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(71) Applicant: **DENTSPLY INTERNATIONAL, INC.**
570 West College Avenue
York Pennsylvania 17405(US)

(72) Inventor: **Gonser, Donald I.**
1749 Crescent Road
York Pennsylvania 17403(US)

(72) Inventor: **Barber, Duane E.**
108 Raypaula Drive
Shrewsbury Pennsylvania 17361(US)

(74) Representative: **Wächtershäuser, Günter, Dr.**
Tal 29
D-8000 München 2(DE)

(54) Power control apparatus with optical isolation feedback means.

(57) The invention comprises transformerless power supply apparatus particularly adapted for supplying regulated power to critically sensitive loads such as tungsten lamp filament loads of designed power rating. Power control is achieved by a triggered triac in series with the load, and regulation is provided by a feedback circuit, voltage or current, which generates the triac trigger signal periodically as a function of the load voltage or current. The feedback circuit is provided with a photo isolator for eliminating premature triggering of the triac due to transients. A timing circuit is also provided for timing the power on condition, the output of which is photo isolator coupled to the triac feedback circuit.

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POWER CONTROL APPARATUS WITH OPTICAL ISOLATION FEEDBACK MEANS

Background of the InventionField of the Invention

This invention relates to transformerless regulated power supply apparatus and, in particular, triac switching power supply apparatus for supplying power to loads which are highly voltage or current sensitive.

Background of the Invention

There are many electrical loads for which very well controlled regulated power supplies must be provided. For example, in the dental field, light source devices are needed for different applications, including curing of photo-curable restorative materials which have been placed in prepared cavities. In other applications, such as the visible light curing of dentures and like objects, it is necessary to have well controlled power sources in order to protect the lifetime of the tungsten halogen lamp filaments and maintenance of light output power under all power line operating conditions. See my co-pending application S.N.

D-152, assigned to the same assignee. Similarly, the power control of a muffle in a furnace device, such as a platinum rodium or a silicon carbide muffle, requires that the power supply be immune to current surges and voltage transients.

In prior art devices that utilize power transformers, the inertia of the transformer magnetic core provides a great deal of protection to high frequency noise and voltage transients. However, this is done only at additional cost, size, and weight compared to simpler switching regulator power supplies. Simple triac switching

power supplies, with a triac firing angle control circuit for controlling the ON time of the triac, are known in the art and provide a substantial reduction in size, weight and expense compared to power transformer type power supplies. However, the simplicity of such power supplies makes them extremely vulnerable to transients, particularly in applications such as above noted where early firing of the triac for so much as only one cycle can burn open a lamp filament or otherwise shorten the life of the load. In specific dental applications using tungsten halogen lamps, a high frequency or high voltage transient which causes early triggering of a triac for just one cycle can cause catastrophic early burnout of the lamp filament. There is thus a basic requirement for such protection if a transformerless power supply is to be a practical approach in design. Incorporating triac switching must, therefore, incorporate effective and reliable means for isolating the apparatus from high frequency or voltage transients, such as are often present from the power line and which may be generated in the nearby or even distant environment.

Summary of the Invention

It is a primary object of this invention to provide a reliable and inexpensive switching regulated power supply for powering very sensitive loads, such as lamp filaments, furnace muffles and like elements which are extremely voltage or current sensitive.

It is another object of this invention to provide a regulated power supply for supplying sensitive loads, which comprises a cyclically switched element which is controlled by a feedback circuit, and which has effective means for preventing early switching which would cause greater than a predetermined amount of power to be delivered to the load during a power cycle.

It is another object of this invention to provide a regulated power supply with timing means for delivering a regulated voltage or current to a load during a predetermined time period, and incorporating photo isolator means for delivering both the timing
5 signal and a feedback signal to the regulator control element of the power supply.

It is another object of this invention to provide power supply apparatus with triac control, having a controllable phase delay for triggering the triac, the triac trigger circuit having
10 photo isolator coupling means for coupling a feedback signal representing delivered voltage or current from which the trigger signal is timed.

In accordance with the above objects, there is provided a power supply apparatus with means for switchably connecting AC power
15 from a power line in series with a load, the switching means comprising a triac or like switching device, and triac control means for generating triac gate trigger pulses with a controllable phase delay referenced to the line power crossover. The triac control circuit includes a feedback path including photo isolator means
20 having a transient response selected to eliminate extraneous high frequency signals, thereby making the triac control immune from unwanted EMI and other interference. Timing circuitry is provided for timing the on state of the regulator, the timing signal being coupled to the triac control through optical isolator means.

25 Brief Description of the Drawings

Fig. 1 is a circuit diagram of a preferred embodiment for supplying a regulated voltage to a voltage sensitive load.

Fig. 2 is a block diagram of a preferred embodiment for supplying a regulated current to a current sensitive load.

Description of the Preferred Embodiments

Referring now to Fig. 1, there is shown a circuit diagram of a preferred embodiment of the invention. Power is taken from the power line, i.e. single phase 115 volts. It is connected through magnetic elements 30, suitably Molypermalloy powder toroids typically wound with 30 turns of number 9 wire to give an inductance of about 53 microhenries. The toroids are designed to take out certain high frequency transients which might be transmitted through the power line. A varistor diode 32 is connected across the two lines of the single phase power, further to eliminate transients.

The circuitry of Fig. 1 is basically broken down into two portions. In the left hand portion of the diagram, there is shown a timing circuit, centered around IC 65 designated MC14536. DC voltages for this circuit are provided through the transformer as designated at 34, the bridge rectifier circuit shown as BR-1, and associated conventional circuitry. The righthand portion of the diagram includes the load circuit comprising load lamps 50 and the triac 51, and the triac control circuit which is centered around the integrated circuit 60 designated TDA1185.

Referring first to the load circuit and the triac control, as illustrated the load is comprised of four tungsten halogen lamps 50, manufactured for rated operation at 41 volts RMS and 200 watts. The circuit illustrated causes the lamps to operate at about 43 volts RMS, or about +5% of rated value. These are extremely sensitive lamps, and can be burned out by overdriving during a single power line cycle. For example, one early misfire of the triac can cause instant burnout of such lamps. The lamps have been designed for a power and voltage rating which results in a structurally strong filament capable of long lifetime use, and for

the desired operating results, such as photo curing in dental applications, it is necessary to operate the lamp filaments close to the peak permissible power and operating color temperature.

However, if excessive power is permitted to be passed to the lamp for one or more cycles, immediate burnout or at least extremely shortened lifetime can result. Thus, the control circuit which controls the triggering of the triac 51 is extremely important.

The apparatus of this invention utilizes a silicon monolithic integrated circuit designated "triac firing angle control circuit", type TDA1185, such as made by Motorola Semiconductors. The TDA1185 generates gate trigger pulses for a triac with a controllable phase delay. An internal saw tooth generator provides a linear ramp for trigger point control. It provides full wave triac drive, i.e., the triac is triggered as the line voltage goes both positive and negative. The trigger pulses are delivered from pin 2 and connected to the triac trigger terminal. The phase angle of the trigger pulses is derived by comparison of a ramp voltage which is initiated at the crossover of the power voltage, and a required predetermined value. This comparison sets the firing angle, i.e. determines the voltage level at which the triac conducts and permits power delivery to the load. The TDA1185 also provides soft-start operation, i.e., the permitted power to the load is ramped up from zero to the desired full load level.

As illustrated, pin 1 of the TDA1185 is connected to -DC voltage, which is generated by the 1N4006 diode and 10K resistor connected to one side of the power line. Pin 2 is the output of the trigger pulse, which is connected through a 100 ohm resistor, to the trigger lead 52 of triac 51. Pin 6 is connected through the resistor to one side of the load, and pin 7 is connected through the

resistor to the minus side of the power source, to provide synchronization of the ramp generation with the line zero-crossing voltage. Pin 12 receives a level of voltage derived from the line signal, which determines the phase angle positioning. A feedback capacitor is connected between pin 8 and the neutral side of the power line; pins 9 and 14 are connected directly to the neutral side of the power line; a resistor is connected between pin 10 and neutral; and the capacitor between pin 13 and the positive power line sets the soft-start characteristic.

0 The comparison signal is taken from the negative side of the power line, and is passed through a 560 ohm resistor and an adjustable resistor 54 to the bulb element 55 of a photo isolator combination. The photo isolator utilized is suitably an CLM5H10A, comprising an incandescent lamp 55 and a photo-transistor 56. This
15 isolator has the requisite optical response to follow the power line, but does not respond to transients that may be on the power line or otherwise picked up by the circuitry. The lamp 55 must have very stable output characteristics in order to maintain long term voltage calibration. For this reason, a incandescent lamp is the preferred light source for this circuit. The photo-resistor is tied between pin 1 and pin 12, providing a voltage variation at pin 12 which the IC compares to its internally generated saw tooth ramp signal, from which the triac trigger pulse is obtained. Between pin 12 and the plus side of the power line is a thermistor 57, which
25 provides environmental temperature compensation for the characteristics of the silicon photo-resistor 55. Thus, in operation, as the negative side of the power line crosses over through zero, going either plus or minus, the IC 60 initiates a ramp. The ramp is internally compared to the voltage level at pin

12, such that the trigger pulse is generated when the ramp signal equals pin 12 voltage. Thus, for higher line voltages the trigger pulse is delayed, and vice versa. Due to the isolation provided in the feedback circuit, only the relatively slowly moving power line changes are transmitted through to pin 12, such that IC 60 is prevented from prematurely triggering the triac 51. The circuit of resistor 85 and capacitor 86, connected across triac 51, aids in preventing holdover triac operation which can be caused by line transients.

The timer circuitry is constructed around IC 65, which is suitably a programmable timer type MC14536, as made by Motorola. This is a programmable timer, comprising a flexible 24 stage ripple binary counter with 16 stages selectable by a binary code. An on chip monostable oscillator circuit is provided, and by selecting the appropriate output in conjunction with the correct clock frequency, a variety of timing can be achieved. For the pin connections as shown, timing is adjusted by operator manipulation of resistor 40, which is connected between pins 4 and 5 as shown. The output, taken at pins 13, 14, is connected through resistor 42 to transistor amplifier 43. The output of transistor 43 is taken from the emitter, and inputted to pin 1 of photo isolator 45, suitably an IC of type H115100. The -DC power which is connected to the TDAl185 chip is also connected to pin 4 of chip 45, and the output signal from pin 5 is connected to pin 12 of chip 60. In operation as long as the timing signal from chip 65 is low, i.e. the load is not to receive power, the output from chip 45 is held low, meaning that pin 12 of chip 60 is held low such that it is inhibited from generating trigger pulses. For the duration that the timer 65 produces a high output, chip 60 is enabled and operates as described above. The

photo isolator 45 prevents any noise or extraneous transients which are picked up in the timer circuitry from being connected through to cause premature or incorrect firing of the triac.

Referring now to Fig. 2, there is shown a block diagram of an embodiment of this invention for supplying regulated current to a current sensitive load. The power 70, taken from the power line as in Fig. 1, is connected across the current sensitive load 80 and triac 79. In series with the load is a current transformer which provides a current signal to a resistor 74 and a bulb 72 of a photo isolator. The bulb 72 is paired with photo transistor 73, which is connected to a threshold pulse generator 77. Generator 77 is the same as that shown in Fig. 1, i.e., it comprises a TDA1185 IC chip with appropriate connections, and a thermistor such as thermistor 57. The trigger pulses from the IC chip are connected to the gate 78 of triac 79. In this manner, the trigger pulse timing follows the sensed current flow through load 80, just as the trigger timing of Fig. 1 follows the voltage across load 50.

1. Transformerless power supply apparatus, comprising source means for providing AC power from a power line, load output terminals, in a series circuit across said source means, for outputting power to a load,

switching means in series with said load output for switching on and off, said switching means having a trigger input and a characteristic of being normally a substantial open circuit and a substantial short circuit when triggered to a conducting state, and

trigger means for developing a trigger pulse at its output, having a feedback circuit connected to said load and an output connected to said trigger input, said feedback circuit including a photo isolator circuit with response characteristics for following power line variations without transmitting transients.

2. The apparatus as described in claim 1, wherein said switching means comprises a triac.

3. The apparatus as described in claim 2, wherein said trigger means comprises a triac firing angle control circuit IC.

4. The apparatus as described in claim 3, wherein said trigger means is synchronized with the zero crossing of the voltage of said power line.

5. The apparatus as described in claim 1, wherein said source means comprises magnetic means for filtering high frequency signals carried by the power line.

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6. The apparatus as described in claim 4, wherein said triac firing angle control circuit IC has a trigger level input pin, and said feedback circuit has an output connected to said input pin.

7. The apparatus as described in claim 6, further comprising timing means for generating timing signals, and second photo isolator coupling means for coupling the output of said timing means to said trigger level input pin.

8. Power supply apparatus adapted to receive power from a power line and for supplying timed regulated power to a load, comprising:

a two state switching device having input means for receiving a switching trigger input;

trigger generator means for deriving said trigger input from variations of said power line and delivering it to said switching device, said trigger generator means having a first photo isolator circuit for isolating transients from said trigger input;

a timing circuit which generates a timing signal for timing periods of power delivery to said load; and

coupling means for coupling said timing signal to said trigger generator means to enable or disable same, said coupling means comprising a second photo isolator circuit for isolating transients from said trigger generator means.



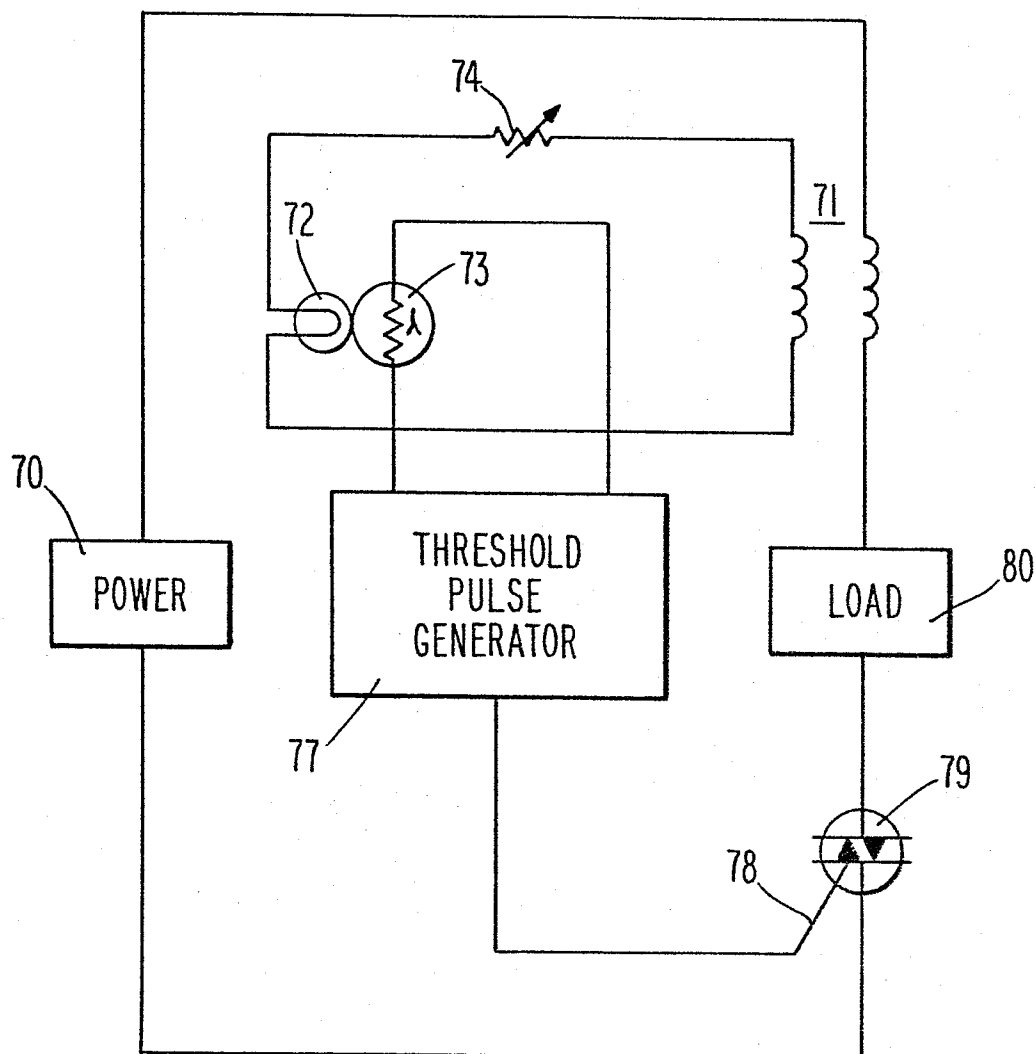


Fig. 2



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
X,Y	US-A-4 224 563 (POLAROID) * Whole document *	1-8	G 05 F 1/455 H 05 B 39/08
Y	--- ELECTRICAL DESIGN NEWS, vol. 26, no. 9, 29th April 1981, pages 176-178, Boston, USA; T. HOPKINS: "Regulate lamp output with one IC" * Whole document *	3,6	
Y	--- US-A-4 344 071 (R.A. HELLER) * Abstract; figure 5 *	7,8	
A	--- US-A-4 064 404 (C.B. WILMOTT et al.) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 7)
			G 05 F H 05 B H 03 K H 01 H
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 13-08-1984	Examiner HOUILLON J.C.P.L.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			