

Feb. 3, 1931.

R. H. RANGER

1,790,722

DUPLEX PHOTO MODULATOR

Original Filed July 16, 1924 3 Sheets-Sheet 1

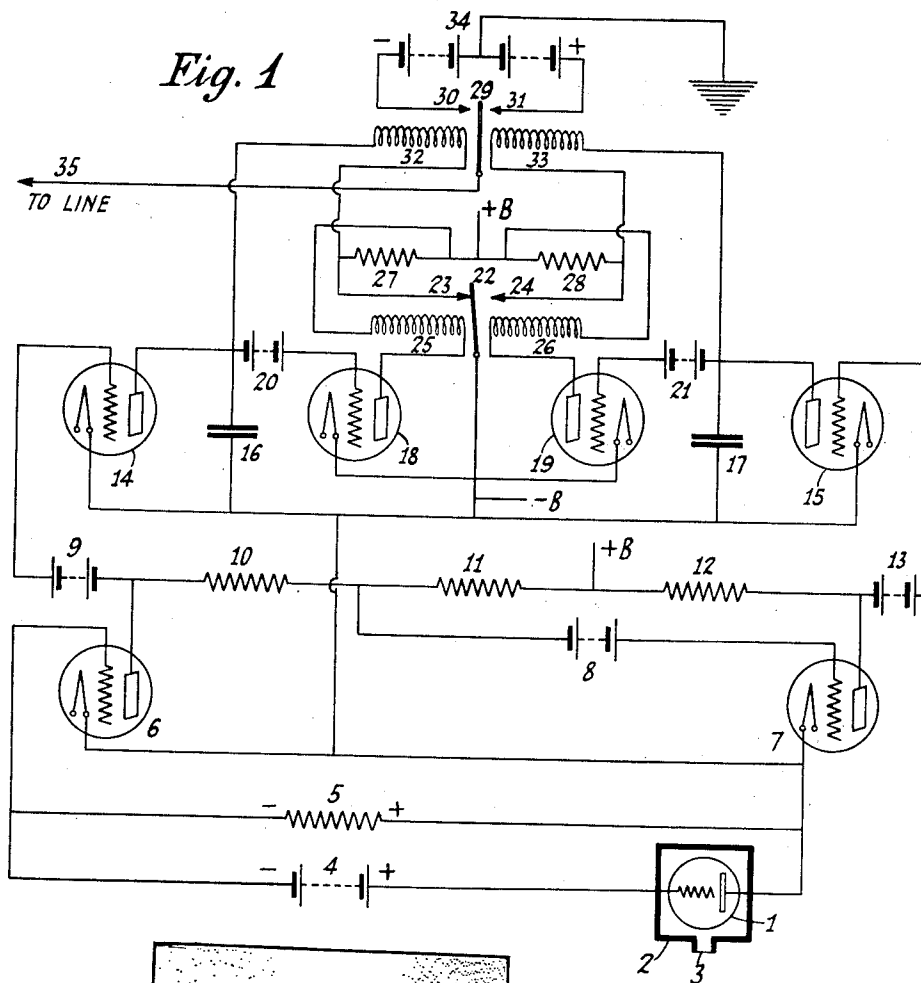


Fig. 5

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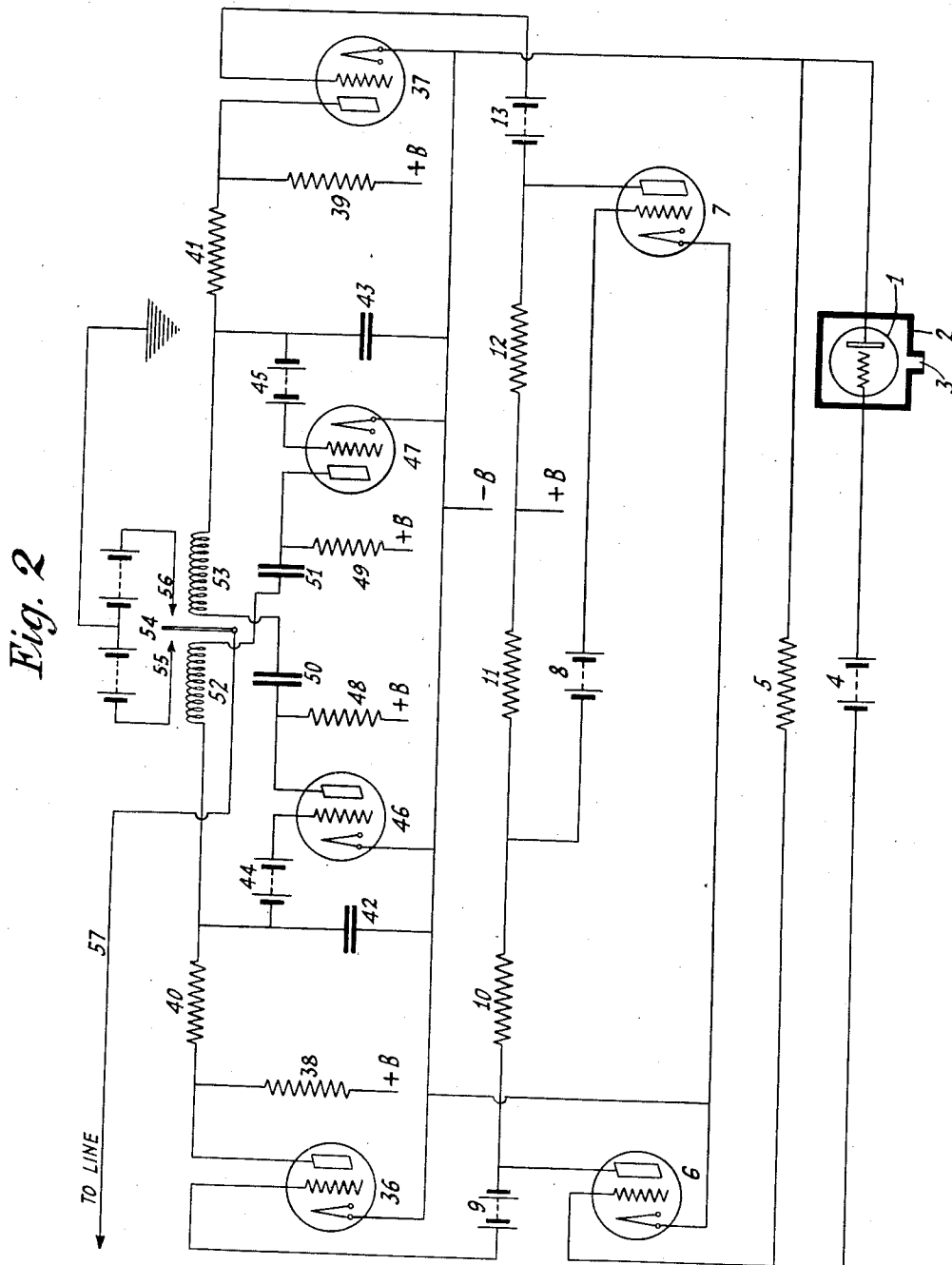
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DUPLEX PHOTO MODULATOR

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DUPLEX PHOTO MODULATOR

Original Filed July 16, 1924 3 Sheets-Sheet 3

Fig. 3

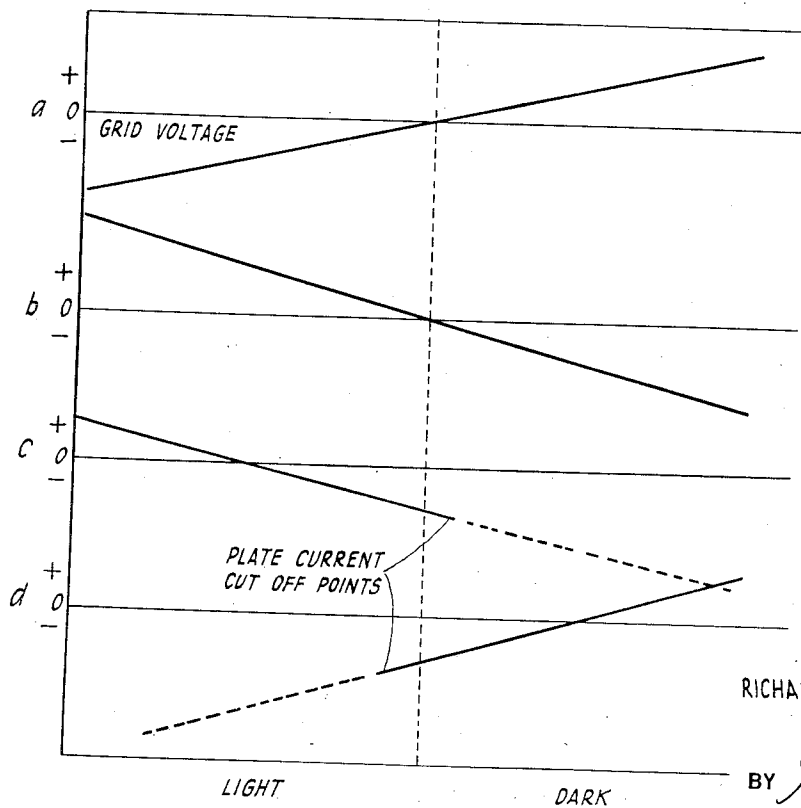
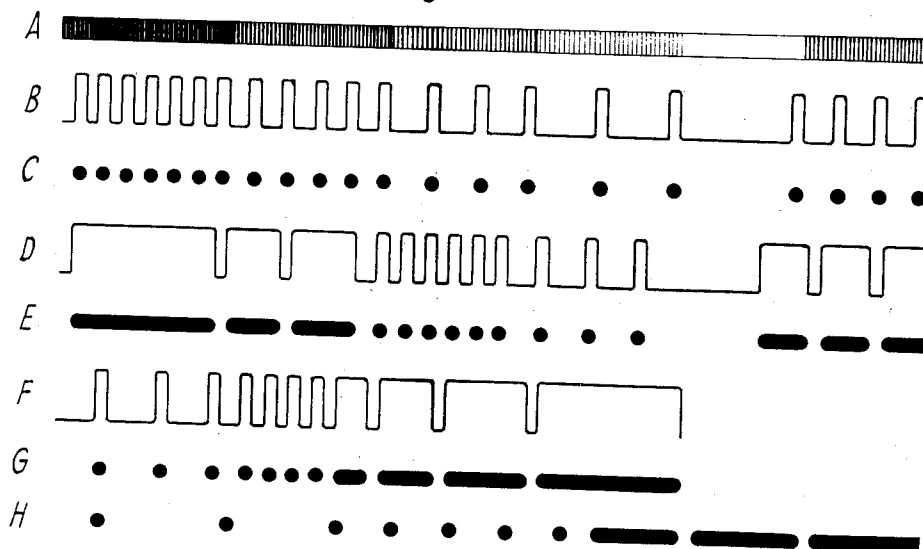


Fig. 4

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DUPLEX PHOTOMODULATOR

Application filed July 16, 1924, Serial No. 726,235. Renewed January 13, 1930.

This invention relates to a new and improved process of duplicating or reproducing pictures or the like and, although my invention may be used for the purpose of producing duplicates of pictures or the like at the place where the originals are found, it is also particularly adapted to produce such pictures at a considerable distance from the originals, utilizing for the purpose of control of the reproduction any existing telephone, telegraph or radio circuits.

The invention herein disclosed and claimed is an improvement on the invention disclosed and claimed in copending application of E. F. W. Alexanderson and R. H. Ranger, Serial No. 669,688, filed October 20, 1923, for Picture transmission by wire or radio, and copending application of R. H. Ranger, Serial No. 695,175, filed February 26, 1924, for Methods and means for reproducing and transmitting pictures, and is a continuation in part of the latter application.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; my invention however, both as to its organization and method of operation, will best be understood by reference to the following description taken in conjunction with the accompanying drawing, in which

Fig. 1 shows one form of apparatus embodying my invention;

Fig. 2 shows another and in some respect more preferable form thereof;

Fig. 3 is an illustration showing the method by which I may reproduce varying values of light intensity according to this invention;

Fig. 4 is a set of curves explaining the operation of my system; and

Fig. 5 is an example of a picture reproduced according to my invention.

My invention contemplates as a new article of manufacture a picture or pictorial representation in which the effects of varying intensities of light are produced in a novel manner and contemplates also a process by which such pictures may be produced and apparatus by which the process may be

carried out. The pictures which I produce and the process by which I produce them render my invention particularly useful for transmitting pictures to a distant point by means of telegraph, telephone or radio circuits, particularly the latter.

While I have referred to the use of my invention for producing duplicates of pictures and the like, it should be understood that my invention is not limited thereto, but that I may produce duplicates of any sort, such for instance as copies of motion picture films, manuscripts, letters or documents, finger prints or the like. I therefore wish it understood that I have used the term "picture" throughout the specification and claims in the broad sense as defined above to include the various objects given by way of example and others as will be understood by those skilled in the art.

It is an object of this invention to produce a picture or visual record in which the effects of varying light intensity are reproduced in a novel manner.

It is another object of this invention to produce a practical and simple method or process for duplicating or reproducing pictures.

It is still another object of my invention to provide improved apparatus by which the reproduction of pictures may be carried out.

It is another object of my invention to provide a method and apparatus by which reproduction and transmission of pictures may be carried out more rapidly than before.

It is another object of my invention to provide a method and apparatus adapted for the reproduction and transmission of pictures, by the use of which a more faithful reproduction of the original is obtained.

It is another object of my invention to provide a method and apparatus for the reproduction of pictures which is adapted for use in transmitting pictures to a distant point by the use of telephone or telegraph circuits.

It is still another object of my invention to produce a method and apparatus for the reproduction of pictures which is particularly adapted for use in transmitting pictures to

a distant point over existing radio circuits at a high rate of speed.

Still other and ancillary objects of my invention will be apparent from the specification.

In my copending application, Serial No. 695,175, referred to above, I have disclosed a picture made up of a mass of dots of substantially uniform size and varying in concentration to produce the effect of varying intensities of light and shadow, together with a method for producing such a picture and apparatus for carrying out the method.

To expedite the understanding of the present invention which embodies in part the principles disclosed in the above identified application, it is of advantage to briefly outline the invention disclosed therein.

In general, it may be stated that the said invention comprises as its fundamental principle the translation of the varying intensities of light and shadow in successive portions of the picture to be reproduced into uniform impulses, separated by spacing periods of varying duration; or to put it differently, successive portions of the picture are translated into successive electric impulses of substantially uniform duration and of a varying number per unit of time, thus enabling pictures and the like to be transmitted over telephone, telegraph or radio circuits, utilizing at all times the full power of the transmitting apparatus, whereby distortion of delicate tonal variations by atmospheric disturbances, static, line noises, etc. is minimized.

The picture may be reproduced from such a series of impulses by utilizing them to control a mechanical or other suitable recorder, as more specifically described in the said applications. In its simplest form such a recorder consists of a drum carrying upon it the fabric on which the picture is to be reproduced. A recording pen or stylus is controlled by any suitable means, such as an electromagnet, in such a way as to be brought into contact with the fabric during the time that an impulse is being received. The receiver drum is rotated in synchronism with the transmitting drum and longitudinal travel between the pen and drum is provided in proportion to the advance of the picture at the transmitter.

Such a system produces a picture made up of dots and bearing a certain resemblance to the well known half-tone engraving. It will be noted, however, that in the case of a picture produced according to the process just described the dots are all of uniform size, but variably spaced; whereas, in a half-tone engraving they are of varying size and spaced a uniform distance between centers. I have discovered in carrying out the invention that in order to obtain heavy black in the said process the dots should be sufficiently close together so as to merge substantially into a single line

and that the speed at which the dots can be transmitted and received over heavy black portions of the picture determines the limit of speed at which the picture can be transmitted. Moreover, since heavy black values are transmitted as a rapid series of dots, it will be apparent that this system involves considerable operation of relays and the like with consequent wear and tear, not only on the apparatus that I may term the "photo-modulator," which includes the apparatus for translating light intensities into current impulses, but also on the transmitting apparatus itself.

I have discovered that these objections, and others not specifically enumerated, may be overcome by providing a system wherein light values below a certain intensity—that is to say, values darker than an intermediate gray, as will be more particularly explained hereafter—are represented, not by a series of dots close together as in the preceding arrangement, but by impulses varying in length according to the intensity of the shadow.

Briefly, high lights are transmitted as uniform short impulses or dots separated by varying spacing periods, as before, until an intermediate gray value is obtained, at which point the impulses and the spacing interval between impulses are of the same time duration. For values of shadow more intense than this, the value is represented by increasing the length or duration of the impulses, and maintaining the spacing interval uniform. This may readily be seen by reference to Fig. 3, wherein line A represents successive values of light intensity of the transmitter, starting with black and gradually fading out to white, then returning to dark gray; B represents the power or current output of the transmitter working in accordance with the invention disclosed in my prior application No. 695,175; C represents the record produced from the series of impulses as shown in B; D represents the power or current impulses produced according to the invention disclosed and claimed herein and E represents the record produced when the transmission is as shown in D.

It will be noted that the extreme left hand portion of line A is represented in line D by a single long dash which is reproduced as shown in E. The next portion of less intensity is represented in the corresponding parts of D and E and it will be noted that the impulses are of shorter duration. The next portion of line A may be taken as the intermediate portion where the changeover occurs and at this point the impulses and the spacing periods are of uniform duration and equal to each other.

From this point on to the right, the impulses are of uniform duration and variably spaced in the same way as in line B. The final right hand portion of a value darker

than the intermediate is again represented by dashes. Line F represents the current or power impulses produced upon a graduation of the light intensity from light to dark and if carried on at slow speed, the record would appear as in line G.

It will be seen, however, that since the dark portions are represented by dashes instead of dots there is no obstacle to increasing the speed of the transmitter and receiver as much as desired. This could not be done with the arrangement disclosed in my copending application No. 695,175 for the reason that if the apparatus were speeded up to too great an extent, the dots, represented by the left hand portion of line C, would be separated by intervals which would appear on the record as white spaces and, therefore, the entire picture would be in effect light; that is to say, all of the relatively dark portions of the picture would be given a lighter value than they should have and changed to a greater extent than the lighter portions of the picture whereby the tonal balance of the picture would be destroyed.

However, according to this invention, it is possible to speed up both transmitter and receiver to about twice the maximum speed obtainable with the previous apparatus without destroying the tonal balance of the picture. This is clearly seen from line H which represents a record produced by current impulses, as shown by line F, when the apparatus is speeded up and will also be seen from Fig. 5, which is a reproduction of a picture made according to this process in about half the time necessary to make the same according to my prior process. The picture per se has been described, claimed and set forth more particularly in my application Serial No. 338,072, filed Feb. 7, 1929, which application forms a divisional part of this parent application.

It will be seen by comparing line H with line G that the dark portions of the picture still retain their proper values, and the tonal balance of the picture is not affected. This point is of great practical advantage since it will be obvious that a decrease in the time necessary to transmit a picture requires less power from the transmitter and a smaller charge to take care of the overhead expenses of the transmitting and receiving apparatus, thereby resulting in a cheaper cost for the transmission of pictures.

Referring now particularly to Fig. 1, I have shown apparatus adapted to translate the intensity of light into current impulses of the type described; that is, wherein values of light lying on one side of an arbitrary boundary zone are transmitted as impulses of uniform duration separated by variable spacing periods, and intensities of light lying on the other side of said zone are transmitted as impulses of varying du-

ration separated by uniform periods, while the intensities of light lying directly upon or in the boundary zone are transmitted as uniform impulses separated by uniform spacing periods, both of which are substantially equal in length.

In this figure, 1 represents a light sensitive cell of any suitable type, such for instance as that shown in my prior application. It is provided with a light-proof casing or container 2 having an opening 3 therein adapted to admit light thereon.

While I have not shown any specific arrangement for projecting light from the picture upon this cell, any suitable arrangement may be used, such for instance as that shown in my prior application, in which I have disclosed a drum carrying the picture and driven by a suitable motor, and a source of light arranged to project light from the picture on the cell. Various lenses may be provided and the drum is arranged for rotational and translational movement simultaneously, the lenses and source of light being so arranged that light from all portions of the picture is successively thrown through the opening 3 and upon the light sensitive cell 1. A suitable source of potential 4, which may be a direct potential of approximately 300 volts, is arranged to tend to force a current through this cell and resistance 5 is connected in the circuit including the source 4 and light sensitive cell 1 in such a manner that a potential drop is produced in this resistance by the flow of current therethrough.

The grid of a suitable vacuum tube amplifier 6 is connected to one portion of resistance 5 and the filament thereof is connected to another portion of the resistance in such a manner that when a potential drop occurs in resistance 5 due to a flow of current through light sensitive cell 1, the grid of tube 6 will be maintained at a negative potential with respect to the filament. To the output or plate electrode of vacuum tube 6 there is connected bias battery 9 and resistances 10, 11, 12 and bias battery 13 as shown.

A second vacuum tube amplifier 7 has its plate or output electrode connected to a point between resistance 12 and bias battery 13 and its grid or control electrode through bias battery 8 to a point between resistances 10 and 11. Any suitable source of potential for energizing the plates of this tube, such as indicated by +B, is connected between resistances 11 and 12. As shown, the control or grid electrodes of vacuum tubes 14 and 15 are connected respectively to the terminals of bias batteries 9 and 13 remote from resistances 10 and 12.

Between the output or plate electrodes of tubes 14 and 15 and the filaments of the same I connect condensers 16 and 17 respec-

tively and a circuit is also established from the plate electrode of tube 14 to one terminal of bias battery 20, through relay coil 32, thence to contact 23 and, in the position of armature 22 shown, to the common filament lead and the negative terminal of the source shown as -B.

A similar circuit from the plate or output electrode of tube 15 may be traced to one terminal of bias battery 21, through relay coil 33, thence to contact 24. Contacts 23 and 24 are connected through resistances 27 and 28 and a connection is made from a point between these resistances to the positive terminal of the source indicated as +B. Vacuum tube amplifiers 18 and 19 are also provided, having their grid or control electrodes connected to the negative terminal of bias batteries 20 and 21 respectively, the positive terminals of which are connected to one plate of condenser 16 and 17 and also to the plates of tubes 14 and 15.

The plate or output electrodes of tubes 18 and 19 are respectively connected through relay coils 25 and 26 to the common source of plate potential +B. Relay coils 32 and 33 control the position of armature 29, attracting it against either contacts 30 or 31, thus selectively energizing line 35 by current reversals from battery 34 for the purpose of transmitting the picture to a distance.

In the arrangement shown, plus current may be used for signalling and the minus current for spacing. Obviously, however, this is merely by way of example and any other suitable arrangement may be provided.

Having now described the circuit arrangement, the operation will be briefly set forth. Fundamentally, the arrangement comprises two systems, each of which is substantially similar to the system disclosed in my copending application No. 695,175, jointed together in such a way that one system controls or varies the duration of the impulse periods without affecting the duration of the spacing periods, while the other controls or varies the length of the spacing periods without affecting the duration of the impulse periods.

The systems are coordinated and controlled in a manner to be explained hereafter, so that for light values lying on one side of an intermediate predetermined value, only one of the systems is modulating, or varying the duration of its periods, the other system operating to produce periods of minimum and substantially constant duration. When the light intensity shifts to the other side of the predetermined value, conditions are reversed; that is to say, the system which was previously modulating or varying the duration of its periods operates to produce periods of minimum and substantially constant duration, while the other modulates or varies the length of its period.

Thus it will be seen that results are produced which are similar to those which would be obtained if one system were, so to speak, inverted when the light intensity reached a predetermined value. This will be clearly seen from line D of Fig. 3, in which it will be seen that the right hand portion of the line is practically the same as the left hand portion except that spacing and marking periods are inverted or the record is turned upside down.

Turning now to the operation of the system, it will be seen by reference to Fig. 1 that in the position of relay 22 shown condenser 16 is completely short-circuited. This circuit may be traced from the lower plate of condenser 16 to armature 22, contact 23, through relay coil 32 and to the upper plate of condenser 16. Therefore, no charge can be accumulated upon this condenser. Bias battery 20 is chosen of such a value that under these conditions, grid of the tube 18 is highly negative and plate current flowing in relay 25 is substantially zero.

On the other hand, condenser 17 is not short-circuited and is therefore free to take or store up a charge. Since the negative terminal of source B is connected to one side of condenser 17 and the positive terminal is connected to the other side through resistance 28 and coil 33, it will be seen that this condenser tends to charge, its rate of charge however being controlled by the value of resistance 28 and the plate current taken by tube 15. It will be assumed for the moment that tube 15 is not drawing any plate current. Ultimately, condenser 17 will be charged to such a value that its potential is equal to the potential of source B. As the charge approaches this value, the potential upon grid of tube 19, which was maintained highly negative by bias battery 21, will gradually be overcome and as the condenser reaches its maximum charge, the potential of grid of tube 19 will be carried beyond the knee of the curve, and the plate circuit of tube 19 will begin suddenly to take current. This current, acting through winding 26, will attract armature 22 away from contact 23 against contact 24.

It will be seen that the closure of armature 22 against contact 24 establishes a circuit from one side of condenser 17 through relay coil 33, contact 24, armature 22 to the other side of condenser 17. This condenser, it will be remembered, has just been charged to its maximum potential. It will therefore be discharged through the path just traced and the rush of current due to the discharge will draw armature 29 against contact 31, thereby energizing line 35, thereby providing for throwing the transmitter key in one direction. If desired, resistances may be inserted for slowing down the condenser discharge. More particularly, a resistance may be inserted in the

lead from armature 22 to the negative terminal of the source shown by -B. In this case only one resistance is necessary.

It may at this time be pointed out that the operation of armatures 22 and 29 is practically simultaneous. In fact, if desired, armature 29 may be omitted entirely and armature 22 used to control the transmitter, by the provision of a suitable set of contacts thereon.

It will now be seen that tube 19 and its associated circuits have been rendered inoperative. No charge can build up on condenser 17, this condenser being short-circuited by armature 22. Bias battery 21 therefore maintains the grid of tube 19 highly negative and this tube ceases to draw plate current for the time being. An identical cycle of operations then occurs with respect to tube 18; that is to say, condenser 16 begins to charge at a rate determined by resistance 27 and the current drawn by vacuum tube 14. When it attains its maximum charge, the negative bias impressed upon the grid of tube 18 by bias battery 20 will be overcome. The plate circuit of tube 18 will begin to take current, armature 22 will be retracted against contact 23 and condenser 16 will discharge through relay coil 32, thus drawing armature 29 against contact 30 and closing the other circuit to throw the armature key to the other position.

It will now be apparent that if condensers 16 and 17, tubes 18 and 19 and resistances 27 and 28 are similar, the time taken by condensers 16 and 17 to attain their maximum charge will be the same and an oscillating system will be obtained; that is to say, armatures 22 and 29 will move back and forth substantially together from left hand contacts to right hand contacts and the period of time intervening between reversals of position of armatures 22 and 29 will be determined by the value of resistances 27 and 28 and the size of condensers 16 and 17, assuming that tubes 14 and 15 draw no plate current. Under these conditions and providing the transmitter (not shown) is controlled in any suitable way, uniform impulses will be transmitted, separated by uniform spacing periods, the spacing and marking periods being equal to each other.

This condition may be regarded as the basic or starting point in explaining the function of tubes 14 and 15. If means can be provided whereby tube 14 will control the length of the marking impulses and have no effect on the spacing impulses and tube 15 can be so arranged as to control the length of the spacing impulses without affecting the marking impulses, the system will give the results desired.

It was previously stated that when armature 22 moved to the right away from contact 23, condenser 16 began to charge and when it had acquired its maximum charge,

its voltage was sufficient to entirely overcome the voltage of bias battery 20 so that the tube 18 suddenly began to take current. If, however, tube 14 is drawing current at the same time that condenser 16 is charging, since both these currents must be supplied from the source B thru resistance 27, it will be apparent that a greater length of time will be required for condenser 16 to attain its maximum charge. The amount of current drawn by vacuum tube 14 and, therefore, the time taken for condenser 16 to reach a point of maximum charge, is controlled by the intensity of light in the picture through the photo-electric cell.

For high lights, a high negative potential is impressed on the grid of tube 6 through the action of photo cell 1 and resistance 5. This cuts off the plate current flowing in tube 6 and the potential of the plate will rise due to the decrease in the drop through resistances 10, 11 and the internal resistance of the tube. This is an effect well known to those familiar with vacuum tube amplifiers.

If bias battery 9 is so chosen that as this change occurs, the potential of the grid of tube 14 will be carried to a point more positive than the point at which the tube begins to take current, then it will be seen that the amount of current taken by tube 14 will be the greater, the greater the intensity of light projected upon the photo cell and therefore the longer the time taken by condenser 16 to reach its fully charged condition.

It will be seen, assuming that vacuum tube 15 is not taking current, that the spacing and marking impulses or the operation of armatures 22 and 29 will no longer be uniform as before. The contacts will move to the left, opening the circuit around condenser 17 which will charge in the same time as before, and thereby causing the armatures to be drawn to the right hand position in the usual time.

If now the conditions with respect to tube 14 are as described, the condenser 16 will charge only slowly and the armatures will remain against the right hand contacts for a considerably longer period than before, the length of the period being controlled for the purpose of this invention by the intensity of light; that is, the more intense the light on the picture is, the greater will be the negative bias on vacuum tube 6, the greater the positive potential of the plate of vacuum tube 6 the greater the positive potential on the grid of tube 14, the greater the amount of current taken by the plate circuit of tube 14 and the longer the time taken by condenser 16 to charge.

If on the other hand, no current is drawn by tube 14, and current is drawn by tube 15, the length of time required for condenser 17 to attain a maximum charge and move the relay contacts to the right will be greatly

increased, exactly as pointed out with respect to vacuum tube 14. To provide that these two systems shall not work together; that is, to arrange that the marking periods shall not begin to increase in duration until the spacing periods have reached their minimum duration, it is only necessary to provide that when one of the tubes 14 or 15 stops taking current by reason of its grid becoming negative, the other of these two tubes is just beginning to take current; the effect of this is that in the operation of the system, either condenser 16 or 17 will always be charging at its normal rate.

The operation by which the intensity of light controls the current flow through tube 14 has already been described. The control of tube 15 is similar except that the phases are reversed. It will be remembered that for a relatively intense light, the plate of tube 6 increases its positive potential, thereby increasing the positive potential on the grid of tube 14. It will be seen that in a similar manner the positive potential on the grid of tube 7 will likewise be increased. This will cause a flow of plate current in tube 7 and a drop in potential of the plate of the said tube, thereby causing the grid of tube 15 to become sufficiently negative to prevent the flow current.

It will thus be seen that tube 14 is active in controlling the time of charge of condenser 16 for intense light on the photo cell and that tube 15 is active in controlling the rate of charge of condenser 17 when no light is thrown on the photo cell. Under this latter condition, tube 14 has been rendered inoperative by its grid becoming negative.

For the purpose of making the action more clear, it may be considered that the grids of tubes 14 and 15 are 180° out of phase. Theoretically, the grid of one of these tubes should not become sufficiently positive to allow current to flow therein until after the grid of the other has just become sufficiently negative to cut off the flow of plate current.

The action of the various tubes may be seen from Fig. 4, in which the grid voltages of tubes 6, 7, 14 and 15 are plotted for variations of light as curves *a*, *b*, *c*, and *d* respectively. The dotted vertical line represents the point at which the impulse periods are equal in duration to the spacing periods.

However, I find it advantageous not to work with plate current cut-off in tubes 14 and 15 exactly at this point, but to provide for a slight overlap, as shown by curves *c* and *d* of Fig. 4 so that the grid of one tube begins to become sufficiently positive to allow a slight plate current to flow before plate current has entirely ceased to flow in the other tube.

It may be pointed out at this time that if the amount of overlap is increased, the changes in spacing and marking time are not

independent of each other. For instance, if this overlap is greatly increased, starting with impulses of relatively short length and widely spaced, as the spacing period decreases, the impulses are increased in length, and conversely, when the impulses are relatively long and separated only by small spacing periods, as the impulses become shorter in length the spacing periods between them will increase.

I find it advantageous to work only with a slight overlap, as shown, since by so doing only one of the groups of impulses is varying in accordance with light intensity and under these conditions, it is easier to adjust the apparatus to obtain the desired results.

The reason for this is that in all representations of light intensity in terms of current, it is advantageous that the summation of the current periods shall be a true representation of the light intensity. This may be stated as meaning that there should be a linear relationship between the value of the length of time the current is on, in any given unit of time, with respect to the strength of light. It is easier to make this ratio approach the theoretically correct ratio when the spacing or marking periods are changed independently of each other, except for the limiting conditions in the center of the light scale. At this point it is necessary to have a certain amount of overlap to maintain a linear ratio between the time the current is on in a given unit of time and the light intensity, due to the bending of the tube characteristics at the limiting position. In this connection, the problem of distortion in audio frequency amplifiers, and its solution by the use of "push-pull" amplifiers, is analogous.

For some cases, I have found it desirable to avoid the use of mechanical relays in order to obtain more reliable operation, and for other reasons; and an arrangement is shown in Fig. 2 in which armature 22 and contacts 23 and 24 are eliminated and their function is performed by vacuum tube relays. In this arrangement the light sensitive cell with its associated tubes 6 and 7, resistances 10, 11 and 12, bias batteries 9 and 13 and tubes 36 and 37 are substantially identical with the arrangement shown in Fig. 1 and will not be described in detail.

Connected to the plate or output electrode of tube 36 I provide resistances 38 and 40. The positive terminal of the source of plate potential is connected to the free end of resistance 38. The other end of resistance 40 is connected to one plate of condenser 42, the other plate of which is connected to the common filament lead. To the output or plate electrode of vacuum tube 37, resistances 39 and 41 are connected in a similar way and the source of plate potential is connected to the free end of resistance 39. Condenser 43 is

connected between the other end of resistance 41 and the common filament lead. From the upper plate of condenser 43 a connection is made through relay coil 53, condenser 60 and to the plate of vacuum tube amplifier 46. The plate of vacuum tube 46 is connected to the positive side of the source of plate potential through resistance 48.

The grid of tube 46 is connected through a suitable bias battery 44 to the upper plate of condenser 42. A circuit connected to the plate of tube 36 is arranged in a similar way including relay coil 52, condenser 51 and leading to the plate of vacuum tube amplifier 47, the grid of which is connected through suitable bias battery 45, to the top plate of condenser 43. The positive terminal of the source of plate potential is connected to the plate of vacuum tube 47 through suitable resistance 49. Coils 52 and 53, armature 54 and contacts 55 and 56 and line 57 correspond to coils 32 and 33, armature 29, contacts 30 and 31, line 35 shown in Fig. 1, their purpose and structure being the same.

The basic principles of operation of this arrangement are the same as those given for Fig. 1. The left hand tube 46 determines the spacing interval, the right hand tube 47, the marking interval and plate current in these tubes is controlled by the potential existing on condensers 42 and 43 respectively. Condenser 42 is charged through resistances 38 and 40 in series. Condenser 43, in a similar manner, is charged through resistances 39 and 41 in series. Assuming for the moment that the grid of tube 36 is sufficiently negative so that this tube takes no current, it will be seen that condenser 42 will charge at a rate determined by the size of resistances 38 and 40 and the potential of the source B. The potential on the top plate of condenser 42 will rise until it begins to overcome the effect of grid bias battery 44 to allow tube 46 to draw plate current through resistance 48. This condition having been reached, we will now pass over to the right hand side of the system to tube 47, which is assumed to be at such a position on the cycle that condenser 43 now begins to charge, assuming that condenser 42 has taken its maximum charge.

Condenser 43 will charge at a rate determined by the value of resistances 39 and 41 and the potential of the source B. When condenser 43 has charged to such a value that the effect of bias battery 45 is overcome and the plate circuit of tube 47 begins to take current, a new situation develops. When the tube 47 begins to take current, it does so very rapidly, which in turn causes a sudden drop in the potential of the plate of the tube.

The right hand plate of condenser 51 is connected directly to the plate of tube 47 so that this drop, which is a drop through resistance 49 due to plate current, will be passed through condenser 51 in such a way

that condenser 51 will take a portion of the charge which has already been built up upon condenser 42. In other words, through the action of tube 47, which begins suddenly to take plate current, condenser 51 becomes suddenly active as a condenser shunted around condenser 42.

This condition may be set forth more clearly by an explanation on the basis of the electron theory. Assuming that condenser 42 is charged to its full value, there will be an excess of electrons on the lower plate of condenser 42 and a deficiency on the upper plate corresponding to the potential of the source B. As long as vacuum tube 47 is taking no current, the potential of the left hand plate of condenser 51 will be the same as that of the upper plate of condenser 42; that is to say, there will be a deficiency of electrons on this plate corresponding to the positive potential of source B. Since, however, the right hand side of condenser 51 is connected also to the positive side of source B, both plates of this condenser are at the same potential and no charge exists thereon.

Assuming that vacuum tube 47 now begins to take current in its plate circuit, there will be a rush of electrons to the plate of tube 47 and to the right hand side of condenser 51, thus partially making up for the deficiency of electrons thereon previously. The right hand plate of condenser 51 thus drops in potential, disturbing the electrostatic equilibrium between these plates and the change in equilibrium of this condenser, resulting from the flow of electrons to the right hand plate, causes a flow of electrons from the left hand plate through coil 52 to the top plate of condenser 42, thus partially neutralizing the charge already upon condenser 42. This in turn lowers the potential of the grid of tube 46 and the plate current flowing therein decreases.

However, condenser 42 immediately begins to charge again, tending to carry the grid of tube 46 to such a potential that this tube begins to take plate current again. When tube 46 begins to take plate current again, the potential of the plate of this tube begins to drop and changes the charge equilibrium of condenser 50, both sides of which were previously at the potential of the positive side of source B.

The action is identical with that previously explained with respect to condenser 51, condenser 50 becoming suddenly active as a parallel shunt to condenser 43 and taking a part of the charge from condenser 43 in the same manner in which condenser 51 took part of the charge from condenser 42.

We thus have a cycle of operations consisting of a charging of condenser 42 to such a point that tube 46 begins to take plate current, whereby the charge on condenser 43 is

partially taken by condenser 50, cutting off the flow of plate current in tube 47. Condenser 43 then begins to charge again, and when it is charged, tube 47 begins to draw plate current again, which causes condenser 51 to take a part of the charge from condenser 42, cutting off the plate current from tube 46. Condenser 42 begins to charge again and the cycle is repeated.

The time taken by condenser 42 to charge determines the period elapsing between the time when plate current begins to flow in the tube 47 and the time when it is cut off by the start of plate current of tube 46, and conversely, the time taken by condenser 43 to charge determines the period elapsing between the time when plate current begins to flow in tube 46 and the time when it is cut off by the start of plate current in tube 47.

The practical effect of this is that plate current flows in tubes 46 and 47 alternately, and the change-over is not slow and gradual, but sudden and very sharp, even when the system is producing a small number of oscillations per second.

It is evident that there must be a limiting action taking place in these cycles, such that condensers 42 and 43 never rise in their total voltage value beyond a certain point. We will assume, for example, that we have come to the point in a given cycle such that condenser 42 has its full charge so as to cause plate current to flow in tube 46. This causes condenser 50 to take a part of the charge from condenser 43 and stop the flow of plate current in tube 47 as explained above.

Under these conditions, the right hand plate of condenser 51 rises in voltage so that it virtually gives back the charge to condenser 42 which it previously took therefrom. The result of this reversing action is cumulative to cause a very rapid rise in the voltage on condenser 42, once it has attained such a charge that the effect of bias battery 44 is overcome and tube 46 begins to take plate current.

A quasi-regenerative action may be obtained by properly proportioning coils 52 and 53 by making them in the right proportion to build up the charge on condenser 42 to a higher value once it starts to rise above the potential sufficient to allow plate current to flow in tube 46. But if it remained at this high value further action would cease if it were not for the fact that a distinct limiting action takes place which prevents the charge on condenser 42 from exceeding a certain value. This is due to the fact that the grid of tube 46 is connected directly through the C battery to the top plate of condenser 42. If condenser 42 rises in potential beyond a certain point, the grid circuit of tube 46 will begin to pass current and thus operate to cause a drop in the charge in such a way that

the charge is kept from exceeding a definite limit.

This is an important factor in obtaining what I may term "pure relay action" from the system, since it always starts from the same point, and under the same conditions, regardless of whether the preceding period has been long or short. The effect of this is that one side of the system, for instance, the marking side, will control the duration of the marking periods strictly in accordance with light intensity, regardless of what may be the conditions in the spacing side, and vice versa.

The various resistances are so proportioned that this condition is always realized. In other words, when condenser 51 gives back a charge direct to condenser 42, any excess charge will pass off through the grid circuit of tube 46 so that there is always a definite and identical starting point. The same is true for tube 47 and condenser 43. To assist this action I find that it is sometimes of advantage to have tubes 46 and 47 so constructed as to be able to pass a comparatively large amount of grid current. A satisfactory way of providing for this is to use tubes having a larger number of turns of wire in the grid than is usually found in the common types of tubes now on the market, but obviously this result may be obtained in other ways, as for instance by the use of a woven screen grid, perforated plate grid, or the like.

The marking and spacing intervals may be varied as in the arrangement shown in Fig. 1 by tubes 36 and 37. The greater the plate current taken by tube 36, the longer it will take for condenser 42 to reach its maximum charge and initiate the next portion of the cycle, and the same is true of tube 37.

Armature 54 is thrown from contact 56 to contact 55 and back again by the surge of current through coils 52 and 53 whenever the condensers 42 and 51 and 43 and 50 respectively divide their charges, as explained above. Obviously this relay may control the transmitter directly or it may be used to control a second relay which controls the transmitter. It is of advantage to use a second relay to control the transmitter to act as a "bug trap", well known in the telegraph art, to prevent reactions from the line connections into the tube circuits, and also to enable relay 54 to be operated with lower currents than would be permissible if this relay were required to control the transmitter circuit directly.

For the purpose of completing this disclosure, but not of limiting myself to the values given, I append a table showing the values of the resistances, capacities, potentials of various batteries, etc. in the above apparatus, which I have found by trial to give satisfactory results, when the tubes are

those known to the trade as Radiotron 201-A.

	Resistances	Ohms	Capacities	Microfarads	Batteries	Voltage
5	5	20 Megohms	16	0.1	8	64
	10	100,000	17	0.1	9	44
	11	75,000	42	0.1	13	34
	12	100,000	43	0.1	20	48
	38	30,000	50	0.5	21	30
	39	20,000	51	0.5	B	120
	40	50,000	-----	-----	44	48
	41	50,000	-----	-----	45	30
	48	15,000	-----	-----	-----	-----
	49	15,000	-----	-----	-----	-----
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For the sake of simplifying the diagrams and descriptions, I have omitted various parts and circuits which are used in practice, such as filament heating sources, filament rheostats and the like, but as these matters are common knowledge in the art, I think it unnecessary to describe them.

While I have shown and described my invention with sufficient particularity to enable those skilled in the art to practice the same and obtain the benefits thereof, various modifications and changes may be made as will be apparent to those skilled in the art without departing from the spirit and scope of my invention.

Having fully described my invention, what I claim is:

1. A method of representing variations of light intensity by electric current which consists in translating values of light intensity lying on one side of a predetermined light intensity into impulses varying in duration according to light intensity and separated by periods of substantially uniform duration, and translating light intensities lying on the other side of said predetermined light intensity into impulses of substantially uniform duration separated by periods varying in duration according to light intensity.

2. A method of expressing variations of light intensity in terms of electric current which consists in translating varying light intensities into current impulses, light intensities at one end of the scale being represented by impulses of substantially uniform duration separated by periods exceeding in duration the duration of said impulses, and light intensities lying on the other end of said scale being represented by impulses separated by periods of substantially uniform duration, the duration of said impulses exceeding the duration of the separating periods.

3. A method of expressing variations of light intensity in terms of electric current which consists in translating light intensities into marking periods separated by spacing periods, and varying the duration of the periods of one group while maintaining the periods of the other substantially constant to correspond to variations of light intensity in one band of intensities and varying the duration of the previously unvaried periods while

maintaining the previously varied period substantially constant to correspond to variations of light intensity lying within a different band of light intensities.

4. A method of expressing variations of light intensity in terms of electric current which consists in representing values of light intensity lying at one end of the scale by current impulses separated by spacing periods, the duration of the periods defined either by the impulse or the spacing being considerably greater than the duration of the period defined by the other, and decreasing the duration of the longer period progressively with progressive changes in light intensity until periods of substantially equal duration are obtained and then increasing the duration of the other period progressively with further changes in light intensity.

5. A method of expressing variations of light intensity in terms of electric current which consists in representing values of light intensity lying at one end of the scale by current impulses separated by spacing periods, the duration of the periods defined either by the impulse or the spacing being considerably greater than the duration of the period defined by the other, and decreasing the duration of the longer period while maintaining the duration of the shorter period substantially constant until periods of substantially equal duration are obtained, then for further changes in light intensity, increasing the duration of the period previously maintained constant while maintaining substantially constant the periods previously decreased in duration.

6. A method of representing variations of light intensity in terms of electric current which consists in normally producing current impulses of substantially uniform duration and separated by spacing periods of substantially uniform duration, the duration of the current impulses having a predetermined ratio to the duration of the spacing periods, for a predetermined intensity of light, and varying said ratio in the direction of increase for variations of light intensity in one direction away from said predetermined value of light intensity while maintaining one of said impulse and space periods constant and varying said ratio in the direction of decrease for variations in light intensity in the other direction from said predetermined value of light intensity while maintaining the other of said impulse and space periods constant.

7. In apparatus for translating variable light intensities into electric impulses, the combination of means for producing periodic impulses normally of substantially equal duration and separated by periods of substantially equal duration, and the duration of the impulses normally being equal to the duration of the separating periods, and means for

varying the duration of either of said periods and producing impulses of equal duration variably spaced for light intensities lying on one side of a predetermined normal intensity and impulses of variable length equally spaced for light intensities lying on the other side of said normal intensity.

8. In apparatus for translating variable light intensities into electric impulses, the combination of means for producing periodic impulses normally of substantially equal duration and separated by periods of substantially equal duration, and the duration of the impulses normally being equal to the duration of the separating periods, and means for varying the duration of either of said periods, independently of the other.

9. In apparatus for translating variable light intensities into electric impulses, the combination of means for producing periodic impulses normally of substantially equal duration and separated by periods of substantially equal duration, and the duration of the impulses normally being equal to the duration of the spacing periods, and means for varying the duration of either of said periods while maintaining the other constant.

10. In apparatus for translating variable light intensity into variations of electric current, the combination of means for producing periodic impulses normally equal in length and separated by spacing periods normally equal in length, the time duration of the impulses normally having a predetermined ratio to the time duration of the separating periods and means for varying the said ratio in either direction in accordance with intensities of light while maintaining one quantity in the ratio constant in each direction of change.

11. In apparatus for translating variable light intensity into variations of electric current, the combination of means for producing periodic impulses normally equal in length and separated by spacing periods normally equal in length, the time duration of the impulses normally having a predetermined ratio to the time duration of the separating periods for a predetermined intensity of light and means for increasing the said ratio while maintaining one of said spacing and impulse periods constant for values of light intensity on one side of said predetermined value and for decreasing said ratio while maintaining the other of said spacing and impulse periods constant for values of light on the other side of said predetermined value of light intensity.

12. In modulating apparatus, the combination of a pair of separate storing means for storing predetermined quantities of electricity, means for supplying electricity to both of said storing photoelectric controlled thermionic means at a predetermined normal rate and means for varying the rate of

supply of electricity to either of said storing means independently of the other.

13. In modulating apparatus, the combination of a plurality of means for storing predetermined quantities of electricity, means for supplying electricity to said plurality of means at a predetermined normal rate, and means controlled by light intensity for varying the rate of supply of electricity to one of said storing means independently.

14. In modulating apparatus, the combination of a plurality of separate means for storing electricity, means for supplying electricity to each of said storing means at a predetermined normal rate and means controlled by light intensity for varying the rate of supply of electricity to any of said storing means independently.

15. In apparatus for translating variations of light intensity into variations of electric current, the combination of a plurality of separate means for storing electricity, means for supplying electricity to said storing means at a predetermined normal rate and means controlled by light intensity for selectively varying the rate of supply of electricity to any one of said electricity storing means independently.

16. In apparatus for translating variations of light intensity into variations of electric current, the combination of a pair of means for storing electricity, means for supplying electricity to said storing means at a predetermined normal rate and means controlled by light intensity for varying the rate of supply of electricity to one of said storing means in accordance with light intensity for variations of light intensity on one side of a predetermined value of light intensity and for varying the rate of supply of electricity to the other of said storing means in accordance with variations in intensity of light lying on the other side of said predetermined light intensity.

17. In apparatus for translating variations of light intensity into variations of electric current, the combination of a plurality of separate means for storing electricity, means for supplying electricity to each of said storing means at a predetermined rate, a variable resistance path in circuit with each of said storing means and means controlled by light intensity for varying the resistance of any of said paths independently.

18. In apparatus for translating variations of light intensity into variations of electric current, the combination of a plurality of separate means for storing electricity, means for supplying electricity to each of said storing means at a predetermined rate, a variable resistance path shunted around each of said storing means and means controlled by light intensity for varying the resistance of any of said paths independently.

19. In a modulator, the combination with a pair of current controlling devices, of current-responsive means associated with each current controlling device for preventing
5 flow of current therethrough in response to predetermined flow of current therethrough and for simultaneously initiating operation of the other current controlling device.

20. In a modulator, the combination with
10 a pair of current-controlling devices of current responsive means associated with each of said current controlling devices and operative in response to predetermined current
15 flow in either of said current controlling devices to interrupt the flow of current therein and to initiate operation of the other current controlling device.

21. In a modulator, the combination with a pair of current controlling devices of current responsive means associated with each
20 of said current controlling devices and operative in response to predetermined current flow in either of said current controlling devices to interrupt the flow of current therein, and
25 to initiate operation of the other current controlling device and means associated with one of said current controlling devices for controlling the operation thereof in accordance with an external condition.

30 22. In a modulator, the combination with a pair of current controlling devices of current responsive means associated with each of said current controlling devices and operative in response to predetermined current
35 flow in either of said current controlling devices to interrupt the flow of current therein, and to initiate operation of the other current controlling device and means associated with each of said current controlling devices for
40 controlling the operation thereof in accordance with an external condition.

23. In a modulator, the combination with a pair of thermionic relays each having a control electrode of a pair of variable potential
45 difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of
50 said relays to fix the potential of one of said variable potential difference devices to interrupt the flow of current in said relay, and to permit the potential difference of the other variable potential difference device to vary
55 to initiate current flow in the other of said relays.

24. In a modulator, the combination of a pair of thermionic relays, each having a control electrode, of a pair of variable potential
60 difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of
65 said relays to fix the potential of one of said

variable potential devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential difference device to vary to initiate
70 current flow in the other of said relays, and means for controlling the variation of potential difference in said device according to an external condition.

25. In a modulator, the combination of a pair of thermionic relays, each having a control electrode, of a pair of variable potential
75 difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of
80 said relays to fix the potential of one of said variable potential devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable
85 potential difference device to vary to initiate current flow in the other of said relays, and means for controlling the variation of potential difference in either of said devices, according to an external condition.

26. In a modulator, the combination of a pair of thermionic relays, each having a control electrode of a pair of variable potential
90 difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of
95 said relays to fix the potential of one of said variable potential devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential device to vary to initiate current flow
100 in the other of said relays, a pair of variable resistance devices, one associated with each of said variable potential difference devices and means for controlling the effective resistance of each of said variable resistance devices.

27. In a modulator, the combination of a pair of thermionic relays, each having a control electrode of a pair of variable potential
110 difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of
115 said relays to fix the potential of one of said variable potential devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential device to vary to initiate current flow
120 in the other of said relays, a pair of variable resistance devices, one associated with each of said variable potential difference devices and means for selectively varying the effective resistance of either of said variable resistance devices in accordance with external conditions.

28. In a modulator, the combination of a 130

pair of thermionic relays, each having a control electrode of a pair of variable potential difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of said relays to fix the potential of one of said variable potential devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential device to vary to initiate current flow in the other of said relays, a pair of variable resistance devices, one associated with each of said variable potential difference devices and means for selectively varying the effective resistance of either of said variable resistance devices while maintaining the resistance of the other constant, in accordance with external conditions.

29. In a modulator, the combination of a pair of thermionic relays, each having a control electrode, of a pair of variable potential difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of said relays to fix the potential of one of said variable potential devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential device to vary to initiate current flow in the other of said relays, a pair of variable resistance devices, one associated with each of said variable potential difference devices and means for varying the effective resistance of one only of said variable resistance devices in accordance with changes in external conditions within a predetermined range, and for varying the effective resistance of the other only for changes in external conditions within another predetermined range.

30. In a modulator, the combination with a pair of thermionic relays each having a control electrode, of a pair of variable potential difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of said relays to fix the potential difference of one of said variable potential difference devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential difference device to vary to initiate current flow in the other of said relays and means associated with each of said variable potential difference devices for selectively controlling the rate of change of potential difference in one of said variable potential difference devices in accordance with external conditions.

31. In a modulator, the combination with

a pair of thermionic relays each having a control electrode, of a pair of variable potential difference devices for controlling the operation of said thermionic relays, and current responsive means associated with each of said thermionic relays and operative in response to predetermined current flow in either of said relays to fix the potential difference of one of said variable potential difference devices to interrupt the flow of current in said relay and to permit the potential difference of the other variable potential difference device to vary to initiate current flow in the other of said relays and means associated with each of said variable potential difference devices for selectively controlling the rate of change of potential difference in one of said variable potential difference devices in accordance with external conditions while maintaining the potential difference in the other constant.

32. In a photo-modulator, the combination of a pair of variable resistance devices, a light-sensitive cell, and means associated with said cell and said variable resistance devices for controlling the effective resistance of one of said variable resistance devices in accordance with light intensity while maintaining the effective resistance of the other constant, for changes in light intensity within a predetermined range, and for controlling the effective resistance of the variable resistance devices previously maintained constant while maintaining constant the effective resistance of the variable resistance devices previously varied, for changes in light intensity within a predetermined different range.

33. In a photo-modulator, the combination of a pair of thermionic vacuum tubes each having a control electrode, a light sensitive cell, and means associated with each of said thermionic tubes and said cell for varying the potential of the control electrode of one of said tubes within a range effective to vary the flow of space current in accordance with changes in light intensity and for maintaining the potential of the control electrode of the other sufficiently negative to substantially prevent the flow of space current therein for changes of light intensity within a predetermined range and for maintaining the potential of the control electrode previously varied, sufficiently negative to substantially prevent the flow of space current in the tube controlled thereby and for varying the potential of the control electrode previously maintained negative to vary the flow of space current in the tube controlled thereby in accordance with changes in light intensity within a predetermined different range.

34. In a facsimile system, means for translating light values into current impulses, means for producing varying duration pulses equally spaced for light values on one side of a predetermined intensity, and means for pro-

ducing equal duration pulses variably spaced for light values on the other side of said predetermined intensity.

5 35. In combination, a pair of elements for storing predetermined quantities of electrical energy supplied thereto, and means for varying the rate of supply of electrical energy to each of said storing means independently of the other.

10 36. In combination, a pair of elements for storing predetermined quantities of electrical energy supplied thereto, and photoelectrically controlled means for varying the rate of supply of electrical energy to each of said storing means independently of the other.

15 37. In a facsimile system, means for translating light values into current impulses, and means for producing varying duration pulses equally spaced for representing light values on one side of a predetermined light intensity.

20 38. In a facsimile system, means for translating light values into current impulses, and means for producing equal duration pulses variably spaced for light values lying on one side of a predetermined light intensity.

25 39. In a facsimile system, means for translating light values into current impulses and representing the impulses on a recording surface as dots and dashes, and means for arbitrarily changing the representation between said dots and dashes in accordance with variance of the light intensity from a predetermined arbitrarily chosen light value.

30 40. In a facsimile system, means for resolving varying intensities of light and shadow on a picture record into electric current impulses, and means for producing equal duration pulses variably spaced for all light values lying on one side of a predetermined chosen light value.

40 41. In a facsimile system, means for translating varying intensities of light and shadow on a record surface to be transmitted into proportionately varied strength electric current impulses, and means for arbitrarily representing said light values as dots and dashes in accordance with the variance of the intensity of light and shadow on the record surface from a predetermined light intensity.

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