VARIABLE SPACING AND WIDTH CONTROL

This invention relates to photographic recording equipment comprising a light beam generating device adapted to generate successive parallel linear beams; beam-modulating means; a support for a photographic negative; and a beam-directing system movable intermediate said beam generating device and said support for directing a succession of beams from said device on to successive side-by-side parallel locations on a negative on said support.

Typical examples of such equipment are photographic type-setting equipment such as page print-out equipment utilizing a cathode ray tube or other light beam sweep device, such as a laser and moving mirror system as described in British specification No. 1,124,967.

Initially a print-out CRT was controlled in conventional raster fashion for printing out complete characters at a time.

However, this was relatively slow and involved other technical problems.

As early as 1952, it was proposed in British specification No. 671,660 (Mergenthaler Linotype) (FIG. 2) that instead of printing out the characters entirely, the print-out tube should display the successive raster lines of a character in the same position on the print-out paper to form the character (and of course a line of characters in turn) by relative movement of the print-out tube and the paper.

The print-out technique is common to photo-mechanical type-setting; photo-electrical type-setting; electrostatic copying; and facsimile telegraph reproduction, for example.

The use of movable optical systems between a stationary print-out light beam and a stationary photo-sensitive film has been well known for many years from U.S. Pat. No. 2,567,240 (Sites) in color facsimile systems (1951); U.S. Pat. No. 2,787,654 (Peery) in electromechanical photographic page printing (1957); British specification No. 691,763 (Higonnet); British specification No. 801,481 (Mergenthaler) in electromechanical page printing (1953); and U.S. Pat No. 2,952,796 (Dick & Co) in electrostatic printing (1960).

More sophisticated photo-electric techniques for generating and transmitting characters raster fashion to a print-out tube were also proposed, for instance, in British specification No. 965,613 (Communication Patents Ltd.). While photo-mechanical type-setting systems have been extensively developed in the last twenty years, and such equipment has been in commercial use for some years.

The introduction of improved electronic devices and circuits led to work for the development of fast, commercially viable CRT to CRT systems based on the above work in U.S.A. and G.B. resulting in workable systems described in U.S. Pat. No. 3,273,476 (Haynes and R.C.A.) and U. S. Pat. Nos. 3,508,245 (Purdy et al.), 3,517,593 (Overacker and L.B.M.), and 3,553,676 (Raciti and R.C.A.).

These systems incorporate the line-by-line CRT print-out technique of British Specification 671,660 Mergenthaler - Linotype with the well known movable optical system and stationary print-out film technique of which examples have been given above, and show the laying-out, on the film, of increments of characters and are provided with means for controlling spacing.

The object of the present invention is to provide modifications to the above type of system to remove certain inherent small but noticeable variations from the normal in the printed page, which are unacceptable to the printing trade.

This object is attained by providing a mini-raster on the print-out tube, controlled according to the identity of individual characters, and of the type found in use, for example. The raster is 'mini', not so much in the number of lines provided, but in their very close spacing.

The invention will be described with reference to the accompanying drawings in which:

FIG. 1 is the basis of the known line-by-line print-out system.

FIG. 2 shows the build-up of a line of print on photosensitive film in known manner,

FIG. 3 shows the build-up of an individual character in known manner.

FIG. 4 shows the known CRT light beam character matrix scanning system.

FIG. 5 shows the gaps in the horizontal 'rules' or lines in a printed page,

FIG. 6 shows kerning between an f and an i.

FIG. 7 shows the mini raster of the present invention on the print-out tube.

FIG. 8 shows an example of overlapped character print-out according to the invention.

FIG. 9 shows the print-out of a character.

FIG. 10 shows the 'set' for an f excluding its overhang, and shows the expanded raster including its overhang, while

FIG. 11 shows intercontrol circuits between index and scanning tube and print-out tube for carrying out the present invention.

In FIG. 1, the spot on the print-out cathode ray tube describes horizontal sweeps only. Assuming that there is no modulation of the brightness of the light spot, horizontal 'lines of light' are seen on the face of this tube.

This light is collected and converted to parallel beams by means of a fixed collimator lens L.

A carriage C arranged to move horizontally along the axis of the CRT carries a plane mirror M at 45° to the horizontal, an objective lens 0, and a ruled optical grating G.

Light from the collimator lens L is intercepted by the mirror M and reflected onto the objective lens 0, which forms a sharp image of the cathode ray tube light spot on the film F.

As the light spot on the cathode ray tube describes a horizontal line, therefore, a line will be photographed on the film. The optical arrangement is such that irrespective of the horizontal position of the carriage, the lines on the film will be sharp and uniformly exposed.

If the carriage makes a continuous horizontal movement from left to right whilst the cathode ray tube light spot is made to produce a succession of linear traces, then a series of parallel lines, displaced from one another horizontally, will be recorded on the film. For example, if the carriage moves at 14 inches per second and the light spot describes 9,100 traces per second, there will be 650 lines recorded on the film per inch, or about 250 lines per centimeter.
The size of the light spot is adjusted so that these lines will just touch. In the absence of modulation of the CRT spot, therefore, a 'bar' will be exposed across the film for each carriage movement as shown in Fig. 2. The height of this bar will be determined by the focal lengths of the lenses used in the optics and by the length of the linear trace on the print-out cathode ray tube.

By modulating the CRT light spot during successive traces (i.e. by brightening and extinguishing the light spot), it is possible to expose characters or signs on the film as shown diagrammatically in Fig. 3. The source of the signal which controls the brightness of the spot will be described later.

It is very necessary for good reproduction that the successive exposed lines referred to above are correctly spaced with respect to each other. In the system described, the spacing depends on two factors;

i. the frequency of the linear traces on the CRT and

ii. the speed of movement of the carriage.

Since the latter is very difficult to control to the required degree of accuracy, a positioned reference system is built into the carriage drive system.

This reference system consists of a moving ruled grating G, Fig. 1, a stationary photocell P and a stationary light source S. The grating consists of a glass strip, at least as long as the maximum carriage movement, and having ruled on it 650 lines per inch. The lines are separated by clear spaces approximately as wide as themselves (1:1 mark/space ratio). The grating G is attached to the carriage C and moves with it. The fixed light source S is arranged to shine a beam of light through the grating onto the fixed photocell P. As the carriage moves, this light beam is interrupted by the grating lines.

The photocell P therefore generates an electrical signal which consists of a series of pulses-each pulse corresponding to the movement of the carriage by 1/650th part of an inch. After suitable amplification, successive pulses are used to control the start of successive linear traces on the print-out cathode ray tube. Irrespective of the speed of the carriage, therefore, the spacing of the photographs of these traces will be constant.

Existing Scanning System: The reproduction of characters by the above print-out system requires a modulating signal to control the brightness of the print-out cathode ray tube light spot. This modulating signal is provided by the simultaneous scanning of one of a number of transparent photographic master images on an opaque matrix sheet. The basic principles of this scanning system are as follows:

At the same time as the light spot on the print-out CRT describes linear traces, the light spot on an 'index' cathode ray tube also makes linear traces also synchronized with the pulses from the above mentioned grating photocell P. The light spot on the Index CRT is not modulated but is bright during the whole of a trace. However, successive traces are not in the same position on the tube but are separated by applying 'X' deflections to the spot during the fly-back periods between traces. Thus the spot on the Index tube describes a conventional raster, i.e. a rectangular shape formed by laying successive linear traces side by side. This is illustrated diagrammatically in Fig. 4.

Light from the Index tube IT is collected by a lens LL and focussed onto a matrix plate M containing a transparent photographic negative image of the character which is to be reproduced. Light passing through this character, while parts thereof within the raster are scanned, is condensed by a lens system CL onto the photo-cathode of a photo-multiplier PM.

The signal from the photo-multiplier controls the brightness of the print-out tube.

Thus, as the print-out carriage moves, pulses from the grating photocell P Fig. 1 cause successive displaced traces on the Index Tube IT and successive superimposed traces on the Print-Out Tube T. The print-out spot is bright or dark depending on whether the Index light spot imaged onto the master character is allowed to pass or not.

In order to be able to reproduce many different characters, the scanning system in practice is more complex than described above, the raster being small and being directed to different parts of the CRT screen for scanning different characters on the coordinate matrix. However, the principle is the same. The complete system is described in British specification No. 1,110,991.

Disadvantages of the Above System

i. One of the problems with the above system is that the time between the end of one print-out trace and the beginning of the next is very short. When one character is 'finished' and a new one is to be started, all the processes of switching etc. have to be carried out within this very short time.

At high operating speeds, it has been found impracticable to perform these operations as fast as is required. In fact, the time occupied by one whole trace (i.e. one grating pulse) is required to switch to a new character. In addition, the first trace on the Index Tube is used to 'search for' the exact position of the new character rather than to scan it; this 'X' Correction system, as it is called is described in specification No. 1,110,991.

For the above reasons, there is a blank period at the beginning of each character during which nothing can be printed out. In our previous system this period corresponds to the loss of two print-out lines. Whilst this is not too serious for most alphanumeric characters, it becomes serious whenever characters or signs are to be reproduced which join in the horizontal direction. A typical and frequently occurring example is the horizontal 'rule' or line. Where such a rule is used to delineate the end of a column or to form a table or box, it has to be made out of many shorter rules joined in the horizontal direction. If a true join is not possible, the resulting gaps render the result typographically unacceptable, see Fig. 5.

ii. A further disadvantage in the system is that it does not give the possibility of kerning in normal type fonts. 'Kerning' is the reproduction of two or more adjacent characters in such a way that the horizontal areas occupied by adjacent parts of the individual characters overlap.

A typical and very common example is the sequence of lower case 'f' and 'i' in a serif typeface. These are normally reproduced so that the top part of the 'f' overlaps part of the 'i' as in Fig. 6. A system which cannot 'join'
characters obviously cannot overlap them, except in the Italic mode described in the above Specification, but this is a special case.

**New 'Overlap Print-Out System'**

The new electrically-controlled overlap print-out system described below overcomes both the above disadvantages: it provides a breathing space between adjacent characters, and provides for kerning.

It will be clear from FIG. 6 that the print-out of overlapping characters requires that print-out of a succeeding character should be possible within the area already included in the print-out of the previous character.

One way to achieve this would be to stop the carriage after each character and to reverse it for a short distance before allowing it to move forwards again for the next character. Obviously, the inertia of the carriage would make this virtually impossible to achieve at high print-out speeds (several hundred characters per second).

However the same effect can be achieved electrically.

In the FIG. 1 arrangement, successive traces of the same character occur in the same horizontal position on the print-out tube T, by reason of the fact that no Y deflection is applied to the tube to vary the vertical positions of the traces. The traces are applied side by side to create a line of print by the movement of the mirror M.

If now gradually increasing Y deflection is applied to tube T upwards during the print-out of a character via the moving mirror M (moving to the right) this Y deflection can be used as a vernier adjunct to the mirror movement.

Fly-back of the Y-deflection control at the end of a character will position the succeeding trace reflection on the film F within the previous character width.

So far as providing a breathing space to allow of resetting the index tube raster to the position for scanning a succeeding character is concerned, an overall Y deflection of say 2 grating lines is sufficient, the fly-back requiring the carriage to move forward by two grating lines before it is correctly positioned for laying down the first line of the next character.

However, the Y deflection technique can also be used to provide kerning, in addition to the breathing space between characters, in the following manner.

In conventional solid type compositing, the relative width of a Kerned character excludes the overhang, and by utilizing the same technique in the computer of the present system kerning can be obtained.

The computer not only determines the number of grating lines required by the character identity and the point size, but expands the width of the raster by an amount which in the case of an overhanging character is sufficient to ensure that the raster covers the whole character including the overhang, while keeping the number of lines in the raster constant.

If the modulated lines were now printed out normally from a fixed position on the print-out tube, a complete overhanging character would be printed in the length of line for the character less its overhang. However, by the creeping Y deflection on the print-out tube during character print-out, the overhanging character is printed out in its correct width, and the fly-back ensures that the next character is printed under the overhang.

Since the print-out raster is to be used for all characters to provide the breathing space, the additional Y deflection required for kerning is applied idly to all non-kerning characters as well to give a uniform operation.

The computer will determine the amount of 'kerning' movement required for a character and will add the constant ' 2 grating line' space, the result being used to control the overall Y deflection AB, FIG. 7, on the print-out tube for the particular character as described below.

This print-out fly-back can be achieved by moving the trace on the face of the print-out CRT in a direction at right angles to its length or linear scan: i.e., by providing a 'frame' timebase. The first trace corresponding to the first grating pulse for a new character will be in a certain start position marked A in FIG. 7. As scanning and print-out proceed, the linear traces will be moved successively across the face of the tube in the 'Y' direction so that the last trace for the character is in some such position as B, FIG. 7. Suppose for simplicity that this Y deflection on the tube is equivalent to a distance of five grating lines on the film and suppose that the reproduction of the character had required carriage movement equal to 10 grating lines, then the position of the printed-out lines on the film will be as shown diagrammatically in FIG. 8 in relation to the grating line spacing.

The spacing of the lines is no longer equal to the pitch of the grating but is 50 percent greater since ten printed-out lines occupy the space of 15 grating lines.

At the end of print-out of the character, the 'Y' deflection of the print-out tube is rapidly brought to the original value so that the first trace for the next character is back in the start position 'A'. As far as the film is concerned, therefore, the first print-out of the next character will be in position 'A' and some of the succeeding lines will overlap regions already covered during the print-out of the first character.

Thus, with this system, it becomes possible not only to join adjacent characters but, where necessary, to overlap them.

This combination of a smooth motion of moving lens system with a stepped or continuous motion of the print-out linear trace gives the advantages of overlapped print-out described above.

When printing characters along a line of text, each character has to be allotted a certain amount of space in the horizontal direction. This space is known as the 'relative width' of the character.

The basic absolute measure of line space is the 'point' and there are 72.27 points to the inch. Every type font is allocated a maximum character width of \( x \) points, called the 'Em of Set', and the individual character widths are in eighteenth parts of the Em of Set, called Units, say \( y \) units.

When type is said to be in 6 point set width, this means that the Em of Set is 6 points (i.e. approximately 6/72, or one twelfth, of an inch) wide, and each unit for such type is \((1/12 \times 18) = 1/216\) inch approximately.

The relation between points (72 to the inch) and grating lines on the carriage (650 to the inch) is approximately 9 grating lines per point.
The relative widths of all characters in units and the 'set' required in points are stored in the electronic circuitry of the control circuits. When a character is to be printed-out, the machine makes a calculation to find out how much space the character will occupy in the horizontal direction. The answer to this calculation must be in grating lines.

The calculation made is:

No. of grating lines for a character = \( \frac{\text{Set in points} \times \text{relative width in units}}{2} \)  \(  \) (18)

Thus an upper case 'M' (18 units relative width) in 6 set needs 54 grating lines to be reproduced correctly. Similarly, a lower case 'i' (6 units) needs only 18 lines.

Since the width of a character to be printed-out varies with the points allocation, the number of grating lines on the print-out carriage corresponding to the width of the character varies with the points allocation in operation. Consequently, since the matrix character to be scanned to develop the number of print-out lines required has a constant width, and must be scanned by a scanning raster of constant width, the spacing of the raster lines therein must vary with the number of grating lines corresponding to the print-out width of the character determined by the point size.

Thus, the number of vertical lines in the scanning raster on the face of the Index or Picture Scanning CRT, as determined by the results of the above calculation, not only varies with the identity of the character (the raster being narrow for a narrow character like i and wide for a character like 'M'), but also varies for the same character according to the point size.

In consequence, the number of lines in the constant width of the scanning raster for a particular character varies, and the distance between the successive lines of the raster (in the X direction) is controlled by the 'set width'.

In the known system, the width of each Index raster was always such that its projection on the master photographic negative was exactly equal to the width of the character thereon being scanned. In other words, the raster lines just fitted neatly over the character. Usually, but not always, the width of a character includes a small amount of clear space on either side. This situation is shown in FIG. 9.

In the present system, the character matrix comprises transparent characters in an opaque background, the characters being suitably spaced to allow the raster for a character to be wider than normal, and to be suitably positioned laterally therein.

When a character is being printed out, its first line will be printed out from the bottom position A, FIG. 7, and its last line will be printed out from the top position B in the print-out tube raster, and since the Y deflection on the print-out tube is immediately removed, the line position returns to the bottom position on the raster, so that referring to FIG. 1, the reflection of the raster line which was passing via the right-hand end of lens O, is now passing via its left hand end and is thus applied to the film F at a position within the previous raster print-out area, as shown at A2 in FIG. 8.

When considering characters which can 'kern' (overlap), the relative width for such characters does not include the portion which overlaps. This will be clear when it is appreciated that the relative width determines where the next character is to be placed. If this includes any overhanging parts the next character cannot be placed so that it is overhung. Thus in FIG. 6, the relative width of the i ends at the broken vertical line and the relative width of the i begins at that line. Note that part of the top of the i extends into the relative width of the i.

The consequence of this is that the Index raster responsible for scanning a complete f must be wider than the relative width if kerned characters are to be reproduced. Two possible ways can be considered for making the raster wider. One is to make the raster wider in proportion to the relative width of the character being scanned. The other way is to make it wider by a constant amount.

Proportional widening is simpler to achieve technically since it merely requires an increase in the amplitude of the X deflection applied to the Index CRT. For example, this signal may be increased by one sixth so that a raster which was equivalent to 18 units wide now becomes 21 units wide and one that was 6 units wide is increased to 7 units, and this technique has been adopted.

The 'extra' scanned area may be wholly to the right or to the left of the character, or it may be equally divided on both sides, depending on how the character is drawn on the master photographic plate. For purposes of illustration, it will be assumed that the extra width is wholly on the right hand side. FIG. 10 shows a raster increased in width and superimposed on the letter f. The relative width of the f is shown by dotted lines and it will be seen that the raster now extends beyond this width sufficiently to scan the overhang. The number of scan lines in the raster is still the number calculated according to the formula given earlier, based on the set width, but the distance between them has been increased.

In order to avoid unwanted inter-character spaces, and to achieve overlapPed print-out, it is proposed to precede successive lines of a character on the face of the print-out CRT during print-out, raster fashion, and to return the line on the CRT to a fixed 'start' position before the next character begins.

This is achieved very simply by coupling the same signal that is applied to the X deflection circuits of the Index CRT to the Y deflection circuits of the print-out CRT. X and Y refer to the orientation shown in the figures. The resultant line spacings on the two tubes are however different; that on the print-out tube being of a lower order.

As a character is scanned, therefore, successive scan lines on the Index CRT progress from left to right to form a raster and, at the same time, the print-out beam moves from its horizontal start position to a higher position. When the character is finished (correct number of lines scanned), the X deflection on the Index CRT is rapidly brought to its start point on the left hand side of the raster and simultaneously the print-out line also reverts to its start position. The strength of the Y deflecting signal applied to the print-out CRT must be adjusted so that the line trace on the latter moves a distance equivalent at the film plane to a fraction, e.g. one-sixth, of the number of grating lines in the scanning raster.
Thus, if an 18 unit character (one set wide) is scanned at 6-point set width:

a. The number of grating lines required to reproduce this character will be 54 (nine lines to a point × 6).

b. The number of lines in the raster on the index CRT will therefore be 54.

c. The index X deflection is expanded by one sixth so that these lines will cover 21 units on the photographic master plate.

d. During scanning, the print-out line will move across the print-out CRT by such a distance that the print-out line in the film plane has moved 54/6 = 9 grating lines.

e. Since the lens carriage has moved 54 grating lines, the printed-out lines will cover a total horizontal distance on the film equal to 54 + 9 = 63 grating lines.

The same adjustment of the Y deflection of the print-out tube will work for all unit widths. However, for different Set Widths, a different adjustment will be necessary because the number of lines in the rasters will vary in proportion to the Set Width. For this reason, a series of pre-set amplifiers is required. One amplifier is switched into use and the others are switched off for each of the SET WIDTHS which the machine is capable of using.

FIG. 11 shows diagrammatically the circuits required. Blocks 1 and 2 are the horizontal time-base and deflection amplifiers for the index CRT. These circuits are also needed in the original system disclosed in specification No. 1,110,991.

Blocks 3, 4, and 5 show three vertical deflection amplifiers VB and A 3, 4, 5 with pre-set amplification factors proportional to the SET WIDTHS for which they are used. These amplifiers only operate when switched into use by control signals sent along conductors 3A, 4A and 5A. The output of whichever amplifier is in use controls the vertical deflection of the print-out trace via the deflection amplifier 6. The required circuits are not shown in detail since they are well known to those skilled in the art.

By the above means, therefore, a larger width than the unit width of each character is scanned. Also, a larger width than the unit width is exposed per character on the print-out film F, FIG. 1. However, after each character, the exposure for the succeeding character starts within the area covered by the previous character. If, therefore, a character has an overhang, the printed result will be corrected, providing the overhang is within the range of the extended index raster.

What is claimed is:

1. Photographic reproduction equipment comprising a scanning cathode ray tube for scanning in raster fashion each of a succession of printing characters on a matrix of characters and thereby generating a modulated light signal thereby generated into an electrical signal, a print-out cathode ray tube having beam generating and modulating means, an electrical signal channel from said translating means to the beam-modulating means of the print-out tube, line scan control means for the print-out tube operable in synchronism with the line scanning of the scanning tube, a support for a photosensitive web, a beam directive system between the print-out tube and the web support movable to direct successive straight parallel line traces on the print-out tube for a succession of characters to form a sequence of modulated line traces in successive side-by-side positions on a web mounted on said support so as to form a line of characters, raster control means for moving the otherwise fixed straight-line trace position on the print-out tube in a direction perpendicular to the line trace to increase fractionally the spacing of the parallel line traces on a mounted web during the print-out of said characters with fly-back at the end of each character, and means for selecting the trace line spacing of each character whereby the spacing of the characters in said line of print can be controlled.

2. Equipment as claimed in claim 1, wherein said raster control means modifies all of the spaces between line traces of a character in a like manner.

3. Equipment as claimed in claim 1, wherein said raster control means is adjustable to vary the extent of the change in spacing of said line traces.

4. Equipment as claimed in claim 1, wherein said beam directive system comprises a carriage which makes a succession of passes along a fixed path in the axis of the beam and optical means carried by said carriage for directing the beam at right angles to said axis.

5. Equipment as claimed in claim 4, wherein the travel of said beam directive system defines the character widths in a line of print whereby the expansion of a character width by said raster control means results in an overlap between the commencement of the next character and the termination of the expanded character width, and which comprises means for automatically blocking out the initial beam or beams of each character generated by said beam generating means.

6. Equipment as claimed in claim 5, wherein said blocking means is adjustable to vary the extent of the change in spacing.

7. Equipment as claimed in claim 1, wherein said raster control means is adjustable in proportion to the relative width of a character being recorded.

8. Equipment as claimed in claim 1, wherein said print-out cathode ray tube comprises line trace deflecting means and said raster control means comprises a plurality of preset amplifiers, and means for selectively associating any one of said amplifiers with said deflecting means.