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[72] Inventor **Roland O. Hildebrand**
P.O. Box 173, Carrollton, Tex. 75006

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[54] **MASTER SLAVE POWER VARYING CONTROL SYSTEM**
16 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **323/24,** 315/144, 315/195, 323/38
[51] **Int. Cl.** **H05b 39/04,** G05f 1/00
[50] **Field of Search** ..... 323/22 SC, 24, 38, 4, 9, 16—22; 315/144, 195—199, 224; 321/27 MS

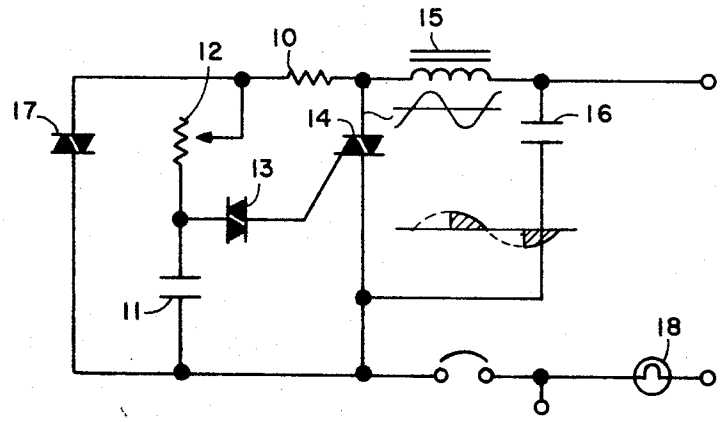
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Primary Examiner—Gerald Goldberg
Attorney—John E. Holder

ABSTRACT: An electronic master-slave system is used for dimming a remote lighting arrangement. The master system limits the time duration that an alternating current power signal is applied to a master lighting system. In response to the passage of the time limited power signal to the master system, a trigger circuit activates a gate for varying the time that positive and negative components of an alternating current signal are passed to a slave lighting system, with the master and slave systems being operated synchronously.



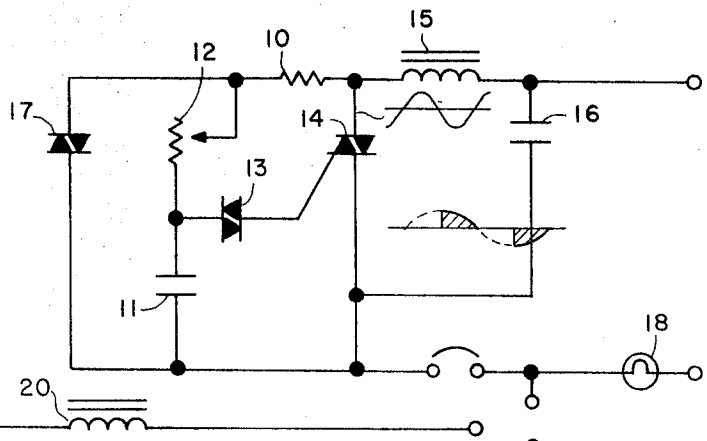


FIG. 1

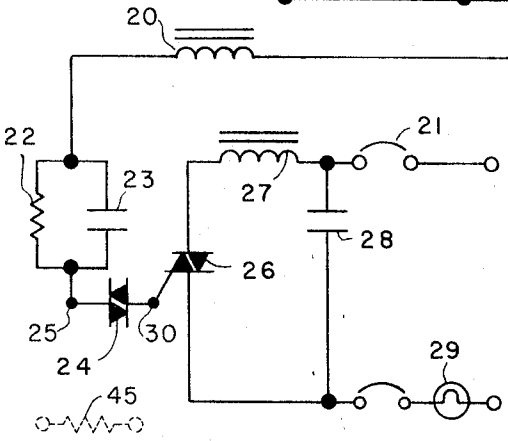


FIG. 2

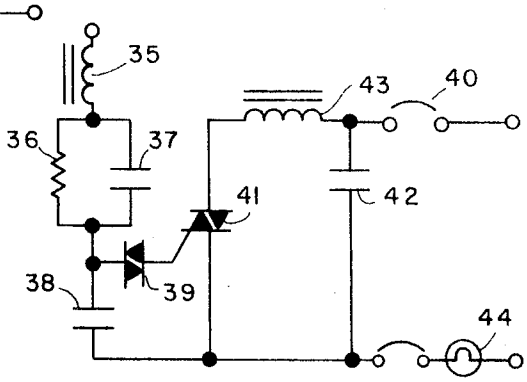


FIG. 3

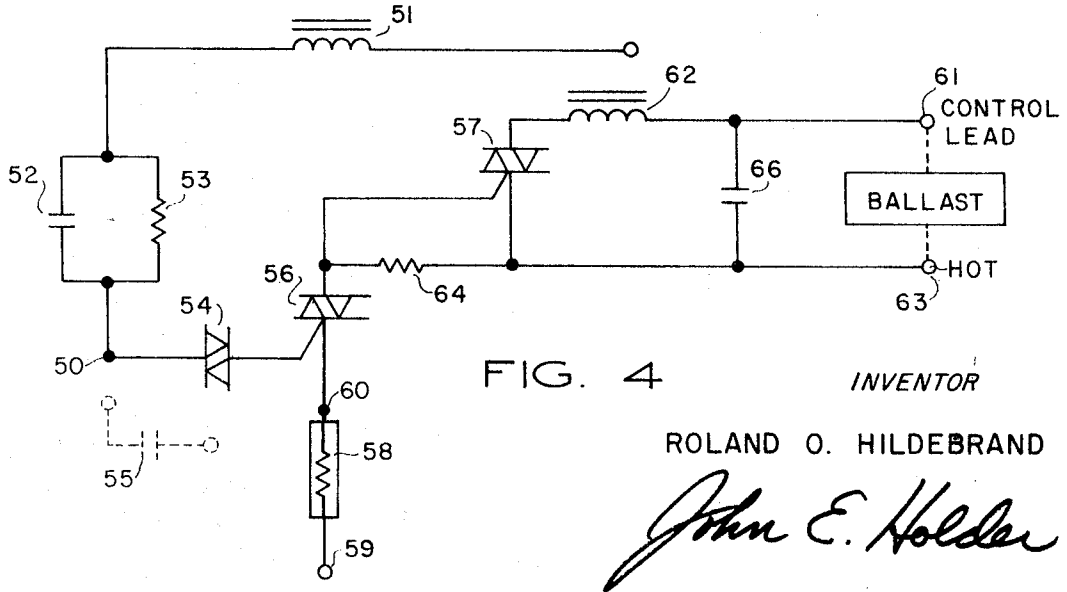


FIG. 4

INVENTOR
ROLAND O. HILDEBRAND
John E. Holder
ATTORNEY

MASTER SLAVE POWER VARYING CONTROL SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to a power control system and more particularly to an electronic slave system operable substantially simultaneously with a master system for controlling the power applied to a load.

The apparatus disclosed herein finds particular application in the control of systems having several loads remotely positioned, such as systems used for dimming remotely located lights in a large lighting system. Systems presently used for such dimming applications involve power driven rheostats or auto transformer systems which slave a remote potentiometer motor control to a master motor control system. The power consumption in large lighting systems, such as in auditoriums and convention halls, requires the use of heavy duty potentiometer or transformer control systems which not only are costly, but also require large amounts of space for their installation. These systems also dissipate a great amount of heat in the form of reactive power losses. This power loss is costly not only from the standpoint of power consumed but also in the measures that must be taken to prevent a safety hazard due to heat dissipation. It is thus desirable to operate remotely located portions of a large lighting system by means of equipment which does not have the cost and space disadvantages of that described above.

It is therefore an object of the present invention to provide a new and improved remote power control system.

SUMMARY OF THE INVENTION

With this and other objects in view, the present invention contemplates an apparatus for controlling a remotely located electrical system. The apparatus includes a master circuit for limiting the time duration during which an alternating current cycle is applied to a master portion of the system and a slave system operable in response thereto. The slave system includes an electronic gate for varying the passage of segments of the positive and negative going components of an alternating power current signal through a power device to a master load and to a slave portion of the system. The electronic gate is operated by an electronic trigger which is operable in response to the power signal applied to the master load.

A complete understanding of this invention may be had by reference to the following detailed description, when considered in conjunction with the accompanying drawings, illustrating embodiments thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic electrical circuit diagram of a master control system for use in the present invention;

FIG. 2 is a schematic electrical circuit diagram of a slave control system embodying principles of the present invention;

FIG. 3 is a schematic electrical circuit diagram of an alternative embodiment of the slave control system; and

FIG. 4 is a schematic electrical circuit diagram of an (alternative) slave control system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1 of the drawings, a master circuit is shown for controlling the application of power to a load such as in the operation of an incandescent lamp dimming system. The master circuit includes a means (not shown) such as a relay, which when energized applies power to the dimming circuit. A first circuit path carries the applied power through a trigger portion of the circuit which includes a resistor **10** for decreasing power to the circuit and variable control resistor **12**. Solid-state device **17** is a trigger which functions similar to a zener diode in a circuit to maintain a constant voltage across a capacitor **11** and resistor **12** in the trigger circuit. Solid state device **13** is a trigger such as a Diac manufactured by General Electric, which controls the application of power to the gate of

a solid-state power device **14**. Device **14** is a gated power switch which will allow current to pass in both directions when its gate is energized by a current of a predetermined threshold value. Such apparatus are commonly termed Triac or Quadrac devices. Power device **14** is arranged to conduct upon the application of a trigger current from trigger **13**. When power device **14** conducts, it applies that portion of line voltage across the load **18**. This line voltage which is applied to the load is filtered for radio frequency interference by means of a circuit comprised of the capacitor **16** and inductor **15**.

In the operation of the circuit described above, power is applied to the dimming circuit by means of a relay or switch (not shown). At the beginning of a half cycle or at zero degrees in the 360° period of a cycle, capacitor **11** is in a discharge condition. Continuing the application of the cycle to the circuit, the voltage increases sinusoidally, passing through the resistors **10** and **12** to charge the capacitor **11**. When the capacitor **11** charges to a voltage equal to the breakover voltage of the trigger **13**, which for example may be **30** volts, the energy of the capacitor **11** is discharged through the gate of the power device **14**. This causes power device **14** to conduct for the remainder of the half cycle or to 180° in the period, when the cycle changes direction. The conduction of the power device **14** in passing the positive half cycle therethrough is shown schematically by the waveform shown emerging from the power device **14**. The dotted line corresponds to the rise and fall of the sinusoidal waveform. From 0° to 90° the power device is shown as not conducting. If the trigger **13** were to conduct when the waveform reached the 90° position then the power device **14** would be gated to conduct line power to the load from the 90° position on the cycle to the 180° position. Such a state of operation is shown in the schematic waveform, wherein the conducting period of the device **14** is represented by the shaded portion of the waveform. Thus it can be seen that the sooner that the trigger **13** conducts to apply current to the gate of power device **14**, the longer the period of conduction will be, which in turn means that a greater portion of the cycle would be within the shaded portion of the waveform representing a greater amount of power passed across the load of the circuit.

Power applied to the load or in this case the dimming circuit, is regulated through the master control circuit by manual or automatic adjustment of the arm of variable resistor **12**. This in turn changes the time in the cycle at which gate current is applied to power device **14**. The current through the gate of power device **14** is dependent on the voltage on capacitor **11** which in turn breaks over the trigger **13** to conduct. The rate the voltage increases on capacitor **11** to trigger the operation of the power device **14**, and allow the power device **14** to become low resistance and conduct, is controlled by the amount of resistance in series with the capacitor **11**. The greater the resistance in series with the capacitor **11**, the longer it requires to develop the voltage needed to ope ate trigger **13** which causes the necessary gate current to lower the resistance in power device **14** to let it conduct. By adjusting the arm of resistor **12**, this change in resistance in series with capacitor **11** is accomplished. Thus, the time duration that is required to operate the trigger may be controlled by movement of the arm of resistor **12**. For example, as resistor **12** decreases in value, capacitor **11** will charge at a faster rate thereby allowing capacitor **11** to reach the breakover voltage of the trigger **13** at an earlier position in the half cycle, which in turn fires the power device **14** sooner, allowing more power to pass through the device which in turn will apply a greater power across the load. In the case of an incandescent lamp control device, the light will become brighter as the power device conducts for greater periods. Due to the nature of the power device **14**, it permits conductions during both the positive and negative going portions of the sinusoidal wave, thus a change of polarity on the next half cycle will cause the process to repeat.

The trigger **17** is positioned in the circuit to act as a limiting device which controls the voltage across the charge circuit

and thus functions in a manner similar to that of a zener diode. Holding such voltage constant across the charging capacitor **11** and resistors **10** and **12** with respect to the line voltage changes, minimizes any fluctuations in the line voltage applied to the circuit, and thus minimizes light changes or flicker due to the fluctuation of the line voltage.

Referring next to FIG. **2** of the drawings, a slave circuit is shown which is operable in response to the operation of the master control circuit described with respect to FIG. **1**. The slave circuit includes a filter **20** and a tank circuit having a resistor **22** and a capacitor **23** in series with a slave current limiting device or trigger **24**. The trigger **24** is connected to the gate of power device **26**, so that when the trigger **24** breaks over to operate, it fires the power device **26**. The slave power device **26** is arranged to fire at approximately four millionths or more of a second after the power device **14** in the master circuit operates. An inductor **27** and capacitor **28** form an inductive-capacitive circuit for suppressing radio frequency interference signals which may be superimposed upon the line power. A circuit breaker **21** is positioned in the input power line to the system.

In the operation of the slave circuit of FIG. **2**, the dimming action of the slave circuit follows that of the master circuit in FIG. **2**. This is accomplished when the power device **14** of the master circuit conducts to immediately apply a voltage across the load **18** of the master circuit and the slave trigger **24**. The current is fed through a coupling means comprised of resistor **22** and capacitor **23** to break over the trigger **24** and fire the slave power device **26**. The coupling means or tank circuit comprised of resistor **22** and capacitor **23** performs a slight phase shift on the signal applied to the trigger **24** which in turn compensates for a very slight time lag which may be affected by the time that it takes the signal to reach the slave control device. When the slave power device **26** fires, line power is passed through the power device **26** to a load **29** of the slave circuit. This occurs substantially simultaneously with the application of power to load **18** of the master circuit, with the light intensity difference, in the case of a dimming circuit, being so minute that it is unmeasurable if both loads have equal wattage. If the circuit breaker **21** in the slave system is opened and the breaker in the master system is closed to operate a load on the master system or other slave circuits, a small current flow takes place through the trigger **24** and power device **26**, since the voltage of the master circuit is on trigger **24**. This situation creates a radio frequency interference in the proximity of the slave system. The filter or inductor **20** however, is sized for low current under low current conditions such as that described above.

Referring to FIG. **3** of the drawings, another embodiment of the slave circuit is shown. This circuit includes a filter **35** and a tank circuit having a resistor **36** and capacitor **37** which feeds a capacitor **38** that charges to break over a trigger device **39**. Trigger **39** is connected to the gate of power device **41** and when it conducts, causes such power device **41** to conduct and apply line power to a load **44**. A radio frequency interference suppression circuit is comprised of an inductor **43** and capacitor **42** across the power line. A circuit breaker **40** is positioned in the input power line to the system. In the operation of the apparatus of FIG. **3**, the power which is applied to the load **18** upon conduction of the power device **14** in the master circuit, is also fed through the tank circuit comprised of resistor **36** and capacitor **37** to a charging capacitor **38**. Charging of capacitor **38** delays the breakover of the trigger **39** which in turn delays the gating of power device **41**. Normally such a delay would be a disadvantage in that it would cause the slave circuit to operate slightly out of coincidence with the master circuit which would be very difficult to measure. However, in the event that a greater current is needed to trigger the power device **41**, the capacitor will delay operation of the trigger **39** until the current is sufficient to operate the power device **41**. Again, the tank circuit including resistor **36** and capacitor **37** affords a slight phase shift to compensate for the slight time shift between the operation of the master and slave control circuits to give the same light level between the two systems. The filter **35** acts as a low current RFI filter as described in the operation of the circuit of FIG. **2**.

In the overall operation of the system described above, power is applied to the trigger **13** in the master circuit through the variable resistor **12**. Varying the resistor **12** regulates the time it takes to charge capacitor **11** to break over trigger **13**. Upon breakover of trigger **13**, current applied to the gate of power device **14** causes the device to conduct which in turn passes the line power applied to power device **14**. The power device continues to conduct until the polarity of the cycle changes whereupon the process is repeated for the other half cycle. As shown in the diagrammatic illustration of the waveform in FIG. **1**, depending on the breakover time of trigger **13**, the line power does not pass through the power device **14** during part of the cycle thus limiting the power applied to load **18**. This limited power signal also passes to one or more slave circuits such as the ones shown in FIGS. **2** and **3**. When the limited or "chopped" signal from the master circuit is applied for example to the slave circuit of FIG. **2**, the trigger **24** breaks over almost immediately to apply sufficient current to the gate of power device **26** to cause it to conduct. When power device **26** conducts, it them passes the remaining portion of its line power cycle which being in phase with the power cycle of the master circuit power signal, will pass substantially the same limited signal to provide equal power to the slave load **29**. One master circuit may not only serve a multiplicity of slave circuits, but the slave circuits may be of various embodiments.

As described in the "BACKGROUND OF THE INVENTION," the use of three-phase systems in large lighting circuits is quite common. However, one of the disadvantages of such a system is that there is a reactive coupling from one line of the system to another which causes in some cases the slave circuit to trigger inadvertently. Such an inadvertent trigger would cause a flicker in the lighting, depending upon what time point the trigger occurs in the cycle of the power signal. By triggering the slave at a threshold level, that is by utilizing the trigger **24** (FIG. **2**) to operate the power device **26**, a protection is afforded against such inadvertent activation due to reactive coupling, since the trigger **24** is only responsive to a threshold voltage level which prevents spurious signals from activating the power device **26** in the slave circuit. The same would be true of course for the slave circuit of FIG. **3**.

Where a single-phase system is in use, an alternative arrangement to the system of FIG. **2** would utilize a resistor **45** (shown in dotted lines) between terminals **25** and **30**, in place of trigger **24**, to act as a current limiting device. Since the resistor would not cause a threshold level of operation as would the trigger, such a resistor would not work as well as the trigger where a three-phase system is in use. Also, the resistor would not permit the slave circuit to track as accurately as the trigger.

In addition to the circuit embodiments described above, FIG. **4** shows still another circuit which finds particular adaptation to high inductance loads such as in a fluorescent lighting device. Normally in an incandescent dimming system, as for example the system of FIG. **2**, there is enough current passing through the power device of gate **26** to keep it conducting once it is turned on until the polarity of the chopped signal from the master circuit changes. However, in a fluorescent lighting system, the dimming ballast offers a high inductive load which in turn causes a phase shift or lag in the current with respect to voltage, and thus the current may be insufficient to keep the power device or gate **26** on throughout the duration of the cycle. In order to alleviate this condition, the circuit of FIG. **4** incorporates certain features which will maintain a high current flow throughout the duration of the power cycle. This circuit is similar to that of FIG. **2** in that it includes an RFI filter **51** and a tank circuit having a capacitor **52** and resistor **53** in series s a slave trigger **54**. The slave trigger is connected to the gate of a first power device **56** which in turn is connected to the gate of a second power

device 57. A load resistor 58 is connected between the first power device 56 and a neutral terminal 59. The second power device 57 has one lead connected to a control lead 61 through a choke 62. The other lead from the second power device is connected to a hot lead 63. This lead is also connected to the first power device through a gate clamping resistor 64. A capacitor 66 is positioned across the power device 57 to form an RFI filter with the choke 62.

In the operation of the circuit described above, the master circuit provides a control signal to the slave circuit of FIG. 4 in the same manner as described with respect of FIG. 2 above. The current is fed through capacitor 52 and resistor 53 to breakover the trigger 54 and fire or gate the first power device 56. The tank circuit comprised of capacitor 52 and resistor 53 performs a phase shift on the signal applied to the trigger to compensate for a slight time lag in signal transmission from the master circuit. When the first power device fires, the second power device 57 is caused to conduct because current passes through the gate of the second power device and is continuously applied to the gate and thereby holds it on until polarity of the signal changes. On the other hand, the first power device is triggered by a trigger 54 which is noncontinuously operating device; i.e., when the trigger 54 fires, it goes to zero until the next cycle or change of polarity fires it again. Since the trigger is noncontinuously conducting, if as in FIG. 2, the gate of the main power device is connected directly to the trigger and if there is a current lag as may be caused by a large inductive load, the main power device may quit conducting and cause a flicker in the lighting system, if that be the load being controlled.

The load resistor 58 in the circuit limits the current which may pass through the gate of the second or main power device and back through the first power device to avoid damage to the circuit.

Similarly to the circuit of FIG. 3, a capacitor 55 (shown in dotted lines) may be positioned in the circuit of FIG. 4 between a terminal 60 and a terminal 50 at the input to trigger 54. Charging of such a capacitor would delay the breakover of the trigger 54 which in turn would delay the gating of power devices 56 and 57 in turn. This arrangement might be necessary if greater current is needed to trigger the first power device 56. The delay in operation of the trigger, which is caused by the capacitor, will permit a sufficient buildup of current to operate the trigger under such conditions.

In addition, as described with respect to FIG. 2, for single-phase operations, a resistor could be substituted for the trigger 54, with such resistor acting as a current limiting device.

In a three-phase operation, the circuits shown in FIGS. 1 and 2 or 1 and 3 would be typical of the master-slave arrangement for handling any one of the three phases of a three-phase system. Therefore, in such a system it would be necessary to utilize a separate master phase system. In addition, the potentiometer 12 in the master circuit would be operated simultaneously in all three master circuits. This could be accomplished, for example, by connecting each of the potentiometers to a single shaft for simultaneous adjustment, or by ganging the potentiometers in any manner suitable for accomplishing the desired result.

While the present invention has been described with respect to the operation of a dimmer circuit in a lighting system, it is readily seen that such a circuit would have application to other master-slave control systems having various load applications. In addition, while particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What I claim is:

1. In an apparatus for controlling an electrical system and having a master circuit for limiting the time duration a power signal is applied to a first portion of such system, means for operating at least one slave portion of the system in synchronization therewith, which means includes: solid-state gate means having a single gating element for each slave portion for varying the passage of at least portions of the positive and negative components of a power signal to a load across said slave portion of the system; and breakover trigger means in each of said at least one slave portions for operating said gate means, said trigger means being operable in response to the limited power signal applied to a load in said first portion of the system.

2. The apparatus of claim 1 wherein said gate means limits the passage of equal portions of said positive and negative components of said power signal.

3. The apparatus of claim 1 and further including means for providing a phase shift of said power signal operating said trigger means.

4. The apparatus of claim 3 wherein said phase shift means includes a reactive circuit positioned in series with said trigger means and the master circuit.

5. The apparatus of claim 1 wherein said trigger means is operable in response to a predetermined voltage level being applied to the input of said trigger.

6. The apparatus of claim 1 and further including means in said slave portion for delaying the operation of said trigger means until current available for passage by said trigger means to said gate means reaches a predetermined level.

7. The apparatus of claim 1 and further including means for suppressing radio frequency signals superimposed on the power signal which is passed by said gate means.

8. The apparatus of claim 1 and further including means for suppressing radio frequency interference signals due to the passage of small amounts of current through said slave portion of said system.

9. In a circuit for controlling the time duration during which a power signal is applied to a three-phase lighting system; first gate means for passing positive and negative components of an alternating power signal to a first portion of the lighting system; first trigger means operable in response to a predetermined voltage level being applied thereto for operating said first gate means; first control means for varying the time during which said voltage reaches said predetermined level to thereby vary the time duration during which said power signal is passed by said first gate means; second gate means for passing a power signal to a second portion of said lighting system; and second trigger means operable in response to the timed passage of the power signal through said first gate means for operating said second gate means, said second trigger means having an operating response level above a level responsive to spurious line signals in a three-phase power system.

10. The apparatus of claim 9 and further including means for providing a phase shift of said power signal applied to sa'd second trigger.

11. The apparatus of claim 9 and further including means for delaying the operation of said second trigger means until the current available for passage through said second trigger means reaches a predetermined level.

12. In an apparatus for controlling an electrical system and having a master circuit for limiting the time duration a power signal is applied to a load across a first portion of such system, means for operating a second portion of the system in synchronization therewith, which means comprises: a first power device for passing at least a portion of the positive and negative components of a power signal to a load across the second portion of the system; a second power device for gating said first power device; and trigger means for operating said second power device; and trigger means being operable in response to the power signal applied to the load across the first portion of the system.

13. The apparatus of claim 12 and further including means for limiting the amount of current passing through said second power device.

14. The apparatus of claim 12 and further including means in said second portion for suppressing radio frequency interference signals due to the passage of relatively small amounts of current from the master circuit through the second portion of the system.

15. In a circuit for controlling the time duration during which a power signal is applied to a load system with at least a portion thereof having a high inductance: first gate means for passing components of an alternating power signal to a first portion of said load system; first trigger means operable in response to a predetermined voltage level being applied thereto for operating said first gate means; control means for varying the time during which said voltage reaches said predetermined level to thereby vary the time duration during which said power signal is passed by said first gate means; second gate means for passing components of a power signal to a second portion of said load system having a high inductance; third gate means for operating said second gate means; and second trigger means operable in response to the timed passage of the power signal through said first gate means for operating said third gate means, said third gate means continuously operating until the polarity of said power signal passed through said first portion of said system changes direction.

16. In an apparatus for controlling an electrical system having a master circuit for limiting the time duration a power signal is applied to a terminal in a first portion of the system and for operating a second portion of the system and for operating a second portion of the system in synchronization therewith: first solid-state gate means for passing portions of the positive and negative components of an alternating power signal to the terminal in the first portion of the system; first control means for varying the time during which said power signal is passed by first gate means to said terminal; second gate means for passing a power signal to the second portion of the system; coupling means between said terminal and said second gate means for limiting current flow to said second gate means; and first and second trigger means in said master circuit and second portion respectively for operating said first and second gate means.