Monitoring Fan Tachometers Using the UCD908x Family

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ABSTRACT
The UCD908x family of power supply sequencers/monitors provides a flexible platform for managing the power sub-system of projects having a variety of power supply rails. Typically, these projects also require thermal management and utilize fans to provide cooling air flow. The supervisor inputs can be used to monitor fan tachometer outputs using a minimal amount of inexpensive external circuitry. This Application Report describes methods to implement fan tachometer monitoring capabilities.

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1 Introduction
This Application Report demonstrates how to add fan tachometer monitoring capability to the UCD908x family of power supply supervisors/sequencers. Using a single SN74HC123 package as a frequency-to-voltage converter, two fans tachometers may be monitored independently. Alternatively, two fans can be monitored with a single supervisory channel by combining the two outputs of the SN74HC123.

Note: In order to make the most sense out of this document, please make certain you are familiar with the features and capabilities of the UCD9080 by reviewing its datasheet and EVM User's Guide. References to these documents are found at the end of this document.
2 Frequency-to-Voltage Conversion using the SN74HC123

The SN74HC123 logic device is a dual mono-stable multi-vibrator (one shot). It is an edge-triggered device that emits a logic pulse, of programmable duration, for each edge that it receives on its trigger input. The average DC value of the pulse train emitted by the SN74HC123 is proportional to fan tachometer frequency since each output pulse has a fixed duration. The SN74HC123 is capable of triggering on either rising or falling edges, but in this particular application the falling edge is used. Most fan tachometer outputs are open-drain or open-collector outputs connected to a pull-up resistor. As such, the falling edge will be a faster edge and is thus a better candidate for triggering the ‘HC123.

Figure 1 shows the functional diagram for the dual one-shot, SN74HC123.

![Functional Block Diagram of the SN74HC123](image)

The duration of the timing pulse generated by each edge detected by the device is determined by the RC time constant of $C_x$ and $R_x$. For the SN74HC123, the duration of the timing pulse is typically $t_w = 0.45 \times R_x \times C_x$, though over process, temperature, and component variation this can vary the timing significantly. Please note that this timing formula may vary from other vendors and should be verified if attempting to dual source this device.

The schematic for a single channel fan tachometer is as follows:

![Single Input, Single Output Fan Tachometer Interface to the UCD908X](image)

The schematic for a dual channel, dual output fan tachometer is as follows:
If only a single supervisory input is available on the UCD908X, the outputs of the SN74HC123 can be combined, shown in Figure 4, to generate an averaged signal monitoring two fans.

The "typical" line shown in Figure 5 is obtained using typical values when the SN74HC123 is programmed to output an 18 ms pulse. The –Tol and +Tol lines represent the deviation from "typical" when using a ±23% pulse variation to account for worst case component tolerances.
Figure 5. Frequency-to-Voltage Gain Variation Due to Component Tolerances

Note that not all fans emit 1 pulse per revolution of the fan. The x-axis of Figure 5 is normalized to Pulse-per-Minute rather than RPM to account for this. When designing a fan tachometer, the Pulse-per-RPM ratio must be understood in order to achieve useful results.

3.1 Numerical Example #1

Assume for this example that the fan requiring monitoring typically emits 5000 PPM during healthy operation, and that the SN74HC123 is programmed to emit pulses of 18 ms duration for each falling edge received from the fan tachometer output. In this case Figure 5 applies to this example. Further, let's assume that a desired error flag generates if the output of the tachometer falls to approximately 2500 PPM, or about half speed.

From Figure 5 notice that the output of the SN74HC123 will typically average out to 80% of $V_{DD}$ at about 2500 PPM; 80% $\times 3.3\,\text{V} = 2.64\,\text{V}$. The supervisor threshold of the UCD908x should then be set to 2.64V. Also from Figure 5, uncompensated component variations can cause the assured measurement limits to fall at 2200 PPM and 3500 PPM respectively. Therefore detection of a fault by the UCD9080 indicates that the fan is operating within this range of values, and well below that expected for a normally operating fan.

While the effects of component variation may seem dramatic, given the go, no-go nature of most fan tachometer applications (either the fan is turning or it's not) this is still a robust and simple method for detecting fan failures.

If additional accuracy is desired there are at least two ways to adjust this circuit. First, the RC timer network that programs the SN74HC123 may be implemented with a traditional or digital potentiometer or a trim-DAC to compensate for the variation. Second, the threshold of the UCD908x may be trimmed up or down to account for component variation such that an alarm is generated at a specific PPM reading. The later method requires no additional hardware, and either method would be trimmed during the final electrical testing of the system.

Stacking multiple tachometers onto a single UCD908x Supervisor input, such as that shown in Figure 4, becomes problematic without compensating for both tachometers due to the component variation issues. Even with two tachometers, care must be taken to design the timing circuitry around the SN74HC123 and the threshold of the UCD908x such that a fault can be detected easily. In the case of Figure 4, the supervisor effectively measures the average of the two HC123 outputs and without proper consideration for tolerance, either a failure to detect a fault condition or a false-failure can result.
3.2 **Numerical Example #2**

Certain applications cannot tolerate the saturating characteristic of Figure 5, and instead a completely linear transfer function is desired. By reprogramming the ‘HC123 for a shorter output pulse the linear range may be extended to higher PPM rates. For instance, programming the ‘HC123 with an 8 ms pulse width results in the following transfer function:

![Diagram](https://via.placeholder.com/150)

**Figure 6. Frequency-to-Voltage Function Using an 8 ms Pulse Duration**

In this case, a fan that typically generates 5000 PPM will output a duty cycle of 67% using typical-valued components. Without compensating for component variations the actual output could vary from 51% to 82%. However, if we make the rather safe assumption that the components will vary little over time once a unit is built, then we can rely on relative changes in the output for the detection of faults.

For example, assume that a unit is built and the component variation stack-up is such that the ‘HC123 output falls along the –Tol line of Figure 6. At 5000 PPM this generates 51% duty cycle. Since we know the output falls along a straight line intersecting the origin, if the fan were to slow to 2500 PPM due to bearing wear, the output would also be only half of the healthy value or 25.5%. Further, if the fan were to begin spinning faster due to a vacuum induced by a plugged inlet that would also be reflected in the pulse rate increasing beyond the initial healthy value.

Using this form of fan detection requires that a calibration value be noted during healthy operation so that deviations may be detected in light of inevitable component variations. The UCD908X is then used to sample the output of the ‘HC123 and embedded firmware in the host processor performs the fault detection.

4 **Conclusion**

The UCD908x family of Power Supply Sequencers/Monitors is capable of monitoring many other analog parameters found in a typical system implementation beyond power rail integrity. Using voltage-mode inputs with digitally programmable thresholds it is capable of measuring other quantities such as temperature. With the appropriate external interface hardware it can measure fan speed. This Application Report outlines how to implement such a fan monitor using an inexpensive logic device, as well as describes the details and issues associated with component variation so that a robust tachometer can be constructed.
5 References

1. SN74HC123, High-Speed CMOS Logic Dual Retriggerable Monostable Multivibrators with Resets (SCHS142F)
2. UCD9080, 8-Channel Power Supply Sequencer and Monitor (SLVS692D)
3. Expanded System Monitoring Functions with UCD9080 (Rev. A) (SLUA426A)
4. Programming the UCD9080 (SLUA441)
5. UCD9080 Power Supply Sequencer and Monitor EVM User’s Guide (Rev. A) (SLVU184A)
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