X-Y IMAGE SCANNER

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Received on May 8, 1975 and in revised form on July 11, 1975

ABSTRACT

An electronically controlled mechanical system has been built to scan light intensity distribution in the image plane. The system has undergone preliminary tests. A resolution of 20 line pairs/mm has been demonstrated. The repeatability of scanned results is reasonably good.

1. INTRODUCTION

In optical computer Preston Jr. [1], the output is in the form of light distribution in the image plane. For quantitative measurement of the output we should convert the light intensity into electrical signal, which may then be recorded on a strip chart recorder or X–Y plotter. One of the simplest method of scanning the image plane is to physically carry a photodetecting element to and fro and up and down the image plane. We have used the above basic concept but with several modifications to build an X-Y image scanner having a resolution of 20 line pairs/mm.

Instead of physically translating a bulky PMT (photo-multiplier tube) we have used a fiber optic guide whose one end is exposed to PMT and the other end is used to scan the image plane. Thus, we have reduced the load on the mechanical system. The scanning is controlled electronically. The system can be mounted on an optical bench.

The entire system, excluding PMT and fibre optic, is made of Indian made component.

DESCRIPTION OF SYSTEM

A. light sensing element in our case an end of fiber optic is mounted on a stable platform, which is translated horizontally and vertically by means of two independent but simultaneously working low power (1/60 h.p.) geared motors. The rotational motion of the motors is transformed into a linear motion through a system of gears and specially designed mechanical arms. The motor for horizontal scanning is controlled electronically. The motor is reversed when the end-of-scan is reached. But, unfortunately, because the motors used had slow response, the time for reversal is approximately 1·5 seconds. The vertical scan motor, however, operates in a continuous manner in one direction until manually reversed. The maximum scan area is 50 mm × 30 mm. Actual scan area can be manually set within the above limit.

The raster generated as a result of above motion is shown in Fig. 1. The slope of the scan lines is $\pm \tan^{-1}\left(\frac{1}{440} - \frac{R_v}{R_h}\right)$

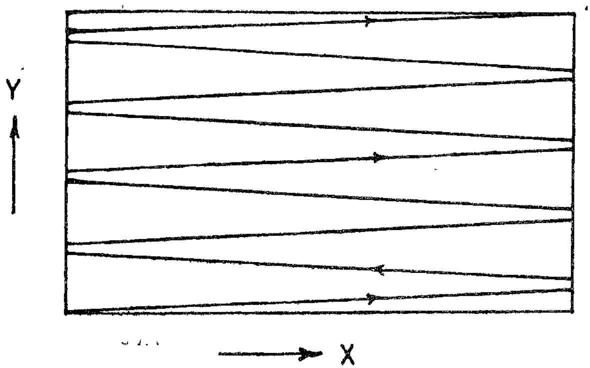

FIG. 1. Raster used in the scanning of image plane.

where R_v is speed of the vertican scan motor (in revolution/ second) and R_h is speed of the horizontal scan motor. It may be noted that ends of two scan lines are shown slightly vertically separated. This is on account of the fact that the vertical motor continues to operate while the horizontal scan is being reversed. This separation is of the order of $0 \cdot 075\ R_v$ (in mm).

The light detecting system consists of a low loss fiber optic whose one end is exposed to PMT and the other is used to scan the image plane. This end is faced with 35 μm pin hole. The output of the PMT is first amplified and then recorded on a strip chart recorder. The amplifier is a current amplifier with frequency response from D.C. to 30 KHz and amplification upto 40 db with gain margin of 1·63. The recorder has a frequency response of 1 Hz. This limits as shown in the next section, the maximum permissible motor speed and hence the total scanning time. A schematic block diagram of the entire system is shown in Fig. 2.

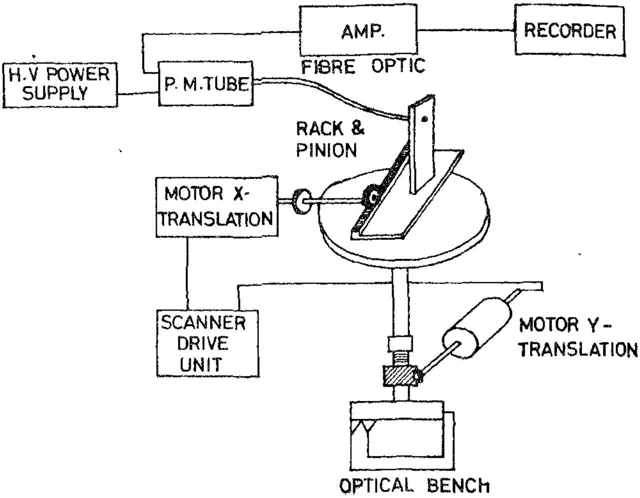

FIG. 2. A schematic block diagram of the entire X–Y image scanning system.

Resolution.—There are two main factors which control the resolution of the system : (1) aperture of the scanning element, in our case the pin hole mounted on the fiber optic, (2) Recorder—amplifier band width. If the fiber optic is faced with a pinhole of diameter d, the resolution is proportional to $1/d$ line pairs/unit length. We have used a pin hole of diameter = 35 μm. The expected resolution is, therefore, 30 line pairs/mm. In principles it is possible to reduce 'd' but then the signal-to-noise ratio comes down leading to other experimental problems.

Let us now look into how the recorder and amplifier bandwidths limit the performance of the scanner. Let the spatial signal bandwidth be B_s (line pairs/mm) and the scanning speed be V (mm/sec), then the bandwidth of the electrical signal is equal to $B_s \times V$. The scanning speed is related to the motor speed

$$V = KR$$

where K is a constant depending up the gear system and R speed of the motor (number of revolutions per second, RPS) let B_s stand for recorder bandwidth. In order that the signal waveform be preserved we must have

$$B_r \geqslant B_s V = B_s KR$$

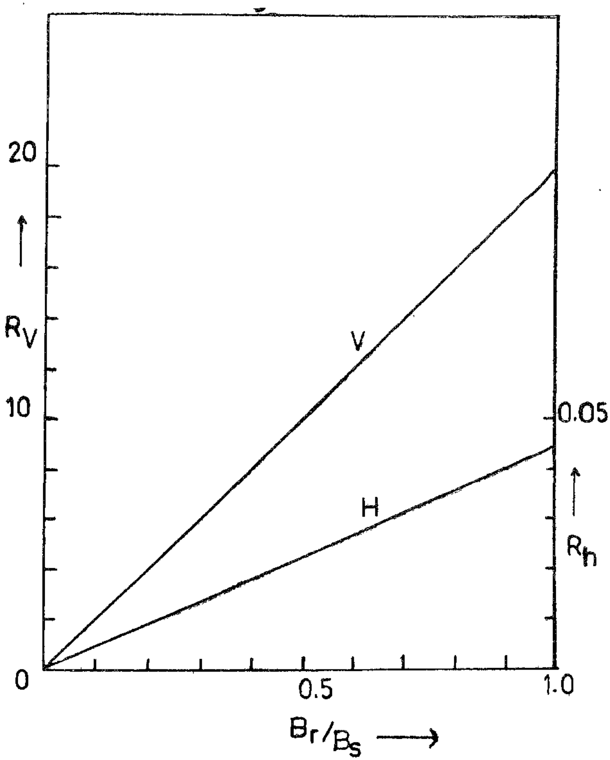

FIG. 3. A relationship between the maximum permissible motor speed (in RPS) and the ratio of recorder bandwidth (CPS) signal bandwidth (in line pairs/mm).

or

$$R \leqslant \frac{1}{K} \frac{B_r}{B_s} \quad (1)$$

This is an important relation which is illustrated for our system ($K_{verticle}$ = 1/20 mm/rotation and $K_{horizontal}$ = 22 mm/rotation) in Fig. 3. Equation (1) (or Fig. 3) tells us what is the maximum permissible speed of motor for a given ratio of recorder bandwidth to signal bandwidth.

3. Test Scans

In order to test the resolution and repeatability of the system we have scanned a transmission grating having 7½ line pairs/mm. The grating was imaged onto the image plane and magnification was so arranged that we could get 20 line pairs/mm. The following motor speeds were selected : (1) horizontal scann motor : 0·0027 RPS and (2) vertical scan motor : 0·5 RPS. The recorder band width was 1 cps. The above motor speeds are within the limits set by Eq. (1).

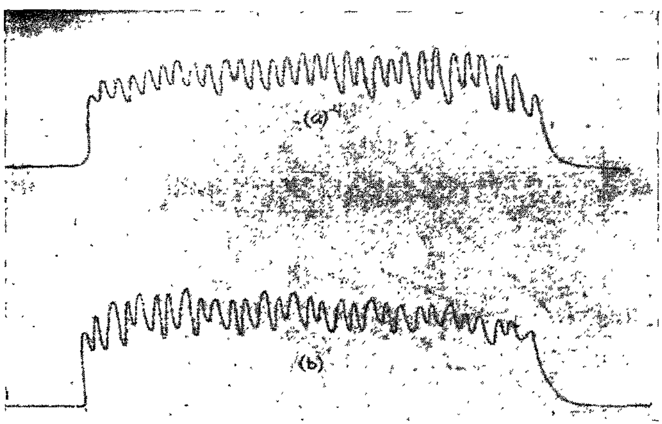

FIG. 4. Test scans in the horizontal direction: (a) direct scan and (b) reverse scan.

In Fig. 4 we present one of the several test outputs of horizontal scan. The lines are well resolved though the repeatability is not very good. This

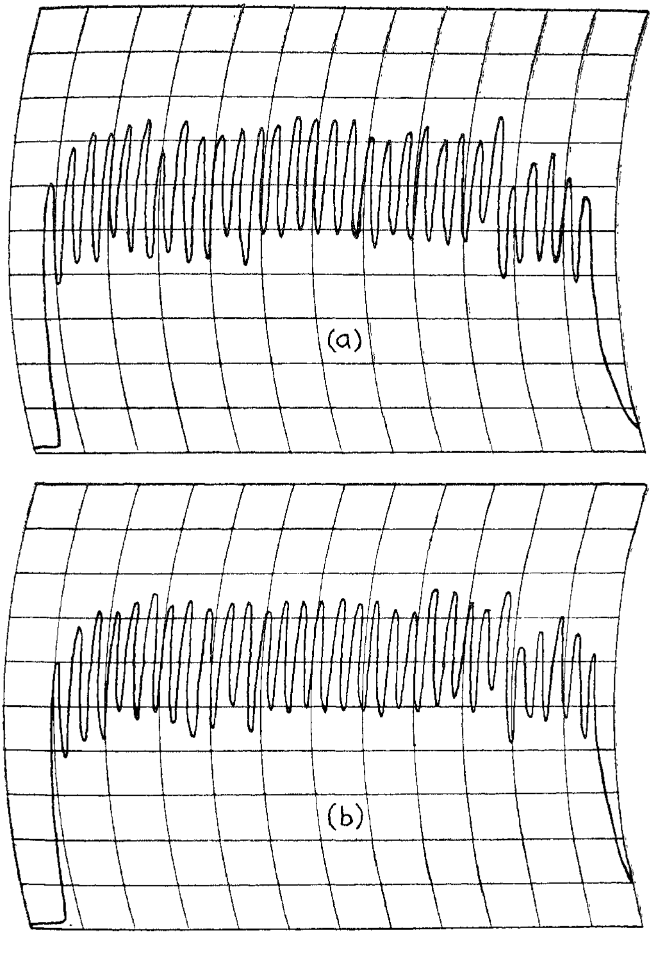

FIG. 5. Test scans in the vertical direction: (*a*) direct scan and (*b*) repeat direct scan.

could be due to motor speed variation as it was not operated at its rated value *i.e.*, ·016 R.P.S. In Fig. 5 we present result of vertical scan. (The same grating was used after turning it up by 90°). We note that the resolution and repeatability are excellent. The improved performance is probably due to the fact that we have operated the vertical scan motor at its rated speed, and also that the operating speed is well below the limit set by Eq. (1).

CONCLUSION

A resolution 20 line pairs/mm has been demonstrated. Higher resolution can be achieved if the recorder bandwidth could be increased. In the next phase we propose to replace the present recorder by one with 50 Hz response and the present induction motors by synchronous motor for better speed uniformity.

ACKNOWLEDGEMENT

We wish to thank Professor B. S. Ramakrishna, Professor-in-charge of Center for Information Processing, for providing facilities to carry out the work described herein. We also like to thank Mr. Syed Usman who fabricated with considerable ingenuity the mechanical arms used in the system.

REFERENCE

Preston Jr., K. .. *Optical Computers*, McGraw Hill Book Co., New York, 1972.