United States Patent

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Continuation-in-part of application Ser. No. 803,612, Mar. 3, 1969. This application May 16, 1969, Ser. No. 825,230

[54] **FACSIMILE SYSTEM WITH PREEMPHASIS VARIED BY SIGNAL RATE**
3 Claims, 10 Drawing Figs.

[52] U.S. Cl. .... 178/6, 178/DIG. 3, 178/DIG. 16, 179/2 C, 307/290
[51] Int. Cl. H04n 1/40
[50] Field of Search .... 178/6, DIG. 3; 179/2 C, 2 DP; 307/290

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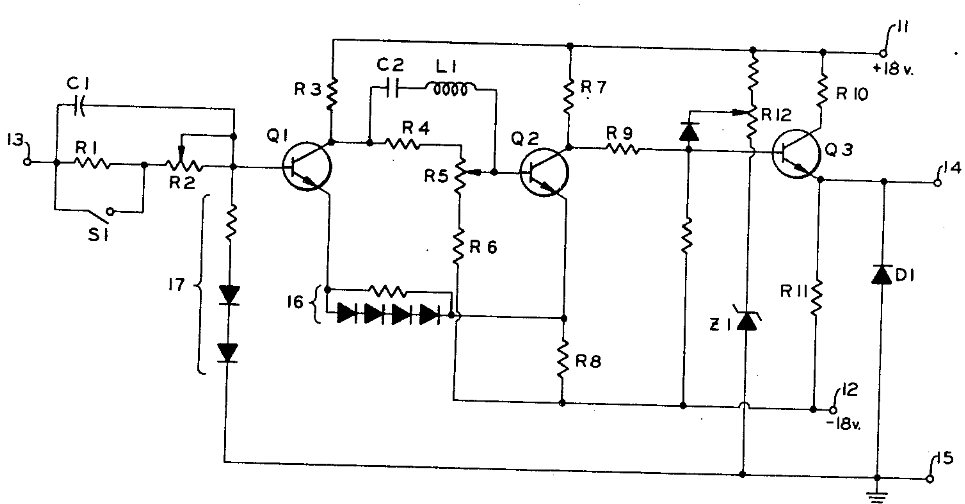
ABSTRACT: An improved facsimile system capable of either yielding improved quality copy at the prior art transmission speed or of yielding copy of quality comparable to the prior art machine in a reduced period of transmission time is disclosed. These improvement result from a modified gray-scale signal circuit at the transmitter which has its gray-scale transfer function-time dependent along with an improved receiver circuit which has a gray-scale time-dependent transfer function. These modifications cause both transmitter and receiver to tend to saturate at lower signal levels for rapidly changing gray-scale inputs.



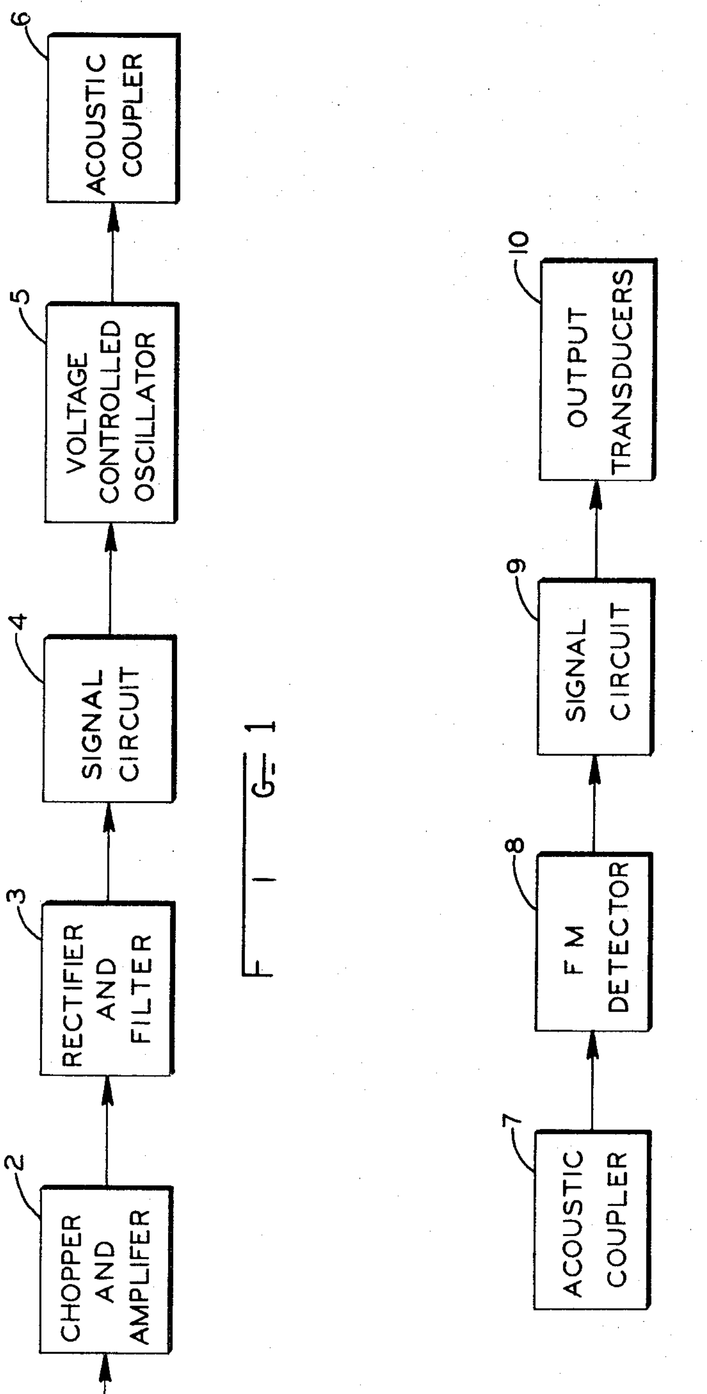


FIG. 1

FIG. 2

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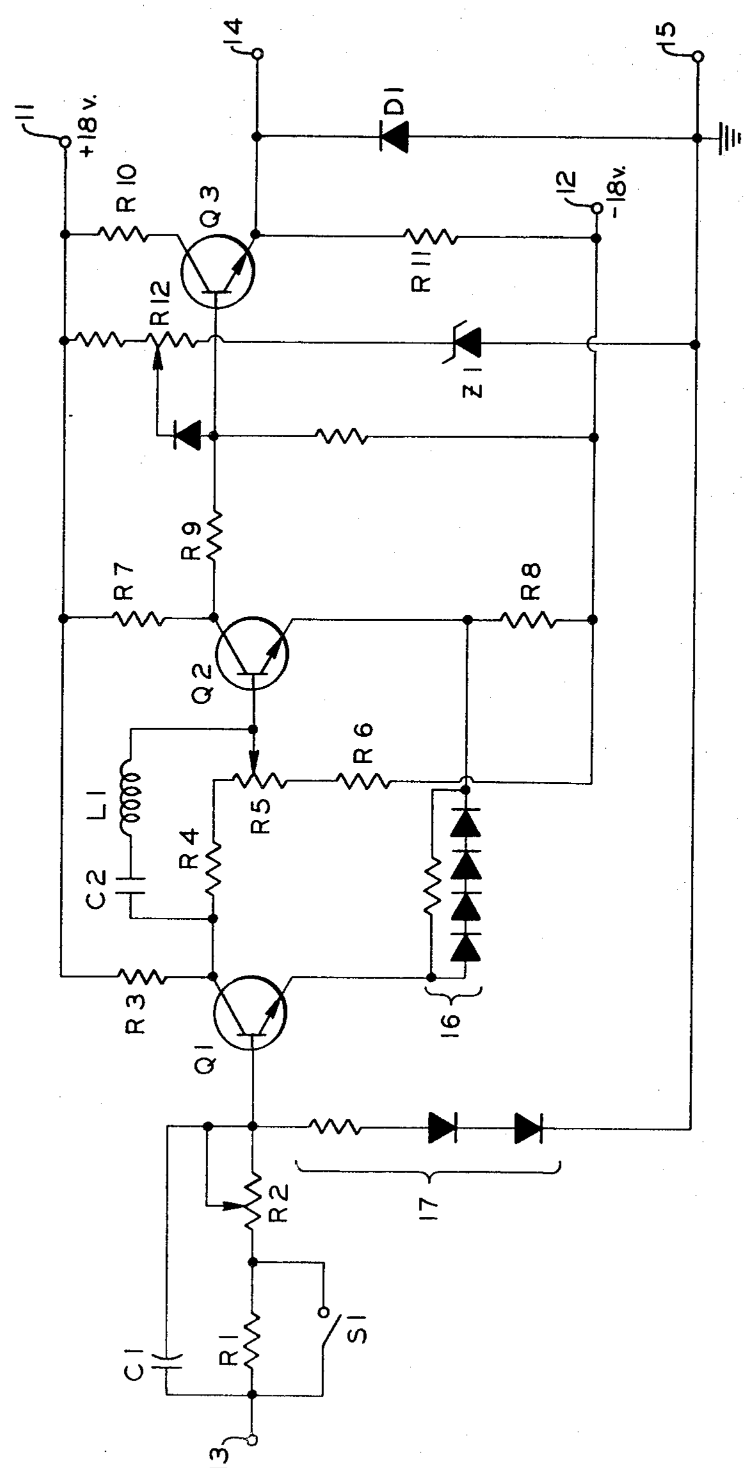

FIG. 3

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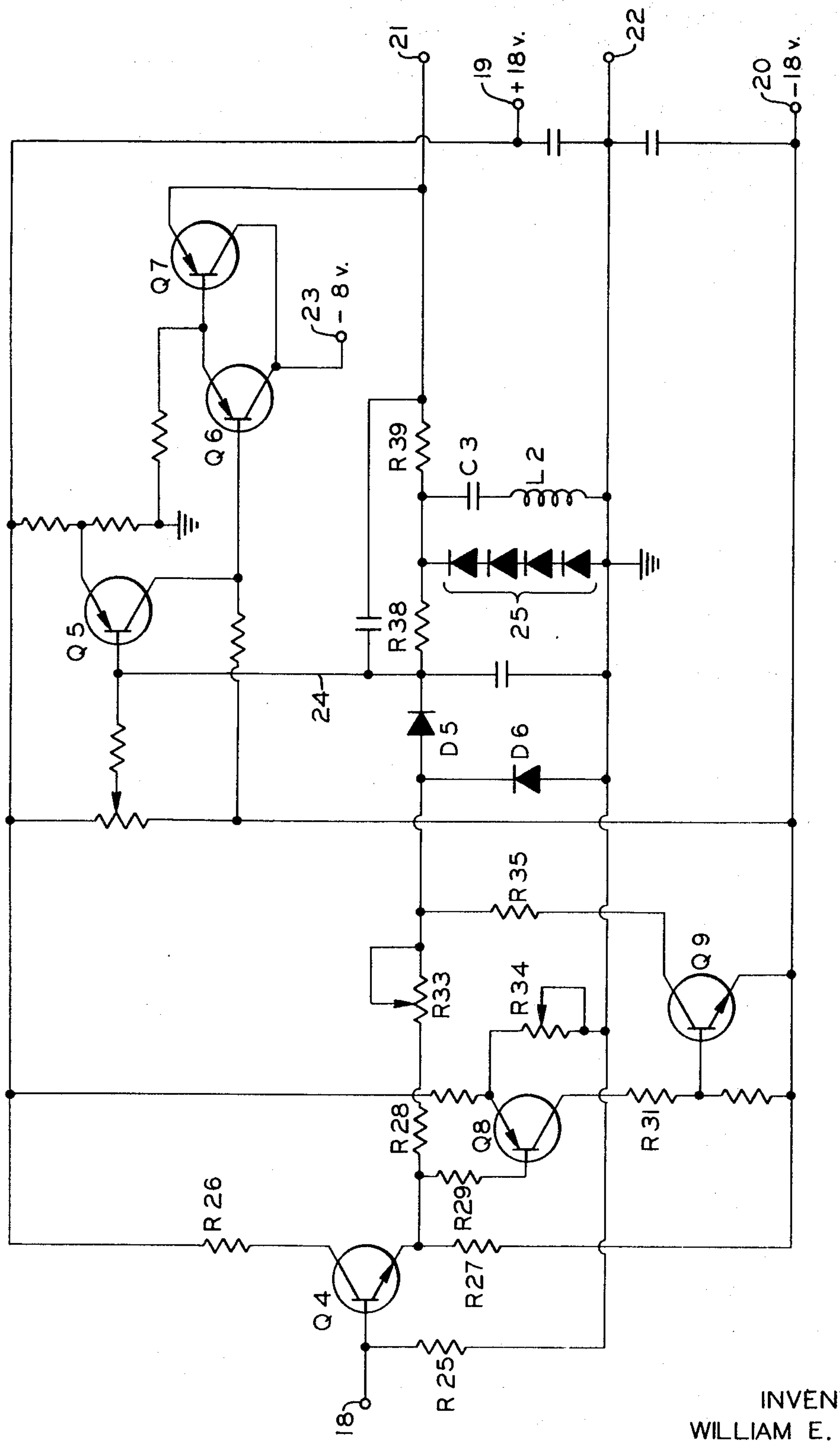

FIG. 4

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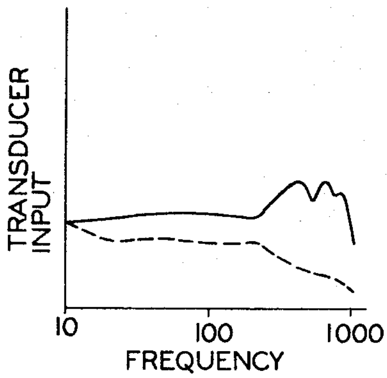

FIG 5a

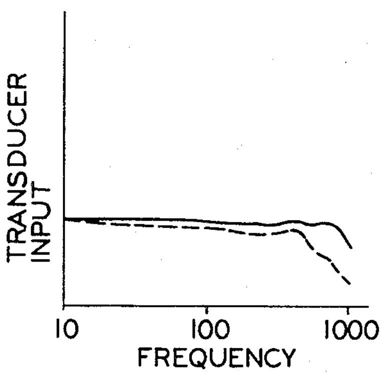

FIG 5b

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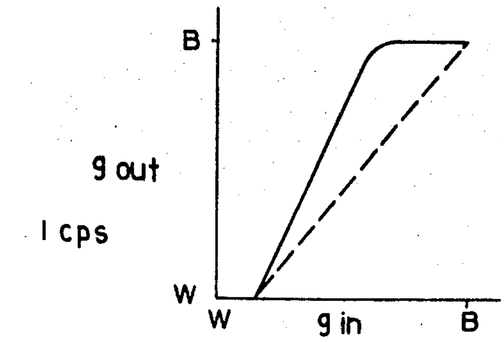

FIG. 6a

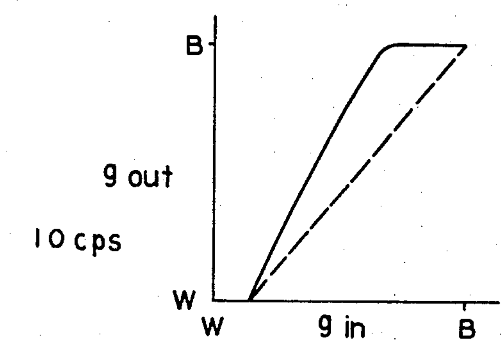

FIG. 6b

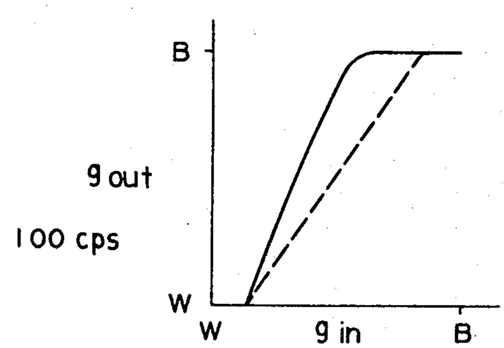

FIG. 6c

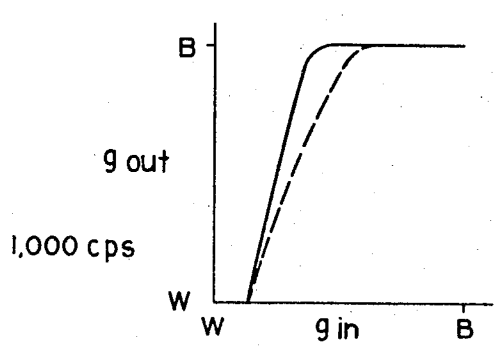

FIG. 6d

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FACSIMILE SYSTEM WITH PREEMPHASIS VARIED BY SIGNAL RATE

RELATED APPLICATION

This application is a continuation-in-part of copending application Ser. No. 803,612, filed Mar. 3,1969, in the names of William E. Richeson and Robert H. Dreisbach and entitled, "Improved Facsimile System." The present invention, as well as the above identified invention, find particularly utility in a facsimile system such as is disclosed in copending application Ser. No. 669,315, filed Sept. 20, 1967, in the names of Glenn A. Reese and Paul J. Crane entitled, "Facsimile Systems."

BACKGROUND OF THE INVENTION

This invention relates to facsimile transmission systems and more particularly to improvements in both the transmitter and receiver circuitry which allows either a lesser transmission time or improved quality of transmission or some combination of the two. The prior art facsimile transmission circuitry is best illustrated by the aforementioned Richeson and Dreisbach application. That application contemplates the transmission of facsimile information over a telephone line utilizing a frequency-modulated audio signal. Such telephone lines have a limited bandwidth and hence limit the resolution of the facsimile copy. The transitions of white to black and black to white represent, in the large part, the data to be sent and it is in these transitions that the resolution is required but limited by the communication link.

SUMMARY OF THE INVENTION

Accordingly it is one object of the present invention to provide an improved facsimile transmission system.

It is a further object of the present invention to provide an improved facsimile transmitter that enhances the gray-scale transitions for transmission over a telephone line.

It is another object of the present invention to provide an improved facsimile receiver that emphasizes these gray-scale boundaries for improved reception from a telephone line.

It is another object of the present invention to provide a facsimile transmission system of improved quality so as to allow faster transmission of comparable quality copy or transmission of improved quality copy at existing transmission speeds.

It is a further object of the present invention to provide a facsimile system having an improved signal-to-noise ratio.

It is a still further object of the present invention to provide a facsimile unit which is compatible with the prior art units to yield improved quality copy and which provides still better quality copy when communicating with another improved unit.

It is a salient object of the present invention to provide a method of improving facsimile transmission and especially for improving the fine line response of such facsimile transmission.

These and other objects and advantages are achieved in the present invention by providing additional circuitry in the transmitter for preemphasizing the gray-scale boundaries and providing circuitry in the receiver for postemphasizing these transitions. This emphasizing process causes the system circuitry to alter the gray-scale transfer function and at times to saturate at a lower level for rapidly changing events than it does for slowly changing events.

BRIEF DESCRIPTION OF THE DRAWING

The above-mentioned objects along with other objects and advantages of the present invention will become more apparent from the following detailed description of a specific embodiment read in conjunction with the drawing in which:

FIG. 1 shows a block diagram illustrating the electrical circuitry involved in a facsimile transmitter;

FIG. 2 is a block diagram illustrating the circuitry in a corresponding facsimile receiver;

FIG. 3 is a detailed schematic diagram of the signal circuit of FIG. 1;

FIG. 4 is a schematic diagram of the signal circuit of FIG. 2;

FIG. 5*a* illustrates the frequency response characteristics of a facsimile system operating in the photo mode with and without the present improved circuitry;

FIG. 5*b* similarly compares the prior art and present invention when operating in the print mode; and

FIGS. 6*a*–6*d* graphically depict the overall system response characteristics at various frequencies with operation in the print and photomodes.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, a block diagram of a typical facsimile transmitter is shown. A light-sensitive transducer or scan photocell 1 supplies a direct current output whose magnitude is indicative of the light reflected from a scanned document. These signals are chopped or broken up for simplified amplification in the amplifier 2. These amplified video signals are then rectified and filtered to produce direct current signals which may vary between selected levels, for example, from 0 to 7 volts. In this selected range, 0 volts represents a white area on the original document and voltages above 0 represent darker shades with the 7 volt maximum representing black. This rectification and filtering takes place in rectifier and filter circuit 3 whose output is then coupled to a signal circuit 4. This signal circuit 4 is shown in detail in FIG. 3 and will be further described subsequently. Briefly, this circuit modifies the direct current signals to make them have different characteristics for shades from white to black and has a switch for altering the circuit for transmission of printed material or photographic type material. Signals from the signal circuit 4 still lie in the selected range of 0 to 7 volts and are applied to a voltage controlled oscillator 5 which has a frequency modulated output varying between, for example, 1,500 and 2,450 cycles per second. The frequency, of course, is directly related to the magnitude of the input voltage. These frequency modulated signals are then applied to an acoustic coupler 6 which serves to couple the system to the telephone line for transmission. FIG. 2 shows a block diagram of a typical facsimile receiver which is coupled to the telephone line by a transducer or acoustic coupler 7 which converts the audio signals coming from an ordinary telephone handset into electrical signals for application to an FM detector 8. The FM detector supplies a direct current output ranging again, for example, between 0 and 7 volts which output is supplied to a signal circuit 9, the details of which are shown in FIG. 4. Briefly, this signal circuit modifies the system response so as to provide a better copy of the original document. The signal circuit drives an output transducer 10 which supplies the physical motion necessary for imprinting the information on a reproduction.

As noted earlier, the signal circuit 4 is shown in detail is FIG. 3. Basically, this circuit comprises a highly modified Schmitt trigger circuit having two NPN-type transistors Q1 and Q2 coupled together partially in known fashion. Signals from the rectifier and filter circuit 3 are applied through a resistor R1 and potentiometer R2 and the parallel capacitor C1 to the base of transistor Q1. Positive and negative direct current sources supply the terminals 11 and 12 respectively. Input signals to the circuit are supplied between terminal 13 and ground and the output of the circuit appears between terminal 14 and the ground terminal 15. The collector of transistor Q1 is coupled through a resistor R3 to the source of positive potential. The output of the transistor Q1 is coupled to the base of transistor Q2 through the L–C network consisting of L1 and C2 and through a resistor R4 to a potentiometer R5 whose movable tap is connected to the base of the transistor Q2. The potentiometer R5 is coupled through an additional resistor R6 to the source of negative potential. The input attenuation to the base of transistor Q1 is seen to be lower for more rapidly changing input signals due to the presence of capacitor C1 in parallel with the series input resistance. Similarly, the impedance of the path coupling the output of transistor Q1 and the input of transistor Q2 is lower for rapidly changing signals due to the presence of capacitor C2 and inductance L1. The collector of transistor Q2 is coupled through a resistor R7 to the positive potential supply and the emitter of Q2 is coupled through a resistor R8 to the negative potential. The output of the transistor Q2 is derived at its collector and coupled through a resistor R9 to an NPN-type transistor Q3. Q3 is merely an amplifier stage. The collector of Q3 receives its bias by way of resistor R10 and its emitter bias by way of R11. Q3 which is connected as an emitter-follower supplies the output signals to terminal 14. The schematic of FIG. 3 also shows several additional circuits and feedback arrangements which function to improve the overall system characteristics and which are described in detail in the aforementioned Richeson and Dreisbach application. Thus, for example, the parallel resistor-varistor circuit 16 functions to alter the graY-scale transfer characteristics in a desired fashion. Similarly, the series resistor-varistor circuit 17 serves to compensate for certain carbon transfer characteristics at the receiver. The switch S1 when in its closed position shorts out the resistor R1 thus reducing the input attenuation to the base of the transistor Q1. When this switch is in its closed position it is said to be in the print mode and when the switch is open the system is operating in the photomode. The potentiometer R12 in conjunction with the Zener diode Z1 is adjusted so as to limit the circuit output to a maximum of 7 volts. Varistor D1 clamps the minimum output to a potential slightly lower than zero, e.g., —0.25 volts.

Turning now to FIG. 4, a detailed schematic diagram of the signal circuit 9 of FIG. 2 is shown. The base of the transistor Q4 is coupled to the input terminal 18 which receives signals from the FM detector. The circuit has a source of positive direct current supplied at terminal 19 and negative direct current supplied at terminal 20 and the output of the circuit is derived between terminal 21 and the grounded terminal 22. A second negative direct current supply is applied at terminal 23. The base of transistor Q4, an NPN-type of amplifying transistor, is returned to ground by way of resistor R25 and the emitter and collector electrodes are connected to the positive and negative current sources by resistors R26 and R27 respectively. The output of transistor Q4 is supplied by way of resistor R28, potentiometer R33 and diode D5 to a current or summing bus 24. Bus 24 is connected to an amplifier comprising three PNP-type transistors Q5, Q6 and Q7. The output of the last transistor Q7 is derived at its emitter and is supplied to the output transducers by way of terminal 21. A threshold control circuit comprising transistors Q8 and Q9 provides a current to the summing bus 24 in operation with a diode rectifier D6 connected between ground and the junction of the potentiometer R33 and the diode D5. Signals from the emitter of the transistor Q4 are applied through a resistance R29 to the base of transistor Q8. The collector of transistor Q8 is coupled through a resistor R31 to the base of transistor Q9. The collector of transistor Q9 is coupled through a resistor R35 to the junction of diodes D5 and D6. The threshold is then adjusted by manually controlling the potentiometer R34. The function of this threshold control circuit is more completely explained in the above-mentioned mentioned Richeson and Dreisbach application. The series combination of inductor L2 and capacitor C3 is connected in parallel with varistor 25 which in this particular case consists of four concatenated diodes between ground and the junction point of resistors R38 and R39. The other end of R39 connects to the output terminal 21. R38, R39 and varistor 25 form a feedback circuit and the extent to which varistor 25 is conducting modifies the degree of negative feedback and hence the gain of the circuit. The series combination of C3 and L2 serves to modify this feedback so as to emphasize rapidly changing signals.

The function of the above-described circuitry is to improve the time-dependent gray-scale transfer characteristics of a facsimile transmission system via edge enhancement. This is achieved by altering the transmitted spectrum by pre- and postemphasis of the rapidly changing components of the gray scale so as to overcome limitations inherent in the transmission link while at the same time overcoming certain undesirable characteristics of the transmitter and receiver circuitry. The above described circuit serves to overemphasize or distort the actual data being scanned so that an actual transition for example, of white to gray to white is caused to be printed at the receiver as white to black to gray to whiter than white and then to white. This problem is best understood when one considers the fact that the scan photocell 1 is responsive to the light reflected from the original document in a given area.

To illustrate further the problem associated with the scanning photocell and the associated finite area which it views during a given instant of scanning, consider what happens when this finite view area or aperture approaches a dark mark on an otherwise white paper. When only a portion or the edge of this black mark is included within the scan view area, the photocell is unable to distinguish how much of the black is included within the viewed area and merely responds as though the entire viewed area were a gray mark. As the black mark moves with relation to the photocell so as to be included in more of the scan view area, the photocell responds by indicating a darker gray for its entire area viewed. Thus, the prior art machine would not respond instantaneously when encountering a black mark but would rather print gradations from white to gray to darker gray and finally to black as the view area or aperture encompassed more and more of the black mark. The improved circuit of the present invention causes even a gray mark to be printed as beginning with a very fine black line and to be discontinued suddenly when passing from the gray mark back to a white background area. Similarly, the prior art machine, when scanning an extremely fine black line, for example one whose width was less than the scan aperture diameter, would cause the receiver to print out a wider gray line. This, of course, is again caused by the finite aperture size. The problem is compounded if the system is scanning a line which is simultaneously fine and less than black. The prior art system would tend to print a very light, fuzzy gray line while with the present circuit an emphasized dark fine line is printed. Thus, the present circuit is capable of responding to and printing lines which would have been lost by the prior art system and in effect, the resolution and fidelity of the system is improved.

To understand why this is true, consider the hypothetical situation in which a sawtooth wave form varying linearly between zero and seven volts is applied to the signal circuit 4. Such a sawtooth wave form approximates the output of the filter 3 when the photocell aperture is beginning to encompass a black mark. Figures 5*a* and 5*b* illustrate the system response to such a sawtooth input. In these two graphs the ordinate is the logarithm of the voltage applied to the output transducers 10 and the abscissa is a logarithmic representation of the repetition rate of the sawtooth waveform. Figure 5*a* illustrates the system response when the transmitter is operating in the photomode, that is when switch S1 is open. The dotted curve shows the response of the prior art system while the solid line shows the system response of the present invention. This curve clearly shows that the present system does not degenerate at the higher repetition rates nearly so much as the prior art system. Similarly FIG. 5*b* shows the system response when the switch S1 is closed or in the print mode. Again the solid line shows the response of the present invention while the dotted line shows the prior art system response and again it is clear that the present invention maintains its flat response characteristics better at the high rates of change of the gray scale. This improved response is predicated on saturation as illustrated in FIGS. 6*a* through 6*d*.

FIGS. 6*a* through 6*d* show the overall system response in the form of a gray-in vs. gray-out curve for both the print and photo modes of operation. The print mode is illustrated by the solid-line curves while the photomode is illustrated by the dotted-line curves. Thus the abscissa indicates the system input of varying degrees of grayness between white and black with white at the origin, while the ordinate indicates the system output of varying degrees of grayness beginning again at the origin which is white. FIG. 6*a* illustrates the system response for a sawtooth repetition rate of one cycle per second, FIG. 6*b* illustrates the response for a 10 cycle per second signal, FIG. 6*c* illustrates the response for a 100 cycle per second signal, and FIG. 6*d* illustrates the system response for a 1,000 cycle per second signal. It should be apparent that the system saturates more and more readily as the rate of change increases, that is, the gray scale is dependent upon the rate of change of the input gray scale, thus FIG. 6*d* shows that, in the print mode, a black output will be obtained for a light gray input while FIG. 6*b* shows that the same black output would be achieved for a dark gray input when operating in the print mode at only 10 cycles per second. Thus this earlier saturation tends to maintain good frequency response throughout the entire spectrum of interest. It should also be clear that fine detail on an original document is transmitted as though the machine were operating in its print mode even though the switch may be in fact set to operate in the photomode. This is a desirable trait because when operating in the print mode the entire system operates at an improved signal-to-noise ratio. The duplicated photos have, in fact, an edge or border enhancement and the items in the print mode are bolder and clearer.

Thus while the present invention has been described in reference to a specific embodiment various modifications will suggest themselves to persons of ordinary skill in this art and the present invention is to be limited only by the scope of the appended claims.

I claim:

1. The method of improving the performance of a facsimile transmission system comprising the steps of:

increasing the amount of regenerative feedback in the receiver for more rapidly changing baseband signals so that the point of receiver saturation decreases as the rate

of change of baseband signals increases; and

increasing the gain of a modified Schmitt trigger circuit in the transmitter in response to an increase in baseband rate of change so that the input to a voltage-controlled oscillator reaches its maximum value at lower Schmitt trigger input levels for higher rates of changes in the signal level.

2. The method of claim 1 wherein the step of increasing the gain comprises the steps of:

lowering the input attenuation of the modified Schmitt trigger circuit and lowering the impedance between stages of the modified Schmitt trigger circuit, both in response to an increase in the signal level rate of change.

3. In a facsimile system comprising a transmitter and a receiver, the improvement comprising:

a modified Schmitt trigger circuit in the transmitter having first and second current control devices therein;

preemphasis means in said modified Schmitt trigger circuit for improving the rapid response characteristics of said transmitter, said preemphasis means comprising a series inductor capacitor circuit in parallel with a resistance coupling the output of said first current control device to the input of said second current control device, and a parallel resistor capacitor circuit for providing an input impedance to said first current control device which decreases as the rapidity of the input signals increases; and

postemphasis means in the receiver for improving the rapid response characteristics of said receiver comprising a series capacitor-inductor circuit across the output of said receiver.

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