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[54] **CIRCUIT FOR DETERMINING AND CONTROLLING THE CURRENT SUPPLIED TO AN ADJUSTABLE RESISTANCE LOAD**

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[51] **Int. Cl.**.....**G05d 23/01**

[58] **Field of Search**.....219/499; 323/19, 22 SC, 24, 323/34, 37, 40

[56] **References Cited**

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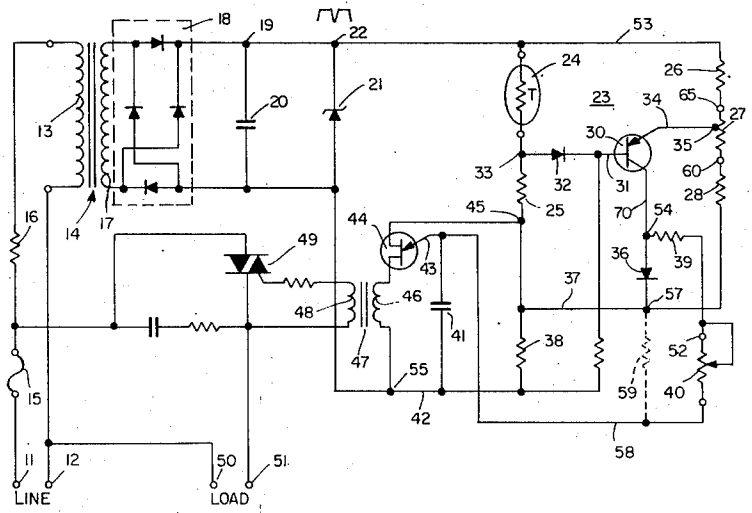
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[57] **ABSTRACT**

A bridge circuit with a current switch connected to the output terminals thereof. The current switch is connected to two current paths, one of which acts to develop a voltage in accordance with the rate of electrical conduction of the current switch. The last mentioned path has a variable resistor therein which can be set to vary the rate of the voltage development. A second current switch is connected to be responsive to the voltage developed but in being so connected the second current switch can be made to fire at the same time with respect to each applied half cycle of power, irrespective of what rate the first current switch conducts. A further current switch is coupled to the second current switch to connect in a heating load when the second current switch conducts.

5 Claims, 3 Drawing Figures



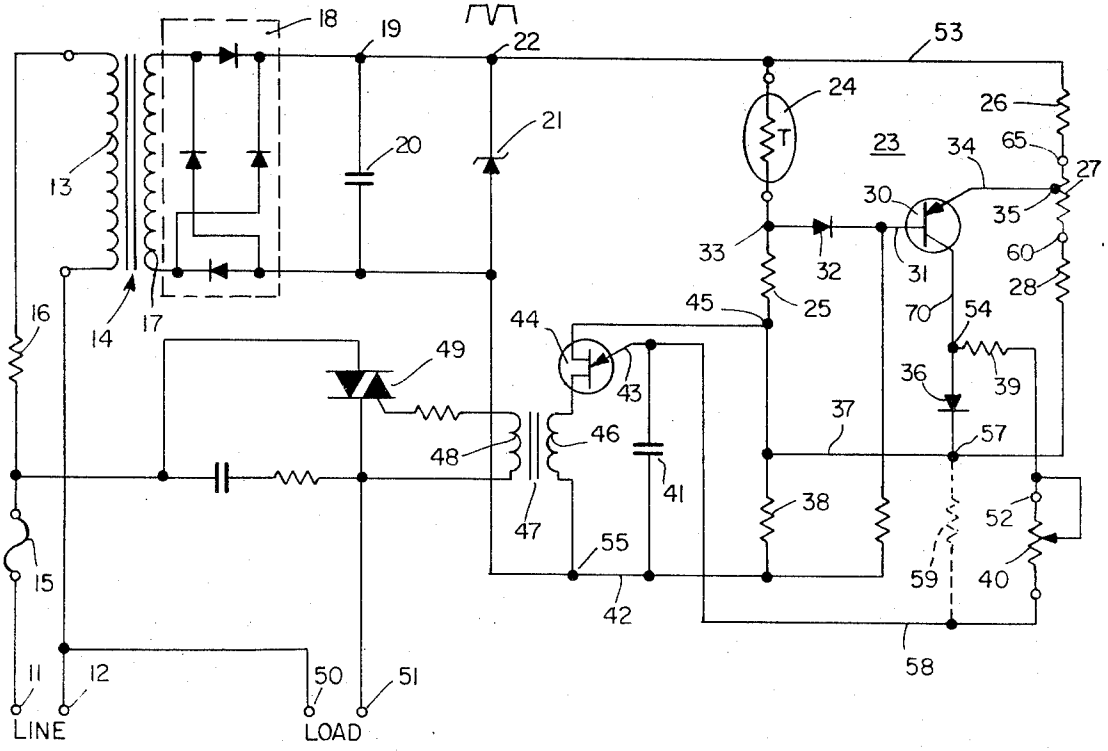


Fig. 1

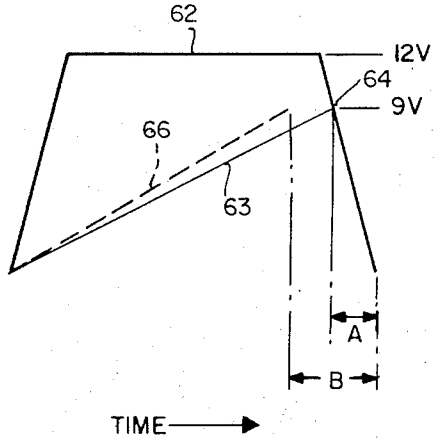


Fig. 2

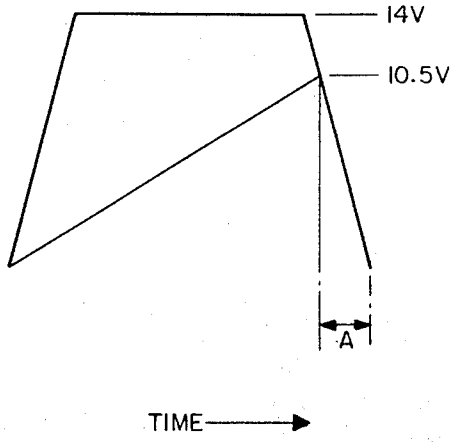


Fig. 3

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CIRCUIT FOR DETERMINING AND CONTROLLING THE CURRENT SUPPLIED TO AN ADJUSTABLE RESISTANCE LOAD

BACKGROUND

In heat tracing applications, such as arrangements for heating pipes, or conduit, carrying water or other liquids over relatively long distances, it has been the practice heretofore to employ a number of temperature monitoring circuits, or temperature controller circuits, with each assigned to different one of a number of segments of heating cable. The heating cable segments are wrapped with or are disposed in close proximity to the pipes or conduit. For instance, if a lengthy liquid-carrying pipe is to be temperature monitored to prevent a freeze-up, it is apparent that the temperature sensitive probe or temperature sensitive element of the control system can only be responsive to a limited length of the pipe. Hence for a long installation there would be a number of segments of heating cable each of which would be connected to its own associated controller circuit. In addition it is very often the case that such a pipe arrangement is not laid out uniformly, that is, there are bends and off-sets and thus the heating cable segments may vary in length to accommodate the various stretches of pipe which can be temperature monitored as a unit.

Normally in such heat tracing applications there is a specified cable current which is calculated to give a maximum allowable temperature rise as related to the pipe and the contents being carried therethrough. For instance, the maximum allowable temperature rise to prevent freezing would be determined, if that is the object of the application of heat. Normally, the voltage required for each segment of the heating cable is determined by multiplying the resistance per foot of the cable by the installed length of the segment. As should be apparent from the discussion above the number of segments required depends upon the length and the lay-out of the installation. Of course the segment lengths differ depending upon the lay-out and the length of the installation. Hence, it becomes apparent that there are a number of different maximum control voltages required by such a system. It therefore has been the practice to provide a transformer with each controller circuit which transformer had to be matched with the heating cable segment to which the electrical power is applied. The matching or setting up of the numerous transformers is a costly item from the standpoint of providing a plurality of adjustable transformers and it is a costly and time-consuming arrangement from the standpoint of the installation itself. With the present system there is no need to match a transformer to the heating cable to effect a heat tracing application.

SUMMARY

The present circuit provides a full wave rectifier and a Zener diode connected thereacross to convert the input alternating current signal to a pulsating direct current signal approximating a square wave. This square wave is applied to a bridge circuit which is made up of a thermistor connected in series with a resistor (to constitute the first and second legs of the bridge circuit) and an adjustable resistor connected in series with a resistor (to constitute the third and fourth legs of the bridge circuit). A transistor is connected across the output of the bridge. The base or control element of the transistor is connected between the thermistor and a first resistor. The emitter of the transistor is connected to an adjustable tap of an adjustable resistor. The collector of the transistor is connected through a diode to a common line side of the bridge circuit and is also connected through a second adjustable resistor and through a capacitor to the same common line circuit. There is a further connection from the last mentioned capacitor to a unijunction transistor whose output is applied to a pulse transformer. The pulse transformer, when pulsed, turns on a triac to provide current to the load. As will become apparent in the discussion hereinafter the first adjustable resistor enables the user to set the temperature point for control while the second adjustable transistor enables the system to readily limit the load current to the particular value necessary for the maximum allowable temperature rise in response to the set temperature control valve.

The objects and features of the present invention will become apparent in accordance with the description hereinafter when taken in conjunction with the drawing.

FIG. 1 is a schematic drawing of the circuit of the present invention.

FIG. 2 is a graphic display of the firing time of unijunction transistor 44 under different conditions.

FIG. 3 is a graphic display of the firing time of unijunction transistor 44 under a condition wherein the variable resistors 27 and 40 have been set to cause unijunction transistor 44 to fire at the same time as under one of the conditions shown in FIG. 2.

Consider the drawing wherein there is shown a pair of line terminals 11 and 12 through which there is applied an alternating current signal to the primary winding 13 of the transformer 14. The applied signal is transmitted through a fuse 15 and a resistor 16. The resistor 16 provides a certain degree of regulation for the commercially available power. The alternating current signal from the secondary 17 of the transformer 14 is rectified at the full wave rectifier 18 and hence there is a pulsating direct current signal available at the terminal 19. The capacitor 20 is provided to short circuit any high frequency transient signals. The pulsating direct current is applied across the Zener diode 21 whereat it is clipped or shaped so that at terminal 22 there is provided a pulsating direct current signal which approximates a square wave as shown.

There is connected in the arrangement a bridge circuit 23 which is composed of the thermistor 24, which constitutes one leg of the bridge circuit; the resistor 25, which represents the second leg of the bridge circuit; the resistor 26 and part of the adjustable resistor 27, which constitutes the third leg of the bridge circuit; and the remainder of the adjustable resistor 27 along with the resistor 28 which constitutes the fourth leg of the bridge.

It will be noted in the drawing that a PNP transistor 30 is connected across the output of the bridge circuit 23. The control element, or base 31 is connected through the diode 32 to the terminal 33 which lies between the thermistor 24 and the resistor 25. The emitter 34 is connected to the tap 35 of the adjustable resistor 27. The collector of the PNP transistor 30 is connected through the diode 36 to the return line 37.

The return line 37 is connected through the resistor 38 to the other side of the Zener diode 21.

It will be noted that the collector 70 is also connected through the resistor 39 and a second adjustable resistor 40 to the upper side of the capacitor 41. The lower side of the capacitor 41 is connected to the return line 42. It will also be noted in the drawing that the upper side of the capacitor 41 is connected to the control element 43 of the unijunction transistor 44. The input element of the unijunction transistor 44 is connected to the terminal 45 while the output element of the unijunction transistor 44 is connected to the primary winding 46 of the pulse transformer 47. The secondary winding 48 of the pulse transformer 47 is connected across the control element and the output element of the triac 49 so that when the pulse transformer 47 has been pulsed the triac 49 will conduct to provide current directly from the line input across the load input terminals 50 and 51. Depending upon the time in the cycle that the triac 49 is fired or caused to conduct the power to the load from the line will determine the voltage applied to the load and hence the cable current.

OPERATION

When the present system is to be used with a heating element or heating cable, the resistor 40 is adjusted so that the tap comes to rest on the terminal 52 and the tap 35, which is really a temperature dial setting, is turned on to the value which is the proposed temperature. Thereafter an ammeter is connected into the circuit between the terminal 51 and the cable. Then the tap on the second adjustable resistor 40 is moved downward from the terminal 52 until the particular cable current which can be tolerated for the maximum allowable temperature rise is determined by the reading on the ammeter. When that particular current has been determined, the resistor 40 has been properly adjusted. With the proper settings having been attained the circuit is then ready for actual operation.

Let us assume for the purpose of this discussion that although the parameters of the circuit could be adjusted to provide other input and output values, that the voltage developed across the Zener diode 21 is 16 volts and hence the voltage applied across the bridge circuit is something less than 16 volts. Let us further assume that the pipe which is being monitored is relatively cold and hence the resistance of the thermistor 24 is relatively high. It should be readily apparent that if the resistance of the thermistor 24 is relatively high and the resistance value of the resistor 26 in series with the upper part of the adjustable resistor 27, which actually is a temperature dial setting, is also properly chosen, then the voltage drop across the thermistor 24 will be greater than the voltage drop across the resistor 26 in series with the upper portion of the adjustable resistor 27 (up to where the tap is set to represent a particular temperature). Hence, the voltage at terminal 33 will be more negative than the voltage at the tap 35 and there will be transistor action in the PNP transistor 30.

With the transistor 30 conducting there will be current flowing from the upper line 53, through the resistor 26, through the upper portion of the resistor 27, through the emitter 34, through the collector 70 to the terminal 54 wherefrom there are two current paths. The first current path is through the diode 36 to the lower line 37, through the resistor 38, through the lower line 42 and to the other side of the Zener diode 21. The second path that the current will flow along is through the resistor 39, through the lower section of the adjustable resistor 40, to the capacitor 41. Accordingly the capacitor 41 will commence to be charged. The unijunction 44 is chosen in the preferred embodiment such that it will fire when the voltage applied to its control element is 75percent of the voltage appearing across its input and output elements). Hence it becomes apparent that when the capacitor 41 is charged to a point where the voltage is equal to 75 percent of the voltage appearing across the terminals 45 and 55 the unijunction transistor 44 will conduct.

To fully appreciate the role that the adjustable resistor 40 plays in this circuit consider that the second path just described, that is, the second current path including the resistor 39 and the adjustable resistor 40 is not connected in the circuit and instead there is a connection between the terminal 57 and the line 58 as shown by the dashed line 59. Also assume that the temperature setting is low, that is, that the tap 35 is set toward the terminal 60. Further assume that the voltage developed across the resistor 38 (therefore across the points 45 and 55) is 12 volts so that the voltage which must be developed across the capacitor 41 would be 9 volts in order to fire the unijunction transistor 44. This would be the circumstance shown in FIG. 2.

In FIG. 2 the amplitude of the applied signal 62 is shown as 12 volts. The rate of charge of the capacitor 41 is shown by the line 63 and the firing time, that is, when the capacitor 41 reaches 9 volts is shown by point 64. Under these circumstances the power applied at the terminals 11 and 12 would be applied to the load across the terminals 50 and 51 for the period shown as A in FIG. 2. Now if this last described circuit were to be used for a higher control temperature, the tap 35 would be raised on the adjustable resistor toward the terminal 65 so that there would be less resistance value in the third leg of the bridge, i.e., less resistance value for the resistor 26 in series with the upper part of resistor 27. Under these circumstances when the transistor 30 is turned on there would be a greater current applied to the capacitor 41 and hence the capacitor 41 would reach the 9 volt value more quickly than it had under the low temperature setting previously considered. This set of circumstances is depicted in FIG. 2 by the line 66 which represents the rate of charge under the high control temperature setting. Hence, the power applied to the terminals 11 and 12 would be applied to the load across the terminals 50 and 51 for the time period B and this would exceed the allowable cable current if in fact the allowable cable current were determined by having the applied power present on the load for period A. Of course, the fixed parameters of the last described circuit could be such that the maximum allowable current could be applied to the load for the highest temperature but then if the controller were used for a lower temperature the heating element would not heat to the maximum temperature and in fact might never heat the cable up to the point where it could effectively accomplish the required task. The addition of the second adjustable resistor 40 eliminates this problem as will become apparent hereinafter.

Reconsider the circuit now with the resistor **39** and the second adjustable resistor **40** connected therein and once again reconsider that there is a low temperature setting on the adjustable resistor **27**, i.e., the tap **35** has been moved toward the terminal **60**. Under these circumstances current will be flowing through the resistor **39** and through the adjustable resistor **40** to charge up the capacitor **41**, and the voltage value at the terminal **54** will be determined by the voltage drop across the resistor **39** and across the adjustable resistor **40** as added to the voltage developed on the capacitor **41**. In other words, as the voltage across the capacitor **41** increases, the voltage at the point **54** will increase. Since there is very little voltage drop across the diode **36**, the point **45** will assume the voltage value of the voltage at point **54** when that voltage value has exceeded the voltage at the point **45**. The voltage at point **45** is initially determined by the resistor network made up of the thermistor **24**, the resistor **25**, and the resistor **38**. It will be recalled that we have set the adjustable resistor **40** to provide the proper cable current for the maximum allowable temperature rise and we have already discussed, with respect to our example, that the effective load current is determined by the period of time that the line signal is applied to the load, as shown by (A) and (B) in FIG. **2**. Accordingly, if we assume that the voltage developed across the terminals **45** and **55**, as the terminal **45** assumes the voltage value of the terminal **54**, is 12 and if we assume that the voltage developed on the capacitor **41** is 9 volts to cause the unijunction transistor **44** to conduct then the circuit with resistors **39** and **40** therein will operate as shown in FIG. **2**. However, this same circuit can be used for a high control temperature situation by merely setting the two adjustable resistors **27** and **40** and herein lies a great advantage over the prior art.

If the control temperature is now going to be used, or set, at a higher value (the tap is moved toward the terminal **65**) and the second adjustable resistor **40** will also be set to provide the cable current for the maximum allowable temperature rise in the same manner as was discussed earlier. Under the new circumstances, that is, the higher control temperature condition, there is more current provided by the transistor **30** but in accordance therewith there will be a greater voltage drop across the adjustable resistor **40**. Hence the voltage developed at point **54** is higher in value for a given applied voltage within the same period of time than existed under the low control temperature condition. The foregoing operation is shown in FIG. **3**. In other words, with a high control temperature setting, the voltage value at the point **54** would be approximately 14 volts since the IR drop across the resistor **40** is greater than it was for the low temperature setting and this IR drop is added to the voltage which is being developed across the capacitor **41**. Thus, as can be seen in FIG. **3**, the voltage applied across the unijunction transistor **44** would be 14 volts. Under these circumstances the capacitor must be charged to 10.5 volts before the unijunction transistor **44** conducts, (see FIG. **3**). It will be noted in FIG. **3** that the rate of charge is somewhat more rapid than was true under the conditions in FIG. **2**, however since the 75 percent value (the control voltage necessary to cause the unijunction transistor to conduct) has increased and therefore the unijunction transistor fires at approximately the same time as it did under the low control temperature condition. Hence the power applied to the terminals **11** and **12** is applied to the load for the period A (see FIGS. **2** and **3**) as was true under the low control temperature setting.

Accordingly, it becomes apparent that the present circuit can be used to readily control the heat tracing arrangement or application for a specified cable current to permit maximum allowable temperature rise. The present circuit can also be readily used for both high temperature and low temperature conditions without doing anything more than simply adjusting the two adjustable resistors as compared with having to change parameter valves throughout the circuit for each change in setting or as compared with having to employ a new matching transformer each time the control temperature is changed.

What is claimed is:

1. A circuit for determining and controlling the electrical current supplied to an adjustable resistance load comprising in combination: a source of pulsating direct current signals; bridge circuit means having first and second input terminal sides, first circuitry means connecting said source of pulsating direct current signals to said first input terminal side; second circuitry means connecting said second input terminal side to said source of pulsating direct current signals; said bridge circuit means having temperature responsive resistor means as a first leg, first adjustable resistor means forming second and third legs and having an adjustable tap thereon as a first output terminal means of said bridge, second resistor means forming a fourth leg; second output terminal means connecting said fourth leg to said first leg; first current switching means having an input element, an output element, and a control element; said input element connected to said first output terminal, said control element connected to said second output terminal; first current path means having an input terminal and an output terminal, said input terminal connected to said output element of said first current switching means, said output terminal connected to said second circuitry means; voltage developing means having first and second terminals, said second terminal connected to said second circuitry means; second current path means connected between said input terminal of said first current path means and said first terminal of said voltage developing means whereby the voltage appearing at said first terminal of said first current path means follows the voltage developed at said voltage developing means, said second current path means including a second adjustable resistor to vary the voltage developed at said voltage developing means in accordance with an adjustment thereof; second current switching means having an input element, an output element and a control element, said control element connected to said first terminal of said voltage developing means, said input element connected to said second terminal of said first current path means, said output element connected to said second circuitry means whereby the voltage appearing at said input element follows the voltage appearing at said first terminal of said first current path means when said last mentioned voltage exceeds the voltage otherwise developed across said input and output elements of said second current switching means; said second current switching means having the capaci-

ty to be rendered conducting when the voltage developed by said voltage developing means exceeds a particular percentage of the voltage appearing across said input and output elements of said second current switching means; and load current switching means adapted to be connected to a source of electrical current and adapted to be connected to a load, said load current switching means coupled to be turned on in response to current conduction through said second current switching means.

2. A circuit for determining and controlling the electrical current supplied to an adjustable resistance load according to claim 1 wherein said first current switching means is a transistor having collector, emitter and base elements, said base element being connected to said second output terminal of said bridge circuit means, said emitter element being connected to said adjustable tap, and said collector element being connected to said first and second current paths.

3. A circuit for determining and controlling the electrical current supplied to an adjustable resistance load according to claim 1 wherein said second developing means includes a capacitor which in conjunction with said second adjustable resistor forms an R-C circuit and wherein output control element of said second current switching means is connected to have applied thereto the voltage developed across said capacitor.

4. A circuit for determining and controlling the electrical current supplied to an adjustable resistance load according to claim 1 wherein said load current switching means includes a pulse transformer connected to said second current switching means and a triac connected to the secondary winding of said pulse transformer and wherein said triac is adapted to be connected to one side of a line supply and to one side of a load supply to provide a return circuit therethrough from said line supply to said load when said triac is turned on.

5. A circuit for determining and controlling the electrical current supplied to an adjustable resistance load according to claim 1 wherein said socond circuitry means includes a resistor across which voltage is developed to provide the voltage across said input and outpue elements of said second current switching means.

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