Whitepaper: Example of VAV Controllers in ApacheHVAC

A Variable Air Volume (VAV) system is one of the most common HVAC systems used in buildings. VAV systems use variable airflow rates to condition a space within a building. A typical VAV control strategy is shown in Figure 1 below, which helps to describe how VAV control strategies are implemented in ApacheHVAC.

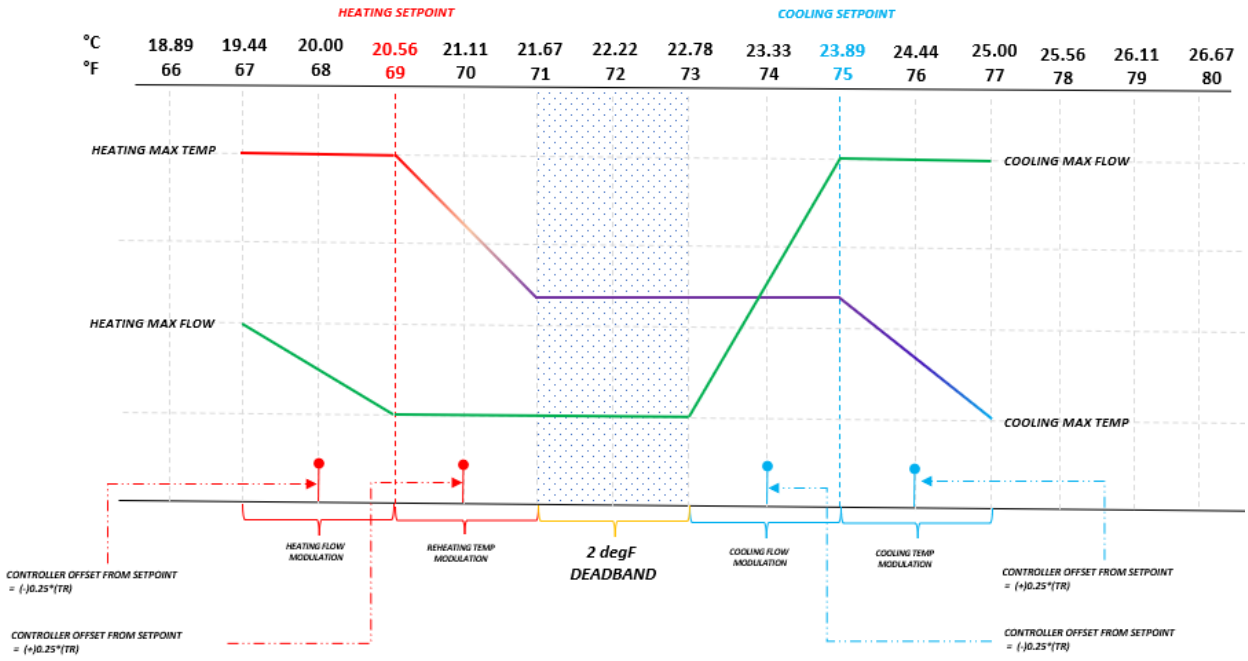

Figure 1: Typical VAV Operation cooling setpoint of 75 °F (23.89 °C) and heating setpoint of 69 °F (26.56 °C)

From Figure 1, there are three different modes of operation:

a) Deadband

A Deadband of 2 °F (1.11 K) is used to prevent the thermostat from activating heating and cooling in rapid succession. This is a period when the system is neither in heating mode nor in cooling mode.

In this scenario above, the temperature range between 71 °F (21.67 °C) and 73 °F (22.78 °C) is shown as Deadband, i.e.

i. Neither cooling nor heating is occurring during this period, and
ii. Airflow is set at the minimum VAV turndown flow.

b) Cooling Mode

As the temperature exceeds 73 °F (22.78 °C) the system goes into cooling mode. In this scenario, there are two actions for different ranges:

i. From 73 °F (22.78 °C) to 75 °F (23.89 °C), the VAV box opens to increase the airflow from minimum flow to maximum flow. The volume of air entering the zone is proportional to the temperature of the zone. If the zone is warmer, the supply airflow into the zone will increase.

ii. Above 75 °F (23.89 °C), the VAV box at the zone level is completely open (maximum airflow); and the cooling coil engages further and the target supply air temperature decreases as the zone temperature increases.

c) Heating Mode

As the temperature drops below 71 °F (21.67 °C) the system operates in heating mode. In this scenario, there are two actions for different ranges:

i. From 71 °F (21.67 °C) to 69 °F (20.55 °C), the heating coil energizes and the temperature of the supply air increases as the zone temperature decreases. If the zone is cooler, the supply airflow into the zone will increase.

ii. Below 69 °F (20.55 °C). Once the zone temperature drops below this setpoint temperature, the heating coil is heating the air to the maximum supply temperature and the VAV box is opened to increase the airflow into the zone.

Modelling VAV in IESVE

The VAV control strategy can be achieved using four controllers in IESVE's ApacheHVAC application. These controllers are shown in Figure 2 below:

1. Cooling Coil Supply Air Temperature reset per zone demand
2. Zone Reheat Coil Supply Air Temperature reset
3. Zone VAV Cooling Airflow Control
4. Zone VAV Heating airflow Control

Note that the 'Reference' dialogs for each controller acts as a reminder for its intention.

- **Controllers 1 and 3** are used for cooling operation.
- **Controllers 2 and 4** are used for heating operation.
- **Controller 1** has an 'AND' connection with **Controller 3**, ensuring that controller 1 only activates when there is a cooling airflow.

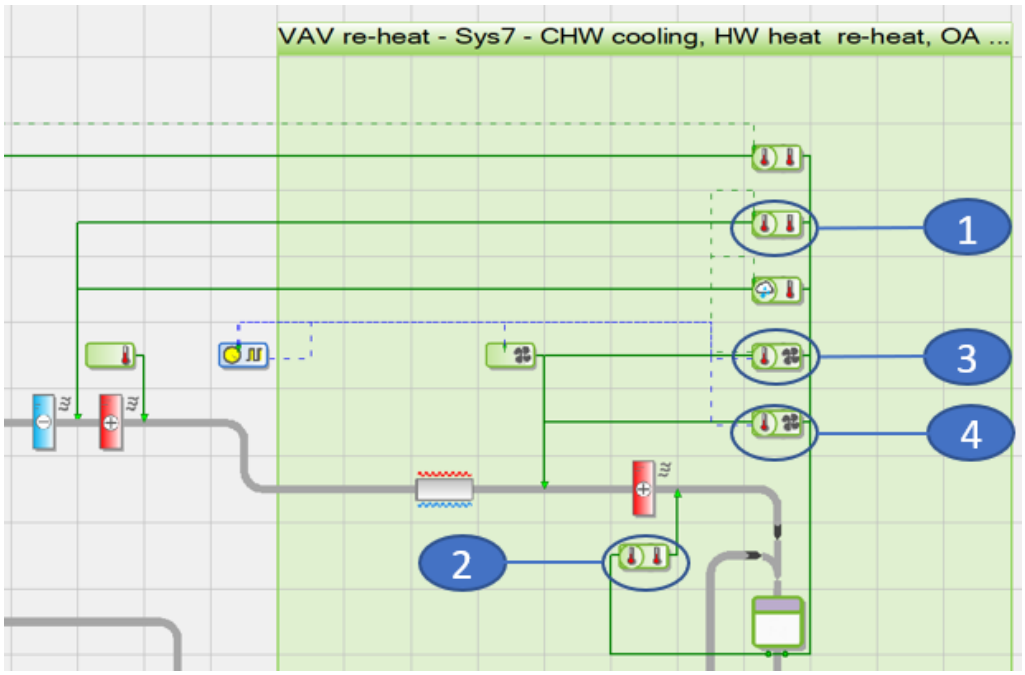

Figure 2: Typical VAV controllers in ApacheHVAC

The following *default* settings are used to explain the VAV operation in ApacheHVAC (Figure 1):

- Zone setpoint is set at 75 °F (23.89 °C) for cooling and 69 °F (20.56 °C) for heating. This can be assigned at the template level.
- Throttling Range (TR) is set to 4 °F (2 K). Assigned in "Zone Temperature, Humidity & Equipment" tab of "System Parameter" dialog.
- Proportional Bandwidth of 2 °F (1.11 K) is used and is assigned in the controller dialog.
- "Offset from setpoint." This is used to control the midpoint of the "Proportional Bandwidth." This is a fraction of the Throttling Range. Assigned in the controller dialog box.

The method to calculate the "Setpoint Offset" is explained:

- If a value of - 0.25 is entered as "Offset from setpoint" for a cooling operation (cooling setpoint 75 °F) and the Throttling range is 4 °F, the "Main SP +/- offset" will be equal to cooling setpoint (75 °F) – [{"offset from setpoint(0.25)} x {throttling range (4°F)}] = 74 °F

<u>Cooling Mode</u>

This is represented by controller 3 (Figure 3) and controller 1 (Figure 4). The operation of both these controllers is shown below, with a plot of temperature setpoint/air volume (on the right side).

Figure 3: Controller 3: Zone VAV Cooling airflow Control (IP Units)

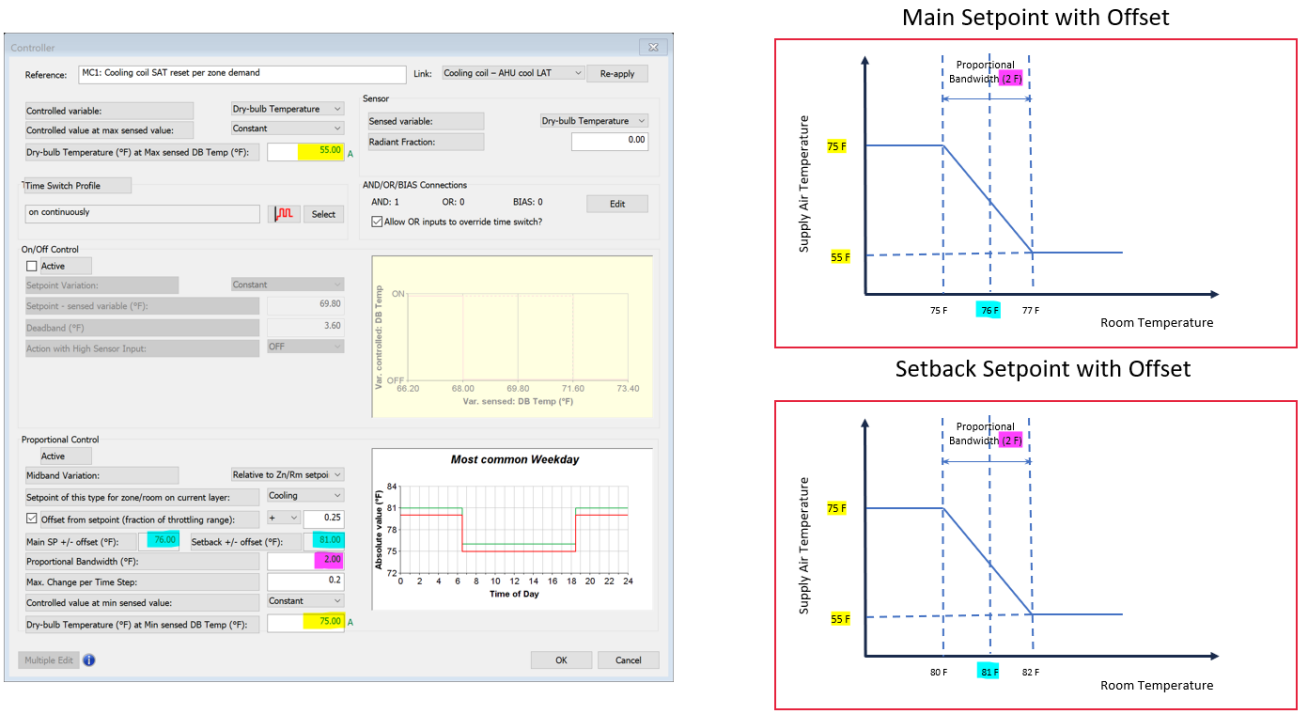

Figure 4: Controller 1: Cooling Coil Supply Air Temperature reset per zone demand (IP units)

Note that in figures 3 and 4, the plot of temperature setpoint/airflow on the right has both "main setpoint offset" (on the top) and "Setback setpoint offset" (at the bottom). For this instance, we will be looking

only at the Main setpoints offset (on the top). The “setback setpoint offset” (at the bottom) is for reference purposes only.

Between 73 °F (22.78 °C) and 75 °F (23.89 °C).

a) Figure 3: the airflow is increasing proportional to the zone temperature, and at 75 °F (23.89 °C) the airflow is at maximum.
b) Figure 4: the cooling coil is cooling air to 75 °F (23.89 °C). In other words, it may not be operational.

Above 75 °F (23.89 °C)

a) Figure 3: the airflow is at maximum; i.e. the VAV box is completely open.
b) Figure 4: the cooling coil energizes and starts to cool the supply air;
    a. in proportional to the zone temperature between 75 °F (23.89 °C) and 77 °F (25.00 °C) (proportional bandwidth)
    b. at the lowest possible temperature above 77 °F (25.00 °C), i.e. cools the air to 55 °F (12.78 °C)

Heating Mode

This is represented by controller 2 (Figure 5) and controller 4 (Figure 6). The operation of both these controllers is shown below, with its temperature setpoint/air volume (on the right side).

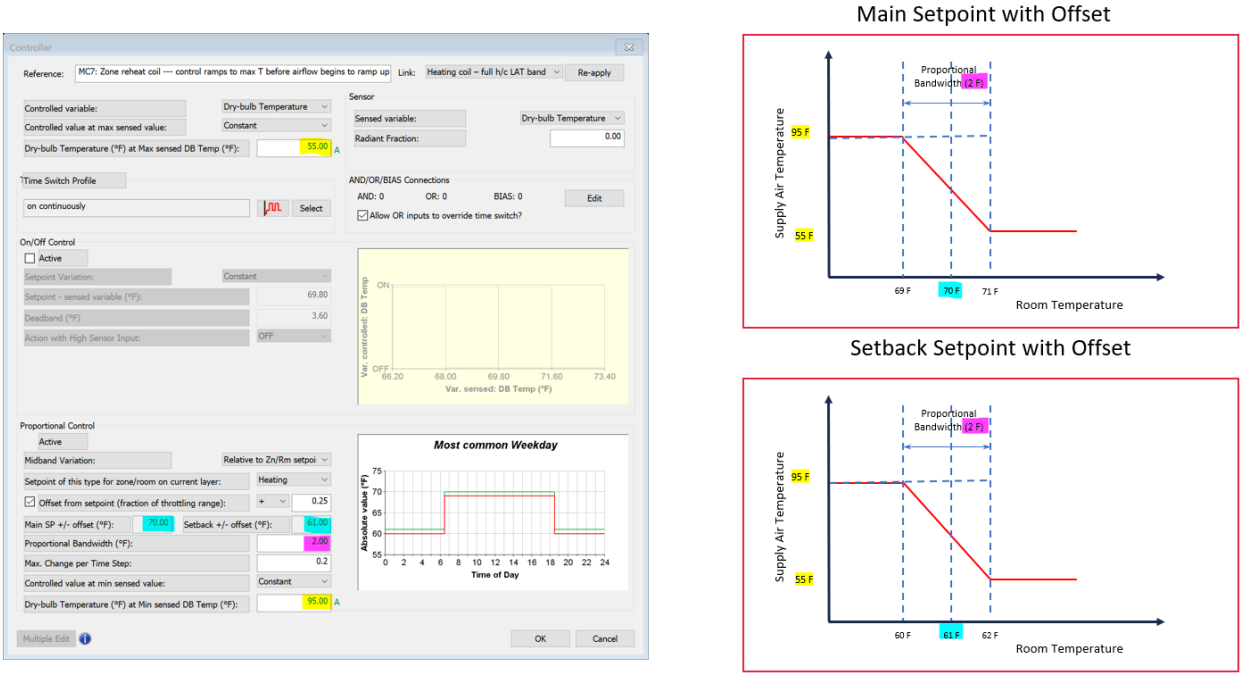

Figure 5: Controller 2: Zone Reheat Coil Supply Air Temperature reset

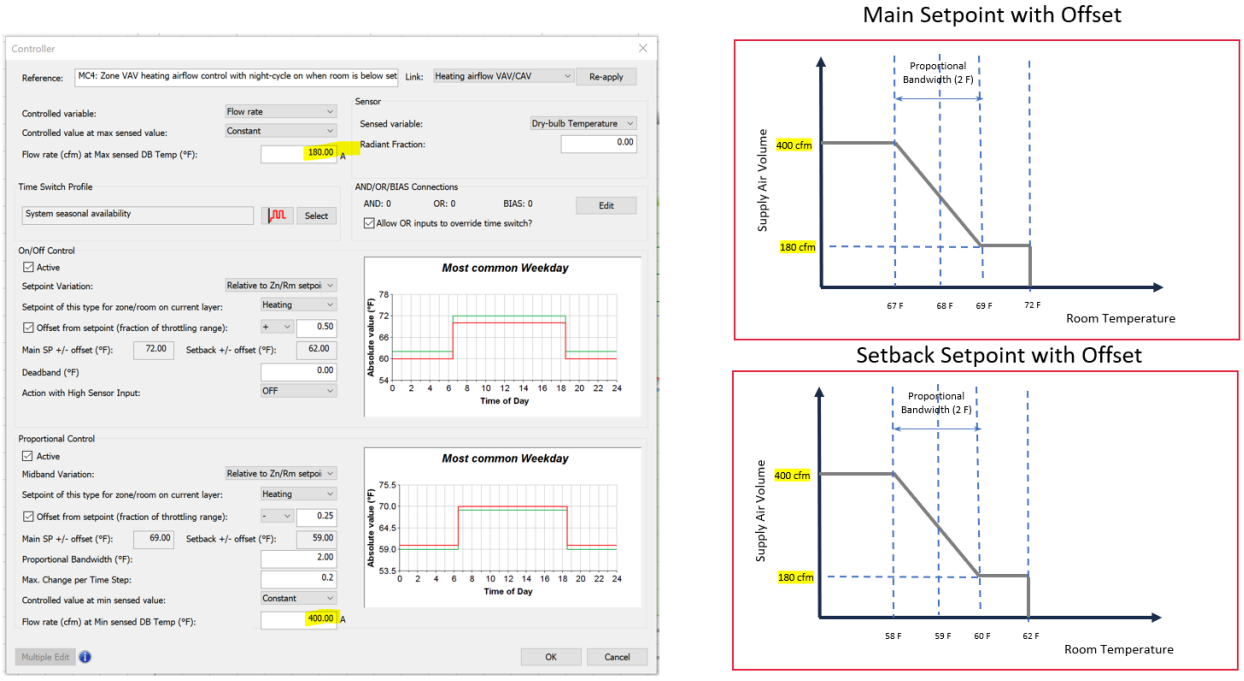

Figure 6: Controller 4: Zone VAV Heating airflow control

Note that in figures 5 and 6, the plot of temperature setpoint/airflow on the right has both "main setpoint offset" (on the top) and "Setback setpoint offset" (at the bottom). In this instance, we are looking only at the Main setpoints offset (on the top). The "setback setpoint offset" (at the bottom) is for reference purposes only.

Between temperatures 71 °F (21.67 °C) and 69 °F (20.55 °C)

a) Figure 5: the heating coil is heating the air proportional to the zone temperature, and at 69 °F the heating coil is heating the air to maximum temperature of 95 °F (35.00 °C)
b) Figure 6: the airflow is set at the minimum flow rate (VAV turndown) during this period.

Below 69 °F (20.55 °C)

a) Figure 5: the heating coil is heating the air to the maximum temperature, 95 °F (35.00 °C).
b) Figure 6: the airflow to the zone is increasing;
    a. Proportional to the zone temperature between 69 °F (20.55 °C) and 67 °F (19.44 °C) (proportional bandwidth)
    b. Below 67 °F (19.44 °C) the VAV box is completely open

Deadband

Between 72 °F (22.22 °C) and 73 °F (22.78 °C).

a) Figure 3: the airflow is set at the minimum flow rate (VAV turndown) during this period.
b) Figure 4: the cooling coil is cooling air to 75 °F (23.89 °C), i.e. is basically turned OFF.

So, the cooling coil and airflow are at a minimum during this period.

Between temperatures 72 °F (22.22 °C) and 71 °F (21.67 °C)

a) Figure 5: the heating coil is heating air to 55 °F (12.78 °C), i.e. is basically turned OFF.
b) Figure 6: the airflow is set at the minimum flow rate (VAV turndown) during this period.