ELECTRICAL TIMING APPARATUS AND MEANS FOR ADJUSTING THE SAME

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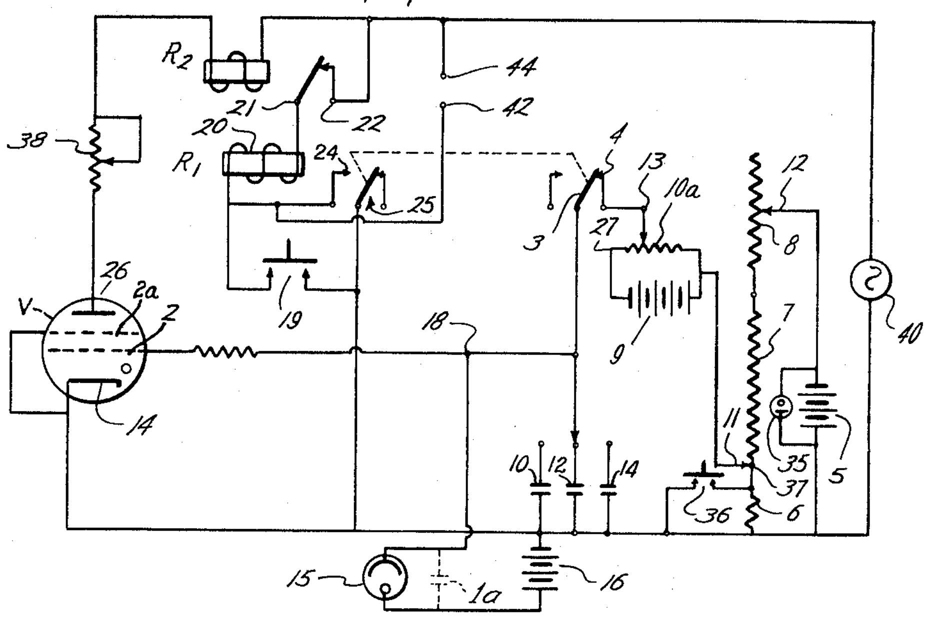
Fig. 1



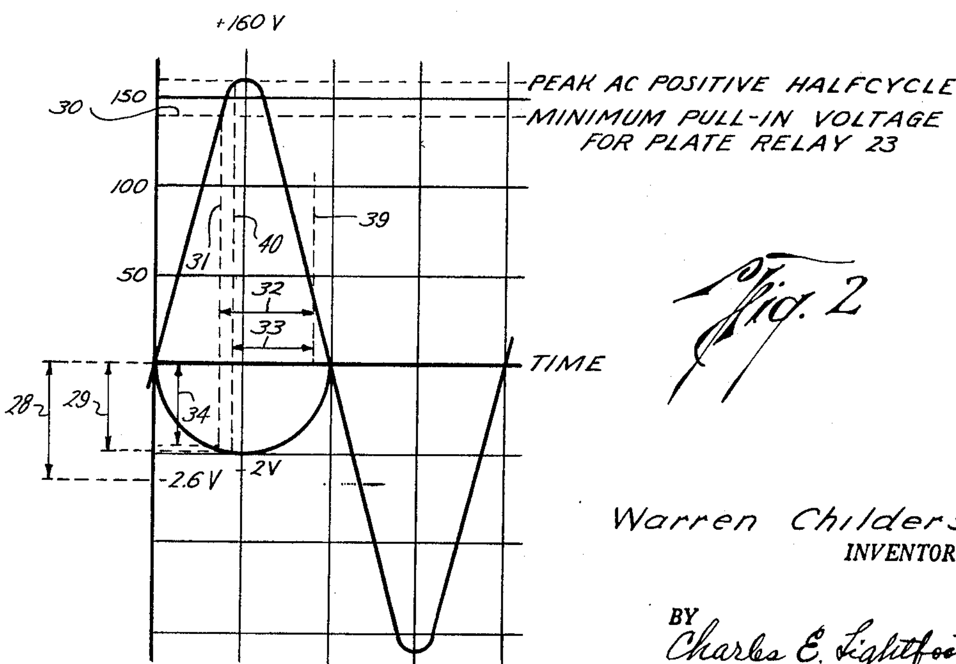


Fig. 2

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This invention relates to timing mechanism and more particularly to an electrical circuit for controlling the timing of electrically operated apparatus and means for accurately adjusting the functioning of such a circuit.

The invention is capable of wide application for the timing of the opening and closing of electrical circuits for various purposes, and finds particular utility in connection with the timing of photographic exposures.

The present invention has for an important object the provision of electrical timing mechanism which is accurate and dependable in operation and in which means is provided for restoring the accuracy of timing in the event that some characteristic of the circuit should be varied or some component of the same replaced.

Another object of the invention is to provide an electrical timing circuit which is adjustable and in which capacity, voltage and rate of current discharge may be utilized to determine the interval of time through which the circuit operates.

A further object of the invention is the provision of an electrical timing circuit which depends for its operation upon the conducting characteristics of a vacuum tube and which employs audible means for adjusting the voltage at which such a tube conducts.

Another object of the invention is to provide electrical timing mechanism of the kind referred to which may be used for the timing of photographic exposures and in which means is embodied for automatically varying the time of exposure in accordance with the intensity of the light source used for the exposure.

The above and other important objects and advantages of the invention may best be understood from the following detailed description constituting a specification of the invention, reference being had to the annexed drawings illustrating a preferred embodiment of the same.

In the drawings, FIGURE 1 is a circuit diagram of the timing mechanism of the invention; and

FIGURE 2 is a diagram illustrating the operational characteristics of the vacuum tube employed in the mechanism of the invention and how the circuit may be adjusted.

Referring now to the drawings in greater detail, the invention is illustrated herein in connection with its use in the timing of photographic exposures making use of filters of different color, or having different light transmitting properties, and in accordance with the density of the photographic transparency being used.

The timing mechanism of the invention includes a thyratron tube V of conventional type into the control grid circuit of which a photoelectric cell **15** is connected. The tube V is of a well known type having a cathode **14***a*, control grid **2**, suppressor grid **2***a* and a plate **26**.

The voltage supply circuit of the control grid **2** of the tube V, includes the photo cell **15**, source of current **16**, and condensers **10**, **12** and **14** of a condenser system preferably in an adjustable decade arrangement. Thus, the voltage applied to the control grid **2** will be the voltage across the decade condenser system plus the voltage of the supply source **16**.

A charging circuit is provided for the decade condenser system, which includes the primary direct current voltage supply source **5**, voltage regulating tube **35**, adjustable resistor **8** having a slider **12**, a potentiometer **7** having a slider **11** and a fixed resistor **6**. The charging

circuit also includes an auxiliary direct current voltage supply source **9** having a potentiometer **10**, which may be connected in circuit with the condenser system through relay contacts **3** and **4** and with the source **5** through slider **11**. By this arrangement the decade condenser system may be charged at any desired voltage.

A relay **R1** is provided having a moving contact **3** and a stationary contact **4**, by which the charging of the condensers is effected. Thus, when the contact **3** is in engagement with contact **4**, the condenser charging circuit is closed, and when contact **3** is out of engagement with contact **4** the charging circuit is open.

The relay **R1** is operated from the same current source **40** through the stationary contact **22** and movable contact **21** of plate relay **R2** through coil **20** of **R1** either through a momentary contact switch **19** or through stationary contact **24** and movable contact **25** of the relay **R1**. Thus, upon energization of the coil **20** by momentary closing of the switch **19**, the moving contact **25** is brought into engagement with contact **24** and held in such contact to keep coil **20** energized during a timing interval of the equipment.

The timing equipment is provided with output connections **42** and **44** for a circuit into which equipment such as a light source may be connected. Output contacts **42** and **44** are energized from the source **40** directly to contact **44** and from contact **42** through stationary contact **24**, movable contact **25** back to the source.

In FIGURE 1, the circuit is in the non-timing state. During this condition negative voltage is supplied from a suitable source of supply such as the battery **5** or other power supply circuit, to the adjustable capacitors **10**, **12** and **14** to the thyratron control grid **2** through relay contacts **3** and **4**. The amplitude of the negative voltage is determined by the voltage supply source **5** by the adjustment of a voltage dividing network including resistors **6**, **7** and **8**, the resistor **7** being adjustable by a slider **11** and the resistor **8**, being adjustable by a slider **12** and by an auxiliary voltage supply source **9** and a voltage dividing circuit associated therewith which includes the variable resistor **10***a* provided with a slider **13**. The adjustable voltage network may be calibrated to represent photographic density, the resistor **7**, for example, being calibrated in increments of .10 of photographic density and the resistor **8** being then calibrated in increments of .01 of photographic density. Slider **11** is used for coarse adjustment of voltage and slider **12** is used for fine adjustment. (In the example given above, resistance **7** is divided for .10 increments of density and resistance **8** is divided for .01 increments of density.) Negative supply **9** is adjusted by means of resistance **10***a* and slider **13** to add (to voltage appearing at slider **11**) negative voltage almost equal to the critical control grid potential of the thyratron. This critical control grid potential is the negative control-grid voltage required to prevent the thyratron from firing when the peak valve of the positive A.C. half-cycle appears at its plate. This adjustment is necessary in order to establish the cathode **14***a* as zero voltage reference for both the voltage divider **6**, **7** and **8** and the capacitors **10**, **12** and **14**.

Charging of the capacitors is completed within a very short time after contact is made through relay points **3** and **4**. After the capacitors are charged current in the photoelectric tube circuit flows from battery **16** through tube **15**, contacts **3** and **4**, slider **13**, part of the resistor **10***a*, part of resistor **7** depending upon the position of slider **11**, and through resistor **6** back to the battery **16**. Since the phototube **15** is usually located in a position remote from the rest of the circuit by means of a flexible cable, the capacitance of the phototube and of its connecting cable **1***a* becomes a factor affecting time.

This capacitance has the same effect as would a capacitor added to the adjustable capacity system 10, 12 and 14 and produces a constant error in the time unit system. This error in a 1000 to 1 capacity decade system may amount to approximately 10% of a single unit and may be corrected by using a smaller value capacitor at the "single unit" position. On unit settings above 10, the error will then become less than 1%.

In other circuits the phototube is sometimes connected to relay point 17 instead of at the grid line 18; thus the phototube and voltage supply 16 are out of the circuit when in its non-timing state. However, this arrangement produces an inconstant error in timing because of the capacity which is left in the phototube cable at the end of a time interval. Immediately following a time cycle, this cable capacity begins to drain off through the leakage path provided by the phototube and may require several seconds or even minutes to drain completely. Therefore the succeeding time cycle will be affected by the quantity of current still left in the cable and the error will vary with the time elapsed since the last timing cycle and with the volume of light falling upon the phototube. In FIGURE 1 the phototube is connected so as to produce a constant error which may be compensated rather than a variable error which may not be compensated.

The timing cycle is begun by momentarily depressing switch 19 which supplies current to the power relay 20. The other side of the A.C. potential is supplied through contacts 21 and 22 of the plate relay R2. Contacts 24 and 25 of the power relay form an electrical latch to maintain the current supply to the power relay R1 after the momentary contact switch 19 is released. When the power relay is energized, the electrical contact between relay points 3 and 4 is broken and current begins to flow from the selected one of the capacitors 10, 12 and 14, through the phototube 15 and to the positive potential of voltage supply 16. As this current flow continues, the grid 2, which monitors the capacitor voltage, becomes progressively less negative with respect to the cathode until the control grid becomes less negative than required to prevent the thyratron from firing. The first positive half-cycle of the A.C. supply which appears at the plate 26 of the thyratron after this critical control grid potential is passed will cause the thyratron to fire, energizing the plate relay R2 and breaking the electrical contact between points 21 and 22 of the plate relay R2. Interruption of the electrical contact between points 21 and 22 of the plate relay breaks the current supply to the power relay R1 causing the electrical latch between points 24 and 25 to be released and the points 3 and 4 to remake. When points 3 and 4 remake sufficient negative grid potential is supplied at the control grid 2 to prevent the thyratron from firing on the following positive half-cycles of the A.C. supply. The selected one of the capacitors 10, 12 and 14 is then recharged and the circuit is again ready for a repeat timing cycle. The time interval in the operation of this circuit is the product of the capacity placed in the circuit, the voltage impressed upon the capacity and the rate of current flow through the phototube. Important constants in the circuit are amplitude of the peak A.C. positive half cycle and the negative voltage between points 13 and 11 of the condenser charging circuit (FIGURE 1). As shown in FIGURE 2, these two voltage values are interdependent. They must be stable and carefully adjusted if optimum accuracy is to be realized from the voltage divider comprised of resistors 6, 7 and 8. In a practical circuit, the constant peak A.C. positive half-cycle is established by the use of a voltage regulating transformer in the A.C. supply. The remaining constant (negative voltage between points 11 and 13 in FIGURE 1) is then dependent only upon the characteristic of the thyratron tube employed in the circuit. Tube characteristics vary because of manufacturing tolerances. With a maximum anode potential of 160 volts as illustrated in FIGURE 2, a particular tube type (2D21) will have a critical grid (firing) voltage between $-1\frac{1}{4}$ and $2\frac{1}{2}$ volts. It is important for the negative voltage supply 9 to exceed $2\frac{1}{2}$ volts to be adequate for normal manufacturing tolerances of this tube type.

The critical nature of the voltage adjustment between points 1 1and 13 may be appreciated by considering the voltage requirements of a density calibration system covering a density range of 2.10 to 00 or a ratio of 125.9 to 1.0. The amplitude of voltage supplied from supply 5 is controlled and regulated by the voltage regulator tube 35 and is limited to approximately 108 volts. Thus, the minimum voltage setting of voltage network including resistors 6, 7 and 8 would be 108/126 or .8571 volt and the next higher increment of change (+.01 density) would increase this value by approximately 2.3% or to .8768 volt.

Due to the critical exposure requirements encountered in the graphic arts field, it is essential that this calibration (adjustment of slider 13) be made with extreme accuracy. This problem is complicated by the fact that commercial versions of the circuit described in FIGURE 1 will ordinarily be used by workers who have little or no knowledge of electronics and do not have access to precision electronic measuring devices. In order to overcome this problem, a simple audible calibration system was devised. A switch 36 was added to the circuit for the purpose of shunting resistance 6 to the cathode. By sliding slider 11 to position 37, all of the voltage from supply 5 is removed from the circuit. The negative voltage remaining on the control grid 2 is then supplied entirely from supply 9. The resistance 38 has previously been adjusted to prevent relay 23 from pulling in at anode potentials of less than a critical value (in this case (FIGURE 2) 140 volts). In FIGURE 2, dotted line 31 begins at a point where the 140 volt line intersects the positive half of the A.C. sine wave. This point represents the minimum pull-in voltage required by the plate relay R2 and its value is dependent upon the series resistance adjusted at 38. Following line 31 down into the critical control grid potential segment it will be found to intersect the critical control grid curve at a control grid voltage of approximately -1.9 volts (34). This is the control grid voltage which would just allow the thyratron to fire at the same instant the amplitude of the anode potential reached the critical pull-in value of the plate relay R2. After the relay armature is pulled in it requires less voltage than the critical pull-in voltage to maintain its "in" position; therefore, it will remain in for a time represented by line 32 drawn between lines 31 and 39. When the amplitude of the positive half cycle reaches the point intersected by line 39 the relay R2 armature returns to its relaxed position. If the control grid voltage were increased by .05 volt as in 29, the effect would be to shift conduction point of the thyratron to a point represented by line 40. Such a shift creates a decided difference in sound since the relay armature is in for a shorter length of time. The addition of another .05 volt control grid potential would prevent the thyratron from firing. Beginning with a control grid potential of 2.6 v. as at 27 and gradually reducing this by means of slider 13, there is, first, no sound, then an erratic sound which is due to the slight (1%) variation of the peak anode potential, and then quite suddenly there is heard a steady 60 cycle buzz. There is no further sound change at control grid potentials less than 34 even though the thyratron fires earlier because the relay R2 pull-in point is determined by its own critical pull-in voltage rather than the firing point of the thyratron.

As is well known, the density of a photographic image may be expressed as a logarithmic function and the photographic exposure required varies as the reciprocal of the photographic transmission.

By the use of the decade capacity system in the timing circuit, as described above, and including the voltage dividing system having the variable resistors 7 and 8, which may be adjusted in accordance with a logarithmic scale, the condenser system may be made to vary as a logarithmic function, so that the voltage supplied to the capacitors may be made to vary in proportion to the antilog of the photographic density.

It will thus be seen that the invention, constructed and operated as described above, provides electrical timing mechanism which is extremely accurate by which the timing of various devices can be regulated throughout a wide range, and which may be easily and accurately adjusted to compensate for variations in vacuum tube characteristics.

The invention is disclosed herein in connection with a certain specific embodiment of the same, but it will be understood that this is intended by way of illustration only, and that numerous changes in the electrical components and circuits may be made, within the spirit of the invention and the scope of the appended claims.

Having thus clearly shown and described the invention, what is claimed as new and desired to secure by Letters Patent is:

1. In electrical timing mechanism a gas thyratron tube having a plate, a control grid, and a cathode, a control grid bias circuit including a primary current voltage source, an auxiliary direct current voltage source, first means for adjustably producing a bias voltage from said primary direct current voltage source, second means for adjustably producing a bias voltage from said auxiliary direct current voltage source, said first and second means being connected in series in said control grid bias circuit between cathode and grid, and a condenser connected between cathode and control grid paralleling said first and second means, a charging circuit for said condenser including said first and second means and said primary and auxiliary direct current voltage sources, means for opening and closing said charging circuit, said latter means being positioned in the charging circuit at a point to disconnect said first and second means and said primary and auxiliary direct current voltage sources from the control grid bias circuit upon opening of the charging circuit, a plate circuit, a source of alternating current in the plate circuit, audible sound producing means including an electromagnetic coil in said plate circuit for producing an audible signal of predetermined frequency upon energization of said coil when the current in said plate circuit reaches a predetermined value, and means for shunting said first means and said primary direct current voltage source out of said control grid circuit whereby said second means may be adjusted to select a

critical control grid bias voltage setting which critical bias voltage setting is determined by an operator when a predetermined audible sound is produced by said audible sound producing means.

2. The apparatus set forth in claim **1** together with a discharging circuit for said condenser, and means in said discharging circuit responsive to light intensity for controlling the discharging of the condenser.

3. The apparatus as set forth in claim **2** wherein said first means includes a voltage divider network which is adjustable to logarithmically vary the charge of said condenser proportionate to the antilog of a predetermined photographic density.

4. The timing mechanism as set forth in claim **1** wherein said audible sound producing means is an electromagnetic relay capable of buzzing at the frequency of said alternating current source.

5. The apparatus as set forth in claim **1** wherein said means for opening and closing said charging circuit includes an electromagnetic power relay having a first set of switch contacts in said charging circuit, a second set of switch contacts and an electromagnetic coil, a timing interval initiating circuit, including said alternating current source, a normally open momentary contact switch and said power relay coil, an electrical latch for said power relay including said second set of switch contacts, said electrical latch being adapted to hold said power relay energized when said momentary contact switch is momentarily closed and subsequently released, a load circuit in circuit with said second set of switch contacts and said alternating current source, which is energized when said second set of switch contacts is closed, and means responsive to the energization of said electromagnetic coil in said plate circuit for de-energizing said power relay.

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