The Fan Company
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Application of PWM speed control

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Introduction:

Regulating fan speed according to the temperature inside an enclosure is the most effective method to cool electronic products. Achieving this by using pulse-width-modulation (PWM) fan-speed control can decrease energy consumption, improve fan reliability and reduce acoustics while providing wider operational speed bandwidth. PWM is the preferred approach to regulating motor speed for these main reasons:

- It is energy efficient because it doesn't generate additional heat.
- It improves fan reliability because the fan doesn't run at full speed all the time.
- It improves the acoustics of the fan with high-frequency driving signals.
- It provides thermal engineers with added operational speed bandwidth because the fan can run at either high or remarkably low speeds.

PWM:

PWM, or Pulse Width Modulation, refers to the method of applying a square wave signal to a fan that will vary its speed by changing the signal duty cycle:

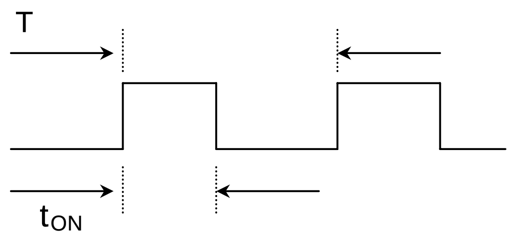

Figure 1: example of a PWM signal

T is the period in (s).

F = 1/T is the frequency in (Hz).

(t_{ON} / T) is the Duty Cycle in (%).

The frequency is always constant, what changes is the duty cycle:

An 80% duty cycle indicates that the fan is ON 80% of the time and OFF 20% of the time. A 50% duty cycle signal indicates that the fan is ON 50% of the time and OFF 50% of the time (similar to a perfect square waveform signal)

The fan speed is directly proportional to the value of the applied PWM duty cycle, In other words, a high duty cycle will produce high speeds and a low duty cycle will produce low speeds.

External PWM 3 or 2- wire fan control, Vs 4-wire PWM:

There are 2 approaches to using PWM for fan speed control:

1st approach uses 2 or 3-wire fan (3rd wire is speed or alarm sensor). The fan Ground or Power line is controlled by N-MOSFET or P-MOSFET. As shown in figure 2

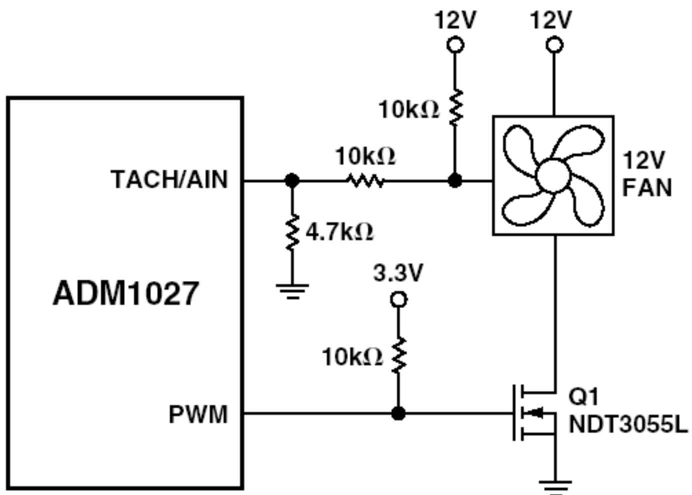

Figure 2: example of Fan with tach output controlled by N-MOSFET on the GND line by PWM

Pulse width modulating (PWMing) the fan directly involves turning the fan's power supply ON and OFF at a fixed frequency. Duty cycle adjustments are then used to control the speed of the fan. Choosing the appropriate frequency for this method can be somewhat tricky. If the frequency of the PWM signal is too slow, the fan's speed will noticeably oscillate within PWM cycle resulting in undesirable fan noise. The frequency can be also too high. But PWMing the fan and therefore the internal commutation electronics too quickly can cause the internal commutation electronics to cease functioning properly. Remember these electronics were designed to run on anything but DC supplies. In the case of a 3-wire fan, powering the fan supply voltage up and down will affect the accuracy of the sensors because the speed and alarm circuitry is also being powered up and down rendering the speed and alarm sensors useless.

A better approach to using PWM speed control is to use a 4-wire PWM fan.

The PWM and the tachometer line are connected to the PWM controller, leaving the fan power and ground lines uninterrupted, as shown in figure 3. In this way, the circuit inside the fan is working normally, sending a valid speed signal and accepting PWM control to change motor speed accordingly. As a result, a simple automatic closed-loop speed control system is formed.

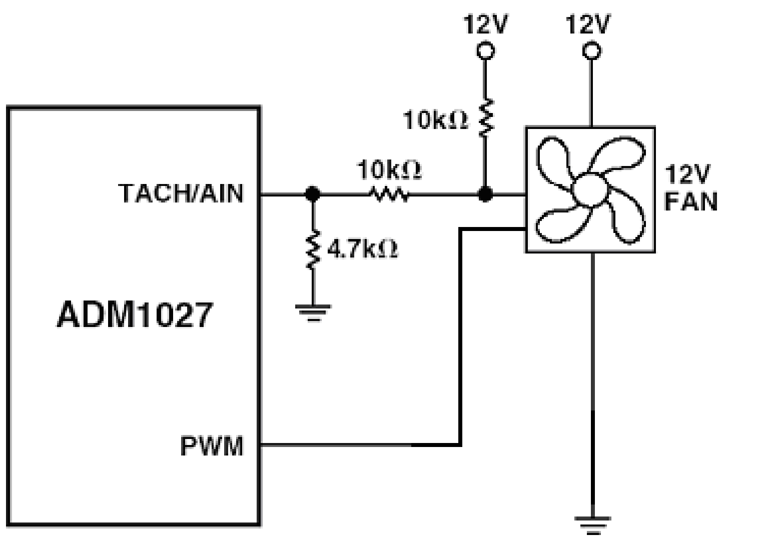

figure 3: 4 wire PWM fan control

With closed-loop speed control, the tolerance of the fan PWM duty cycle vs. the speed curve can be very wide. The controller can command the fan to achieve a desired speed (RPM) goal by adjusting the PWM duty cycle. If the speed is below the goal, the PWM duty cycle will be increased, and vice versa. The speed goal will also be maintained when there is voltage variation or load variation on the fan.
PWM controllers for brushless DC fans are available from companies such as, Analog Devices, Microchip, and National Semiconductor.
Some controllers can provide the possibility of controlling multiple fans by setting their speeds in response to different temperature readings in different locations of the system.
Or it can also set the fan to full speed in case of failure of any of the other fans. As shown below in figure 4.

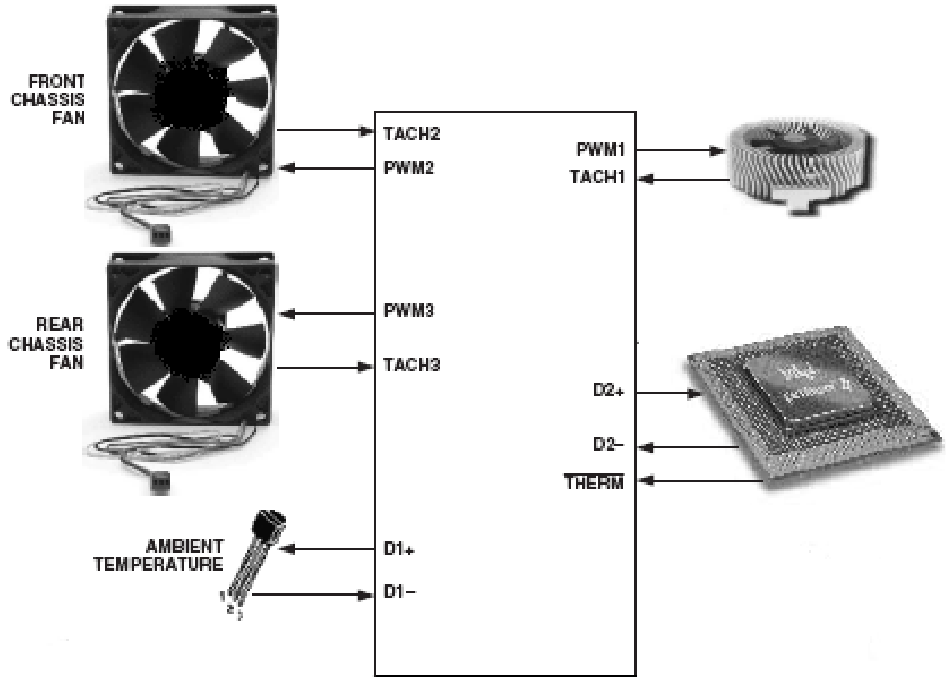

Figure 4: PWM controller with multiple fans

JMC 4-wire PWM fan speed Response to PWM Control Input Signal:

The PWM input signal is delivered to the fan through the control signal Pin. Fan speed response to this signal is continuous and monotonic function of the duty cycle of the signal.

If no control signal is present, the fan is going to operate at maximum RPM.

JMC Products offers 2 types of PWM fan speed responses:

Minimum Speed Operation:

At 0% duty cycle and below a specified minimum PWM duty cycle, Fan speed stays at a defined Minimum RPM. Between Min PWM duty cycle and 100% duty cycle, the fan speed increases almost linearly to reach Max RPM at 100% duty Cycle as shown in Figure 5:

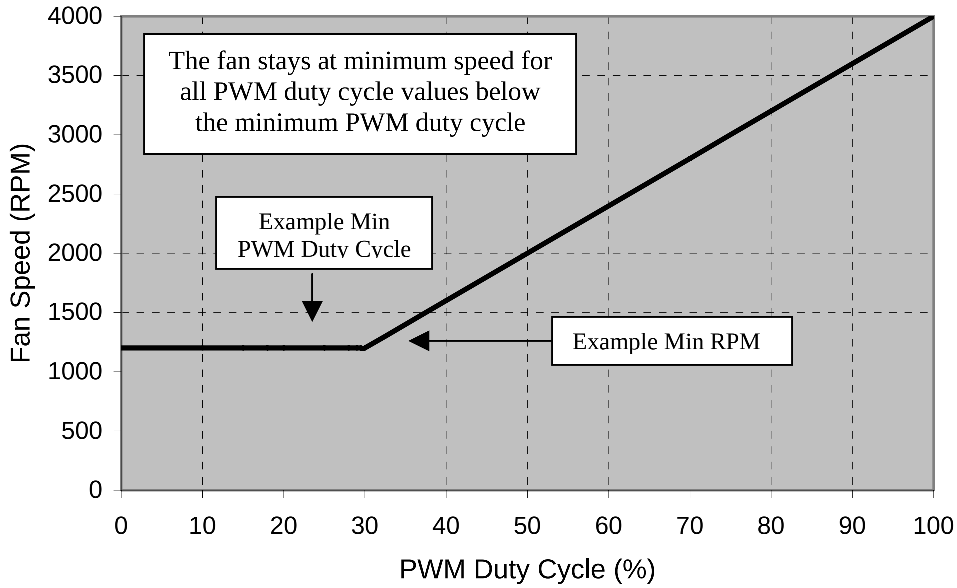

Figure 5: example of Minimum speed operation response

Fan stops at 0% duty cycle operation:

This future offers the ability to completely shut off the fan at 0% duty cycle, as opposed to idling the PWM fan at a minimum speed, thus completely eliminating fan noise and vibration, saving power and extending the life of the fan. As shown in figure 6: a minimum startup duty cycle should be applied to start the fan. At that minimum starting duty cycle the fan runs at a minimum fan speed. Once the fan starts, the speed maybe reduced below the minimum speed by applying duty cycles below the minimum starting duty cycles but the fan will stop completely when 0% duty cycle is applied.

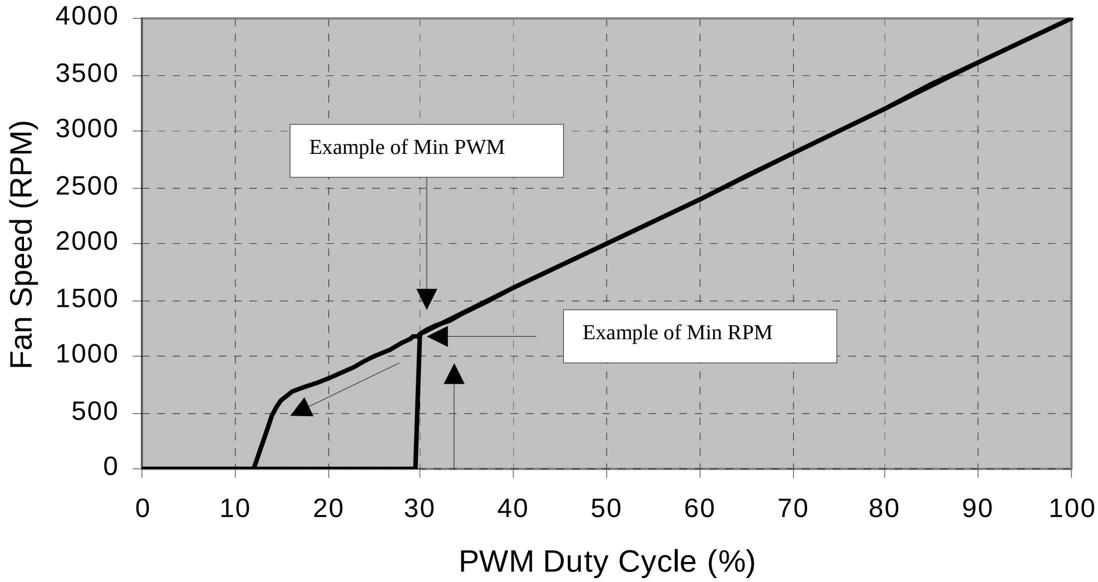

Figure 6: An example of speed vs. PWM Duty cycle of a fan with 0 RPM at 0% feature

Conclusion:

Each enclosure or application requires a customized, thermal solution approach. General equations and rules have not yet been developed. Potential PWM fan applications include computer systems motherboards, chassis systems fans, and microprocessors with active heat sinks in consumer electronics products such as televisions and TV set top boxes. One PWM fan model can replace many models of similar top speed and CFM fans. Currently, designers require a multitude of different temperature and RPM curves, which will generate many different fan models, which can make a designer's logistical process very complicated. However, when using only one PWM fan, a designer can program a desired temperature/RPM curve by simply changing the PWM controller software.

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