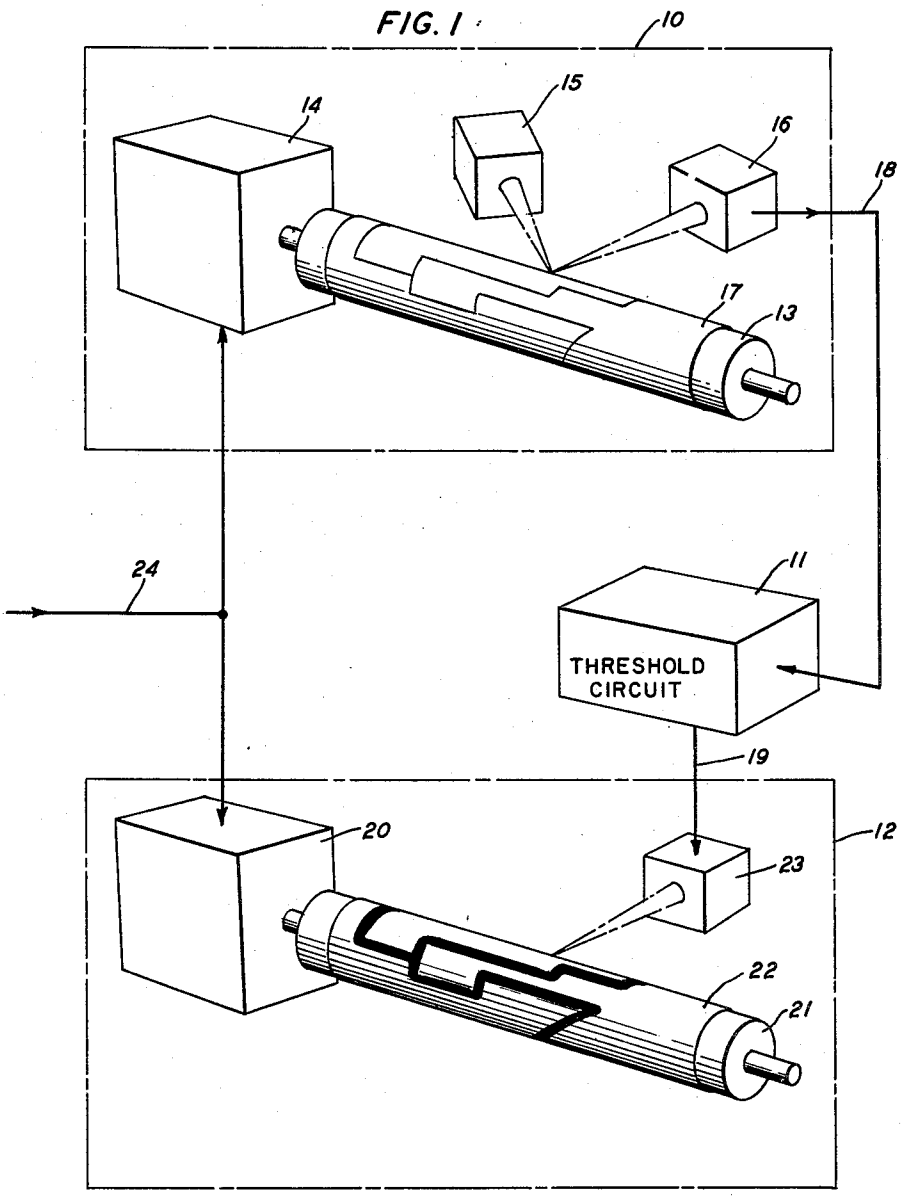
Nov. 5, 1963 R. A. RICHARDS 3,109,889

PRINTED CIRCUIT APPARATUS

Filed Dec. 29, 1960 2 Sheets-Sheet 1

FIG. 1



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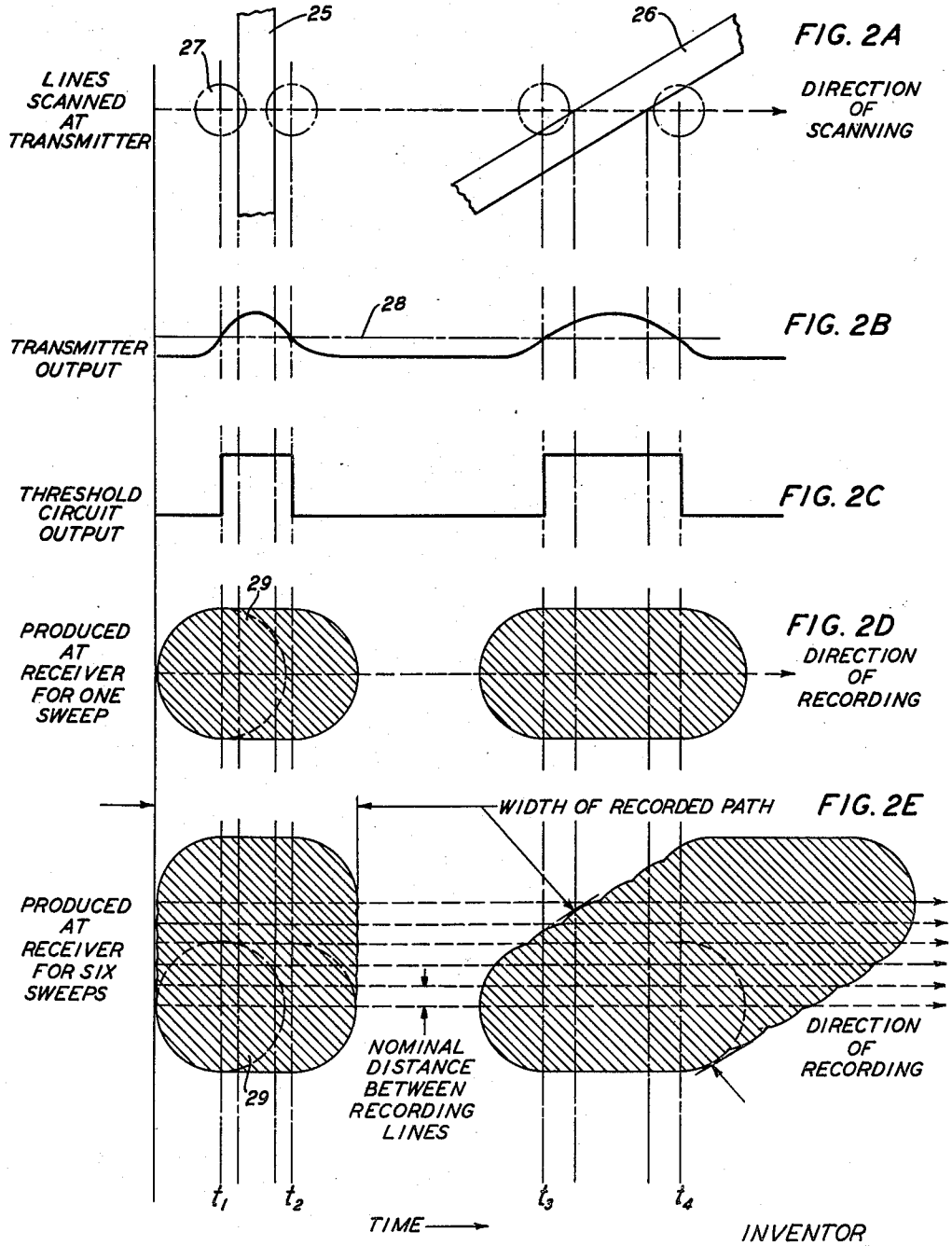

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PRINTED CIRCUIT APPARATUS

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The present invention relates to printed circuits and in particular to apparatus for producing printed circuit masters.

Although printed circuit masters having a one-to-one scale are sometimes produced directly, they are more often produced by first making a large-scale master and then reducing the large-scale master by photographic techniques. This latter procedure generally results in more accurate one-to-one scale masters than when producing such masters directly. The art work required to produce the original masters when using either procedure is, however, very tedious and time consuming and has placed a restraint on the manufacturing of printed circuits.

An object of the present invention is to produce acceptable printed circuit masters more quickly than heretofore possible.

This and other objects are achieved in accordance with the present invention through the use of apparatus that produces printed circuit masters from drawings comprising only the center lines of the paths and lands of the desired printed circuits. More broadly stated, the present invention produces broad-lined drawings from thin-lined drawings.

In one of its broader aspects, the invention takes the form of apparatus that scans drawings in a line-by-line manner with a circular scanning spot having a diameter less than the nominal distances between the scanning lines. A threshold sensing action produces a first signal when less than a predetermined amount of the spot is within markings on the drawings while a second signal is produced when more than the predetermined amount of the spot is within the markings. Recordings are produced in a line-by-line manner with a circular recording spot which is responsive to the first and second signals and has a diameter greater than the nominal distance between the recording lines. When the markings on the drawings comprise lines, the lines produced on the recordings are wider than those on the drawings as a result of both the threshold sensing action and the size of the recording spot.

One embodiment of the present invention includes a facsimile transmitter having a circular scanning spot. As the circular spot sweeps into and then out of a line, the output from the transmitter changes in a continuous manner from a first signal level to a second signal level and then back to the first signal level. The circular scanning spot, as explained subsequently, causes the width of a scanned line to appear the same in the transmitter output for all slopes of the scanned line. The transmitter output is applied to a threshold circuit which produces a first output when the transmitter output is below a predetermined level and a second output when the transmitter output is above the predetermined level. In accordance with a feature of the invention, the threshold circuit outputs may be made to represent different line widths by changing the predetermined level of the threshold circuit. The threshold circuit outputs are applied to a facsimile receiver having a circular recording spot which, in accordance with another feature of the invention, has a diameter greater than the nominal distances between the recording lines of the receiver. This feature of the invention causes lines to be produced at the receiver which are wider than the line widths indicated by the threshold circuit outputs. The lines produced at the receiver are therefore wider than those scanned at the transmitter as a result of both the threshold circuit and the large recording spot.

The centerline or thin-lined drawings for use with embodiments of the invention may be drawn by various media. Thin-lined pencil drawings have, for example, been found to be satisfactory.

Embodiments of the invention may be used to produce either one-to-one scale or large-scale printed circuit masters. One-to-one scale masters may be produced, for example, from centerline drawings having the same overall dimensions as the desired one-to-one scale masters. By taking advantage of the inherent size reducing characteristics of facsimile apparatus, one-to-one scale masters may be produced from centerline drawings having overall dimensions greater than those of the desired one-to-one scale masters. Furthermore, large-scale masters may be produced from centerline drawings having overall dimensions greater than those of the desired one-to-one scale masters. These large-scale masters may then be reduced photographically. The particular approach used to produce a desired one-to-one scale master will depend, among other things, upon the printed circuit involved and the apparatus being used.

The present invention may also be used in a manner to take advantage of several well known features of facsimile apparatus. The electrical input to the receiver may, for example, be stored for future use. Furthermore, the electrical input to the receiver may be transmitted to another location, thus eliminating the necessity of mailing printed circuit masters.

Other objects and features of the invention will become apparent from a study of the following detailed description of an embodiment.

In the drawings:

FIG. 1 is a pictorial representation of an embodiment of the invention;

FIGS. 2A through 2E show various sketches useful in understanding the operation of the embodiment of FIG. 1.

The embodiment of FIG. 1 comprises a facsimile transmitter **10**, a threshold circuit **11** and a facsimile receiver **12**. Only the elements of transmitter **10** and receiver **12** necessary for the present explanation are shown. Transmitter **10** comprises a copy holding drum **13**, a drum driving mechanism **14**, an illumination circuit **15** and a reflected light sensing circuit **16**. A centerline drawing **17** of the printed circuit master to be produced is shown around drum **13**. Illumination circuit **15** produces a circular scanning spot that is caused to scan drawing **17**. Reflected light sensing circuit **16** scans drawing **17** in synchronism with illumination circuit **15** and produces on lead **18** an output related to the intensity of the light reflected from drum **17**.

Lead **18** is connected to the input of threshold circuit **11**. Threshold circuit **11** produces on a lead **19** a first output when the output from reflected light sensing circuit **16** is below a threshold level and a second output when the output from circuit **16** is above the threshold level. Threshold circuit **11** may comprise a reverse biased active device that is switched from an OFF or non-conducting condition to an ON or fully-conducting condition when the input to the device exceeds the bias. Such circuits are well known in the art.

Receiver **12** comprises a drum driving mechanism **20**, a drum **21** on which is mounted recording medium **22** and a recorder circuit **23**. A lead **24** applies inputs to drum driving mechanism **20** and drum driving mechanism **14** of transmitter **10** so that drums **13** and **21** are driven in synchronism. Lead **19** from threshold circuit **11** is connected to recorder circuit **23**. Recorder circuit **23** scans recording medium **22** in synchronism with the scanning action of illumination circuit **15** and sensing circuit **16** of transmitter **10**. Recorder circuit **23** produces a re-

cording spot on medium **22** for only one of the threshold circuit outputs appearing on lead **19**.

A more detailed explanation of the operation of the embodiment of FIG. 1 is now presented in conjunction with FIGS. 2A through 2E. FIGS. 2A through 2E all have the same time base. FIG. 2A shows greatly magnified portions of a vertical line **25** and a sloping line **26** from a typical thin-lined drawing that may be placed on drum **13** of transmitter **10**. A circular scanning spot **27** which has a diameter less than the nominal distances between scanning lines and scans from left to right is shown at times t_1, t_2, t_3 and t_4 during one of its sweeps. FIG. 2B is the waveform of the output from transmitter **10** as spot **27** of FIG. 2A makes one sweep through lines **25** and **26**. The amplitude of the waveform increases to a maximum level as spot **27** sweeps into each of lines **25** and **26**, holds this maximum level while the spot is within the lines and decreases to its initial level as the spot sweeps out of the lines. As shown in FIG. 2C when the amplitude of the transmitter output waveform is less than a threshold level **28**, threshold circuit **11** produces a first output whereas when the amplitude of the transmitter output waveform exceeds threshold level **28**, threshold circuit **11** produces a second output. As shown in FIG. 2C, threshold circuit **11** switches from its first output to its second output at times t_1 and t_3 and from its second output to its first output at times t_2 and t_4. In accordance with a feature of the invention, the times at which threshold circuit **11** switches from one output to another may be changed by adjusting the threshold control of the circuit. This feature permits the threshold circuit outputs to represent greater line widths than those scanned by the transmitter.

The two shaded areas shown in FIG. 2D represent those areas of the receiver recording medium that are swept by a recording spot **29** as a result of the threshold circuit output shown in FIG. 2C. In FIG. 2E the shaded areas represent those areas of the recording medium that are swept by spot **29** as a result of six consecutive sweeps of spot **27** through lines **25** and **26** of FIG. 2A. In accordance with a feature of the invention, spot **29** is circular and has a diameter greater than the nominal distances between recording lines. The widths of the lines produced on the recording medium are equal to

$$2\left(\frac{W}{2}+f+\frac{D}{2}\right) \text{ or } D+W+2f$$

where W is the width of the line being scanned at the transmitter, f is the perpendicular distance from the edge of the line being scanned to the center of the scanning spot at the time threshold circuit **11** changes its output condition and D is the diameter of the recording spot. Because spot **27** is circular, the perpendicular distance from the edge of a line of any slope to the center of the spot at the time threshold circuit **11** changes its output condition is always the same. This expression therefore represents the width of a line of any slope. Furthermore the lines appearing on the recording medium are $(D+2f)$ wider than the scanned lines. The width of the recorded lines may be increased or decreased in accordance with features of the invention by changing the diameter of the recording spot or the threshold level of circuit **11**.

As apparent in FIG. 2E the edge of the lines appearing on the recording medium have a slight ripple. This ripple decreases when the ratio of the recording spot diameter to the nominal distances between recording lines is increased. The ripple, however, is generally within acceptable limits.

The above explanation is related to the producing of a broad-lined drawing having the same overall dimensions as those of the thin-lined drawing from which it is made. When size reduction is produced by the facsimile apparatus, the thickness of the lines produced on the recording medium are equal to $D+K(W+2f)$ where K is the reducing factor of the facsimile apparatus.

The invention has been described only with respect to a particular embodiment. It is to be understood that various other embodiments may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, means for scanning a sheet of markings in a line-by-line manner and producing signals indicative of said markings, means responsive to said signals for producing a first output when said signals have an amplitude less than a predetermined level and a second output when said signals have an amplitude greater than said predetermined level, and means responsive to said first and second outputs for recording in a line-by-line manner with a circular recording spot having a diameter greater than the nominal distances between the recording lines.

2. In combination, means for scanning a sheet of markings in a line-by-line manner with a circular scanning spot having a diameter less than the nominal distances between the scanning lines to produce signals indicative of said markings, means responsive to said signals for producing a first output when said signals have an amplitude less than a predetermined level and a second output when said signals have an amplitude greater than said predetermined level, and means responsive to said first and second outputs and synchronized with said scanning means for recording in a line-by-line manner with a circular recording spot having a diameter greater than the nominal distances between the recording lines.

3. In combination, a facsimile transmitter that scans in a line-by-line manner with a circular scanning spot, means responsive to the output from said transmitter for producing a first output when said transmitter output is less than a predetermined level and a second output when said transmitter output is greater than said predetermined level, and a facsimile receiver responsive to said first and second outputs and synchronized with said transmitter for recording in a line-by-line manner with a circular recording spot having a diameter greater than the nominal distances between the recording lines.

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