February 6, 1967
2-7822-20-129

To: O. W. Ritchey

cc: ✓ F. K. Preikschat
P. D. Macdonald
M. L. Reeves

Subject: Facsimile Transponder

Attachment #1 is a supplement of Attachment #2 which is a report describing the Facsimile Transponder Development that appears as Paragraph 4.6 of Document D2-113478-1 entitled Summary of Technology Research for calendar year 1966, Telecommunications (2-7822).

Prepared by *W. L. Regier*
W. L. Regier

Approved by *K. J. Meerdink*
K. J. Meerdink

WLR:jmd
Attachments

Supplement to paragraph 4.6 called Facsimile Transponder Development of Document D2-113478-1

Introduction

After the above document was completed, additional modifications were made to the Scanning Matrix as shown in Figure 9 of Attachment #2 and to the scanner and recorder shown in Figures 6 and 7. These changes resulted in a marked improvement in performance of the transponder. The resolution is now limited by the scanner and recorder and not by the electronics, as was the case at the writing of the original document.

Details

The test set-up is shown in Figure S-1. The breadboard in the foreground contains the circuitry with its power supplies at the left. The scanner and recorder are mounted on an X-Y plotter with the scanner above the recorder. The power supply and the stepping switch circuit on the right provide steps in voltage for vertical movement of the plotter. The photo also shows the two methods of print out with a hard copy on the left of the plotter table and a partial print out on the reusable note pad at the bottom right.

Figure S-2 shows the relation of the scanner and recorder heads to each other. In this test layout, their distance apart is about four inches. Also shown are the mountings used to control the distance of the heads above the paper.

Figure S-3 presents a close-up of the bottom sides of the heads with the scanner on the left. The scanner window is made up of 8 light guides per photo-diode, a total of 56. The window is 0.026 inch x 0.180 inch in size and is divided into seven equal areas which are identified with seven different photo-diodes that are also in the head. These seven areas are equal in size to the areas of the recorder hammer heads so that a given hammer head is uniquely associated with a given photo-diode (See Figures 4.6-6 & 7). Also shown in this photo is the shield which not only confines the viewing area of the light guides but also serves a sort of shoe on which the head rides at a set height above the paper being scanned. The shoe approach was used because of problems in keeping the paper being scanned flat (See Figure S-2). Not visible from the photo are the improvements in mechanical matching and movement optimizing of the hammers.

The modified Scanning Matrix is shown in Figure S-4. This arrangement allows continuous bias to be applied to the photo-diodes so that the waveform in Figure S-5b is the output of the Scanning Matrix instead of the one in Figure 4.6-12 which shows the slow, non-uniform voltage rise. The degradation in the first configuration was due to the high junction capacitance present when the bias was applied to the photo diode. Comparison of the two photos shows that the new circuit allows for an evaluation of the impinging light level throughout the complete sampling period. This is achieved by applying a constant bias to the photo-diodes so that the junctions stay formed and so that the diodes are always sensitive to changes in impinging light. The output voltages of the seven diodes are then sequentially sampled to obtain the output of the scanning matrix (or decision circuit input) shown in Figure S-5b. This waveform represents one sync pulse plus one complete read-out of the seven diodes in the scanning head where the output of a particular diode (labeled by a number) represents a unique resolution element 0.025 of an inch square. This information is then used by the decision circuit, which introduces a 1/2 sec. delay, to generate the waveform of Figure S-5a. The waveform shows in this case that only the resolution element represented by diode #4 was black. Another advantage of the modified circuit is shown by Figure S-6b which displays the matched response of the photo diodes to black resolution elements. The improvement can be noted by a comparison with Figure 4.6-12 which also shows an all-black condition. The matching is accomplished by adjusting the amount of bias on the diodes to match their responses to a given black condition with the 10M variable resistors. Once the match is obtained, a precise decision level can be then set for maximum resolution.

Figure S-7 presents a sample sketch, the top half of which was scanned and duplicated on the bottom half by the transponder. This sample, although still somewhat below the desired resolution of 40 lines per inch, gives an indication of the possibilities of the transponder as most of the desired details have been transmitted. The sample does show however, that there is an overall lack of resolution. This is because, in the present experimental scanner, the light guides of a given photo-diode are viewing parts of the resolution elements of the adjacent diodes. This results in a vertical smearing or crosstalk between the resolution elements. This can be seen clearly from Figure S-7. Horizontal smear, while still a problem, has reduced by the shield shown in Figure S-3. Figure S-7 also shows that there is still a problem with this recorder because the print-out dots made by the hammers are not of a uniform quality or of sufficient darkness.

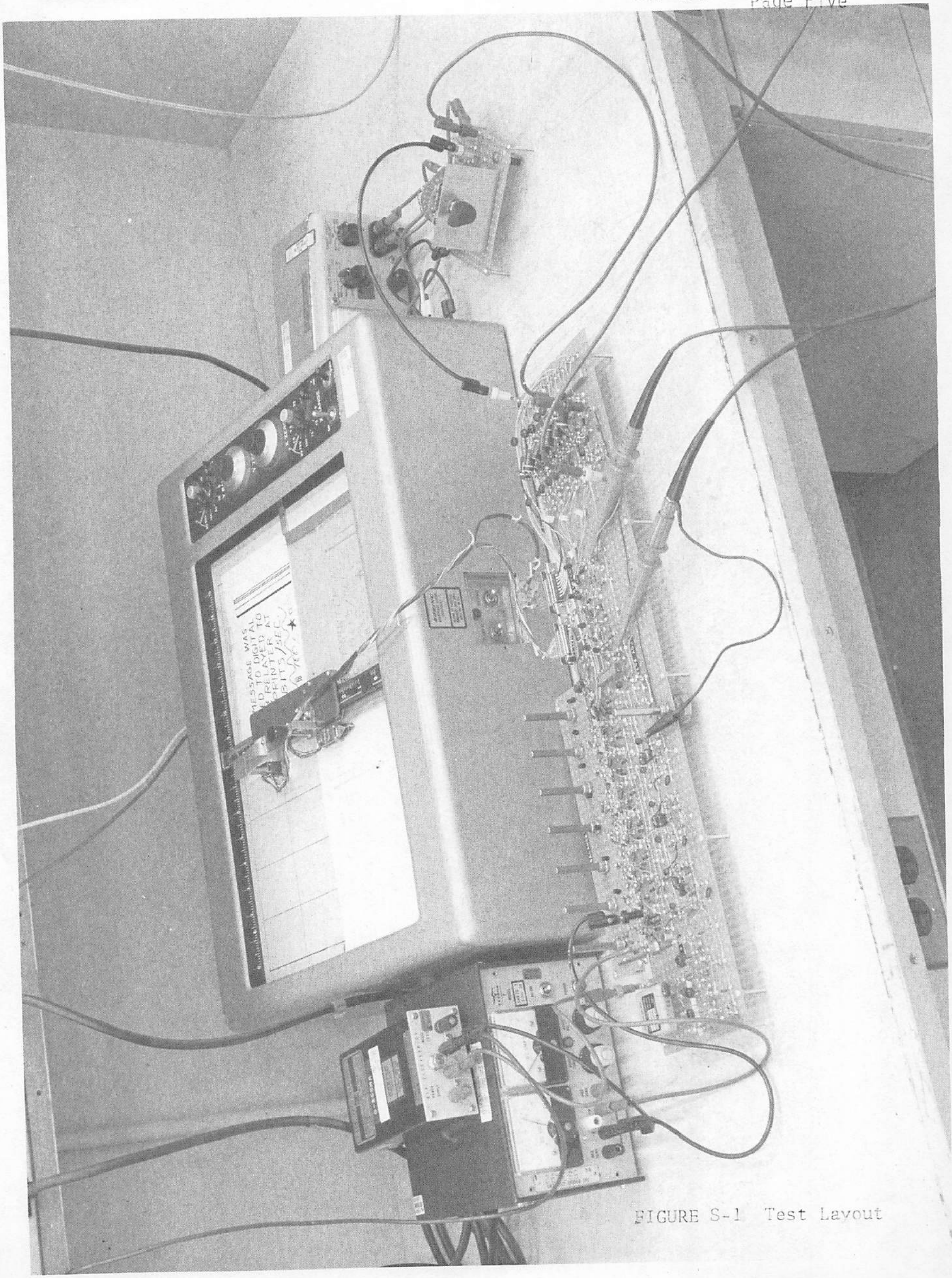
Results

The present scanner design has allowed for a very dense packaging of the components. The main problem is the inability of the light guides which scan the paper to focus on a small enough area. One way this can be solved is by placing seven small lenses, one for each resolution element, over the faces of the light guides to precisely control the resolution element size as seen by a group of guides. This would eliminate both vertical and horizontal smearing. These lenses would not have to be of very high quality as long as they easily passed light in the near infrared region where the photo diodes are the most sensitive and provided proper restricted viewing area to its bundle of light guides. The light sources would also be repositioned to present a uniform light coverage under the seven lenses. The use of a lens for each resolution element could also allow the light guides to be eliminated as the resolution element could be directly focused on the photo diode. Recent developments in Integrated Photosensor Arrays by several companies including Fairchild make it possible to compactly package many small photo diodes as close as 0.006 inches from center-to-center, all on one silicon chip. Thus, by using one common lens along with an array of seven diodes, the image of the paper can be accurately placed directly on the plane of the array and cross talk can be reduced. Another method would be to use the present method of packaging the light guides but to illuminate only the resolution element that is to be scanned. This could be done by a diode junction light source which would be emitting only during time period that its related photo diode was being sampled. This would require seven sources, the outputs of which would be carefully focused so as to illuminate the precise area of one resolution element, probably through the use of additional light guides and/or lenses. Other methods emply various types of shields to restrict the viewing areas of the seven groups of light guides and to columnate the light to the proper areas.

The recorder design presently used is very compact but in its present form does not generate enough force with its hammers. This results in the need for very precise control of the height of the recorder above the print-out medium and as well as a medium which is highly pressure sensitive. Both of these problems could be eliminated with the use of more powerful hammers. The most efficient configuration would be one that would bring the maximum force to bear on the pressure-sensitive medium per unit of momentum generated. A possible solution would be to make the magnet and a printing wire to both move in the same direction so that the momentum of both the magnet and wire will be concentrated on the resolution element to be printed. This method was proven to be highly satisfactory in a teletype device referenced in Attachment #2 where up to six carbons could be cut at once. The use of seven wire-magnet printers would allow for a precise control of dot size and intensity which is not available in the present design.

Conclusions

The results that have been achieved to the present are very encouraging because the major electronics problems have been solved. The present scanner and recorder heads have provided valuable information about their operating characteristics. The weakest areas in the system are in the optical scanner and the electro-mechanical recorder. Evaluations of the present scanner and recorder head designs have led to the several possible modifications described above which would improve the present design. In conclusion, it is now possible to build a small, completely portable facsimile transponder.



KENT - FACSIMILE TRANSPONDER 2A243688
BREADBOARD. 1-11-67

FIGURE S-1 Test Layout

KENT - FACSIMILE TRANSPONDER 2A243687
BREADBOARD. 1-11-67

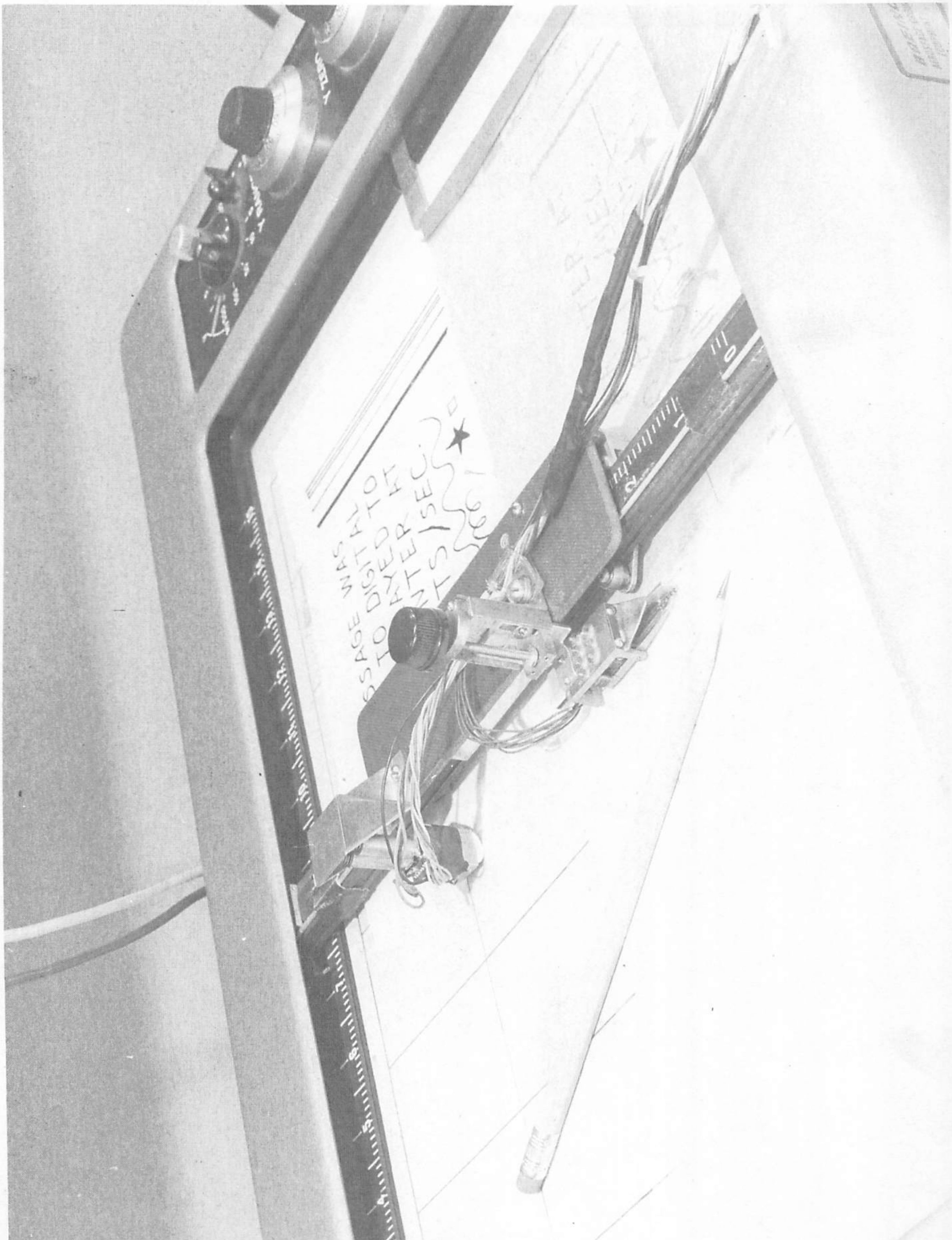


FIGURE S-2 Scanner and Recorder

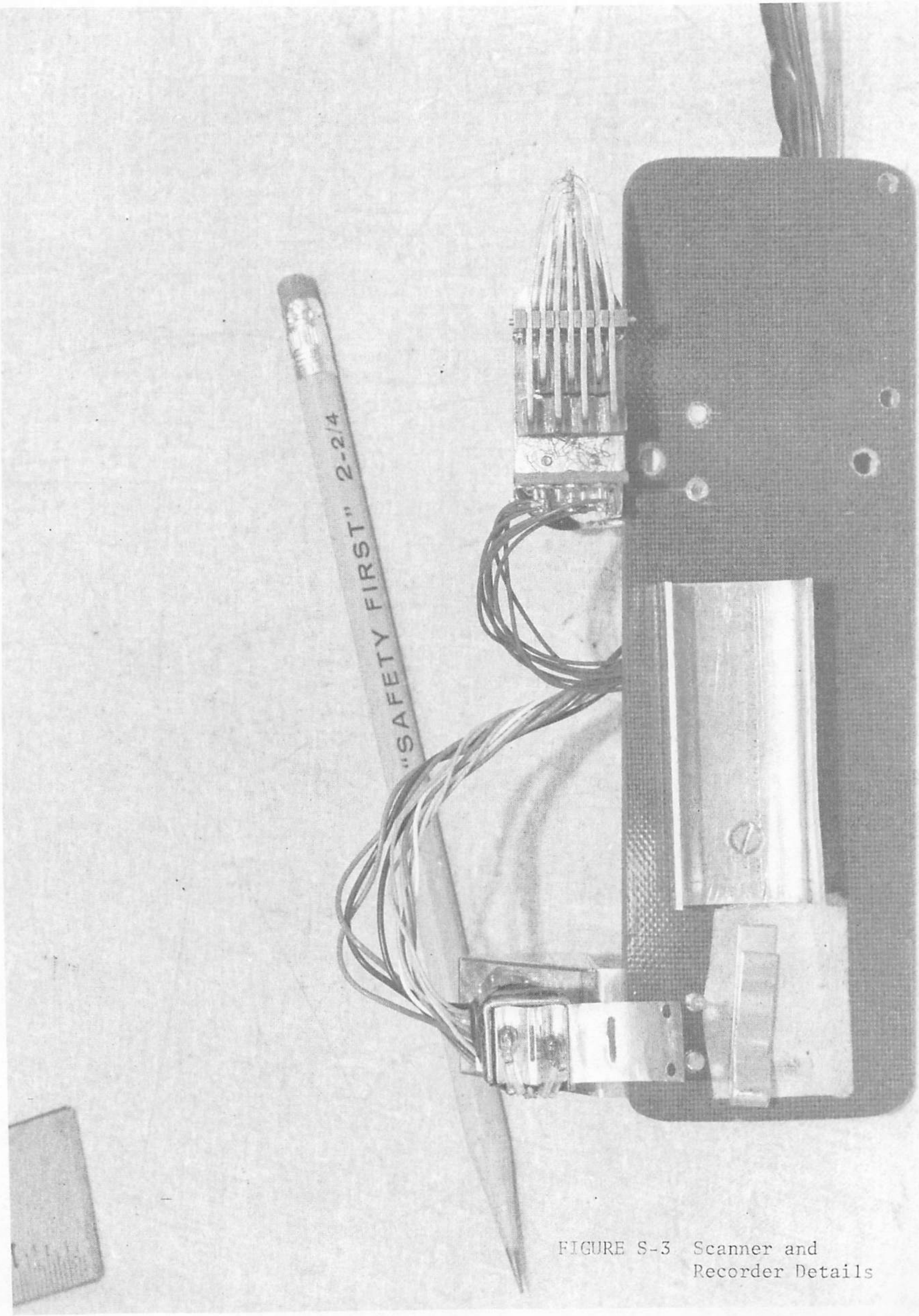


FIGURE S-3 Scanner and Recorder Details

KENT FACSIMILE TRANSPONDER BREADBOARD. 1-11-67 2A243689

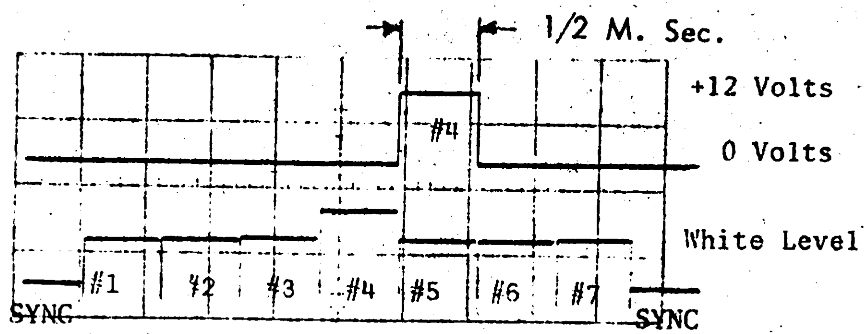


FIGURE S-5

a. Decision Circuit Output

b. Scanning Matrix Output
(Point A, Fig. S-4)

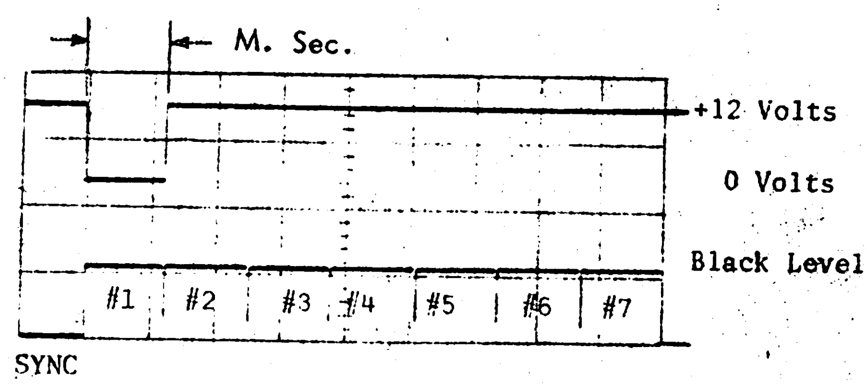


FIGURE S-6

a. Decision Circuit Output

b. Scanning Matrix Output

USE FOR TYPEWRITTEN MATERIAL ONLY

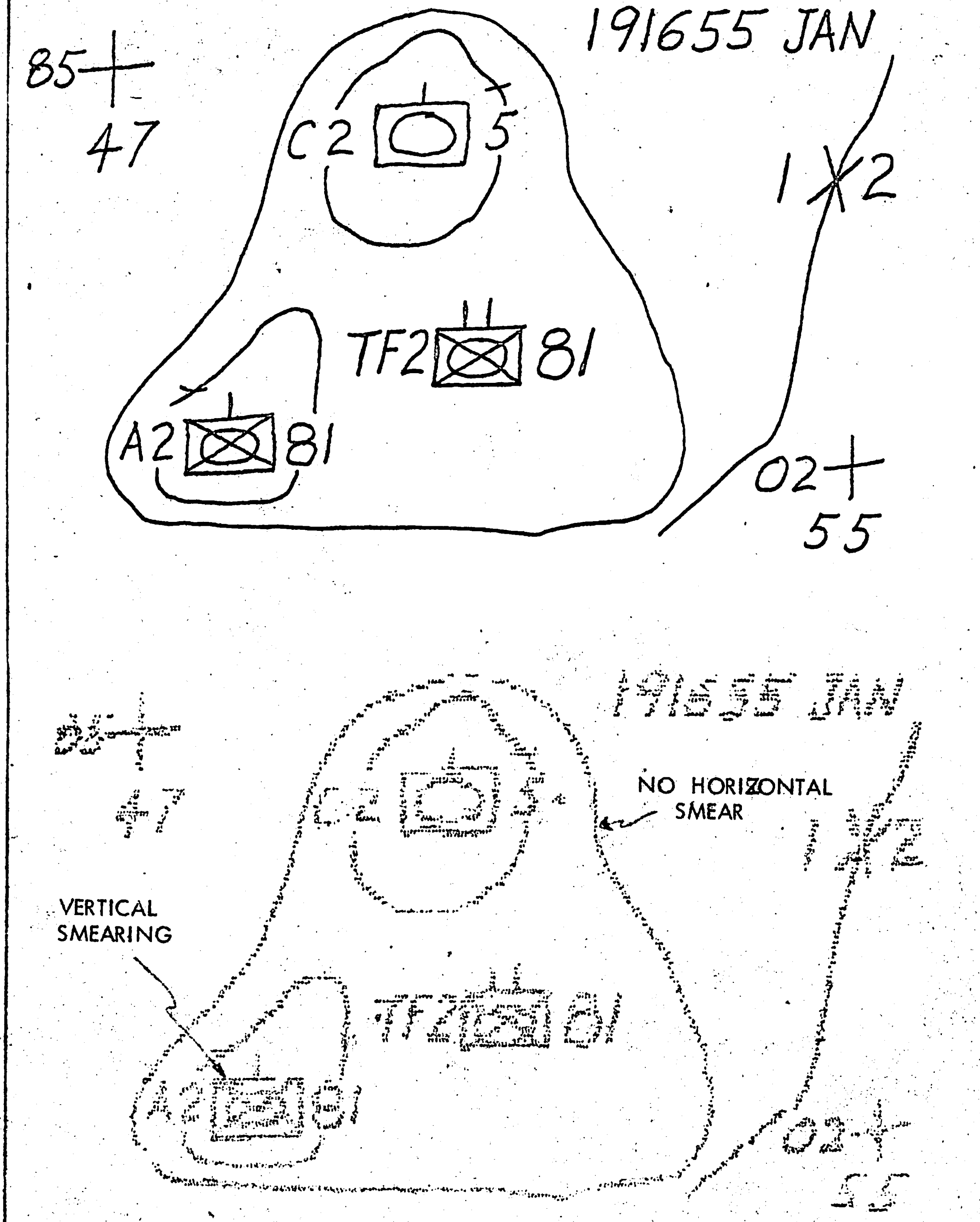


FIGURE: S-7 SAMPLE

4.6 Facsimile Transponder Development

F. Preikschat
W. L. Regier

4.6.1 Introduction

The purpose of the effort is to develop a device that transmits and receives two-tone facsimile information. The device would have a reusable notepad on which drawings and handwritten messages could be drawn for transmission and would be reproduced upon reception. The transponder must be capable of transmission over any voice-quality channel.

4.6.2 Description

The following initial description is a patent disclosure submitted by Fritz K. Preikschat on August 14, 1966 and witnessed by Orral Ritchey and John Nitardy. A detailed description of the laboratory model follows the disclosure.

4.6.2.1 Patent Disclosure

FACSIMILE TRANSMISSION

On August 23, 1966, Orral Ritchey and Fritz K. Preikschat discussed a teletypewriter developed by the latter ten years ago. This machine transmits the "picture" of a character in a 5 x 7 = 35 dot matrix from a "pattern" produced and stored by the Keyboard of the transmitting part of the machine.

A modification of this design will permit its use for facsimile transmission. By omitting character and line spacing the machine is able to receive and reproduce line drawings and handwritten characters.

Orral Ritchey pointed out the advantage of portable Facsimile communication equipment to augment voice communications in a tactical military situation. For instance a real-time-map sketch, designating target and deployment as known by a ground observer can be transmitted and displayed to supporting aircraft; a two-way transmission can be used for correction and updating the map as viewed jointly from the aircraft and ground observer. This communication technique should prove a valuable aid to voice communications and can be implemented to be compatible with existing voice communication equipment. (See Fig. 1)

For surveying teams (terrestrial or else) the reusable notepad with a communication link to an operational center will provide the means to transmit and store, on magnetic tape or paper, a large amount of sketches and written notes without the need to carry around any amount of paper and with the possibility to recall previous notes and the advantage that the sketches and notes are immediately available in the operational center.

DESCRIPTION OF THE FACSIMILE COMMUNICATION EQUIPMENT

The equipment (Fig. 2) consists of:

1. A Reusable Notepad.
2. An Optical Scanner.

3. The Scannel control, electronics and mechanics.
4. A receiver with magnetically operated recorder.
5. The transmitting and receiving means.

They are described as follows:

1. THE REUSABLE NOTEPAD -- The notepad may have a window of for instance 5 x 5 inches, Figure 3, which is covered by a thin, elastic and transparent plastic sheet, Figure 4, for protection of the inner apparatus against dirt and moisture. Any pointed instrument (ball point) may be used to draw line drawings or write into the notepad.

Behind the window in Figure 2 a hard metal plate (2) provides the backing for the pressure sensitive recording surfaces of two plastic films (3 & 4), which are supplied as endless belts which can be moved by rollers (5,6) where roller 5 has sprockets which fit into holes in film 3 for proper guidance past the scanner .

The recording surface, Figure 4, is provided by the two films 3,4. Film 3 at the front side is a hard mylar film which on its backside is ground to a dull appearance. As seen through the front face, this film appears light gray.

The other film, 4, behind film 3, is made of a slightly elastic plastic material and is covered on its front face with an adhesive wax, 9, of dark blue or black color.

Between films 3 and 4, an air-space acts as an interface with a refractive index different from that of the front film 3. Thus the front film will appear light gray.

For writing, the front film is pressed down by an instrument with a slightly rounded tip. At the points of contact, the dark wax will adhere (11) to the ground rear surface of film 3.

With the air space removed, the film 3 will show the color of the wax behind it, thus providing a dark blue or black recording of line drawings or writings on a light gray background. The recording can be erased by sliding a blade, 7, between films 3 and 4 to separate them again.

(Erasable notepads of this kind were made about 30 years ago). This Notepad should last for several months without exchanging the films.

2. THE OPTICAL SCANNER -- Of several different possibilities of scanning, the most appropriate way seems to be that the scanner moves across the film in horizontal direction while the film is moved one scan width vertically during the scanner's retrace, thus covering the whole two dimensional drawing.

The resolution may be 40 lines to the inch (as an example) and with a frame size of 5 x 5 inches, the picture would consist of 40,000 dots.

The transmission speed should not exceed the band width of a voice communication channel (Radio, telephone), that is about 2500 to 3000 cps. Let the transmission rate be 2000 bits per second, one line of a 5 inch picture of 40 lines per inch resolutions or 200 dots across would have to be scanned within

USE FOR TYPEWRITTEN MATERIAL ONLY

0.1 seconds with the scanner retrace being only a fraction of this time. This would definitely be too fast for a mechanical movement of 5 inches distance.

Thus the same technique may be applied as it was described for the teletype-writer:

The scanner (Figure 6) scans 7 lines at a time using 7 photodiodes, (12). in a linear arrangement across the scan direction. The time then for one scan is 0.7 seconds with 0.2 seconds for retrace; therefore the whole 5 x 5 picture may be transmitted within a time of about 26 seconds. The number of 7 photodiodes was chosen for the following reason:

3. THE SCANNER CONTROL, ELECTRONICS AND MECHANICS (Fig. 5) -- The receiver needs to be synchronized with the transmitter for the whole transmission time. For this purpose both the receiver and the transmitter contain identical sets of synchronizing equipment consisting of a fork oscillator and an 8 bit - 3 binary counter. The counter activates the 7 photodiodes in sequence 1-7 to scan 7 lines of the picture in vertical direction while the scanner is moved the distance of one line horizontally across the picture. This movement is controlled by the recurrent 8 bits count.

For the transmission of 2000 bits per second, the clock frequency will be 1000 cps. Before each scan of steps #1-7, one extra pulse #0 is transmitted and received but not recorded. This pulse will provide synchronization of the fork oscillator in the receiver and also set the 8 bit - 3 binary counter to zero. A tuning voltage derived from the coincidence of the #0 step of the counter and the received #0 pulse will tune the oscillator so that it will keep pace even when the radio transmission fades for one second or more.

At the start of a transmission, the transmission of a row of #0 pulses will pre-cede the actual transmission of the picture for about one second, thus causing the receiver to be ready to receive the start pulse for the first line and synchronize or set the oscillator, counters and A.G.C. for the reception within the one second preceding the picture transmission.

A start pulse will precede the transmission of every line so that the retrace time of scanner and recorder will not influence the start of a next line scan, while it has not to provide synchronization of the transmission itself. An 8 binary counter in the transmitter and the receiver operated from the #0 pulses will count down the whole scan plus retrace time of 256 pulse #0 units (200 dots scan across 5" and retrace of 0.2 sec). Its #256th step will coin-cide with the start pulse for the new scan line and in the transmitter being used to start the scan of the transmitter, transmit the start pulse and in the receiver, synchronized with the received start pulse provide start of the receiver scan so that even in case of radio fade out the proper synchronization of the line scan continues.

4. THE RECEIVER -- The receiver consists of essentially the same equipment as the transmitter; that is, oscillator, counters, scanner transport and trans-port of the recorded picture.

Instead of the photodiodes of the scanner in the transmitter, the receiver will carry a 7 styli recorder, Fig. 7.

With electrosensitive paper, the seven styli would be direct contacts to electro-deposit metal ions onto the treated paper.

The early version of the teletypewriter, however, used magnets to move mechanically, the wires which printed the character by pressing an ink ribbon against a paper surface the same way a typewriter operates. The magnets were powerful enough to produce up to 6 carbon copies.

Also, as tests showed, the magnets were able to run up to 250 pulses per second.

With some refining, these magnets should be able to print up to 300 dots per second which is fast enough to follow the transmission speed of 2000 bits per second since every magnet has to be activated only at every eighth pulse of the sequence, that is, 250 dots per second.

Such a magnetic recorder would open the possibility to use the same erasable notepad for the receiver as in the transmitter, pushing down the gray front film against the dark waxed backing, thus producing the recording by mechanical means.

Since the timing equipment for transmitter and receiver is the same, a transceiver would need only the duplication of the scanners (transmitting and receiving) on the same notepad.

Such equipment would afford the possibility of a two-way communication, with the one side transmitting a map sketch, the other side adding information and returning the picture, etc. A possible design is shown in Fig. 2.

5. THE TRANSMITTING AND RECEIVING MEANS -- The transmitting part has to condition the outgoing signals for acceptance by the transmitting means and will have to be built to those requirements. It can be a pulse amplifier only or it may have to provide a pulse or frequency modulated carrier frequency or whatever else may be the case.

Most probably, for portable equipment, the means of communication will be radio links. Thus the transmission will require accommodation to a voice channel or if access to the transmitter is possible, a direct modulation as PCM or FM. The output will be DC pulses or pulses on an audio-carrier which have to be demodulated.

Accommodation of the inputs and outputs to whatever communication means are available could be made with interchangeable modules.

4.62.2 Experimental Breadboard

The laboratory circuit as shown in Figures 8-11 was used to test the basic concepts and to establish the characteristics and capabilities of the scanner photo-diodes and the recorder hammers. The movement of the scanner and recorder heads is simulated with an X-Y plotter. This allows an analysis of the resolution at any sweep rate as the movement is generated external to the circuit. The print out is either through a carbon onto regular paper or onto a reusable notepad as described in section 4.6.2.1. The scanning head used Fairchild FPM-200 photo-diodes.

USE FOR TYPEWRITTEN MATERIAL ONLY

The print-out hammers (Fig. 7) are capable of operation in excess of the present rate of 250 cps. They have a delay of 1.5 m sec (See Fig. 13) from the time the drive pulse starts until the hammer hits. This means that a holding circuit had to be incorporated into the drive circuit (Fig. 11) because the decision pulse lasts only 0.5 m sec.

The timing circuit (Fig. 8) was designed to be used on a temporary basis because of the lack of an adequate fork-oscillator. The present circuit is unsatisfactory because of its dependence on a stable voltage supply.

The present circuit uses no micro-logic because of the relatively large currents that they draw. The current must be held at a minimum since the final product is designed to be powered by batteries which cannot supply large amounts of current for any length of time.

The present circuit has no provision for scanning and sweep synchronization due to the lack of time. The concepts have been indicated in the disclosure above but have not been realized. Also missing are the transmitter, the receiver and the timing synchronizer as called for in Fig. 5.

4.6.3 Results and Conclusions

Preliminary tests indicate that both the scanning and print-out circuitry operate satisfactorily for this data rate of 2000 bps. The scanning head (Fig. 6) has enough sensitivity to make a decision as to the presence of a dark pencil line (See Fig. 12). The photo-diodes in the scanning head are sensitive in the near infrared therefore they respond well to pencil marks because of the reflective characteristics of graphite. Both black and blue inks do not work satisfactorily. This means, if the present diodes are used, the reusable notepad must use a graphite impregnated wax and a fairly coarse grinding on the mylar sheet so that infrared light can pass through easily. Modifications are presently being made to the light guides to obtain the sensitivity required to scan a reusable notepad such as a "Magic Slate".

Additional modifications need to be made to the diode sampling circuitry because the present method limits the sampling rate and provides no capability for matching the responses of the diodes. The sampling rate is limited because of the internal junction capacitance of photo-diodes which is at its highest when bias is first applied to the diode junction. After the junction depletion region is established, the capacitance is reduced drastically and the diode becomes sensitive to changes in impinging light levels. The sensitivity is established only after the initial surge of current dies out which takes about 0.25 m sec. with a 12 volt bias. If the diode is biased continuously, it is always sensitive to changes in impinging light and this level of sensitivity can be sampled at any rate. This method also allows a matching of the sensitivities of the different photo-diodes by adjustment of the sampling circuit. Thus, the overall decision capability of the device can be increased because a precise decision level can be selected for any type of writing pad, i.e. paper or "Magic Slate".

The present hammers have the required speed but have difficulty generating enough force to make a mark on anything but highly pressure sensitive surfaces. This problem can be reduced by redesigning the print-out unit to accommodate larger drive coils.

It can be concluded that the present breadboard operates satisfactorily and that the validity of the concept has been verified. The problems encountered are a matter of modification and optimization to increase the capability of the system. These problems could not be anticipated without the experimental circuit but are presently being corrected. Additional work needs to be done to develop the rest of the system. The specific needs are for a synchronization circuit and for the receiver and transmitter as shown in Fig. 5.

- Extending High-Quality Teletype Through Low-Quality Channels

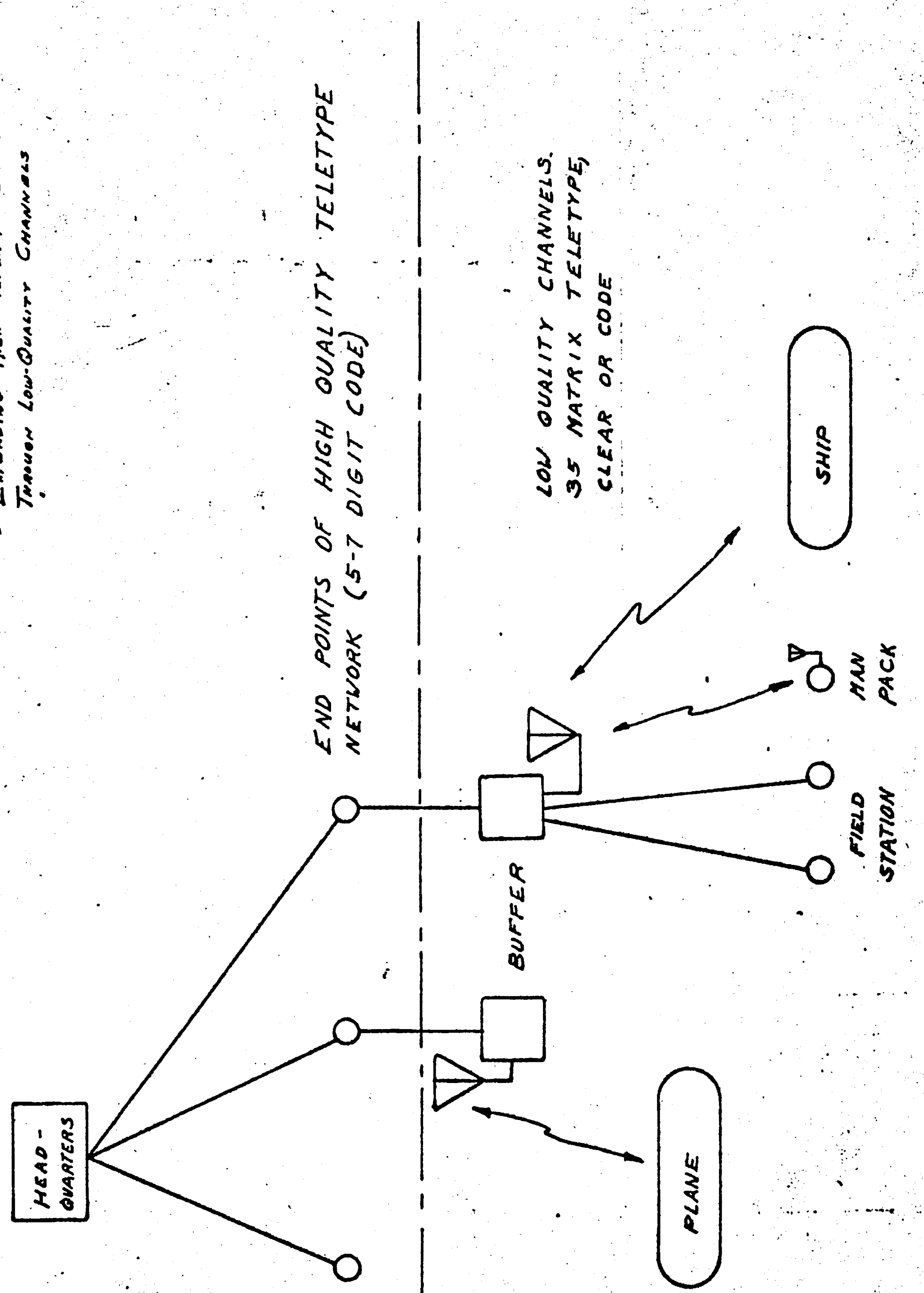


Figure 1

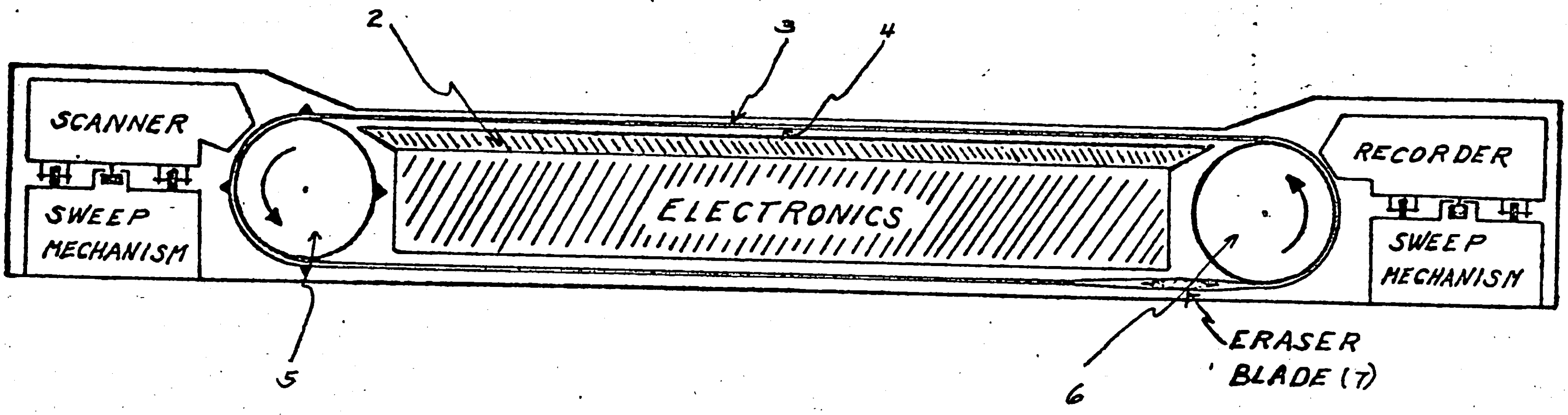

SCANNER
SWEEP MECHANISM
2
3
4
ELECTRONICS
RECORDER
SWEEP MECHANISM
5
6
ERASER BLADE (7)

FIGURE 2

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

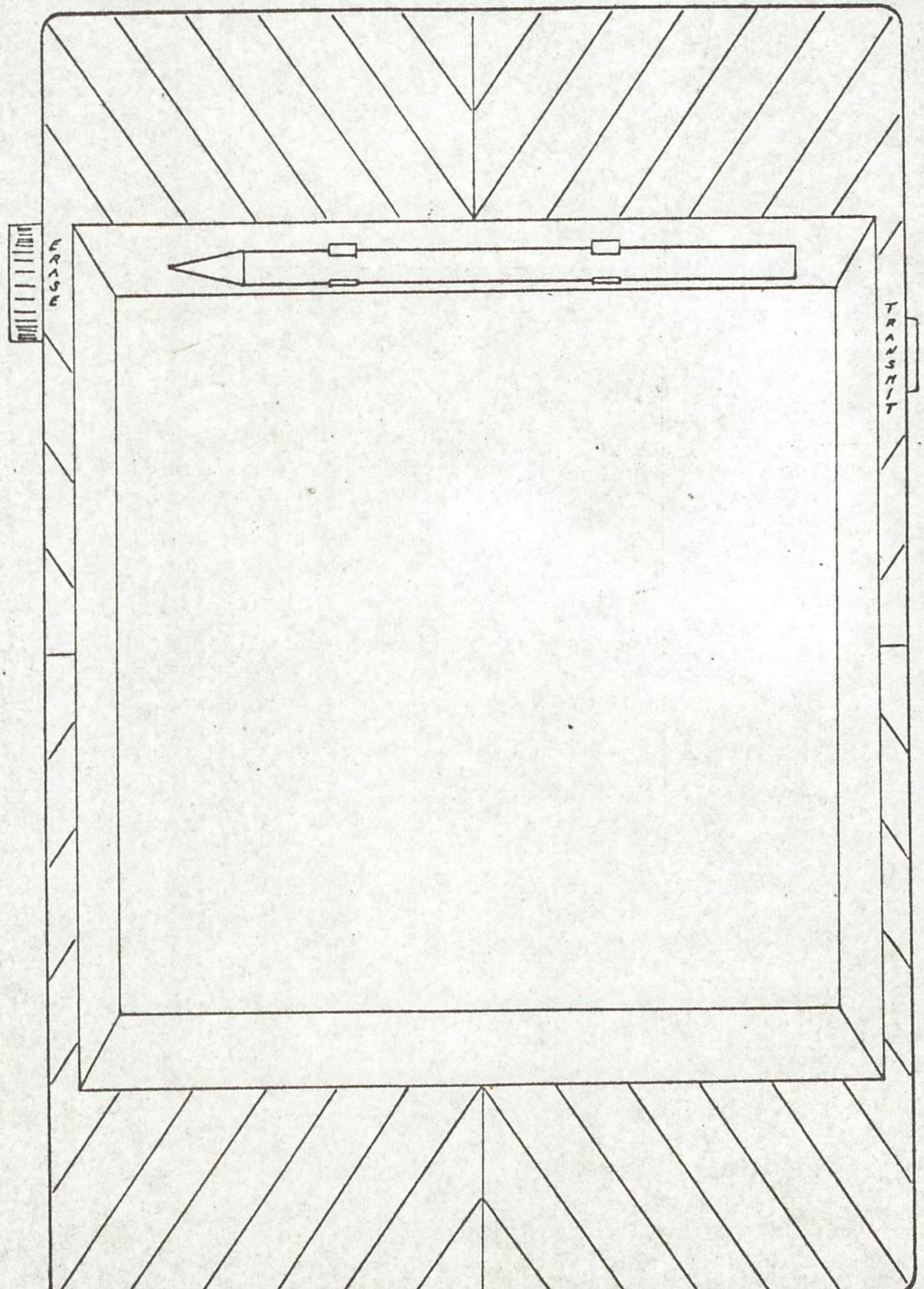


FIGURE 3

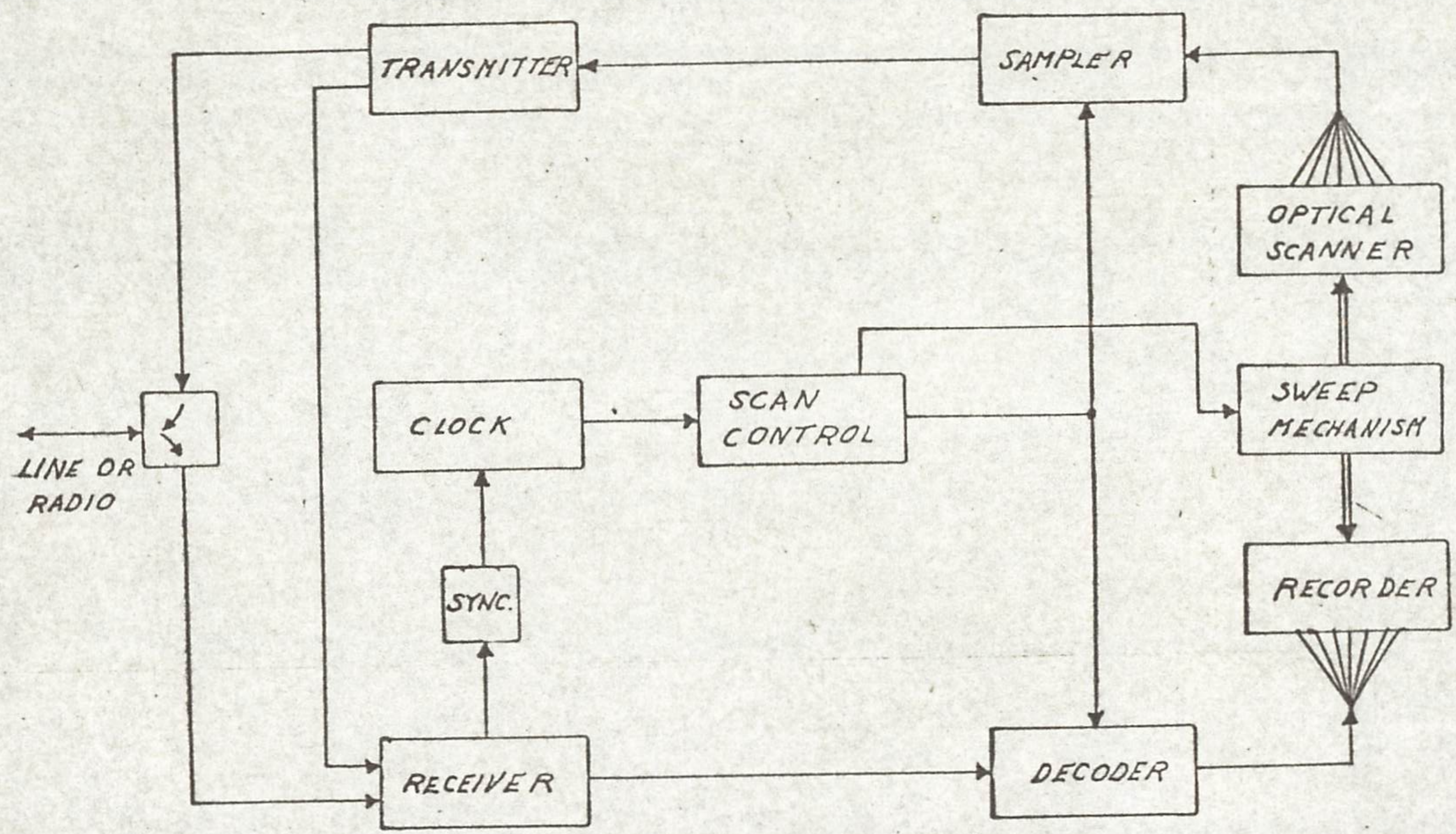


FIGURE 5 - TRANSPONDER

WR

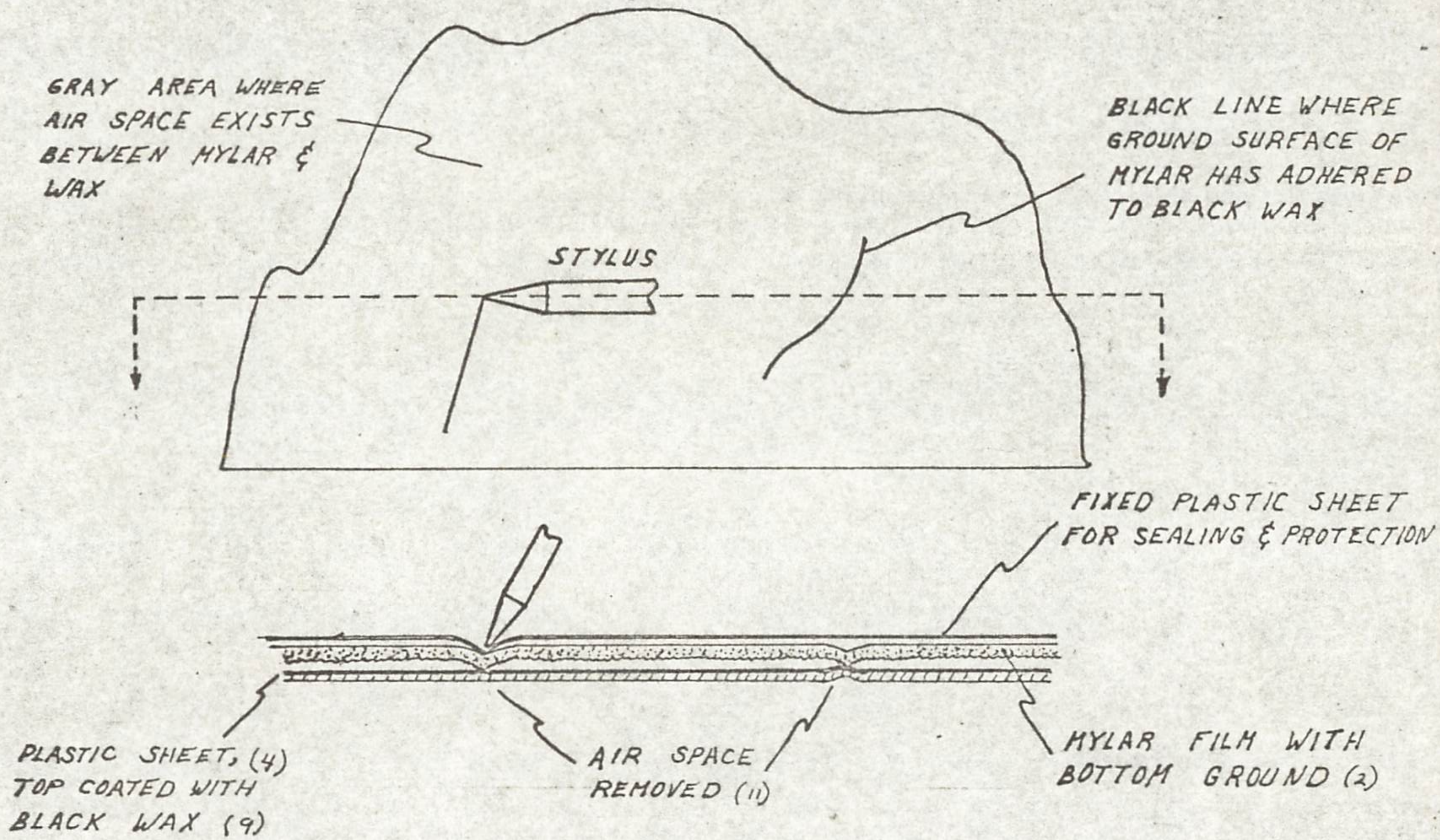


FIGURE 4 - NOTEPAD DETAILS

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

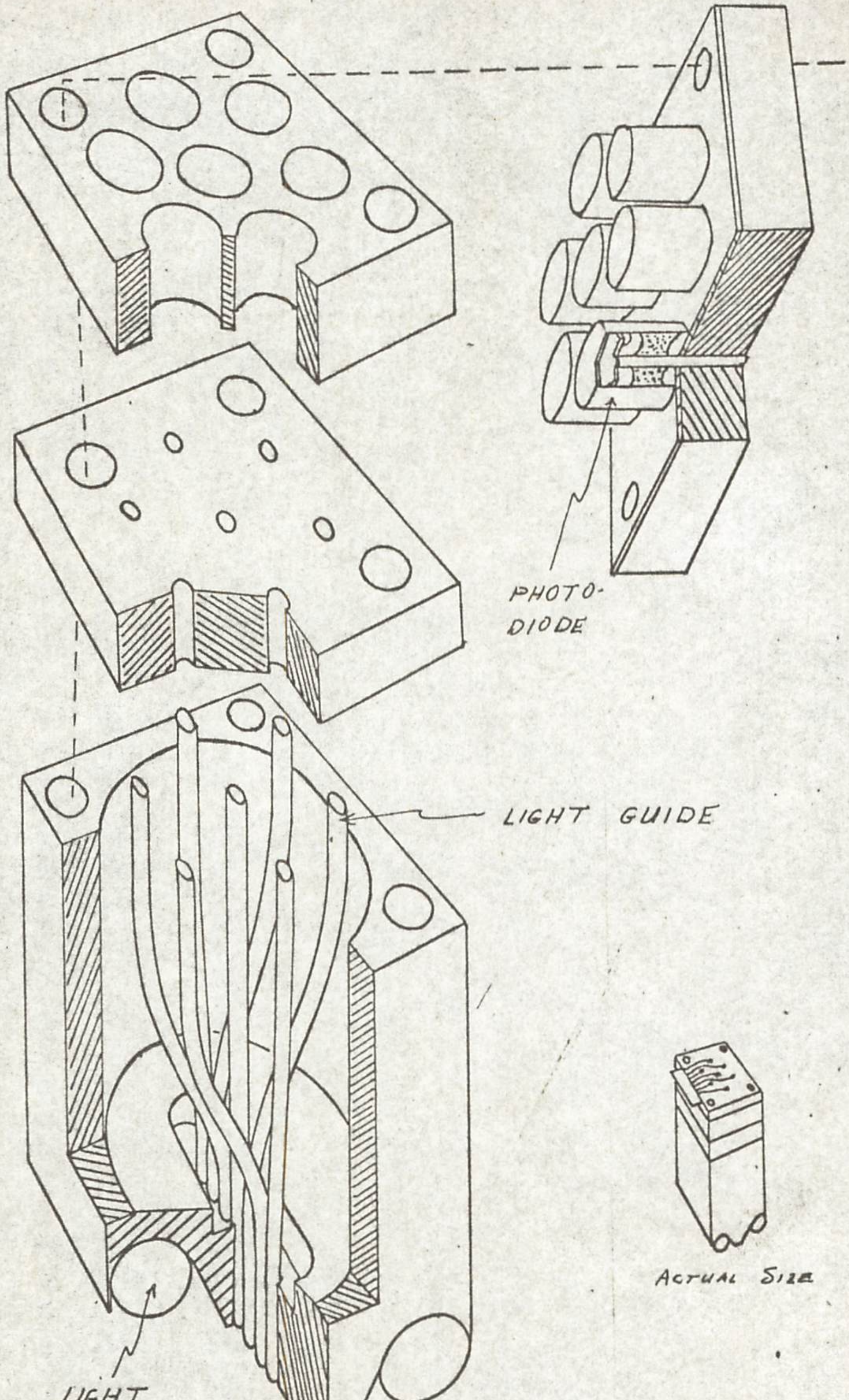


FIGURE 6 - SCANNER

W.B.

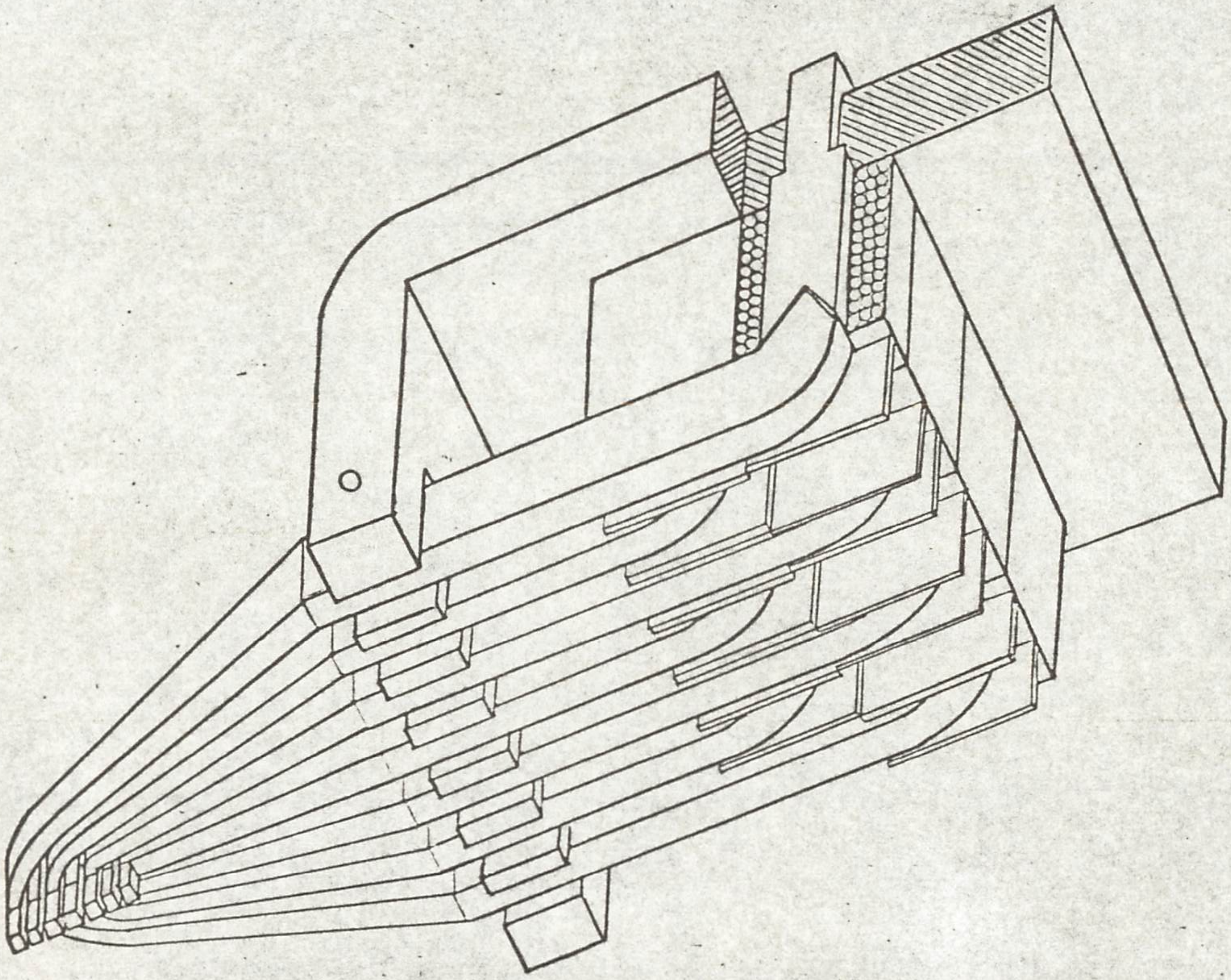


FIGURE 7 - RECORDER

W A

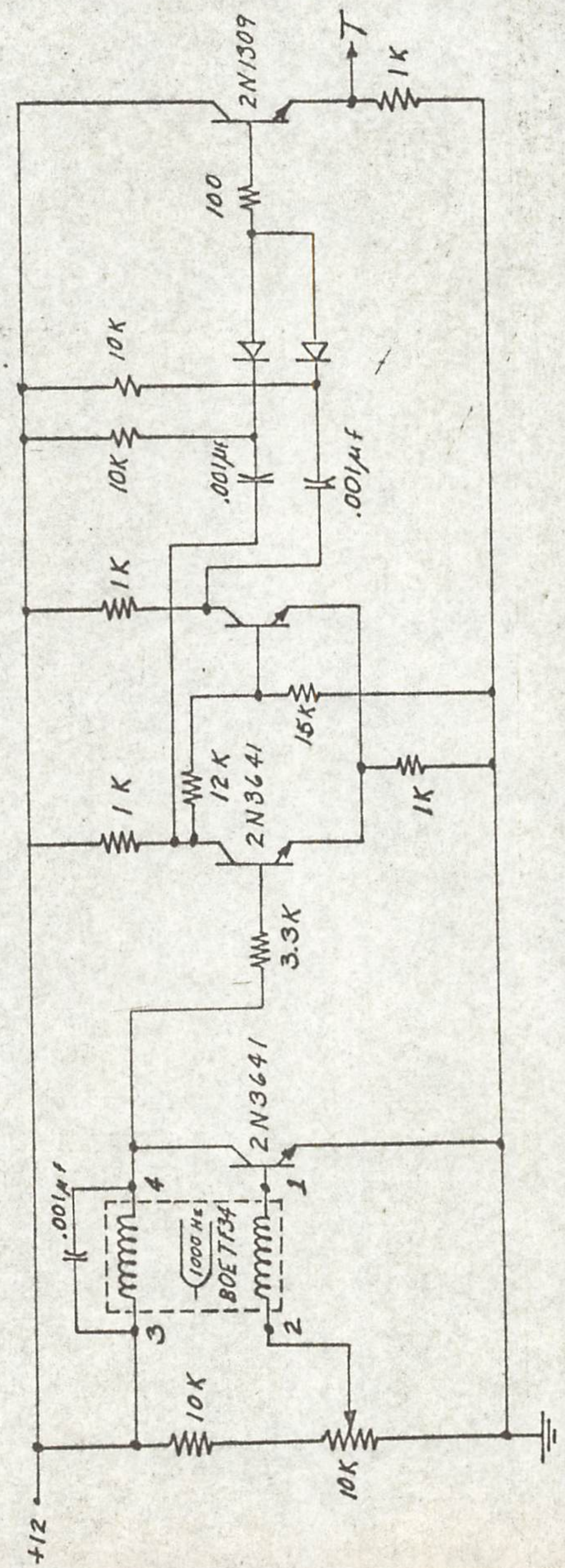


Figure 8 - Timing Generator

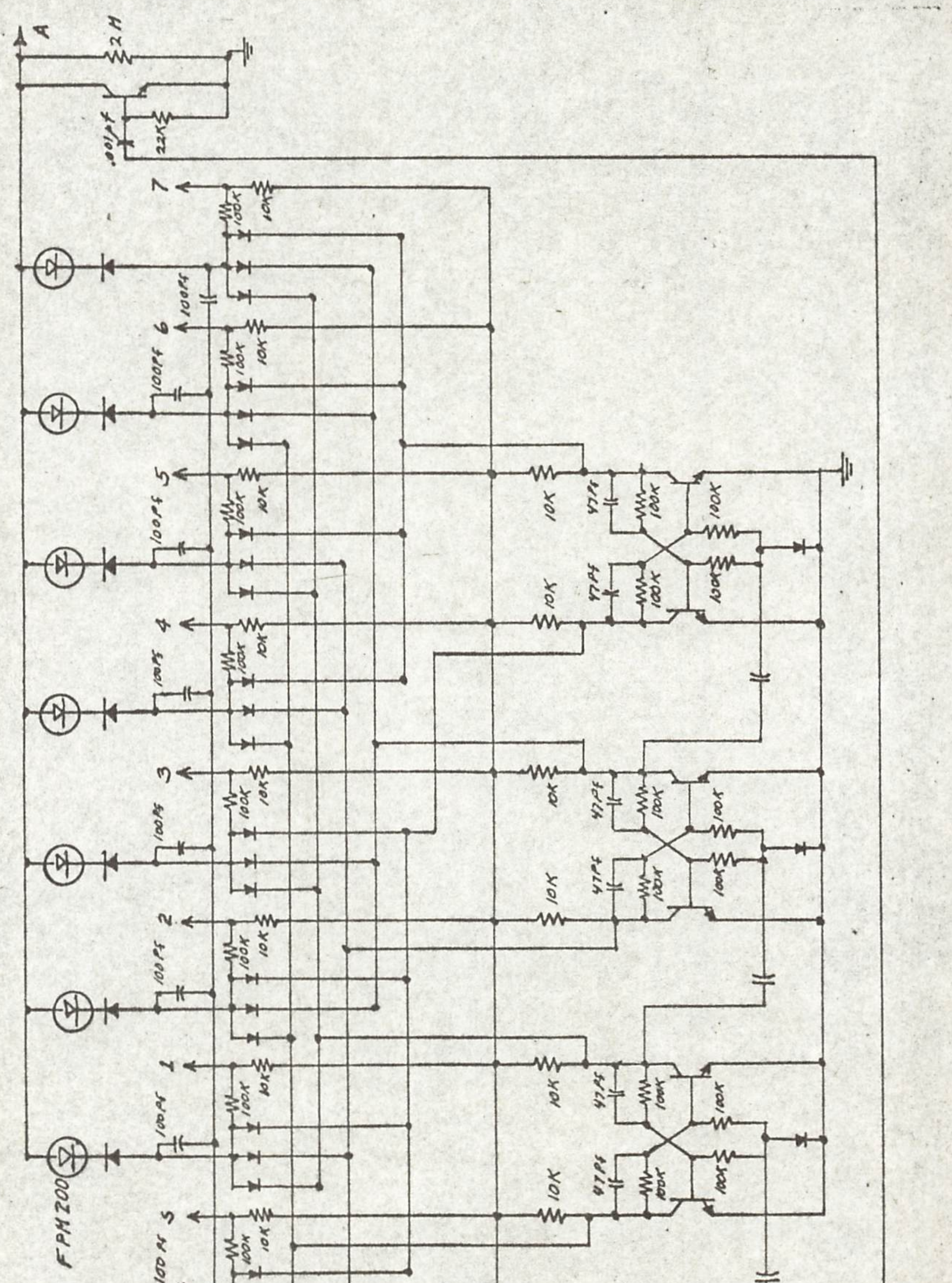


FIGURE 9 - SCANNING MATRIX

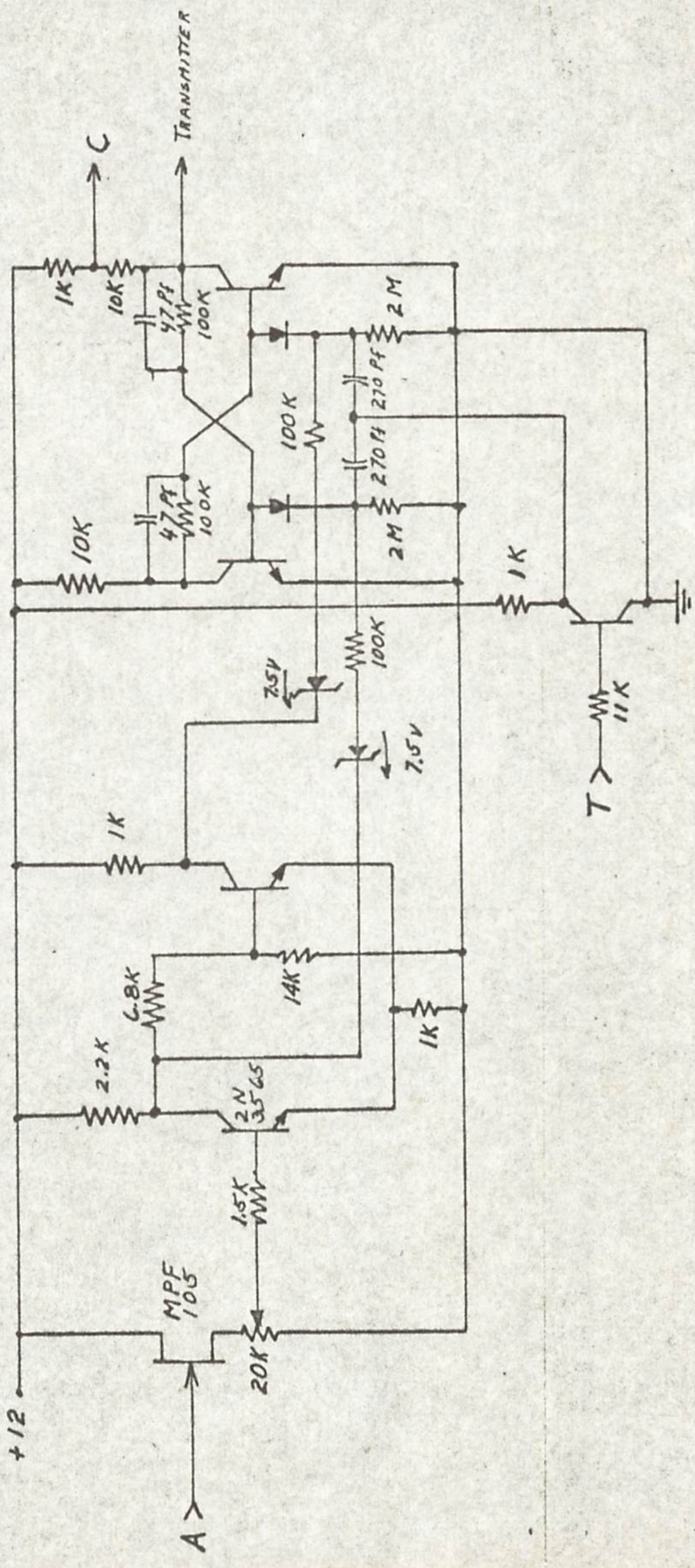


Figure 10 - Decision Circuit

THE BOEING COMPANY

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

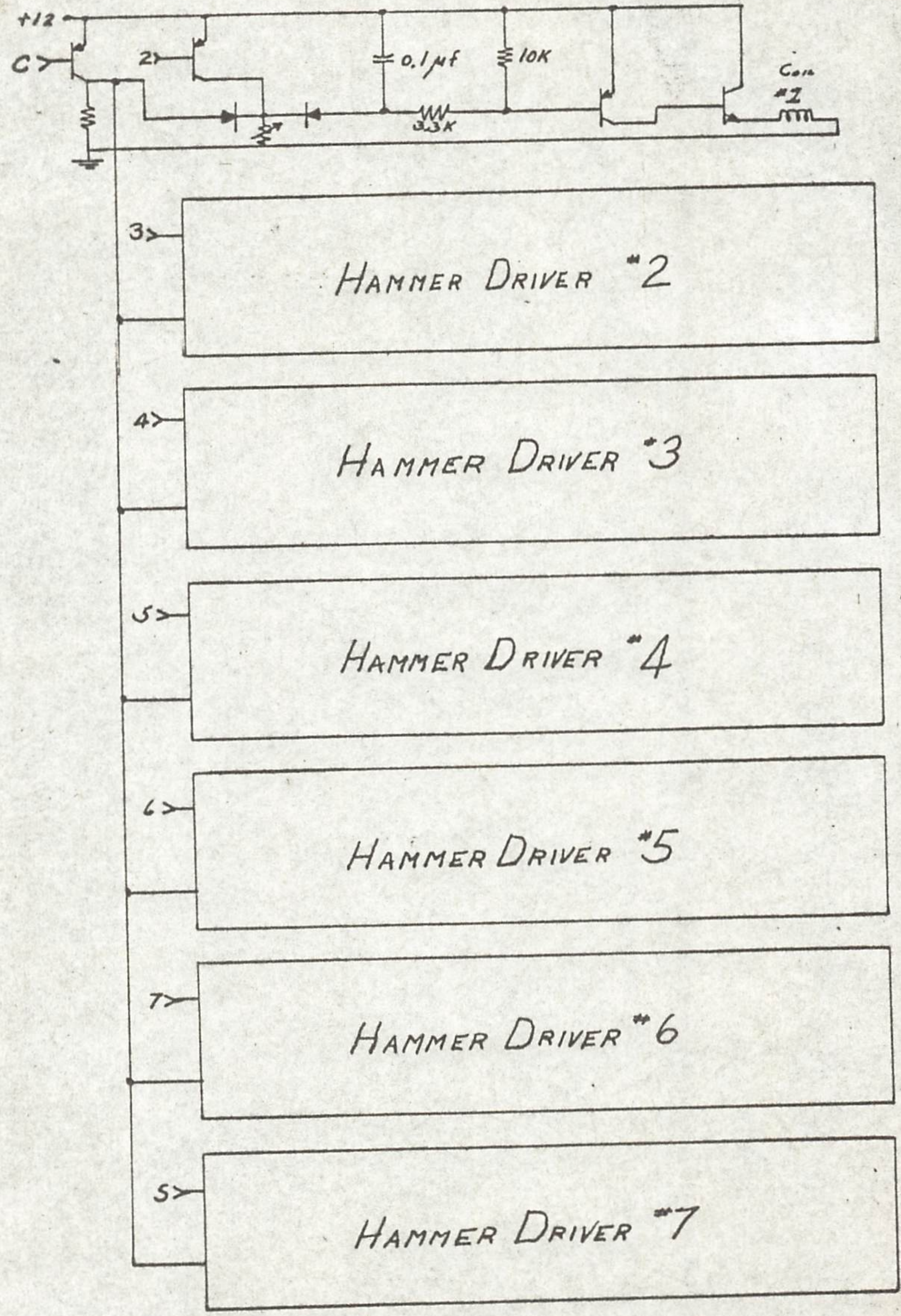


FIGURE 11- PRINTER

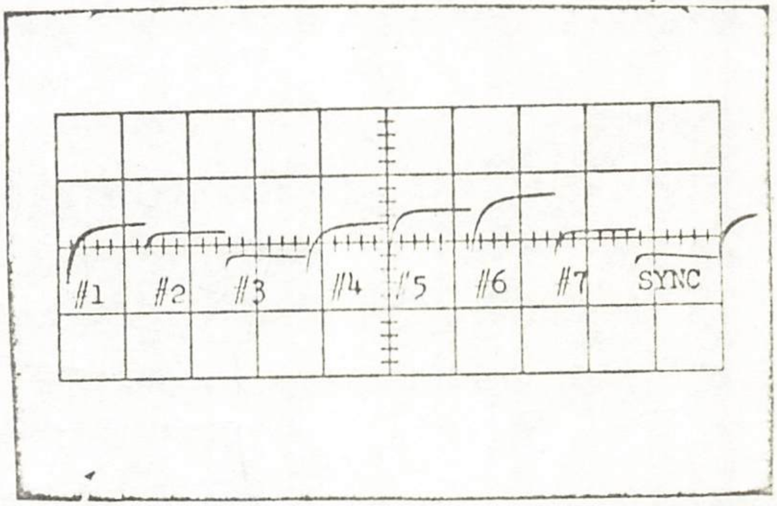


FIGURE 12 - SCANNING MATRIX OUTPUT

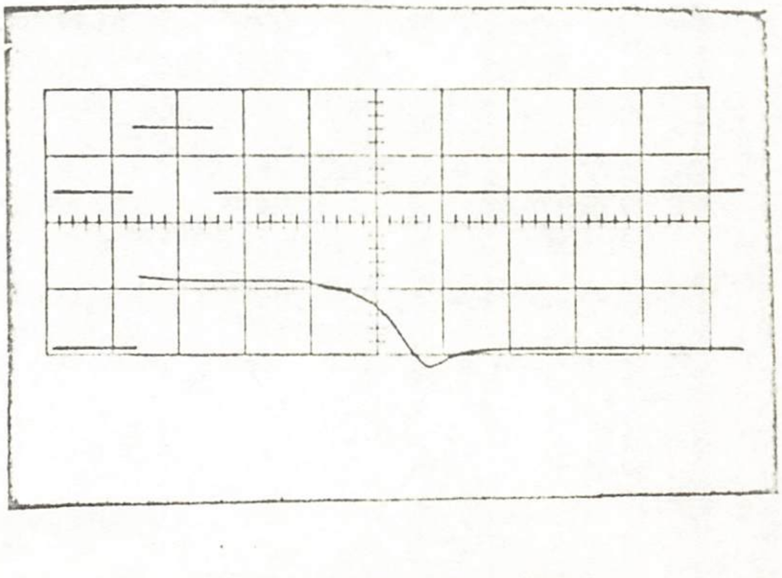


FIGURE 13 - PRINTER WAVEFORMS

a. Input

b. Output