Proportional-ac-power controller doles out whole cycles of ac line

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In industrial and process control, it is often necessary to accurately control the temperature of a process. You control most heating elements using the "bang-bang" method—turning the power to them on and off at a predetermined setpoint. The temperature of the heated substance constantly hunts back and forth around the setpoint. You can achieve much greater temperature precision using proportional power control. With this method, the controller monitors the temperature, proportionally varying the heater power to keep the temperature as close as possible to the setpoint. A PID (proportional-integral-derivative) control loop usually accomplishes this function. Varying the ac power to the heating element in a linear-proportional manner is neither easy nor simple.

This Design Idea borrows from the delta-sigma-modulator concept. The controller sends cycles of the ac line to the load as the delta-sigma modulator determines. For example, when the input-control voltage is 15% of full-scale, only 15 of 100 ac cycles arrive at the load. Likewise, at 85%, 85 of 100 arrive (**Figure 1**). The control-voltage-input stage, IC_{1A}, is an inverting amplifier with a gain of negative one. This stage makes the control-voltage range over the positive side of 0V. In this example, the control-voltage input ranges from 0 to 2V full-scale. The control

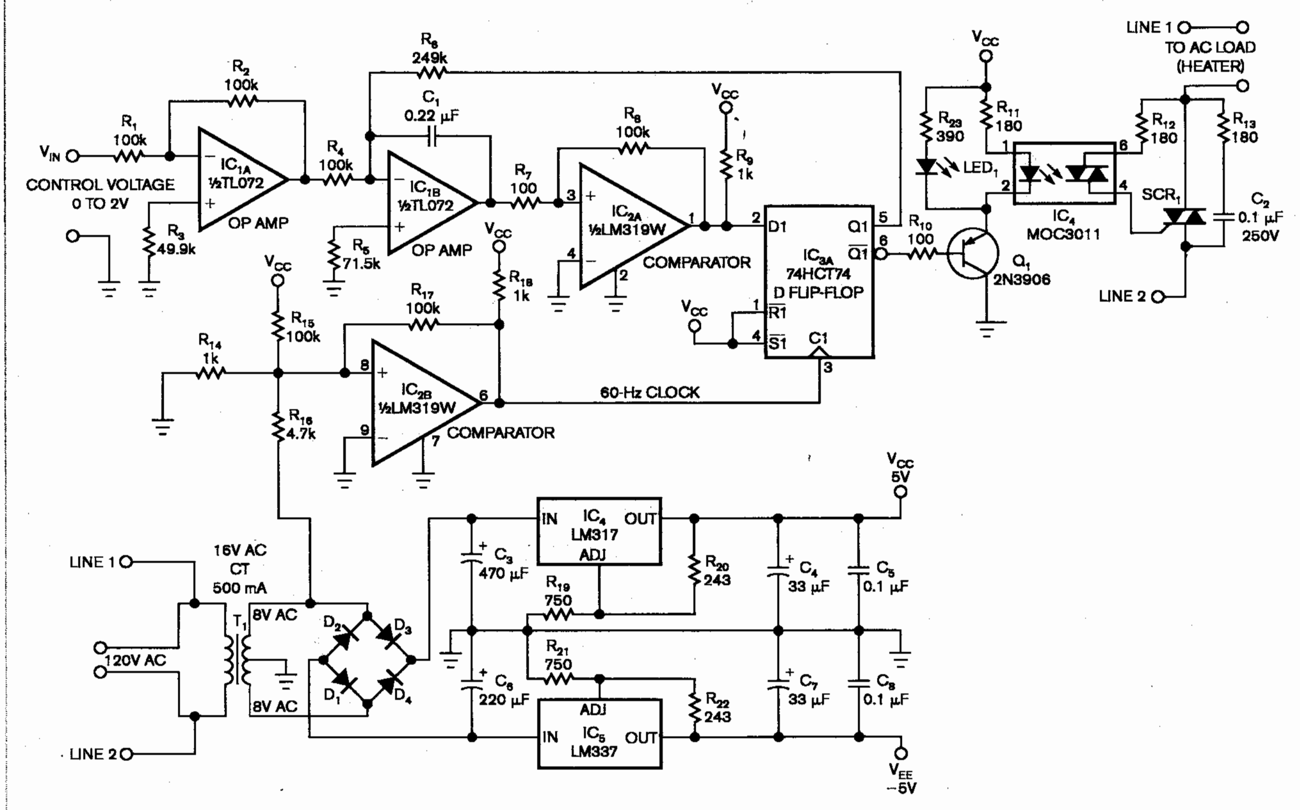

Figure 1 This ac controller borrows from a sigma-delta converter to output a number of whole cycles of ac-line power according to an input-control voltage.

voltage's input impedance is 100 kΩ.

The next stage, IC_{1B}, is an integrator. The integrator output ramps either up or down depending on the polarity of the input current. The speed at which it ramps depends on the magnitude of the input current. The integrator is the heart of the delta-sigma modulator. It forces a balance, on the average, between the control-voltage current in R_4 and the feedback current in R_6. In other words, the duty cycle of the output of IC_{3A}, a CMOS D-type flip-flop, must match the control-voltage percentage of full-scale.

Comparator IC_{2A} detects whether the integrator's output is positive, thus requiring more feedback current, or negative, thus requiring less feedback to maintain the balance. The output of the comparator switches between 0 and 5V. The flip-flop latches the comparator's decision on the next rising edge of the 60-Hz clock.

PNP transistor Q_1 and optoisolated SCR (silicon-controlled rectifier) IC_4 drive load-switching SCR_1 into conduction whenever the flip-flop provides feedback current to the integrator. Indicator LED_1 lights when the load SCR is on. The secondary of transformer T_1 detects the zero crossings of the ac-power line; these crossings provide the 60-Hz clock. The output of comparator IC_{2B} switches high during the positive half-cycles of the ac line and low during the negative half-cycles. Resistor R_{15} provides a small positive bias, causing the edges of the 60-Hz clock to occur slightly early—which is better than late in this case. If you turn off the SCR too late, its self-latching nature may cause it to stay on for an extra half-cycle when it should have been off.

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Both comparators IC_{2A} and IC_{2B} use a small amount of hysteresis to promote fast, clean switching. The remaining components generate the regulated 5 and −5V power supplies. Transformer T_1 and optoisolator IC_4 provide isolation from the ac-power line.

This Design Idea works well for an application such as a spa-heater control but does not work for light-dimming or motor-speed control because the output power is pulsating in nature. You can easily adapt the design for 240V-ac or 50-Hz operation. **EDN**