TYPE 645: FIVE STAGE ROOM THERMOSTAT

General Description

This ON/OFF differential device models a five stage room thermostat which outputs five control signals that can be used to control an HVAC system having a three stage heating source and a two stage cooling source. The controller contains hysteresis effects and is equipped with a parameter that allows the user to set the number of controller oscillations permitted within a single time step before the output values "stick." Type645 was made standard TRNSYS component Type108 with the release of TRNSYS v. 16

Detailed Description

Controller Stability

Very often, controllers pose difficulties in simulations because in defining a mathematical model of a piece of equipment, simplifying assumptions are inevitably made. These simplifying assumptions often disregard physical realities of the system components in order that they might actually be solvable. The side effect is that some of the component's robustness or insensitivity to input changes disappears. Take the example of modeling a room in a building that is equipped with a thermostat and a heating device. The common way of modeling such a system would be for the thermostat to look at the difference between the room temperature and a set point temperature. If the room temperature is below the set point temperature, the heating device is turned on and energy is added to the space. The room model then recalculates its air temperature based on the new information about the addition of energy to the space. The thermostat then senses that the air temperature is higher and recalculates its decision and so on. Often ignored is the fact that the heater is placed within the room and that it does not add energy evenly to the space – it heats up the air in its immediate surroundings. Convection within the space develops and there is a time lag between when the heater begins adding energy to the space and when the air in the space is uniformly warmer enough that the thermostat would register a new temperature. While room models that perform convection calculations no doubt exist, they are often more detailed than is needed for the purposes of a building energy simulations. In an effort to slow down the reaction time of simulated systems, it is often necessary to add "stickiness" to controller components. In the case of this model and of many other controllers in TRNSYS, the stickiness comes in the form of a parameter that controls how many times a controller may change states within the iterations of a single time step before its newly calculated value sticks to one setting or another. As soon as the controller sticks, the system ought to get out of whatever iterative process it is in and converge upon a solution. Very often an odd number is chosen for the number of allowable state changes (NSTK) so that the controller makes altering decisions, turning equipment ON and OFF in such a way that the system moves away from its non convergent state. The second parameter in Type645 is the NSTK value that will be used throughout the simulation. If the controller was stuck for more than 10 % of the time steps in a given simulation, the actual percentage of stuck time steps will be reported to the TRNSYS list and simulation log files.

Multiple Stage Heating and Cooling

Type645 is designed to control up to three stages of heating equipment and two stages of cooling equipment. A stage might consist of a particular power setting on a furnace, or might consist of an entirely unique piece of equipment. For example, some furnaces are designed with a low and high burner setting. If the monitored temperature falls to a certain point, the low burner and fan come on. If the temperature continues to fall past a second set point, the furnace will switch over to high burner and fan speed, adding more energy to the space. Such a furnace would be referred to by this model as a two stage heating device. The same furnace could be used in such a way that if even the high burner setting

was still not sufficient to bring the zone temperature back up, an electric resistance heater (completely separate from the furnace) could be brought on as a third stage heating device. Type645 is able to control up to three stages of heating and two stages of cooling. Thus the user must specify three heating set points and two cooling set points as inputs (since they may vary with time). Type645 checks to insure that the set point temperature are all realistic. That is to say that the second stage cooling set point much be higher than the first stage cooling set point, which in turn must be higher than the first stage heating set point, which must be higher than the second stage heating set point, which must be higher than the third stage heating set point temperature. The relative placement of the various set points is shown graphically on a temperature scale in Figure 1.

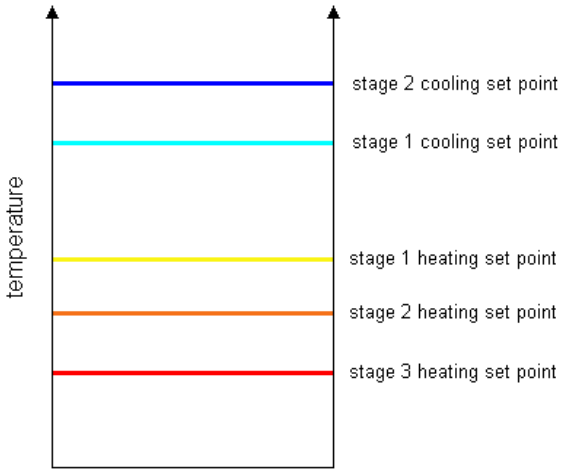


Figure 1: Set Point Definition

If the zone temperature goes above the stage two cooling set point temperature, it may be desirable for both the equipment associated with stage two and the equipment associated with stage 1 cooling to be ON simultaneously. Alternatively, it may be desirable for the stage 1 cooling equipment to shut OFF and for only the stage two equipment to be running. Similarly for heating it may be desirable for stage 1 heating equipment to shut off in stage 2 but to come back on in stage 3. To this end, Type645 requires the user to specify a series of parameter values to indicate exactly when a stage may be enabled and when it should be disabled. The following table summarizes the parameters, their values and the corresponding equipment enabling.

Table 1: Controller Stage Enabling

PARAMETER NUMBER	PARAMETER VALUE	INTERPRETATION
3	0	Stage 1 Heating will be DISABLED when Stage 2 Heating is ON
3	1	Stage 1 Heating will be ENABLED when Stage 2 Heating is ON
4	0	Stage 2 Heating will be DISABLED when Stage 3 Heating is ON
4	1	Stage 2 Heating will be ENABLED when Stage 3 Heating is ON
5	0	Stage 1 Heating will be DISABLED when Stage 3 Heating is ON
5	1	Stage 1 Heating will be ENABLED when Stage 3 Heating is ON
6	0	Stage 1 Cooling will be DISABLED when Stage 2 Cooling is ON
6	1	Stage 1 Cooling will be ENABLED when Stage 2 Cooling is ON

Dead Bands and Hysteresis

Often times, controllers are designed with dead bands to prevent them from turning equipment ON and OFF in fast succession when the monitoring temperature and set point temperature are close to one

another. Dead bands essentially replace a set point temperature with a bracketed range of set point temperatures. In heating mode, equipment would remain OFF until the monitored temperature had fallen to the specified set point minus the lower dead band temperature difference. Once ON, the equipment would remain ON until the monitored temperature exceeds the specified set point temperature plus the upper dead band. In some controllers, both upper and lower dead bands are specified. Type645 simply centers the specified heating and cooling dead band temperature differences on each set point. A heating set point temperature and its dead band temperature difference are shown graphically in Figure 2.

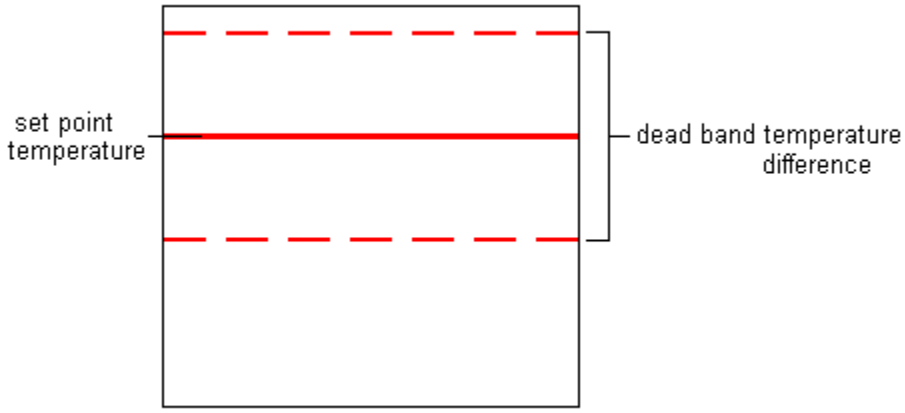


Figure 2: Type645 Dead Band Temperature Difference

Component Operation

At any given iteration, Type645 checks to note whether it has changed states more than the allowable number of times. If so, the state is stuck for all remaining iterations in the time step and will only be unstuck once a new time step has started. At the end of each iteration's calculations, the state of each controller is stored for comparison during the following iteration.