United States Patent

Brungsberg

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[54] **NOISE SUPPRESSING A C PHASE CONTROL SYSTEM**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ....**307/257,** 307/247, 307/252 W, 307/262, 315/DIG. 4, 323/22 T, 323/34

[51] **Int. Cl.** **H03k 17/00,** G05f 1/44

[58] **Field of Search** ....307/247, 252 W, 253, 254, 257, 307/262; 323/22 T, 34, 7 SE; 315/DIG. 4

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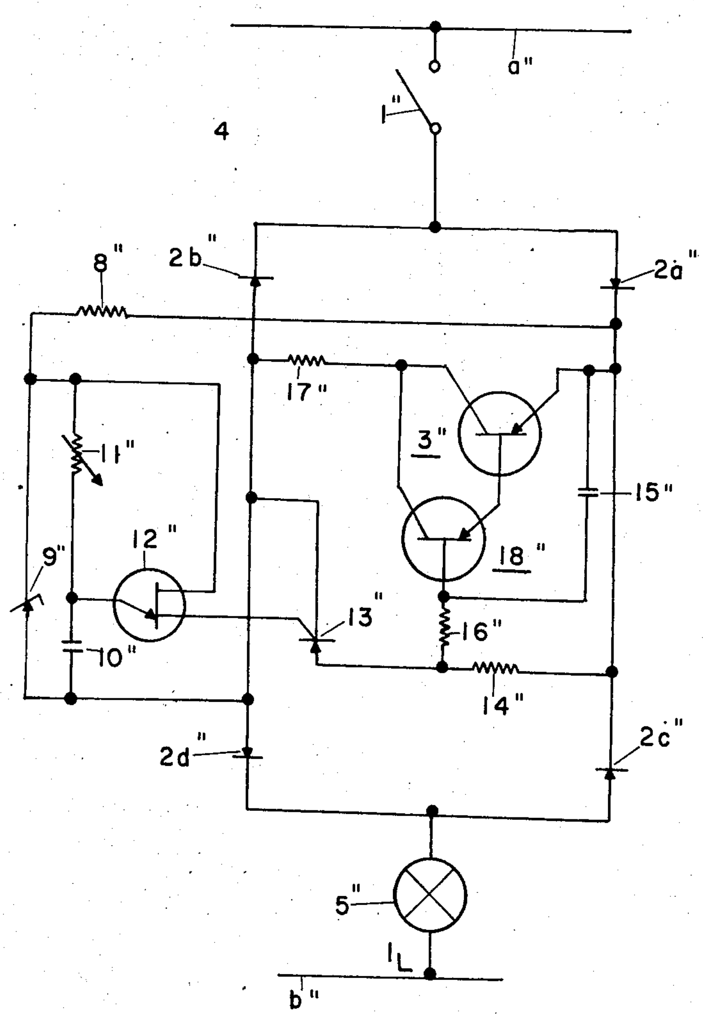
[57] **ABSTRACT**

An a-c phase control circuit includes a power transistor for phase control replacing the thyristor generally used for this purpose.

4 Claims, 8 Drawing Figures



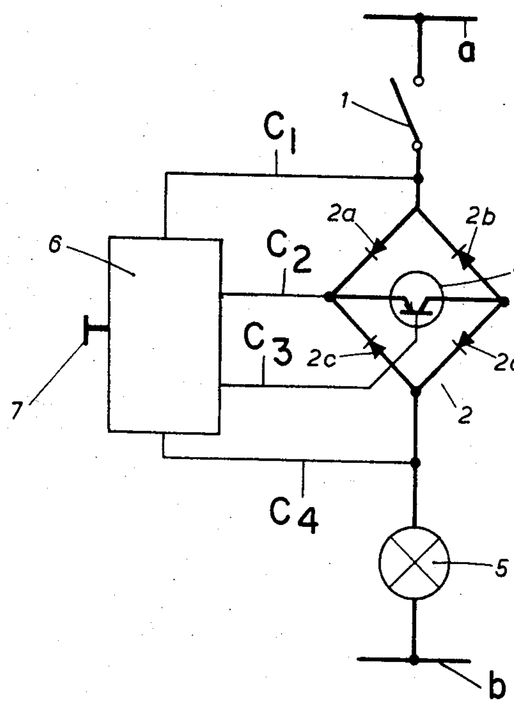


Fig. 1

Fig. 2a

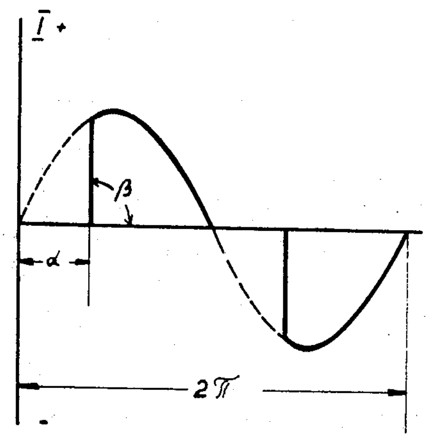
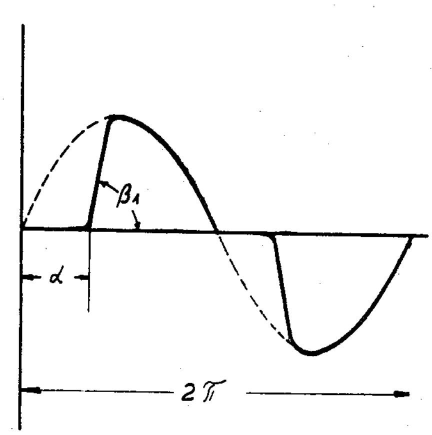


Fig. 2b



PRIOR ART

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FIG. 3

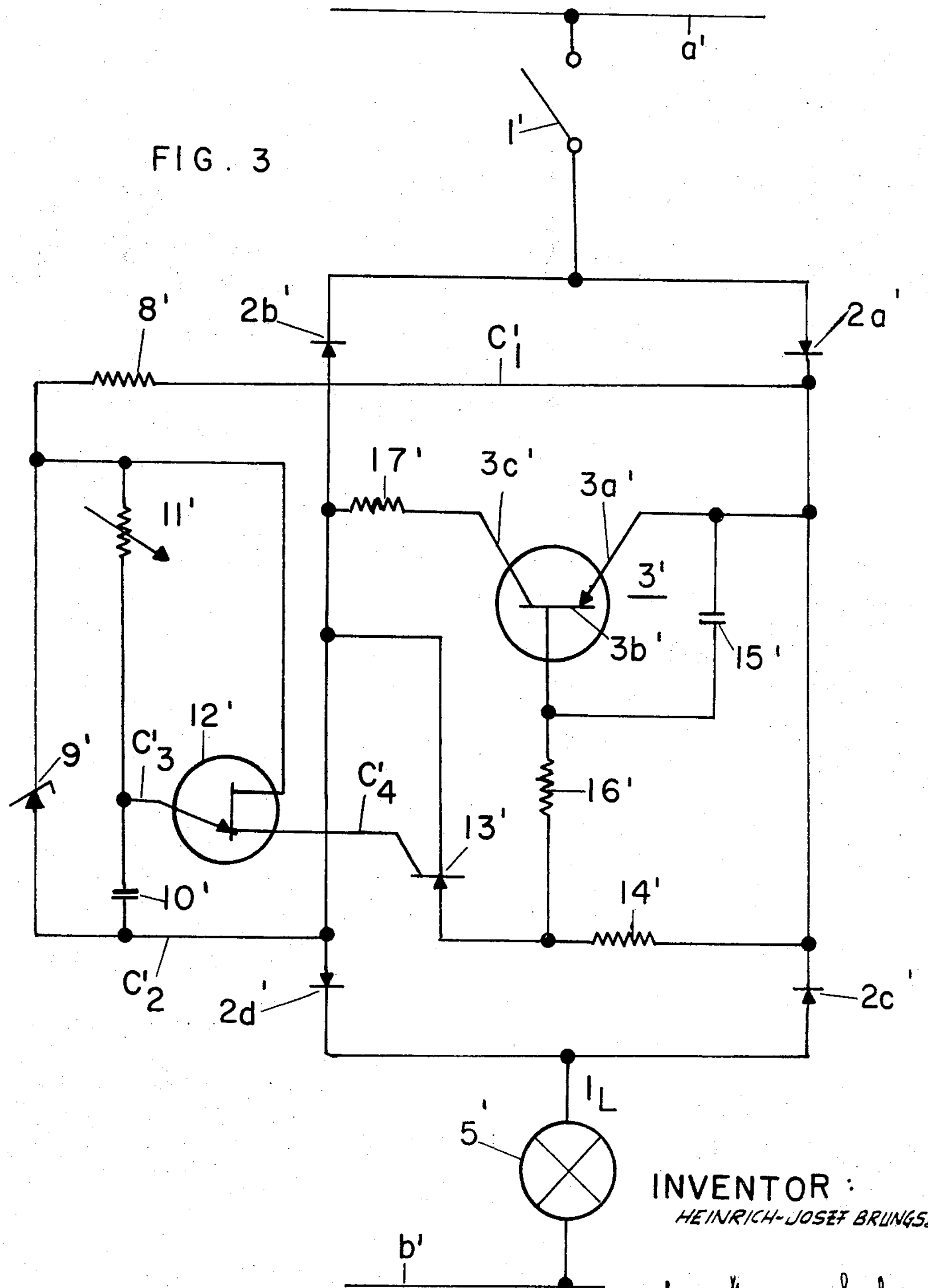

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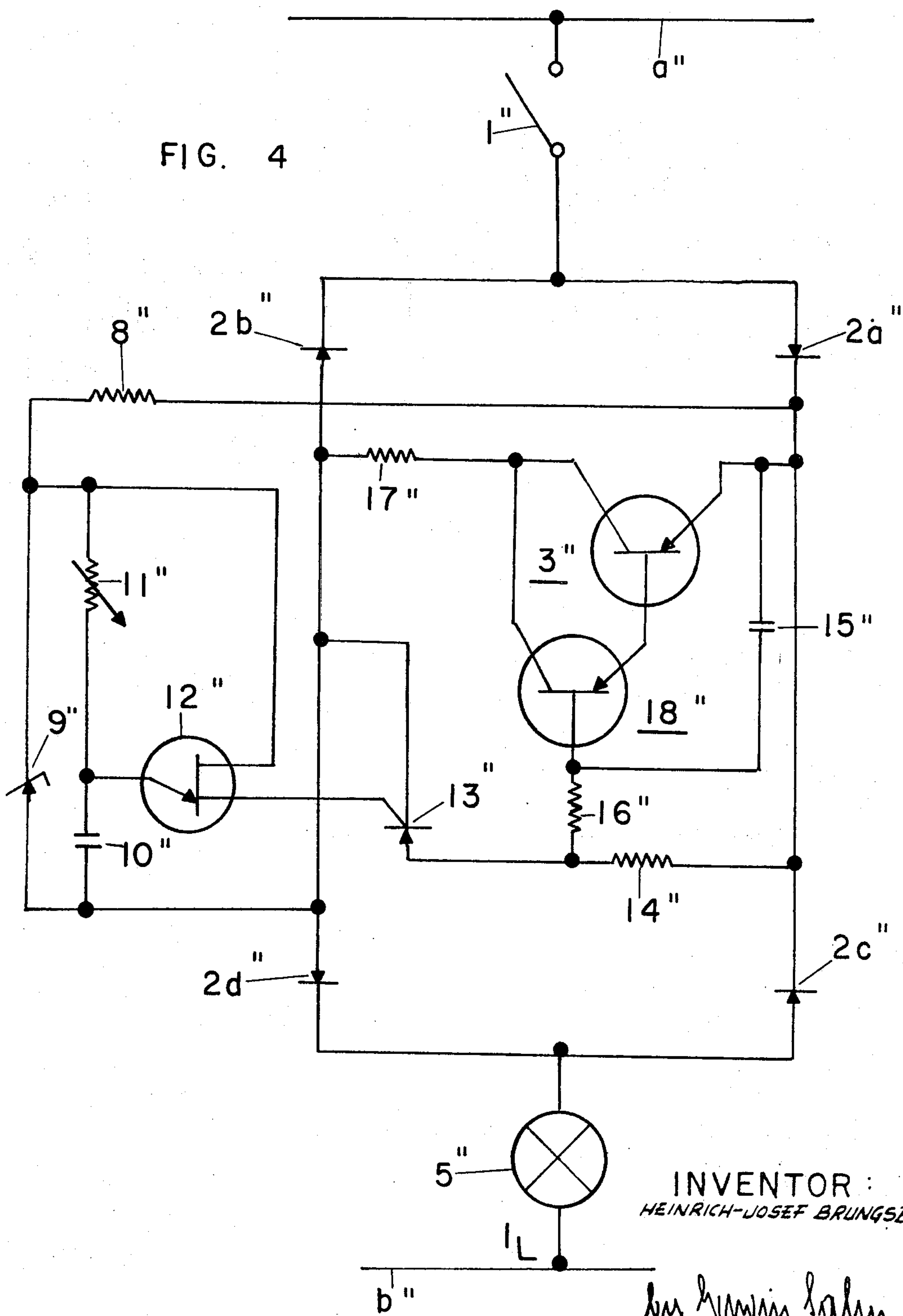
FIG. 4



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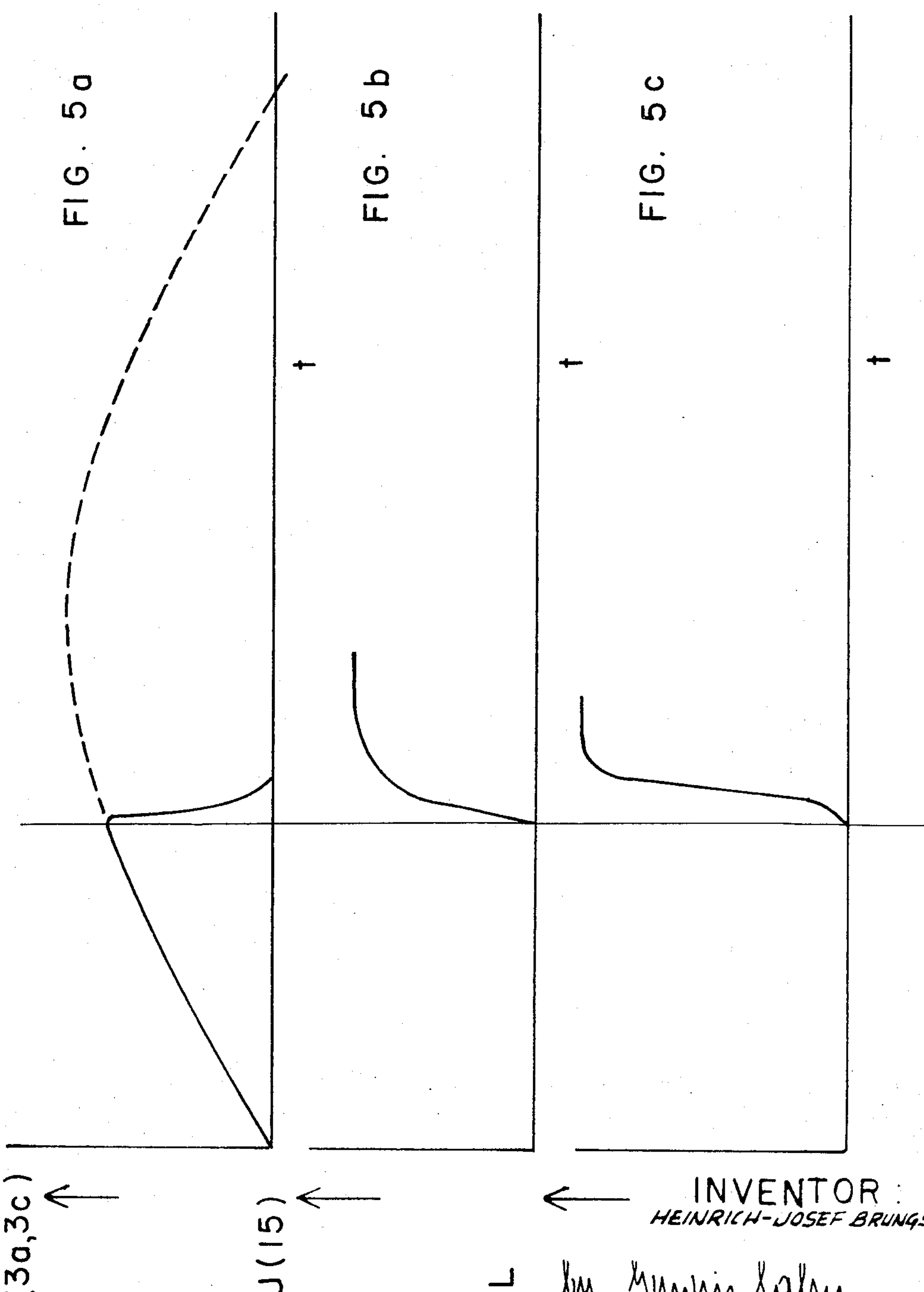

FIG. 5a

FIG. 5b

FIG. 5c

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NOISE SUPPRESSING A C PHASE CONTROL SYSTEM

BACKGROUND OF INVENTION

The term a-c phase control is applied in reference to a process of rapid On-OFF switching which connects an a-c supply to a load for a controlled fraction of each cycle. A-C phase control is applied extensively as a means for controlling the average power to various loads such as, for instance, electric lamps, electric heaters and electric motors. Electric circuitry for controlling the average power to an electric lamp by means of a-c phase control is referred to as a phase control dimmer. This invention lends itself well to a-c phase control dimmers.

Generally a-c phase control is achieved by thyristor circuitry including one or more power thyristors. In any circuit including a power thyristor the rate of rise of the current following triggering of the power thyristor is very high. The frequency spectrum of the steeply rising currents encompasses frequencies ranging from about 150 k Hertz to 30 m Hertz. These frequencies constitute radio noise.

Generally chokes and capacitors may be used as effective radio noise suppressors. Such noise suppressors are effective where relatively high noise frequencies occur, but are relatively ineffective at frequencies less than 1 m Hertz, i.e., in the range of medium and long wave radiation. Even complex filter circuits which are applied to suppress radio noise resulting from mechanical switching devices are relatively ineffective to suppress radio noise resulting from a-c phase control by means of thyristors, and the bulk and cost of such filter circuits tend to be excessive.

The prime object of the present invention is to provide means applicable in conjunction with a-c phase control for avoiding radio noise, and more particularly to control the rate of rise of the a-c phase controlled load current in such a way as to keep the high frequency components thereof at a permissible level, and to achieve these ends with a minimum of bulk, a minimum of cost and a minimum of parts.

SUMMARY OF INVENTION

An a-c phase control circuitry embodying this invention includes an a-c power source, a load supplied from said power source, a power transistor controlling the flow of current from said power source to said load, means for effecting rapid ON-OFF switching of said power transistor to conductively connect said power source for a controlled fraction of each cycle of said power source to said load, and manually operable means for varying said controlled fraction of each cycle of said power source during which said power source is condúctively connected to said load by the intermediary of said power transistor.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a diagrammatic representation of a dimmer circuit embodying the present invention;

FIG. 2*a* shows diagrammatically a current trace of a current occurring in a prior art a-c phase control circuit wherein a-c phase control is effected by a thyristor;

FIG. 2*b* shows diagrammatically a current trace of a current occurring in the circuit of FIG. 1 wherein a-c phase control is effected by a transistor;

FIG. 3 is a complete circuit diagram of an a-c phase control circuit embodying the present invention;

FIG. 4 is a complete circuit diagram of a modification of the circuit of FIG. 3 particularly intended to form a monolithic integrated circuit of the LSI type; and

FIGS. 5*a*–5*c* are voltage and current traces referring to the circuitry of FIG. 3.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

In FIG. 1 reference characters *a* and *b* have been applied to indicate a pair of conductors or leads. An a-c voltage prevails between conductors or leads *a* and *b*. Reference numeral **5** has been applied to indicate a load, and more particularly an incandescent electric lamp. The circuit of load **5** includes disconnect switch **1** and full wave rectifier bridge **2**. The latter is provided with four power diodes **2***a*,**2***b*,**2***c*,**2***d*. Power transistor **3** conductively interconnects two of the terminals of full wave rectifier bridge **2**, i.e., its d-c terminals. Reference character **6** has been applied to generally indicate a control circuit for transistor **3**. Control circuit **6** can be adjusted by adjusting means such as knob or handle **7**. By adjusting knob or handle **7** the fraction of half cycles during which power transistor **3** carries current from lead *a* to *b* may be varied. Control circuit **6** is connected by leads C_1,C_2,C_3 and C_4 to bridge circuit **2**, the ends of leads C_1,C_2 and C_4 remote from control circuit **6** being conductively connected to terminals of bridge circuit **2** and the end of lead C_3 remote from control circuit **6** being conductively connected to the base of power transistor **3**. Control circuit **6** may take various forms as long as it performs the function of a-c phase control of power transistor **6**, i.e., controls the phase angle at which power transistor **6** is turned on periodically.

When lead *a* is positive a current may flow from lead a through closed disconnect switch **1**, diode **2***a*, power transistor **3**, diode **2***d*, load **5** to lead *b*. When lead *b* is positive a current may flow from lead *b*, through load **5**, diode **2***c*, power transistor **3**, diode **2***b*, closed disconnect switch **1** to lead *a*. The rapid ON-OFF switching by transistor **3** conductively connects the a-c power supply *a*,*b* to load **5** for controlled fractions of each cycle, the particular fraction depending in each instance on the position of adjusting means **7**.

FIGS. **2***a* and **2***b* show current plotted against time, or electrical angles, respectively, for a total of 2 π. In both instances current flow is initiated at the same electrical angle α. FIG. **2***a* referring to a thyristor a-c phase control circuit shows a very steep rise of the current I following triggering of the thyristor at the electrical angle α. The rate of rise of the current is β, and β is virtually 90°. According to FIG. **2***b* referring to the circuit of FIG. **1** wherein phase-control is effected by turning transistor **3** on and off, the rate of rise β_1 of the current is much less than in FIG. **2***a*, i.e. β_1 β , or β_1 90°. The current trace of FIG. **2***a* involves a wide band of frequencies, up to the highest frequencies. The current trace of FIG. **2***b* involves a much narrower band of frequencies, and these may be kept below a specified permissible band width N.

Referring now to FIG. **3**, a-c lead *a'* is conductively connected to a-c lead *b'* by the intermediary of a full wave rectifier bridge including diodes **2***a'*,**2***b'*,**2***c'***2***d'* and power transistor **3'**. Power transistor **3'** includes emitter **3***a'*, base **3***b'* and collector **3***c'*. Leads C_1' and C_2' are connected to the two d-c terminals of the above referred-to bridge circuits and the emitter **3***a'* and the collector **3***c'* of transistor **3'** are conductively connected to the same terminals, a resistor **17'** being included in the collector circuit of power transistor **3'**. A resistor **8'** is arranged in lead C_1', and leads C_1' and C_2' are conductively interconnected by Zener diode **9'** limiting the d-c voltage prevailing across leads C_1',C_2' substantially at a predetermined level. Capacitor **10'** and regulating resistor **11'** are connected in series and shunted across Zener diode **9'**. Reference character **12'** has been applied to generally indicate a unijunction transistor or silicon double base diode. The emitter of the latter is conductively connected to a point between capacitor **10'** and regulating resistor **11'**. One base of unijunction transistor **12'** is conductively connected by lead C_3' to one terminal of regulating resistor **11'**, and the other base of unijunction transistor **12** is conductively connected by lead C_4' to the gate of auxiliary thyristor **13'**. The latter interconnects the d-c terminals of bridge circuit **2***a'*,**2***b'*,**2***c'*,**2***d'*,**3'**, and resistor **14'** is included in the anode circuit of auxiliary thyristor **13'**. Resistor **16'** connects the anode of auxiliary thyristor **13'** and the base of power transistor **3'**. Reference character **15'** has been applied to indicate a capacitor of which one terminal is conductively connected to the base **3***b'* of power transistor **3** and the other terminal is conductively connected to the emitter **3***a'* of power transistor **3'**.

The circuitry of FIG. 3 operates as follows:

When disconnect switch **1'** is closed a d-c voltage appears across the d-c terminals of full wave rectifier bridge *2a',2b',2c',2d'*,3. This d-c voltage prevails across leads C_1' and C_2' and is suitably reduced and stabilized by the operation of Zener diode **9** and the voltage drop occurring across resistor **8'**. The voltage across Zener diode **9'** may be in the order of 10 volts and relatively constant, except around the points of time when the supply voltage across leads *a',b'* drops to zero. Capacitor **10'** is charged during each consecutive half cycle, the rate of charge of capacitor **10'** depending upon the adjustment of regulating resistor **11'**. When the voltage across capacitor **10'** reaches a predetermined level unijunction transistor **12'** is turned on and capacitor **10'** is discharged through a circuit including conductor C_4' and the gate of auxiliary thyristor **13'**. Thus auxiliary thyristor **13'** is triggered. Triggering of auxiliary thyristor **13'** establishes a direct current path from the positive to the negative terminal of full wave bridge *2a',2b',2c',2d'*,*3'* through auxiliary thyristor **13** and resistor **14** which are connected in series.

Initially the voltage across capacitor **15'** is zero and, therefore, the voltage across emitter *3a'* and base *3b'* of power transistor **3'** is also zero. Hence the load current I_L from lead *a'* through power transistor **3'** and load **5'** is also zero. Upon triggering of auxiliary thyristor **13'** a voltage prevails across capacitor **15'** and capacitor **15'** is charged through resistor **16'**. As a result the voltage between emitter *3a'* and base *3b'* of power transistor **3** increases and the load current I_L through load **5'** increases likewise. The rate of rise of the load current I_L through power transistor **3'** depends upon the magnitude of resistor **16'**.

During the time power transistor **3'** is turned on the required base current flows for the remaining portion of one-half cycle through a circuit which includes auxiliary thyristor **13'**. In that period of time the triggering voltage for auxiliary thyristor **13'** has collapsed.

Because the a-c phase control of load **5'** is effected by means of a full wave diode bridge, the operation of the circuitry of FIG. 3 is the same during each positive half cycle and during each negative half cycle.

Resistor **14** is dimensioned in such a way that the holding current of auxiliary thyristor **13'** is reached shortly after the time of voltage zero. Resistor **17** is required for the proper control of the base current of power transistor **3'**.

In FIG. 4 the parts corresponding to parts in FIG. 3 have been indicated by the same reference characters to which two primes rather than one single prime as in FIG. 3 have been added. Hence FIG. 4 is substantially self-explanatory, and requires additional description only to the extent that the circuitry shown therein differs from that shown in FIG. 3.

FIG. 4 differs from FIG. 3 only inasmuch as the power transistor **3'** of the latter has been substituted in the former by a cascade of two transistors, i.e., auxiliary transistor **18''** and power transistor **3''**. Auxiliary transistor **18''** operates as an amplifier. Assuming that there is the same time constant in the circuitry of FIG. 3 and that of FIG. 4, the provision of auxiliary transistor **18''** makes it possible to greatly increase the magnitude of resistor **16''** relative to that of resistor **16'** and to greatly reduce the magnitude of capacitor **16''** relative to that of capacitor **16'**. This is of considerable importance when it is intended to achieve an a-c phase control embodying this invention by integrated monolithic circuitry, for it is extremely difficult, or impossible, to include in monolithic integrated circuits capacitors having a relatively high capacitance.

Referring now to FIGS. *5a,5b* and *5c*, the first mentioned figure shows the voltage U(*3a,3c*) across the emitter *3a'* and the collector *3c'* of power transistor **3'** plotted against time. This voltage rises sinusoidally and collapses relatively rapidly when power transistor **3'** is turned on. FIG. *5b* shows the voltage U(15) prevailing across capacitor **15'** plotted against time *t* and FIG. *5c* shows the load current I_L flowing through power transistor **3'** and through load **5'** plotted against time.

As indicated above, the kind of a-c phase control which has been disclosed above is not only applicable to dimmer circuits, but also to many other a-c phase control circuits including, for instance, speed controls of electric motors.

It will be apparent from the above that unijunction transistor **12'** and capacitor **10'** operate as a free running oscillation generator under the control of variable resistor **11'**. This free running oscillation generator is energized by the voltage prevailing across the d-c terminals of full wave rectifier bridge *2a',2b',2c',2d'*,*3'* and triggers auxiliary thyristor **13'**. The latter, in turn, controls the flow of current I_L through power thyristor **3'** and load **5'**.

I claim as my invention.

1. An a-c phase control circuitry with reduced radio noise including in combination

a. an a-c power source;

b. a load supplied from said power source;

c. a full wave diode rectified bridge having a-c terminals conductively connected to said power source and d-c terminals conductively connected to a power transistor;

d. a free running oscillation generator energized by the d-c voltage prevailing between said d-c terminals of said rectifier bridge and controlling rapid ON-OFF switching of said power transistor;

e. an auxiliary transistor cascade connected with said power transistor, said cascade connected power transistor and said auxiliary transistor being shunted by a capacitor;

f. said capacitor and other constituent circuit elements of said circuitry being formed by a monolithic integrated circuit; and

g. manually operable means for varying the fraction of each cycle of said power source during which said power source is conductively connected to said load.

2. An a-c phase control circuitry with reduced radio noise including in combination

a. an a-c power source;

b. a load supplied from said source;

c. a full wave diode rectifier bridge having a-c terminals conductively connected to said power source and d-c terminals conductively connected to a power transistor;

d. a free running oscillation generator energized by the d-c voltage prevailing between said d-c terminals of said rectifier bridge and controlling rapid ON-OFF switching of said power transistor, said free running oscillation generator being formed by a capacitor and a unijunction transistor, said unijunction transistor controlling the gate circuit of an auxiliary thyristor to trigger said auxiliary thyristor;

e. a capacitor shunted across two electrodes of said power transistor and charged by a voltage depending upon the flow of current through said auxiliary thyristor; and

f. manually operable means for varying the fraction of each cycle of said power source during which said power source is conductively connected to said load.

3. An a-c phase control circuitry as specified in claim **2** including lead means conductively connecting said d-c terminals of said rectifier bridge, a serially connected resistor and Zener diode providing reduced and stabilized operating voltage for said free running oscillation generator being included in said lead means.

4. An a-c phase control light dimmer circuitry with reduced radio noise including in combination

a. an a-c power source;

b. an electric lamp supplied from said power source;

c. a power transistor controlling the flow of current from said power source to said electric lamp;

d. means for effecting rapid ON-OFF switching of said power transistor including an auxiliary transistor and a capacitor, said auxiliary transistor and said power transistor being cascade connected and said auxiliary transistor and said power transistor being shunted by a capacitor, and said capacitor and other constituent elements of said dimmer circuitry being formed by a monolithic integrated circuit; and

e. manually operable means for varying a controlled fraction of each cycle of said power source during which said power source is conductively connected to said electric lamp.

* * * * *