

# “Take-Back-Half” HVAC Thermostat Is Precise And Energy-Efficient

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Implementing tight control of environmental temperature is essential in many critical areas. For instance, it's necessary when research laboratories house sensitive instrumentation and for manufacturing facilities involved in high-precision microlithography. However, the conventional ways to achieve such control can run directly afoul of responsible energy conservation practices.

In one commonly used technique, for example, the refrigeration side of the air-handling system is allowed to run continuously at full throttle. Meanwhile, the addition of opposing heat is used to close the temperature feedback loop. This energy-intensive arrangement is a popular ploy considering how difficult it is to achieve accurate temperature control in systems

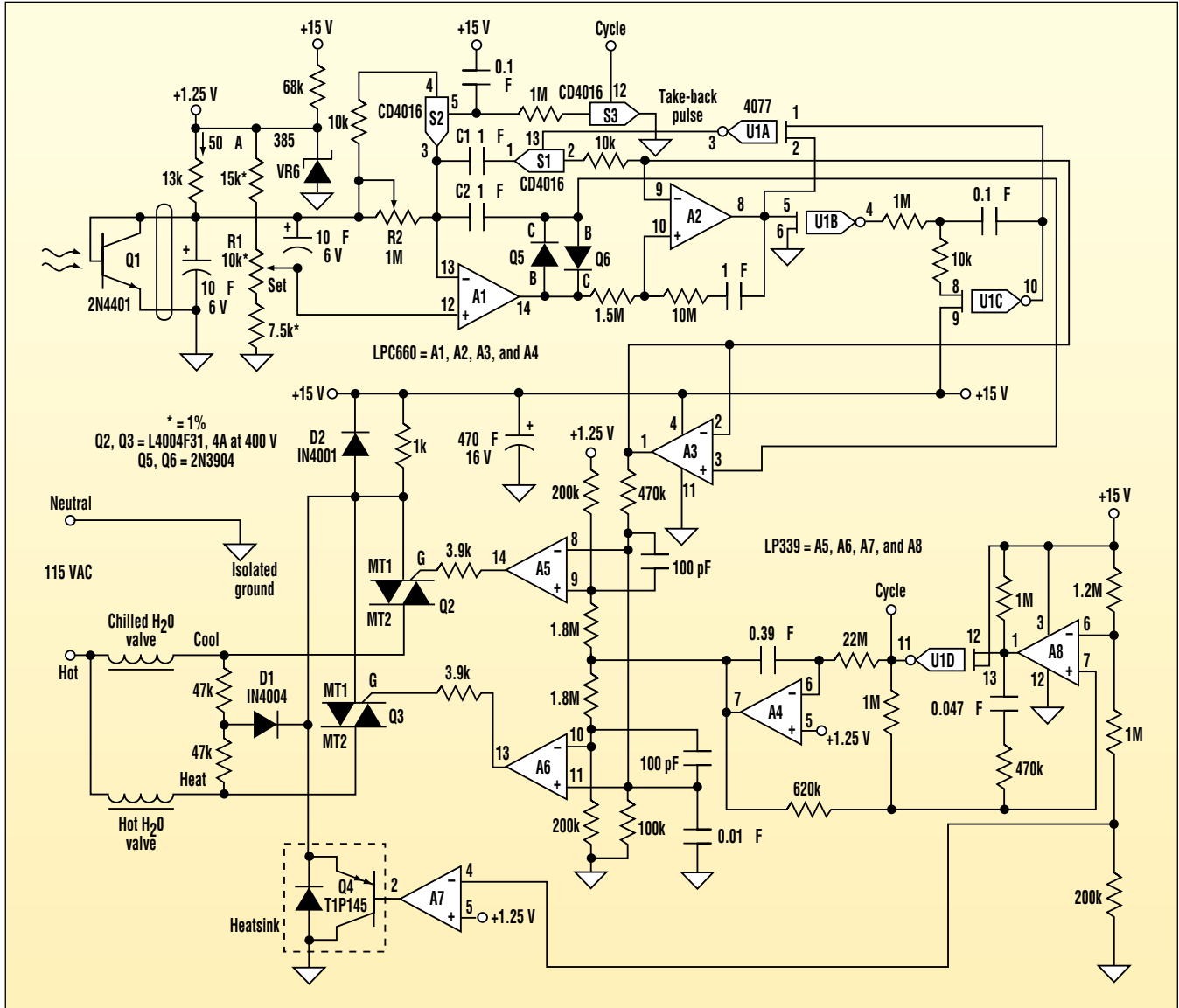
that are capable of switching freely between heating and cooling modes.

In such systems, errors arise from the unavoidable time delays and shifts in feedback parameters that occur whenever the direction of heat flow is reversed. Undesirably complex and hard-to-tune feedback algorithms would typically be required to cope with these parametric shifts. Consequently, the energy cost of the simpler heat-only feedback method, although regrettable, is often perceived as the lesser of the two evils.

Fortunately, there's an unconventional control algorithm that offers a suitably robust yet simple-to-tune alternative that largely avoids both difficulties (see “Take Back Half: A Novel Integrating Temperature-Control Algorithm,” ELECTRONIC DESIGN, Dec. 4, 2000;

“Circuit Enables Precision Control In Radiant Heating Systems,” ELECTRONIC DESIGN, Jan. 8, 2001; and “Linear-RMS Phase Control Improves Thyristor-Based Thermostat,” ELECTRONIC DESIGN, March 5, 2001). As illustrated in the figure, TBH makes accurate environmental temperature control ( $\ll \pm 1^\circ\text{C}$ ) possible. Plus, it's optimized with a single tuning variable and avoids the undesirable energy consumption of a traditional variable-heat-only approach.

Circuit operation centers around the diode-connected temperature sensor Q1. Temperature-dependent  $V_{Q1}$  (about  $-2\text{ mV}/^\circ\text{C}$ ) is compared to the setpoint voltage developed by R1. The difference is then integrated by A1. Next, the integrated error is scaled by the adjustable R2-C2 time constant, buffered by A3, and applied to the A4-



This TBH-based thermostat provides accurate and efficient environmental temperature control ( $\pm 1^\circ\text{C}$ ), optimized with a single tuning variable.


A6 dual-PWM circuit. Circuit topology is such that when  $V_{R2} > V_{Q1}$  (ambient temperature is greater than the setpoint), A1 ramps positive. As a result, comparator A5 triggers TRIAC Q2 for proportionally greater duty cycles. This action progressively opens the chilled-water solenoid valve, thereby cooling the ambient temperature and forcing it toward the setpoint.

Conversely, when  $V_{R2} < V_{Q1}$  (ambient temperature is less than the setpoint), the error voltage ramps negative. As a result, A6 and Q3 cause the hot-water valve to admit increasing amounts of hot water into the air-handling system, thereby warming the ambient. Bias voltages developed by the passive summing network surrounding A5 and A6 prevent the over-

lap of hot/cold valve operation, promoting efficient energy use.

The 70-second period of the timing ramp generated by the A4-U1D-A8 oscillator was chosen to be appropriate for both ripple-free ambient temperature control and acceptable mechanical valve life (typical valve-life expectancies of  $2 \times 10^6$  actuation cycles imply a valve MTBF greater than four years). By tuning the feedback-loop time constant (TBH "F" factor), the A2, S1, U1A, U1B, U1C logic chain implements the crucial convergence-by-bisection principle of the TBH algorithm. By adjusting R2, this time constant can be set to accommodate a particular HVAC heat exchanger and air handling system. S2 and S3 act to accelerate initial settling of the circuit

on power turn-on.

The prototype of the TBH thermostat has been in service for over eight years. During this time, it has maintained a stable and accuracy-enhancing environment in a nuclear magnetic resonance (NMR) facility of several thousand square feet. 

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