May 12, 1970 D. F. LOMBARDO 3,511,995

AUTOMATIC SHUTTER CONTROL FOR MAINTAINING CONSTANT A PREDETERMINED IMAGE FIELD SIZE

Filed Aug. 16, 1967

2 Sheets-Sheet 1

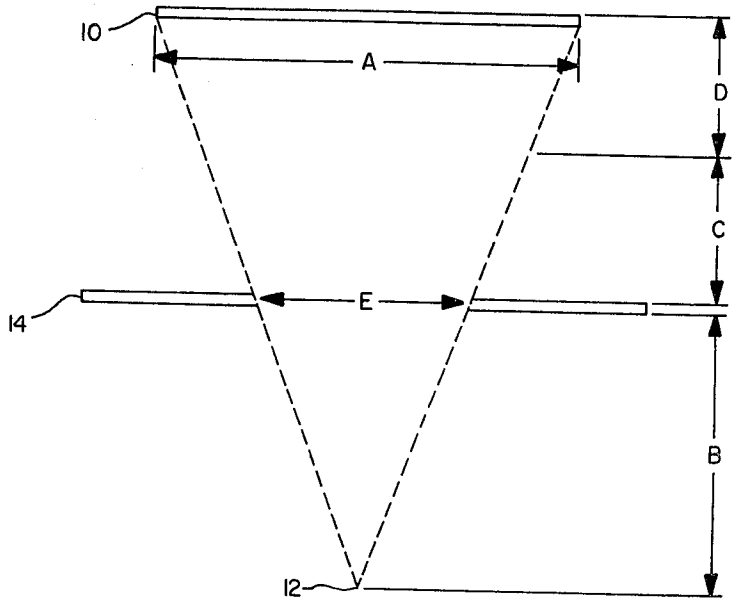


FIG. 1

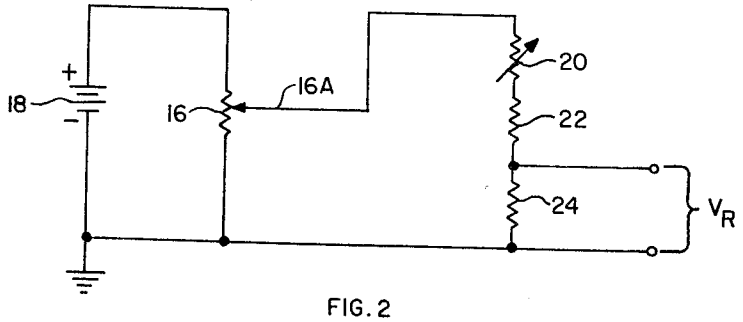


FIG. 2

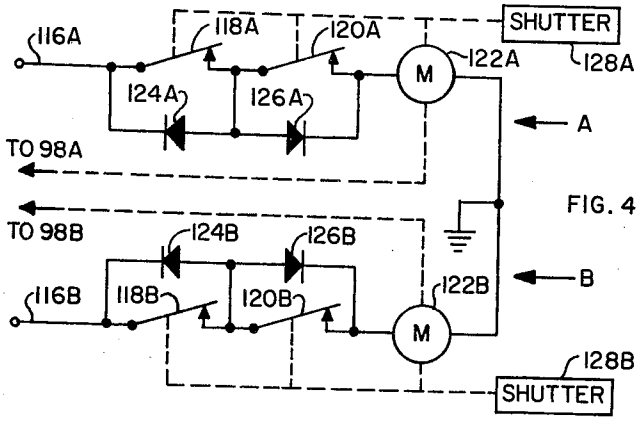


FIG. 4

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2 Sheets-Sheet 2

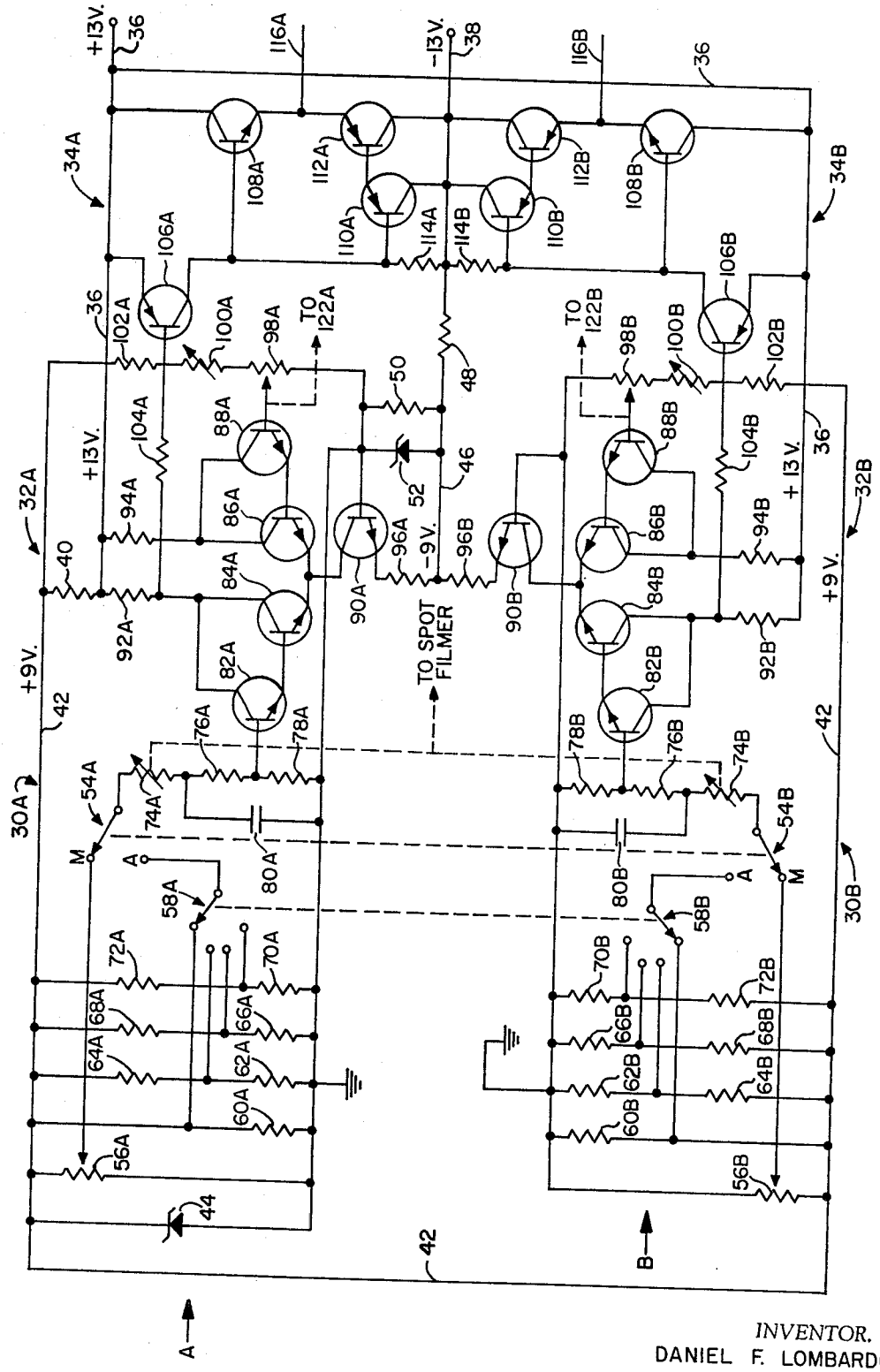


FIG. 3

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United States Patent Office 3,511,995
Patented May 12, 1970

3,511,995

AUTOMATIC SHUTTER CONTROL FOR MAINTAINING CONSTANT A PREDETERMINED IMAGE FIELD SIZE

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Filed Aug. 16, 1967, Ser. No. 660,962
Int. Cl. H05g 1/00
U.S. Cl. 250—93 12 Claims

ABSTRACT OF THE DISCLOSURE

Shutter opening for delineating the size of an X-ray beam is controlled electronically by a servo circuit to maintain constant a predetermined image field size as distance between the shutter and image plane is varied. Field size may be manually selected or one of a number of preselected field sizes may be chosen.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to X-ray apparatus and, more particularly, to automatically operated shutters for use in such apparatus to maintain constant a predetermined image field size as distance between the shutters and image plane is varied.

Description of the prior art

In known types of X-ray and fluoroscopic apparatus, radiation from an X-ray tube passes through a quadrangular opening whose two dimensions are defined by opposed edges of a pair of movable shutters. The radiation then passes through a portion of the body of a patient under examination, in the case of a medical application, and impinges on an X-ray sensitive film or fluorescent viewing screen. The distance between the shutters and the X-ray tube is generally constant, but the distance from the shutters to the X-ray sensitive film or screen must be variable. This latter requirement arises because it is desirable to have the film plane (also referred to herein as the image plane) as close to the patient as possible. If it is assumed that the position of the patient being X-rayed is fixed with respect to the position of the shutters, it is apparent that the distance of the image plane from the shutters will vary depending upon the size of the patient and the portion of the patient's body being examined. For example, if a patient's hand or arm is being examined, the image plane will be closer to the plane of the shutters than if a thicker portion such as the trunk of the patient's body is being examined.

It is often desirable to maintain a fixed image field size on the X-ray sensitive film or screen, even though the distance between the image plane and the shutter plane is varied for different applications. This has normally been done manually by physically adjusting the shutters. In the case of X-ray photography as opposed to fluoroscopy, it has been exceedingly difficult, if not impossible, to adjust the shutter openings to the proper size, because of the lack of a visible image in the image or film plane. Therefore, it has been customary to perform X-ray photography with the shutters in an over open or even full open position. This is undesirable in many cases because it exposes a greater portion of the patient's body to potentially dangerous X-ray radiation than is necessary to produce the required size of image. In addition, it may expose the operator to the direct X-ray beam if the field size is larger than a shielded portion of a spot filmer or the like.

SUMMARY OF THE INVENTION

In accordance with the present invention, two servo systems are provided for independently controlling the length and width of the shutter opening. In each system, two variable voltages are provided, which are respectively proportional to a desired image field size dimension and to the distance of the image plane from the X-ray tube. These two voltages are provided in analogue circuitry, which produces a third voltage proportional to the proper shutter opening in a corresponding dimension.

The third or shutter reference voltage is supplied along with a voltage that is proportional to the actual shutter opening in the corresponding dimension, to a differential amplifier, which produces an output voltage that is proportional to the difference between its two input voltages. The output voltage of the differential amplifier is used to control a power amplifier, which supplies current to the armature of a direct current (D.C.) motor that mechanically opens and closes the shutter. The power amplifier has the capability of reversing the polarity of the current supplied to the motor, thus allowing it to be driven in either direction. If the two inputs to the differential amplifier are not equal, the power amplifier supplies current to the D.C. motor to drive it in a proper direction to correct the shutter opening. When the shutter has the correct opening, the two signals applied to the differential amplifier are equal and the output signal to the power amplifier will be such as to apply no driving current to the motor.

Each shutter can be controlled manually by adjusting a potentiometer to provide an output voltage proportional to a desired image field dimension. In addition, fixed voltages corresponding to various image field dimensions can be selected by means of a selector switch for automatic shutter size adjustment.

It is again pointed out that two servo circuits are provided, so that the length and width of the shutter opening can be individually controlled. Each comprises circuitry for providing a voltage proportional to the proper shutter opening in one dimension, a differential amplifier, a power amplifier and a D.C. motor, as previously described.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram useful in understanding the geometric considerations involved in practicing the invention;

FIG. 2 is a simplified schematic drawing of circuitry for developing a reference voltage that is a function of an image field dimension and distance between the image plane and an X-ray tube;

FIG. 3 is a schematic diagram illustrating a complete automatic shutter control (except for power supplies) embodying the invention; and,

FIG. 4 is a schematic diagram showing connections of motors that open and close the shutters.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates the geometry necessary to an understanding of the invention. Although only a two-dimensional diagram is shown, it is understood that a third dimension is involved. In other words, only one dimension of the two dimensions (length and width) that define the shutter opening size and image field size are shown. A similar diagram could be drawn using height as one dimension and the other shutter opening and field dimensions as its other dimensions. As shown, A represents a desired image field dimension (a variable) in an image plane **10**. B represents distance from a point source **12** (X-ray tube) to a shutter plane **14** (a constant). C represents a minimum allowable distance between the

image plane **10** and the shutter plane **14** (a constant). D represents distance between the plane **10, 14** (a variable) minus the distance C, and E represents on dimension of the shutter opening (a variable).

The following proportionality equations can be written for the diagram of FIG. 1:

$$\frac{E}{A}=\frac{B}{B+C+D} \quad (1)$$

or

$$E=\frac{AB}{B+C+D} \quad (2)$$

It is noted that Equation 2 has the same form as the well-known electrical equation $I=V/R$, where I is current flowing through a resistance R, and V is voltage applied across the resistance R. It follows then that Equation 2 can be set up using electrical parameters rather than spacial parameters. FIG. 2 shows a simple analogue circuit that may be used for solving that equation.

As shown, a potentiometer **16** having a movable arm **16A** is connected across a source of direct current, shown as a battery **18**. The negative side of the battery **18** is grounded. The position of the movable arm **16A** of the potentiometer determines the voltage applied to the remainder of the circuit, and it is set to obtain a voltage that corresponds to the term A in Equation 2. The terms in the denominator of Equation 2 are represented by series-connected resistors **20, 22, 24** connected between the potentiometer arm **16A** and ground. The resistor **20** is variable, and the resistors **22, 24** are of fixed value. The variable resistor **20** represents the variable distance D in Equation 2 and the resistors **22, 24**, respectively represent the constant distances B and C in that equation. The current that flows through the resistors **20, 22, 24** is a function of their resistance values and the potential applied across them from the arm **16A** of the potentiometer **16**. That current is a measure of the desired shutter opening E in Equation 2. A potential V_R representing that shutter opening is taken from across the resistor **24**, and is proportional to the current flowing through the resistors.

FIG. 3 is a schematic diagram of an automatic shutter control embodying the invention. As previously mentioned, two servo circuits are provided so that the length and width of the image field can be individually controlled. As shown in FIG. 3, the two servo systems or channels are designated generally as A and B. Inasmuch as the circuitry of the channels A, B is identical, a detailed description will be given of channel A only. In the drawing, the elements of the circuitry of channel A are designated by reference numerals having a suffix A, and corresponding elements in channel B have similar reference numerals with the suffix B. The analogue computing circuitry shown in simplified form in FIG. 2 is shown in FIG. 3 in a more detailed form, and is generally designated as **30A**. The differential amplifier previously referred to is designated generally by the numeral **32A**, and the power amplifier for supplying power to the shutter drive motor is designated generally as **34A**. The motors which are driven by the outputs of the power amplifiers **34A, 34B** are shown in FIG. 4, which is to be considered in conjunction with the following description of FIG. 3.

Power is supplied for the circuitry from one or more direct current power sources (not shown), which are connected to supply +13 volts on a line **36** and −13 volts on a line **38**. The line **36** is connected through a resistor **40** to a line **42**, which is in turn connected to ground through a Zener diode **44**. The line **42** is maintained at +9 volts by the breakdown action of the Zener diode **44**. The line **38** is connected to a line **46** through a resistor **48**, and the line **46** is connected to ground through a resistor **50** and a Zener diode **52** connected in parallel. The Zener diode **52** maintains the line **46** at −9 volts.

The analogue circuitry **30A** provides a shutter reference voltage to the differential amplifier **32A**. The shutter reference voltage is proportional to a proper shutter opening in one dimension as a function of the distance of the image plane from the X-ray tube and as a function of a desired image field size in a corresponding dimension, as described with reference to FIGS. 1 and 2. A voltage proportional to a desired image field dimension may be adjusted manually or various voltages proportional to various dimensions can be selected by means of a selector switch for automatic shutter opening adjustment. Either manual or automatic operation is selected by a single-pole, two-contact switch **54A**, whose movable pole is mechanically connected to a pole of a similar switch **54B** in channel B. One contact of the switch **54A** is connected to the movable arm of a potentiometer **56A** connected between the line **42** and ground. The movable arm of the potentiometer **56A** may be adjusted manually to provide a voltage on the pole of the switch **54A** that is proportional to a desired image field size dimension when the switch **54A** is in the "Manual" position shown. The second contact of the switch **54A** is connected to a pole of a single-pole, multiple-contact switch **58A**, which is ganged to a similar switch **58B** in channel B. When the switch **54A** is in its "Automatic" position, the pole of the switch **54A** is connected to the pole of the switch **58A**.

The various contacts on the switch **58A** are connected to a plurality of voltage dividers to provide different voltages to the pole of that switch that are porportional to various preselected values of the chosen dimension of the image field. For example, a first contact of the switch **58A** is connected directly to the line **42** and to ground to a resistor **60A**. A second connector of the switch is connected to the juncture of resistors **62A, 64A** connected in series between the line **42** and ground; a third contact is connected to the juncture of resistors **62A, 68A** similarly connected between the line **42** and ground; and a fourth contact is connected to the juncture of resistors **70A, 72A** connected in series between the line **42** and ground. Thus, various preselected voltages may be provided from the pole of the switch **52A** to the pole of the switch **54A**, when the switch **58A** is in the "Automatic" operation position. Similar voltage dividers are provided for the switch **58B** in channel B.

The pole of the switch **54A** is connected to ground through a series combination of a variable resistor **74A** and fixed resistors **76A, 78A**. A capacitor **80A** is connected across the series-connected resistors **76A, 78A**. A juncture point of the resistors **76A, 78A** is connected to the base of an NPN transistor **82A** in the differential amplifier **32A**. The variable resistors **74A, 74B** in channels A and B are mechanically connected together and, through suitable gearing (not shown), to mechanism (not shown) for holding an X-ray sensitive film and defining the image plane **10** (FIG. 1). Such a film holding mechanism is commonly known in the art as a "spot filmer." The spot filmer is mounted for movement toward and away from an X-ray tube **12**, through the distance D shown in FIG. 1. As the spot filmer moves through the distance D, it mechanically adjusts the variable resistors **74A, 74B** to reflect its position in terms of their resistances. Such an arrangement is described in detail in application Ser. No. 656,448, filed July 27, 1967 by E. A. Norgren and entitled, "X-Ray Apparatus Including Counterbalancing Mechanism for Spot Filmer or the Like." Variations in the resistance of the resistor **74A** cause variations in the voltage drop across the resistor **78A**. The resistors **74A, 76A, 78A** respectively correspond to the resistors **20, 22, 24** shown in FIG. 2 and the voltage supplied across the resistor **78A** to the base of the transistor **82A** corresponds to the shutter reference voltage V_R as shown in FIG. 2. The various voltages provided to the pole of the switch **54A**, either from the manually adjustable potentiometer **56A** or through the switch **58A**, correspond to the voltage on the movable arm **16A** of the potentiometer **16** shown in FIG. 2. In view of the expla-

nation of the operation of such a circuit in connection with FIG. 2, it is not believed necessary to repeat it again. Suffice it to say that the potential provided on the base of the transistor 82A is proportional to a desired shutter opening in one dimension corresponding to a desired image field size in the corresponding dimension. The same explanation, of course, is applicable to channel B, wherein the voltage provided on the base of the transistor 82B is proportional to a desired shutter opening in another dimension corresponding to a desired image field size in that same dimension.

The differential amplifier 32A provides a signal to the power amplifier 34A to cause the motor driven by the power amplifier to rotate in the proper direction to adjust the shutter opening to a desired size. The power amplifier will provide no power to the motor if the shutter is correctly adjusted. The differential amplifier 32A comprises the transistor 82A and four NPN transistors 84A, 86A, 88A, 90A. The collector of the transistor 82A is connected directly to the collector of the transistor 84A and to the positive potential line 36 through a load resistor 92A. The emitter of the transistor 82A is connected directly to the base of the transistor 84A. The collectors of the transistors 86A, 88A are connected together and to the line 36 through a load resistor 94A. The base of the transistor 86A is connected directly to the emitter of the transistor 88A. The emitters of the transistors 84A, 86A are connected together and the collector of the transistor 90A. The base of the transistor 90A is connected directly to ground, and the emitter of that transistor is connected to the negative potential line 46 through a load resistor 96A. The transistor 90A serves as a fixed current source for the transistors 84A, 86A. The base of the transistor 88A is connected to the movable arm of a potentiometer 98A, which is connected in series through a variable calibration resistor 100A and a fixed resistor 102A to the line 42. The output from the differential amplifier 32A is taken directly from the collector of the transistor 84A and supplied through an "anti-hunt" resistor 104A to the base of an amplifier transistor 106A in the power amplifier 34A. The movable arm of the potentiometer 98A that supplies potential to the base of the transistor 88A is mechanically connected to be positioned by the motor that drives the shutter corresponding to the dimension controlled by channel A. Thus, the voltage present on the movable arm of the potentiometer 98A is made directly proportional to the actual or existing opening of the shutter in the chosen single dimension. Similarly, in channel B, the voltage present on the movable arm of the potentiometer 98B is directly proportional to the actual or existing opening of the second shutter in the second dimension.

The power amplifier 34A comprises the transistor 106A, an NPN transistor 108A, and two PNP transistors 110A, 112A. As previously noted, the base of the transistor 106A is connected to receive the output signal from the differential amplifier 32A. The emitter of the transistor 106A is connected directly to the positive potential line 36. The collector of the transistor 106A is connected directly to the bases of the transistors 108A, 110A and to the negative potential line 38 through a load resistor 114A. The collector of the transistor 108A is connected directly to the line 36 (+13 volts), and the collector of the transistor 112A is connected directly to the line 38 (−13 volts). The emitters of the transistors 108A, 112A are connected together and to a motor supply line 116A. The motor supply line 116A is connected through limit switches 118A, 120A to one end of the armature of a motor 122A, the other end of the motor armature being grounded. A diode 124A is connected across the limit switch 118A, and a diode 126A is connected across the limit switch 120A, the diodes 124A, 126A being connected with opposite polarity. The motor 122A is mechanically connected to open and close a shutter 128A, which is also mechanically connected to the limit switches 118A, 120A. The shutter 128A will be opened or closed depending upon the direction of current through the armature of the motor 122A. The shutter 128A is mechanically connected to open the limit switches 118A, 120A, respectively, when the shutter reaches its full-open and full-closed positions. The purpose of the diodes 124A, 126A shunting the limit switches is to permit the shutter 128A to move in its closing direction after the full-open limit switch has been opened, and to permit the shutter to move in its opening direction after the full-closed limit switch has been actuated. For example, if the limit switch 118A is open, the motor 128A may still be energized through the limit switch 120A and the diode 124A to cause it to move the shutter in a closing direction to close the limit switch 118A. Similarly, if the limit switch 120A is open, the motor may be energized through the switch 118A and the diode 126A to move the shutter in an opening direction and thus close the switch 120A

In operation, the potentials on the bases of the transistors 82A, 88A in the differential amplifier 32A will be equal to each other when the shutter opening is of the proper size in the dimension controlled by channel A. In this condition, the transistors 82A, 84A, 86A, 88A are all conducting to some extent. The potential on the collector of the transistor 84A which is somewhat less than +13 volts because of the voltage drop across the resistor 92A, is supplied to the base of the transistor 106A in the power amplifier 34A. This potential causes the transistor 106A to be partially conductive, so that its collector is essentially at ground potential. This places the bases of the transistors 109A, 110A also at ground potential, and causes both of those transistors to be non-conductive. The variable calibration resistor 100A is adjusted to obtain this condition when the shutter opening is correct. When the transistor 110A is non-conductive, the transistor 112A assumes the same condition. It is seen that when both transistors 108A and 112A are non-conductive, no current can flow in either direction through the motor supply line 116A. Thus, the motor 122A has no power supplied to it and it does not rotate. The opening in the shutter 128A and the position of the arm of the potentiometer 98A remain fixed.

If now the potential applied to the base of the transistor 82A becomes more positive than the voltage on the base of the transistor 88A, either because of a change in the desired field size dimension or in the distance of the spot filmer from the X-ray tube, the differential amplifier 32A becomes unbalanced. The transistors 82A, 84A will go into full conduction, and the transistors 86A, 88A will be cut off. When the transistors 82A, 84A go into full conduction, the potential on the collector of the transistor 84A drops, which causes the transistor 106A to go into full conduction. When the transistor 106A is fully conducting, the base of the transistor 108A goes positive and causes that transistor to become fully conductive. At the same time, the base of the transistor 110A goes more positive, which causes the transistors 110A, 112A to remain cut off. Current thus flows from the +13 volt line 36 through the transistor 108A, through the motor supply line 116A, and through the armature of the motor 122A to ground to cause the motor to rotate at full speed in a first direction. As the motor 122A rotates to change the opening in the shutter 128A, it also causes the arm of the potentiometer 98A to move until the voltage on the base of the transistor 88A is the same as that on the base of the transistor 82A. When this occurs, the differential amplifier is again in a balanced condition and no further power will be supplied to the motor 122A until the differential amplifier 32A is again unbalanced.

Assume now the condition wherein the voltage on the base of the transistor 82A becomes less positive than that on the base of the transistor 88A. In that case, the transistors 86A, 88A go into full conduction, which causes the transistors 82A, 84A to be cut off. When the tran-

sistors **82A**, **84A** are cut off, the potential provided to the base of the transistor **106A** rises to +13 volts because there is no voltage drop across the resistor **92A**, and conduction through the transistor **106A** is cut off. When the transistor **106A** is cut off, the potential on the bases of the transistors **108A**, **110A** drops to −13 volts. This causes the transistor **108A** to remain cut off, and causes the transistors **110A**, **112A** to become fully conductive. Thus, current flows from ground through the armature of the motor **122A**, the line **116A** and the transistor **112A** to the −13 volt line **38**. The motor **122A** rotates at full speed in a second direction to vary the opening of the shutter **128A** and simultaneously to reposition the arm of the potentiometer **98A** until the differential amplifier **32A** is again in a balanced condition. When that balanced condition is obtained, the transistors **110A**, **112A** will become non-conductive and rotation of the motor **122A** will stop.

If for some reason the circuit should not operate properly and tend to drive the shutters beyond their full-closed positions, one of the limit switches **118A**, **120A** will be opened to prevent further movement of the shutter **128A** in that direction. However, as previously noted, because of the diodes **124A**, **126A**, the motor **122A** can be driven in a reverse direction to correct the overdriving condition.

The circuitry of channel B operates in the same manner as that of channel A to energize the motor **122B** to vary the opening in the shutter **128B** and move the arm of the potentiometer **98B** until the potentials on the bases of the transistors **82B**, **88B** are equal and the differential amplifier **32B** is balanced. Of course, channel B controls the shutter opening in a second dimension at right angles to the dimension controlled by channel A. The shutters **128A**, **128B** act together to define a square or rectangular shutter opening. If the shutter opening is always to be square, one of the channels A, B may be eliminated and a single motor used to control both shutters.

It is apparent from the foregoing explanation that the invention attains its general objective in providing a shutter control for adjusting a shutter opening automatically as the distance from an image plane to a shutter plane is varied. Although an embodiment of the invention has been shown and described in detail, it is apparent that many variations and modifications may be made by one skilled in the art without departing from the true spirit and scope of the invention.

What is claimed is:

1. In X-ray apparatus having a source of X-rays for forming an image of predetermined image field size in an image plane, said image plane being variable in distance from said source, a shutter system comprising:

(a) shutter means defining a variable size shutter opening therein, said shutter means being interposed between said source and said image plane whereby some of said X-rays pass through said shutter opening in a shutter-defined beam, said shutter means defining a shutter plane a distance from said source;

(b) power means for varying the size of said shutter opening and hence the size of said shutter-defined beam;

(c) a voltage source;

(d) variable impedance means connected directly across said voltage source for providing a first voltage signal proportional to said predetermined image field size;

(e) first and second impedance means connected in series to receive said first voltage signal;

(i) said first impedance means being proportional in value to distance from said shutter plane to said image plane;

(ii) said second impedance means being proportional in value to distance from said shutter plane to said source;

(f) a connection across one of said first and second impedance means for providing a second voltage signal proportional to a desired shutter means opening size to provide a proper shutter-defined beam size for said predetermined image field size and said distance of said image plane from said source;

(g) third impedance means for providing a third voltage signal proportional to actual shutter means opening size; and

(h) comparison means for comparing said second and third voltage signals and providing a fourth signal to said power means for varying the size of said shutter means opening to vary said actual shutter means opening size until said second and third signals are equal.

2. Apparatus according to claim **1**, wherein said comparison means includes a differential amplifier.

3. Apparatus according to claim **1**, wherein said comparison means includes differential amplifier means and power amplifier means, an output of said differential amplifier means controlling said power amplifier means.

4. In X-ray apparatus having a source of X-rays for forming an image of predetermined image field size in an image plane, said image plane being variable in distance from said source, a shutter system comprising:

(a) shutter means defining a variable size shutter opening therein, said shutter means being interposed between said source and said image plane whereby some of said X-rays pass through said shutter opening in a shutter-defined beam, said shutter means defining a shutter plane a distance from said source;

(b) power means for varying the size of said shutter means opening and hence the size of said shutter-defined beam;

(c) selector switch means for selectively providing a first signal from a predetermined plurality of signals that are correspondingly proportional to said plurality of predetermined image field sizes;

(d) first impedance means for providing a second signal proportional to said distance of said image plane from said source;

(e) second impedance means responsive to said first and second signals for providing a third signal proportional to a desired shutter means opening size for said predetermined image field size and said distance of said image plane from said source;

(f) third impedance means for providing a fourth signal proportional to actual shutter means opening size; and

(g) comparator means for comparing said third and fourth signals and providing a fifth signal to said power means for varying the size of said shutter means opening to vary said actual shutter means opening size until said third and fourth signals are equal.

5. Apparatus according to claim **4**, wherein said comparator means includes a differential amplifier.

6. Apparatus according to claim **4**, wherein said comparator means includes differential amplifier means and power amplifier means, an output of said differential amplifier means controlling said power amplifier means.

7. Apparatus according to claim **6**, wherein said power amplifier means provides power to said power means for varying the size of said shutter means opening.

8. Apparatus according to claim **7**, wherein said power means for varying the size of said shutter means opening comprises reversible motor means.

9. In X-ray apparatus having a source of X-rays for forming an image of predetermined rectangular image field size in an image plane, said image plane being variable in distance from said source, a shutter system comprising:

(a) first and second adjustable shutters respectively defining length and width of a variable size, rectangular shutter opening, said shutters being interposed

between said source and said image plane whereby some of said X-rays pass through said shutter opening in a shutter-defined beam, said shutters lying substantially in a shutter plane fixed in distance from said source;

(b) first and second power means connected to said first and second shutters for respectively varying said length and width of said shutter opening; and hence the size of said shutter-defined beam;

(c) first and second selector switch means for respectively providing first and second signals from a predetermined plurality of signals that are correspondingly and respectively proportional to length and width of said plurality of predetermined rectangular image field sizes;

(d) first impedance means for providing a third signal proportional to said distance of said image plane from said source;

(e) second impedance means responsive to said first and third signals for providing a fourth signal proportional to a desired shutter opening length for said predetermined image field length and said distance of said image plane from said source;

(f) third impedance means responsive to said second and third signals for providing a fifth signal proportional to a desired shutter opening width for said predetermined image field width and said distance of said image plane from said source;

(g) fourth impedance means for providing a sixth signal proportional to actual shutter opening length;

(h) fifth impedance means for providing a seventh signal proportional to actual shutter opening width;

(i) first comparator means for comparing said fourth and sixth signals and providing an eighth signal to said first power means to adjust said first shutter until said fourth and sixth signals are equal; and

(j) second comparator means for comparing said fifth and seventh signals and providing a ninth signal to said second power means to adjust said second shutter until said fifth and seventh signals are equal.

10. Apparatus according to claim **9**, wherein said first and second comparator means each include differential amplifier means and power amplifier means, an output of said differential amplifier means controlling said power amplifier means.

11. Apparatus according to claim **10**, wherein the two power amplifier means respectively provide power to said first and second power means for adjusting the length and width of said shutter opening.

12. Apparatus according to claim **11**, wherein said first and second power means each comprise reversible motor means.

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U.S. Cl. X.R.

250—105; 318—28