

Nov. 25, 1941.

W. G. H. FINCH

2,263,986

FACSIMILE RECORDING SYSTEM

Filed May 11, 1940

2 Sheets-Sheet 1

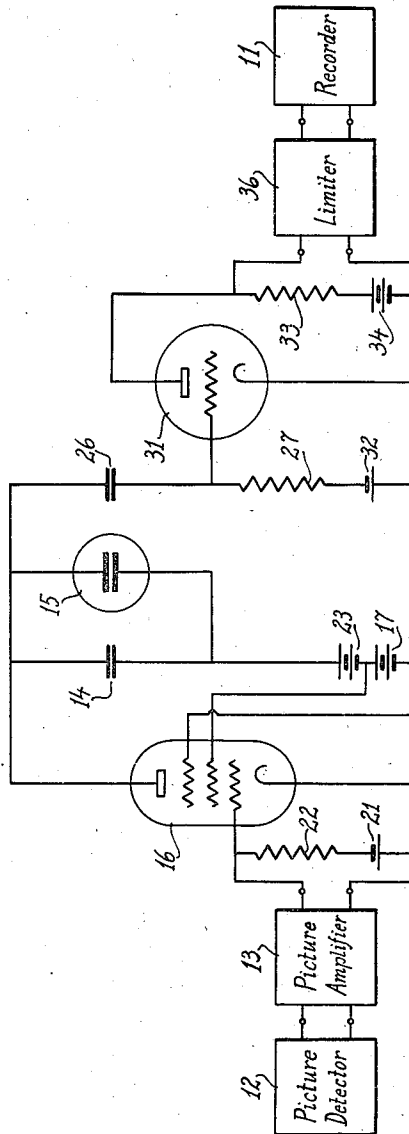


Fig. 1

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2 Sheets-Sheet 2

Fig. 2

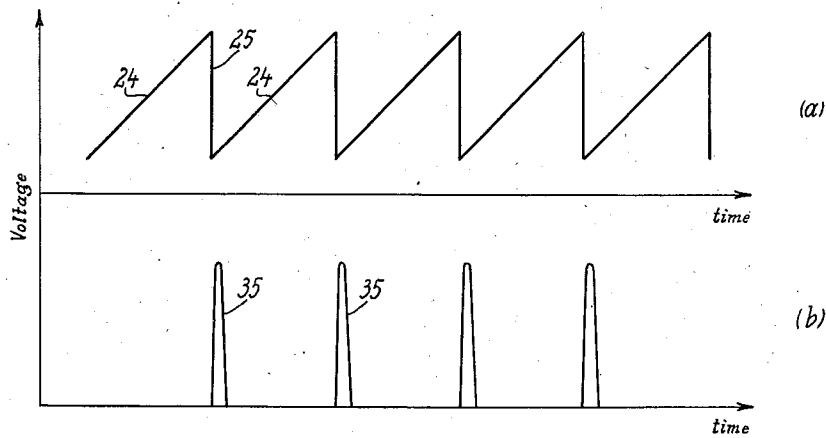
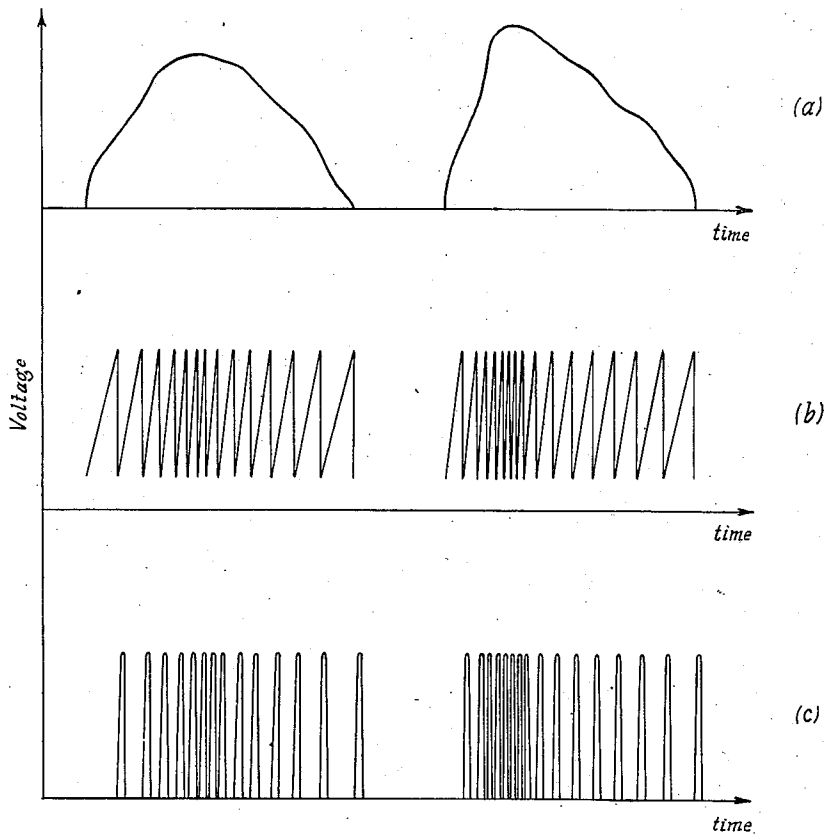


Fig. 3



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FACSIMILE RECORDING SYSTEM

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Application May 11, 1940, Serial No. 334,481

6 Claims. (Cl. 178-6.6)

My invention relates in general to facsimile recorders and more specifically concerns an improved method for directly recording electrical picture signals in apparatus employing the discoloration of chemically treated dry paper.

Heretofore, direct recording facsimile systems employing paper sensitized by chemical means, depended upon the variation of the degree of discoloration with impressed variations in the received electrical picture signals. Thus the detected and amplified picture currents were connected in circuit with a recording stylus, which was in contact with a sheet of this chemically treated paper and which traveled under the influence of a scanning mechanism.

The recording sheet, was mounted on a conductive platen or drum which was also in circuit with the output of the picture amplifier. Therefore, currents would flow through the sensitized paper and the degree of discoloration at any particular point in the picture would be dependent upon the current flowing therethrough, which in turn would be dependent upon both the intensity of the picture signal, and the electrical impedance of the paper at that point.

In order to manufacture recording paper at a price which would not be prohibitive to owners of home facsimile recorders it is necessary to use an inexpensive stock of paper and to automatically and continuously impregnate it with the required chemicals, such as titanium oxide.

It has been found that with even reasonably strict control of the manufacturing process there still are irregularities in the chemical coating which varies the electrical resistance of the coating at various points. Thus, a given current when passing through different points of the paper does not produce equivalent discolorations.

Another factor which considerably reduces the fidelity of reproduction in electrochemical recording is the non-linear relation between the intensity of discoloration and the magnitude of the picture signals. That is, it has been found that even for a homogeneously impregnated recording sheet, a variation in current from zero to a predetermined maximum does not cause a corresponding linear variation in tones from white to black on the recording sheet.

Predistortion of the electrical image currents to compensate for the non-linear characteristic of the sensitized paper has been found to be difficult, as no simple relation exists between the discoloration and the magnitude of the picture current.

In order to eliminate the drawbacks encountered in the recording on dry sensitized paper, I have discovered that I may dispense with the method for producing the various tones of a picture by employing a single and reproducible constant current intensity to reproduce the entire tonal range of a picture, by the expedient of varying the spacing between recorded currents of this single intensity in accordance with the desired shades or picture intensities.

My novel means for recording facsimile pictures overcomes the drawbacks encountered in the variations of resistance in the recording paper. I have found that I need not replace present day transmitting equipment and may employ all of the mechanical features embodied in present day receivers, as I need only add a single circuit in the output of the picture amplifier in order to obtain my novel and improved picture recording means.

My invention contemplates the usual reception and detection of a transmitted picture signal. This detected signal, which may comprise as usual, a current of varying amplitude varying in accordance with the lights and shades of the image being transmitted is then applied to act as a control over the frequency of an electrical impulse generator which may be in the form of the well known relaxation oscillator, multivibrator or the like.

Thus, the output of my pulse generating circuit will be a succession of discrete electrical impulses of approximately constant amplitude but varying in frequency in accordance with the amplitude of the picture signal. The frequency variations of the output current are predetermined so that the highest frequency will correspond with the blackest portions of the transmitted images and the lowest frequency with the lightest or white portions of the transmitted pictures.

This series of varying frequency electrical impulses are then applied to the stylus of the recorder, as in the prior art devices, subsequent to amplification of the pulses to a value sufficiently great to insure that each pulse will record as a uniform deep black spot on the sensitized paper, regardless of the inherent variations in the electrical properties of the sheet.

Thus, my recording circuit produces varying intensity images by means of a series of black, irregularly spaced points on the recording paper. Furthermore, I provide means to prevent the amplitude of the individual electrical impulses which comprise the picture currents from obtaining a

magnitude sufficient to cause deterioration or perhaps burning of the recording paper.

It is therefore an object of my invention to provide a facsimile recorder which can reproduce the full tonal scale of an image and which is independent of the heterogeneous electrical characteristics of the recording paper.

A further object of my invention is to provide for a facsimile image in which the various half tones are produced by means of a series of constant intensity diversely spaced spots.

A still further object of my invention is to provide means for recording a facsimile image on chemically treated recording paper by a series of electrical impulses amplified sufficiently to insure uniformity of the recorded spots.

Another object of my invention is to provide means for recording a facsimile image with large intensity electrical impulses, while insuring that the recording paper will not be burned.

These objects and others become evident from the following specification taken in connection with the accompanying drawings in which,

Figure 1 is a schematic diagram of the recorder of my invention.

Figure 2 is a graphical illustration of the wave form of the electrical currents in the impulse generating circuit, and,

Figure 3 is a graphical illustration of the wave form of the currents in the circuits of my facsimile recorder.

The embodiment of my invention illustrated in Figure 1 records the received picture currents on a sheet of dry chemically treated paper mounted upon a scanning unit which may be of the types illustrated in my Patent Nos. 2,141,975 and 2,036,128. In these units, a stylus continuously scans the recording paper under the influence of a mechanical drive, while the picture currents are passed through the paper to a conductive platen.

My recorder 11 may employ any of the above mentioned devices, or others known in the art, to record the picture currents subsequent to their passage through my novel controllable impulse circuit which will hereinafter be completely described.

The picture signals are received over the ordinary communication channels such as telephone lines or modulated radio frequency carrier currents, and when detected in my detector 12, as required by the particular transmission means, comprise currents of varying amplitude as indicated in Figure 3a. Accompanying the picture currents are corresponding synchronizing signals which occur in the interval between scanning lines, and which are of the type more fully described in my copending application Serial No. 203,222, filed April 21, 1938. The synchronizing signals do not pass through the recording channel, but are switched to the synchronizing means by means of a cam operated by the stylus driving mechanism.

The picture signals when detected vary in amplitude in accordance with the lights and shades of the image at the transmitter, and in the recording devices described in the hereinabove mentioned patents, these currents are directly coupled to the recording stylus and platen. The discoloration produced in the process of a line by line scanning of the recording paper will result in a completed picture similar to that at the transmitter.

In order to overcome the previously described difficulties encountered in the recording process, I first amplify my picture currents in the ampli-

fier 13, indicated schematically in Figure 1, and then employ these picture currents to serve as a control over an impulse generator, the output currents of which are impressed upon the recording paper.

The impulse generator is designed to generate currents of relatively large magnitude for a short interval of time, which when impressed upon the recording paper through a scanning stylus will record as a series of sharply defined black points. These distinct points, as will be pointed out in the following, may be controlled to produce a line of the transmitted picture by varying the spacing or frequency thereof.

The circuit which I employ for generating these distinct electrical impulses is illustrated schematically in Figure 1. However I need not be limited to this embodiment but may employ any of the well known impulse generating circuits in my novel combination for producing a facsimile image. Thus, although I have indicated a glow tube relaxation oscillator coupled to a resistance-capacitance circuit for the generation of these impulses, I may employ thyatron or multi-vibrator circuits. However, I have chosen a glow tube circuit for schematically illustrating my invention, in order to facilitate the following description.

It is well known that electrical impulses may be generated from the output of a relaxation oscillator circuit, which comprises a resistance-capacitance circuit controlled by a gas discharge or glow tube such as neon tube.

Thus, if a constant source of electromotive force is impressed upon a circuit comprising a resistance and condenser in series, the voltage across the condenser will rise exponentially with time, and approach the source potential as a limit. By suitably designing the constants of this resistor and condenser and by paralleling the condenser with a glow tube as for instance, a neon tube or the like, a series of oscillations, more commonly referred to as "relaxation oscillations," will be produced.

The oscillation of such a circuit may be explained briefly, by noting that a glow tube will "break-down" or offer a very low impedance to an electrical current when the potential impressed thereupon reaches that required for the ionization of the gas contained between the electrodes, and will thus almost completely discharge the parallel condenser. The deionization or extinction voltage of the glow tube is less than the break-down voltage thereof, and therefore the condenser will discharge rapidly through the tube until this lower value of extinction voltage is attained.

Immediately after deionization the charging cycle will be repeated, and the voltage across the condenser will rise again. Therefore, the voltage wave appearing across the condenser in this elementary circuit will be approximately triangular in form, that is, a sloping exponential rise from the deionization or extinction voltage to the ionization or ignition voltage, and a sharp, almost vertical drop to the extinction voltage, at which point the cycle is repeated.

Obviously, the frequency of such a circuit is determined by the time required for the voltage to rise from the extinction to the ignition point, which in turn is dependent upon the characteristics of glow tube employed and the values of the impressed electromotive force, resistance and capacitance.

The approximately triangular alternating wave

generated by such an oscillator, when appropriately connected in circuit with a resistor and condenser in series will generate current pulses of reasonably large amplitude and for a short interval of time.

This basic impulse generating circuit has several disadvantages; the most notable being the exponential, non-linear rise in voltage. The impulse generating circuit illustrated in Figure 1 is a modification of the basic circuit hereinabove described, in that it provides for a linear rise in voltage between the extinction and ignition potentials of the glow tube employed.

To obtain this linear rise I charge the condenser 14, which is paralleled by the glow tube 15, through a constant current source, which in this embodiment is a high-vacuum screen grid tube 16.

It is well known in the art that a screen grid tube such as the pentode 16 will supply a constant current for a wide swing in plate potential when the control and screen grids are maintained at constant potentials.

Thus, to fulfill these requirements I maintain the screen grid at a constant potential above the cathode equal in magnitude to that of the battery 17, and the control grid at a suitable negative potential with respect to the cathode determined by the battery 21. This potential is applied to the control grid through the resistor 22 in order to safeguard against currents of large amplitude in the grid circuit.

The condenser 14 is charged by the plate current derived from the series batteries 17 and 23 of suitable magnitude. As the tube 16 is of the pentode type, the suppressor grid is maintained at a very low potential which in this instance is the cathode or ground potential.

When this circuit is in operation, the condenser 14 is charged by the plate current flowing through the pentode 16, which remains at a constant value regardless of the diminishing potential between plate and cathode due to the increasing potential across the condenser 14. The variation in plate potential of the pentode 16 is limited so that the plate current remains at a substantially constant value throughout the charging cycle. The charging cycle of the condenser 14 is indicated graphically by the sloping line 24 of Figure 2a.

When the voltage across the condenser 14 reaches the ignition or break down potential of the glow tube 15, the tube will conduct a current and it is characteristic of these tubes to offer a very low resistance during the conducting cycle. Accordingly, condenser 14 will rapidly discharge through the glow tube until the deionization potential of the tube is reached. This rapid discharge is indicated in Figure 2a by the vertical slope 25 of the voltage wave.

Immediately as the condenser potential arrives at the deionization potential the glow tube again assumes a relatively high resistance and the charging cycle is repeated. Thus, the voltage wave form appearing across the condenser 14 will assume the "saw-tooth" characteristic shown in Figure 2a. The voltage variation of these relaxation oscillations is the difference between the ignition and extinction potentials of the glow tube 15. As this variation in potential is relatively small, it may be necessary to resort to a grid controlled thyatron or gas filled triode for an oscillation generator of comparatively greater voltage.

An important advantage of the circuit illus-

trated, is that the frequency of the relaxation oscillations, of the wave form indicated in Figure 1a, varies linearly with the plate current of the pentode 16. This linear variation is extremely important and is prerequisite to faithful recording of the received image as will be fully described in later paragraphs. The linearity between variations in plate current and frequency may be proved mathematically as follows:

The electrical charge q on the condenser at any time following the extinction of the tube may be expressed as

$$q = q_0 + i t \quad (1)$$

where,

q_0 is the charge remaining on the condenser at the instant of extinction,
 i is the charging current, and
 dt is a differential increment of time.

If the charging current i remains constant during the cycle; Equation 1 reduces to

$$q = q_0 + i t \quad (2)$$

This condition is essentially true for the constant current pentode circuit employed.

The voltage V across the parallel combination of condenser 14 and glow tube 15 at any instant is,

$$V = \frac{q}{C} = \frac{q_0}{C} + \frac{i t}{C} \quad (3)$$

where,

C is the capacitance of the condenser 14, and
 q is the value expressed in Equation 2.

But,

$$\frac{q_0}{C} = V_e \quad (4)$$

where, V_e is the extinction or deionization potential of the tube, and therefore,

$$V = V_e + \frac{i t}{C} \quad (5)$$

Assuming that the discharge of the condenser 14 is instantaneous when the tube 15 breaks down, then the time t will be equal to the period T or the time elapsing during one cycle of the triangular wave indicated in Figure 2a, when the voltage V has risen to the ignition potential V_i . Thus, Equation 5 becomes,

$$V_i = V_e + \frac{i T}{C} \quad (6)$$

and,

$$T = \frac{(V_i - V_e) C}{i} \quad (7)$$

The frequency of oscillation f is equal to the reciprocal of the period T , or

$$f = \frac{1}{T} = \frac{i}{(V_i - V_e) C} \quad (8)$$

Thus the frequency output of the relaxation oscillator is a linear function of the plate current of the pentode 16 which is constant for any particular value of control grid potential. Although the extinction and ignition potentials vary slightly with the frequency of the oscillations, the deviations are sufficiently small to be insignificant in this instance.

If the grid voltage-plate current characteristic of the pentode employed is substantially linear, it is therefore possible to continuously vary the frequency of the output of the relaxation oscillator by means of signals impressed upon the control grid. The frequency control character-

istic of this circuit will be referred to again in later paragraphs, but first, the actual generation of the electrical impulses will be considered.

As indicated in Figure 1 the potential across the condenser 14 is impressed upon a series circuit of condenser 26 and resistance 27. Considering the complete circuit now of the batteries 17 and 23, the parallel combination of condenser 14 and its associated glow tube 15, and the circuit comprising condenser 26 and resistor 27, the generation of discrete electrical impulses may be explained briefly as follows: During the charging period of condenser 14, the glow tube 15 constitutes a relatively high and almost infinite impedance and thus conducts no current. Condenser 26 has a relatively small capacitance and will charge in a relatively small period of time and maintain the current in the circuit of resistor 27 and condenser 26 at a negligible value.

The potential drop across condenser 26 will accordingly be approximately equal to the difference between the potential of the series batteries 17 and 23 and the potential drop across the condenser 14. However, upon the break down of the glow tube 15 the potential across the condenser 14 is almost instantaneously reduced to the extinction potential and accordingly there is a surge of current through this circuit which develops a voltage across resistor 27 sufficiently large to actuate the grid of the vacuum tube amplifier 31 to cause a corresponding fluctuation in the plate current thereof.

In this analysis of the impulse generating circuit the potential of the amplifier grid biasing battery 32 has been neglected; which assumption introduces no error as this value may merely control the magnitude of the generated impulses. Furthermore this battery may be omitted if direct coupling is employed.

The electrical impulses are amplified by the vacuum tube 31 which utilizes battery 34 as a source of energy and thus the voltage appearing across the load resistance 33 is of the form indicated in Figure 2b. That is, the amplified impulses 35 are of relatively short duration and occur at approximately the time of the discharge of the glow tube 15, graphically illustrated as the vertical drop 25 in voltage, Figure 2a.

The duration of the individual impulses 35 indicated in Figure 2b is controlled by the relative magnitude of the constants of condenser 26, resistance 27 and the potential applied to the circuit.

In order to generate an impulse 35 of a magnitude sufficient to record on dry recording paper, it may be necessary to employ several stages of amplification, or it may be preferable to first amplify the relaxation oscillations indicated in Figure 2a by means of a suitable amplifying device such as a resistance-capacitance coupled or direct coupled amplifier.

The discrete electrical impulses 35 illustrated in Figure 2b are coupled to the recording device, which may be of the type indicated in the above mentioned patents wherein each impulse is recorded as a distinct point.

Prior to the recording of these pulses, however, they are amplified sufficiently to insure that each will record as a distinct spot of the maximum possible density obtainable on the various dry recording papers known, regardless of the inherent differences in the electrical characteristics of the recording paper. Accordingly, the magnitude of these electrical impulses must be

great enough so that a true black will be recorded thereby at the point at which the paper has its maximum electrical impedance, inasmuch as this will certainly result in a true black at a point of lower impedance.

As electro-chemical recording may constitute a fire hazard, for large amplitude currents, I provide a current limiter 36 connected in series with the output of the pulse generator, in order to limit the impulse magnitude to a value below that required to ignite the paper.

This current limiter 36 may assume the form of one of the devices I have described in my co-pending patent application No. 203,851, filed April 23, 1938.

Returning again to the frequency characteristics of the impulse generating circuit it may be seen from Equation 8 that the frequency is directly proportional to the plate current of the pentode 16. If now, the incoming signal currents are impressed upon the control grid of the pentode 16, as indicated in Figure 1, and if the plate current grid voltage characteristic is sufficiently linear, the frequency of the relaxation oscillations and the corresponding impulse frequencies of substantially constant amplitude will vary directly in accordance with the amplitude of the picture current.

This result is indicated in Figure 3 wherein two cycles of the picture currents are illustrated by Figure 3a. The corresponding variations in frequency of the relaxation oscillations are indicated in Figure 3b and it may be seen that the increased frequency corresponds to increased amplitude of the picture current. The electrical impulses appearing across the amplifier load resistance 33 are also illustrated in Figure 3c. These impulses are at a frequency equal to that of the relaxation oscillations illustrated in Figure 3b, and are connected in circuit with the recording stylus after first passing through the current limiter 36.

It is important that the stylus be moved at a constant velocity across the recording sheet in order that the spacing between electrical impulses be determined solely by the frequency thereof.

The maximum frequency of these electrical impulses will determine the black or the densest portion of the recorded image, and this frequency will be a function of the speed of the scanning stylus. That is, if one facsimile system, such as my high speed printer and transmitter, operates the stylus at a relatively higher speed than another, it may be necessary to design the impulse generating circuit to operate at a higher frequency in order that the maximum number of black impulses appearing per inch of scanning line on the recording sheet shall be the same.

In order to secure a clear white or the natural color of the recording paper, I may reduce the frequency of the discrete electrical impulses to zero by negatively biasing the control grid of pentode 16, by means of battery 21, so that the plate current at no signal will be equal to zero.

The maximum frequency which may be employed is determined by the definition of the recording sheet. Thus if the stylus is moved relative to the recording paper at a velocity of ten inches per second, and it is desired that the densest of the portion of the picture contain five hundred distinct impulses per linear inch, I adjust the maximum frequency of my oscillator to five thousand cycles per second.

If as previously mentioned, the pentode 16 pro-

viding the condenser charging current, is biased to cut off, I will obtain a linear variation in frequency, from zero to the maximum of the impulses generated, with respect to the amplitude of the incoming signal and will thus secure a picture containing the full tonal scale of the original at the transmitter.

Although, it is possible to obtain a pure white by biasing the pentode 16 to cut off, it may be desirable to operate with a minimum frequency of perhaps thirty or fifty points per inch, as this will produce a picture that simulates a screened half-tone. Also, the very low frequencies, which may print five or ten points per linear inch, may not be easily accommodated by the eye because of the relatively large spacing. The minimum frequency desired will be dependent upon the speed of printing, and may be obtained by adjusting the control grid biasing battery 21 of the pentode 16.

It is important to note that I obtain my improved picture without resorting to changes in the transmitting equipment now installed and that all of the mechanical features of the present day facsimile recorders may be employed with most of the associated electrical circuits. I need only add a final stage which is an impulse generator of the form indicated in Figure 1. If the facsimile receiver already contains a current limiter I need add no additional equipment other than the impulse generator and need only adjust the current limiter to limit the currents flowing therethrough to a magnitude less than that which may possibly constitute a fire hazard when passing through the record sheet.

My improved recording means allows me to employ a relatively inexpensive grade of paper for recording purposes. However, with improvements in the recording paper and increased definition thereof, I will be able to employ still higher frequencies for my impulse generator and increase the quality of the printed picture while eliminating the need for a paper and paper impregnation process requiring constant electrical impedance, and a linear variation between electrical currents and the intensity of discoloration.

In frequency modulation circuits my improved recorder is directly applicable and obviates the need for a circuit which translates deviations in frequency to corresponding deviations in amplitude. For example, I may use deviations in frequency above the carrier to correspondingly deviate the frequency of my impulse generator which is coupled to the recording stylus.

Although ordinarily in facsimile recorders a positive picture is produced directly by the discoloration of the recording sheet and increased amplitude increases the intensity of the discoloration, I may electrically invert the image, as is well known in the art, to produce a negative record image, if required.

While I have described one embodiment of a means for faithfully reproducing facsimile image without dependency upon the characteristics and quality of the recording sheet, many other modifications of this basic idea may be devised by those skilled in the art.

Therefore, although I have illustrated a basic type of impulse generator and means for controlling the same, I do not wish to be limited to this particular modification, but prefer that the scope of my invention be considered as that covered by the appended claims.

I claim:

1. A facsimile recording system comprising a

receiver for receiving currents varying in amplitude in accordance with the lights and shades of a picture to be recorded; said receiver including means for translating said received currents of varying amplitude into signals of corresponding varying frequency; a recording sheet responsive to electric currents flowing therethrough for recording images in accordance with said currents; and means for impressing said currents from the output of said receiver across said recording paper.

2. A facsimile recording system comprising a receiver for receiving currents varying in amplitude in accordance with the lights and shades of a picture to be recorded; said receiver including means for translating said received currents of varying amplitude into signals of corresponding varying frequency and substantially constant amplitude; a recording sheet responsive to electric currents flowing therethrough for recording images in accordance with said currents; and means for impressing said currents from the output of said receiver across said recording paper.

3. A facsimile recording system comprising a receiver for receiving currents varying in amplitude in accordance with the lights and shades of a picture to be recorded; said receiver including means for translating said received currents of varying amplitude into signals of corresponding varying frequency and substantially constant amplitude; a recording sheet responsive to said currents of substantially constant amplitude and variable frequency for recording images in accordance with said frequency variation; means for operatively effecting said recording sheet by said currents, and means for obtaining a uniform intensity of all said recorded currents.

4. A facsimile recording system comprising a conductive platen, and a sheet of electro-chemically sensitized recording paper in juxtaposition with said platen, means for scanning said sensitized paper with a conductive stylus, a receiver for detecting and amplifying transmitted signals varying in amplitude in accordance with the lights and shades of a picture, and means for translating said variable amplitude picture currents into discrete electrical impulses, said impulse current frequency being directly proportional to the amplitude of said variable amplitude picture currents, and circuit means for impressing said impulse currents between said conductive platen and stylus, to reproduce said transmitted picture.

5. A facsimile recording system, comprising a conductive platen, and a sheet of electro-chemically sensitized recording paper in juxtaposition with said platen, means for scanning said sensitized paper with a conductive stylus, a receiver for detecting and amplifying transmitted signals varying in amplitude in accordance with the lights and shades of a picture, means for translating said variable amplitude picture currents into discrete electrical impulses, said impulse current frequency being directly proportional to the amplitude of said variable amplitude picture currents, and circuit means for impressing said impulse currents between said conductive platen and stylus, the amplitude of said impulse currents being sufficiently great to insure uniformity of all said recorded impulses.

6. A facsimile recording system, comprising a conductive platen, and a sheet of electro-chemically sensitized recording paper in juxtaposition with said platen, means for scanning said sensitized paper with a conductive stylus, a receiver

for detecting and amplifying transmitted signals varying in amplitude in accordance with the lights and shades of a picture, means for translating said variable amplitude picture currents into discrete electrical impulses, said impulse current frequency being directly proportional to the amplitude of said variable amplitude picture currents, and circuit means for impressing said

impulse currents between said conductive platen and stylus, the amplitude of said impulse currents being sufficiently great to insure uniformity of all said recorded impulses, and means in circuit with said stylus for precluding the burning of said recording sheet.

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