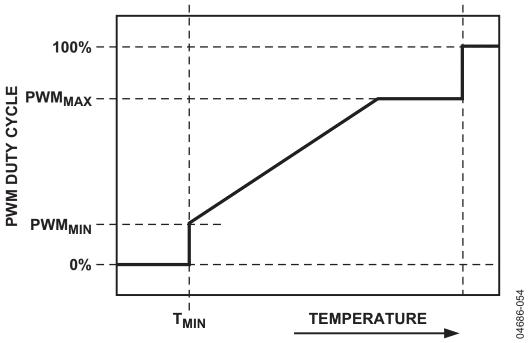

Figure 52. PWM_{MAX} Determines Maximum PWM Duty Cycle Below the THERM Temperature Limit

Programming the PWM_{MAX} Registers

The PWM_{MAX} registers are 8-bit registers that allow the maximum PWM duty cycle for each output to be configured anywhere from 0% to 100%. This allows the maximum PWM duty cycle to be set in steps of 0.39%.

The value to be programmed into the PWM_{MAX} register is given by

Value (decimal) = $PWM_{MAX}/0.39$

Example 1: For a maximum PWM duty cycle of 50%

Value (decimal) – 50/0.39 = 128 (decimal)
Value = 128 (decimal) or 80 (hex)

Example 2: For a minimum PWM duty cycle of 75%

Value (decimal) = 75/0.39 = 85 (decimal)
Value = 192 (decimal) or C0 (hex)

PWM_{MAX} Registers

Register 0x38, PWM1 Maximum Duty Cycle = 0xFF (100% default)

Register 0x39, PWM2 Maximum Duty Cycle = 0xFF (100% default)

Register 0x3A, PWM3 Maximum Duty Cycle = 0xFF (100% default)

See the Note on Fan Speed and PWM Duty Cycle section.

STEP 6: T_{RANGE} FOR TEMPERATURE CHANNELS

T_{RANGE} is the range of temperature over which automatic fan control occurs once the programmed T_{MIN} temperature is exceeded. T_{RANGE} is a temperature slope, not an arbitrary value, that is, a T_{RANGE} of 40°C holds true only for PWM_{MIN} = 33%. If PWM_{MIN} is increased or decreased, the effective T_{RANGE} changes. Refer to Figure 53.

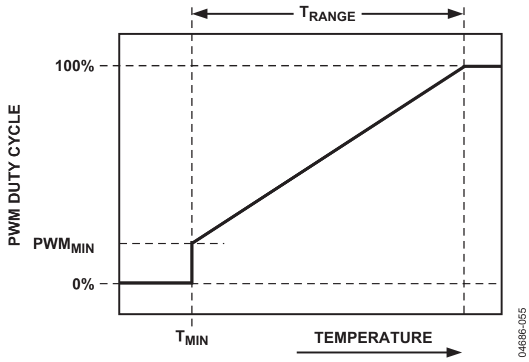

Figure 53. T_{RANGE} Parameter Affects Cooling Slope

The T_{RANGE} or fan control slope is determined by the following procedure:

1. Determine the maximum operating temperature for that channel (for example, 70°C).
2. Determine experimentally the fan speed (PWM duty cycle value) that does not exceed the temperature at the worst-case operating points (for example, 70°C is reached when the fans are running at 50% PWM duty cycle).
3. Determine the slope of the required control loop to meet these requirements.
4. Graphically program and visualize this functionality using the ADT7473 evaluation software. Ask your local Analog Devices representative for details.

Figure 54 shows how adjusting PWM_{MIN} affects T_{RANGE}.

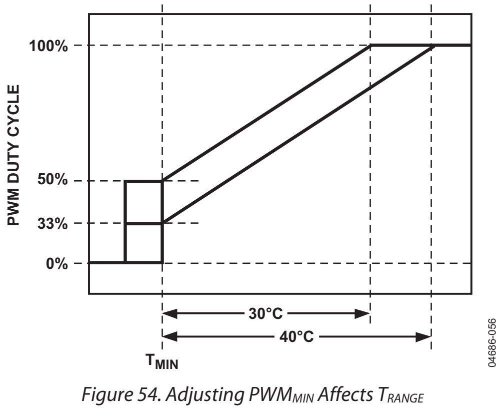

Figure 54. Adjusting PWM_{MIN} Affects T_{RANGE}

T_{RANGE} is implemented as a slope, which means that as PWM_{MIN} is changed, T_{RANGE} changes, but the actual slope remains the same. The higher the PWM_{MIN} value, the smaller the effective T_{RANGE}, that is, the fan reaches full speed (100%) at a lower temperature. Figure 55 shows how increasing PWM_{MIN} changes the effective T_{RANGE}.

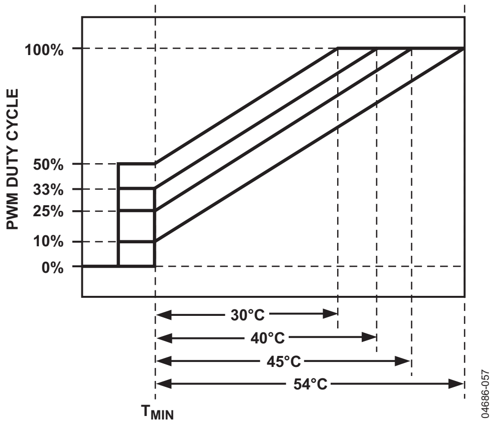

Figure 55. Increasing PWM_{MIN} Changes Effective T_{RANGE}

For a given T_{RANGE} value, the temperature at which the fan runs at full speed for different PWM_{MIN} values can be easily calculated as follows:

$$T_{MAX} = T_{MIN} + (Max\ DC - Min\ DC) \times T_{RANGE}/170$$

where:

T_{MAX} is the temperature at which the fan runs full speed.
T_{MIN} is the temperature at which the fan turns on.
Max DC is the maximum duty cycle (100%) = 255 decimal.
Min DC is equal to PWM_{MIN}.
T_{RANGE} is the duty PWM duty cycle vs. temperature slope.

Example 1: Calculate *T*, given that T_{MIN} = 30°C, T_{RANGE} = 40°C, and PWM_{MIN} = 10% *duty cycle* = 26 (decimal).

$$T_{MAX} = T_{MIN} + (Max\ DC - Min\ DC) \times T_{RANGE}/170$$
$$T_{MAX} = 30°C + (100\% - 10\%) \times 40°C/170$$
$$T_{MAX} = 30°C + (255 - 26) \times 40°C/170$$
$$T_{MAX} = 84°C\ (effective\ T_{RANGE} = 54°C)$$

Example 2: Calculate T_{MAX}, given that T_{MIN} = 30°C, T_{RANGE} = 40°C, and PWM_{MIN} = 25% *duty cycle* = 64 (decimal).

$$T_{MAX} = T_{MIN} + (Max\ DC - Min\ DC) \times T_{RANGE}/170$$
$$T_{MAX} = 30°C + (100\% - 25\%) \times 40°C/170$$
$$T_{MAX} = 30°C + (255 - 64) \times 40°C/170$$
$$T_{MAX} = 75°C\ (effective\ T_{RANGE} = 45°C)$$

Example 3: Calculate T_{MAX}, given that T_{MIN} = 30°C, T_{RANGE} = 40°C, and PWM_{MIN} = 33% *duty cycle* = 85 (decimal).

$$T_{MAX} = T_{MIN} + (Max\ DC - Min\ DC) \times T_{RANGE}/170$$
$$T_{MAX} = 30°C + (100\% - 33\%) \times 40°C/170$$
$$T_{MAX} = 30°C + (255 - 85) \times 40°C/170$$
$$T_{MAX} = 70°C\ (effective\ T_{RANGE} = 40°C)$$

Example 4: Calculate T_{MAX}, given that T_{MIN} = 30°C, T_{RANGE} = 40°C, and PWM_{MIN} = 50% *duty cycle* = 128 (decimal).

$$T_{MAX} = T_{MIN} + (Max\ DC - Min\ DC) \times T_{RANGE}/170$$
$$T_{MAX} = 30°C + (100\% - 50\%) \times 40°C/170$$
$$T_{MAX} = 30°C + (255 - 128) \times 40°C/170$$
$$T_{MAX} = 60°C\ (effective\ T_{RANGE} = 30°C)$$

Selecting a T_{RANGE} Slope

The T_{RANGE} value can be selected for each temperature channel: Remote 1, local, and Remote 2. Bits [7:4] (T_{RANGE}) of Register 0x5F to Register 0x61 define the T_{RANGE} value for each temperature channel.

Table 14. Selecting a T_{RANGE} Value

Bits [7:4][1]	T_{RANGE} (°C)
0000	2
0001	2.5
0010	3.33
0011	4
0100	5
0101	6.67
0110	8
0111	10
1000	13.33
1001	16
1010	20
1011	26.67
1100	32 (default)
1101	40
1110	53.33
1111	80

[1] Register 0x5F configures Remote 1 T_{RANGE}; Register 0x60 configures local T_{RANGE}; Register 0x61 configures Remote 2 T_{RANGE}.

Summary of T_{RANGE} Function

When using the automatic fan control function, the temperature at which the fan reaches full speed can be calculated by

$$T_{MAX} = T_{MIN} + T_{RANGE} \qquad (1)$$

Equation 1 holds true only when PWM_{MIN} is equal to 33% PWM duty cycle.

Increasing or decreasing PWM_{MIN} changes the effective T_{RANGE}, although the fan control still follows the same PWM duty cycle to temperature slope. The effective T_{RANGE} for different PWM_{MIN} values can be calculated using Equation 2.

$$T_{MAX} = T_{MIN} + (Max\ DC - Min\ DC) \times T_{RANGE}/170 \quad (2)$$

where $(Max\ DC - Min\ DC) \times T_{RANGE}/170$ is the effective T_{RANGE} value.

See the Note on Fan Speed and PWM Duty Cycle section.

Figure 56 shows PWM duty cycle vs. temperature for each T_{RANGE} setting. The lower graph shows how each T_{RANGE} setting affects fan speed vs. temperature. As indicated by the graph, the effect on fan speed is nonlinear.

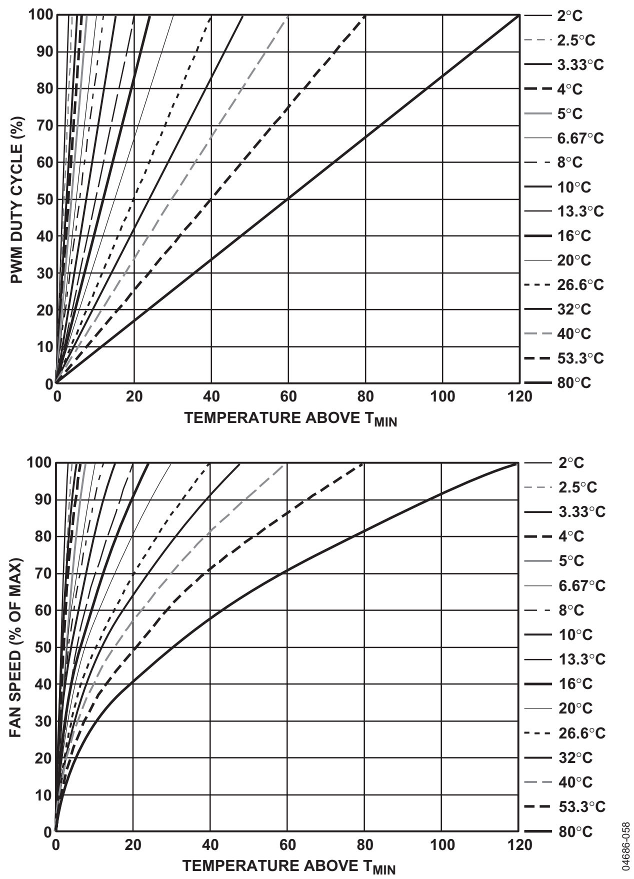

Figure 56. T_{RANGE} vs. Actual Fan Speed Profile

The graphs in Figure 56 assume the fan starts from 0% PWM duty cycle. Clearly, the minimum PWM duty cycle, PWM_{MIN}, needs to be factored in to see how the loop actually performs in the system. Figure 57 shows how T_{RANGE} is affected when the PWM_{MIN} value is set to 20%. It can be seen that the fan actually runs at about 45% fan speed when the temperature exceeds T_{MIN}.

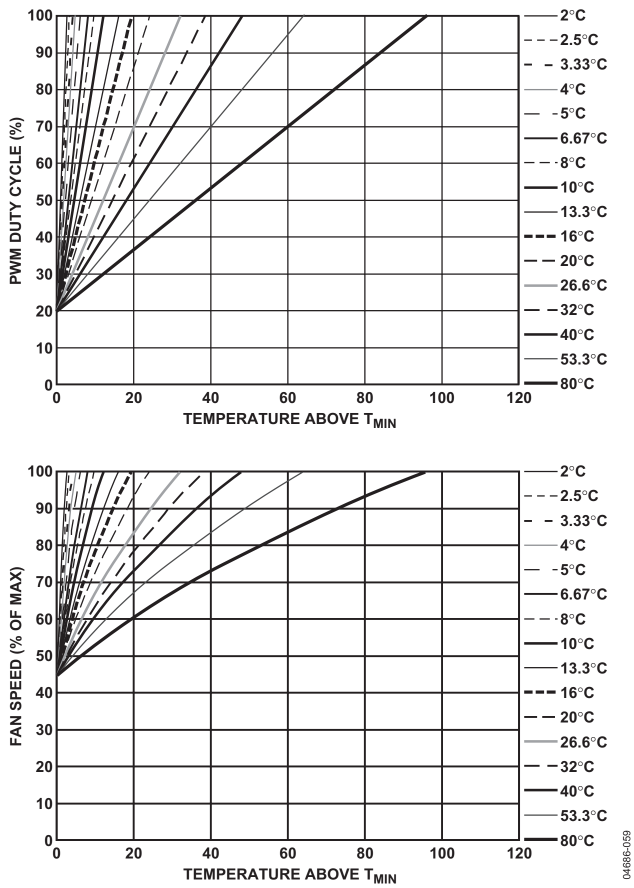

Figure 57. T_{RANGE} and % Fan Speed Slopes with PWM_{MIN} = 20%

Example: Determining T_{RANGE} for Each Temperature Channel

The following example shows how the different T_{MIN} and T_{RANGE} settings can be applied to three different thermal zones. In this example, the following T_{RANGE} values apply:

T_{RANGE} = 80°C for ambient temperature
T_{RANGE} = 53.3°C for CPU temperature
T_{RANGE} = 40°C for VRM temperature

This example uses the mux configuration described in the Step 2: Configuring the Mux section, with the ADT7473 connected as shown in Figure 58. Both CPU temperature and VRM temperature drive the CPU fan connected to PWM1. Ambient temperature drives the front chassis fan and rear chassis fan connected to PWM2 and PWM3. The front chassis fan is configured to run at PWM_{MIN} = 20%. The rear chassis fan is configured torun at PWM_{MIN} = 30%. The CPU fan is configured to run at PWM_{MIN} = 10%.