Airflow and time domain frequency stability

The effect of airflow on reference oscillator time domain frequency stability.

While we do everything we can as an oscillator manufacturer to ensure the best possible performance in our oscillators by design, there are some steps that the system designer can take to maximize the effectiveness of the oscillator they select.

One of the key factors influencing the performance of a precision oscillator is the thermal characteristics of the end environment. As the space available on standard card level assemblies gets reduced the volume of air available for cooling heat sensitive components through simple convection is insufficient and so forced air techniques are more common.

Modeling the effects of turbulent air currents on individual components is a complex process and so we undertook a simple experiment to just give the user a qualitative understanding of the extent of the influence these effects can have on the performance of precision reference oscillators.

We conducted a short experiment to illustrate the effect of air flow on the time domain frequency stability of a TCXO, Small Form Factor OCXO and 1" x 1" OCXO. The ADEV (root of AVAR) was used for this measure and plotted against averaging time for three scenarios:

1, Still air.

2, Turbulent airflow (from a fan).

3, Oscillator protected from turbulent airflow by cover.

The measurement time for each case was 180 minutes so that ADEV could be calculated up to tau = 2,000 seconds. For measurements with airflow the fan was turned on 60 minutes into the test. For the remaining 120 minutes the fan was switched on and off for 5 minutes at a time. The oscillator under test was placed on an evaluation board 10cm away from a fan – the entire assembly was in turn placed inside a 40cm x 50cm x 35cm enclosure to minimize the effect of disturbances in the lab environment. Tests were conducted at 'room temperature', so the system under test saw long term ambient changes but no temperature extremes. For the third scenario a plastic cover was placed over the evaluation board – see figures 1a and 1b.

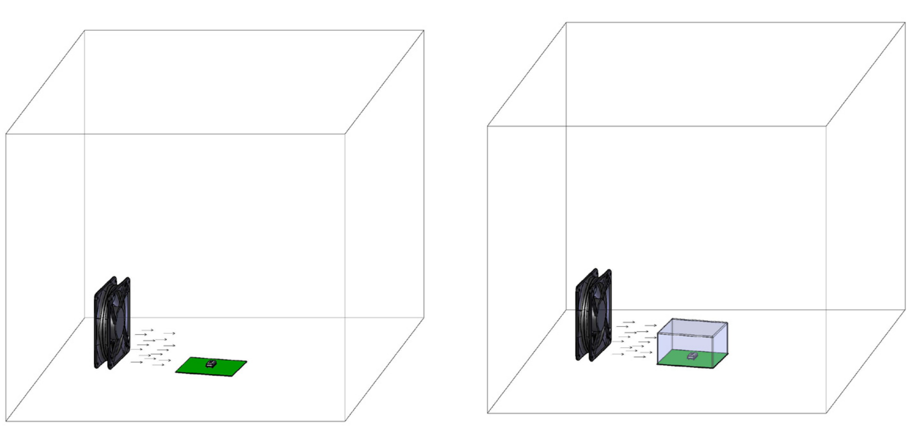

Figure 1 – experiment setup. A, oscillator in chamber subjected to turbulent airflow. B, oscillator in chamber protected by an additional enclosure.

Sitting in still air at room temperature the performance of the oscillator is chiefly influenced by its own internal characteristics – how long it has been running, the noise processes associated with the crystal type and oscillator design. Figure 2 illustrates this case for a TCXO.

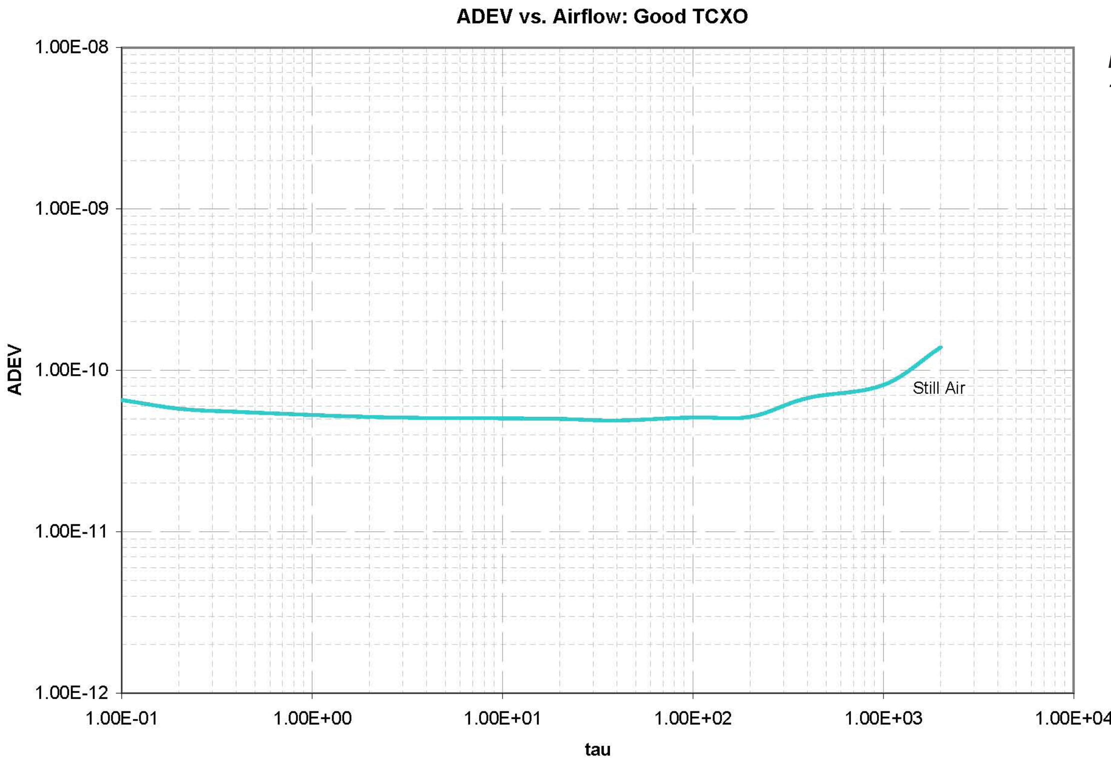

Figure 2.
TCXO in still air.

When air moves around the oscillator the performance is degraded quite significantly – the ADEV across all averaging times is increased, with the most dramatic effect taking place in the 10 to 100s averaging periods. Over longer averaging periods the effect of short-term thermal instabilities is reduced, as one would expect. However long term instabilities can still come into play and it should be noted that the temperature in the chamber was no controlled. Figure 3 shows this effect on the TCXO.

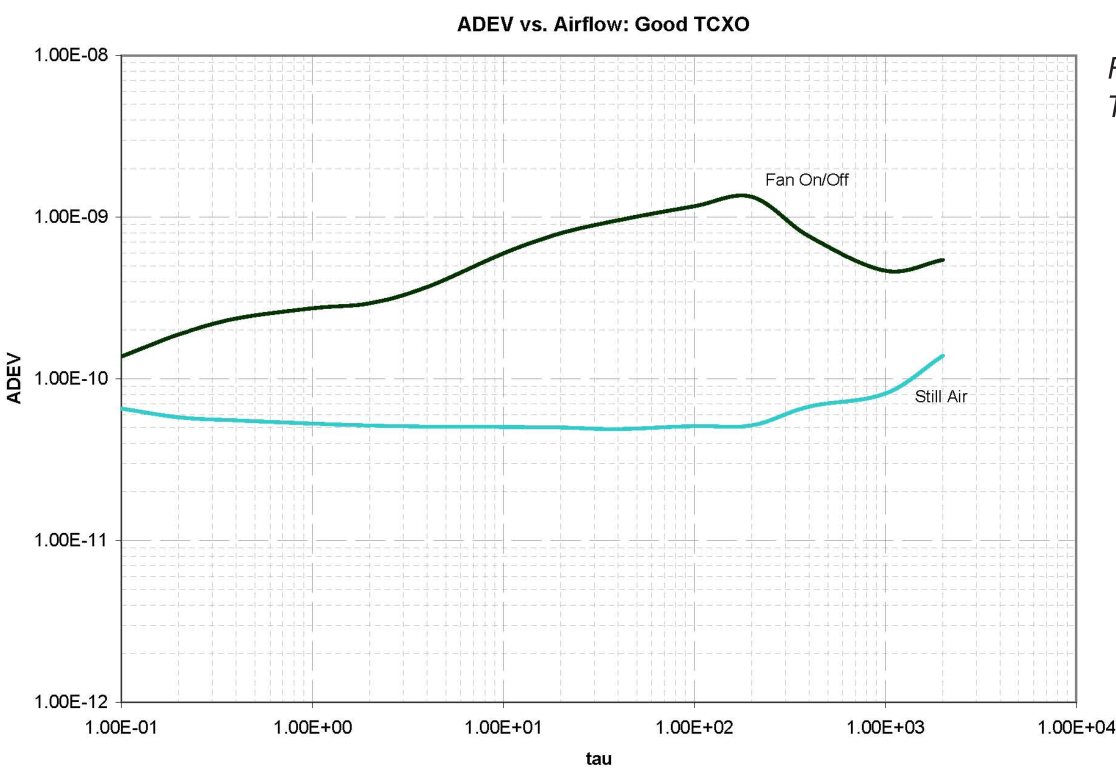

Figure 3.
TCXO with Fan On.

Adding a cover can mitigate the effects of airflow on the oscillator – the performance again resembles that when there was no airflow present (as one would expect). Figure 4 shows all three cases for the TCXO under test.

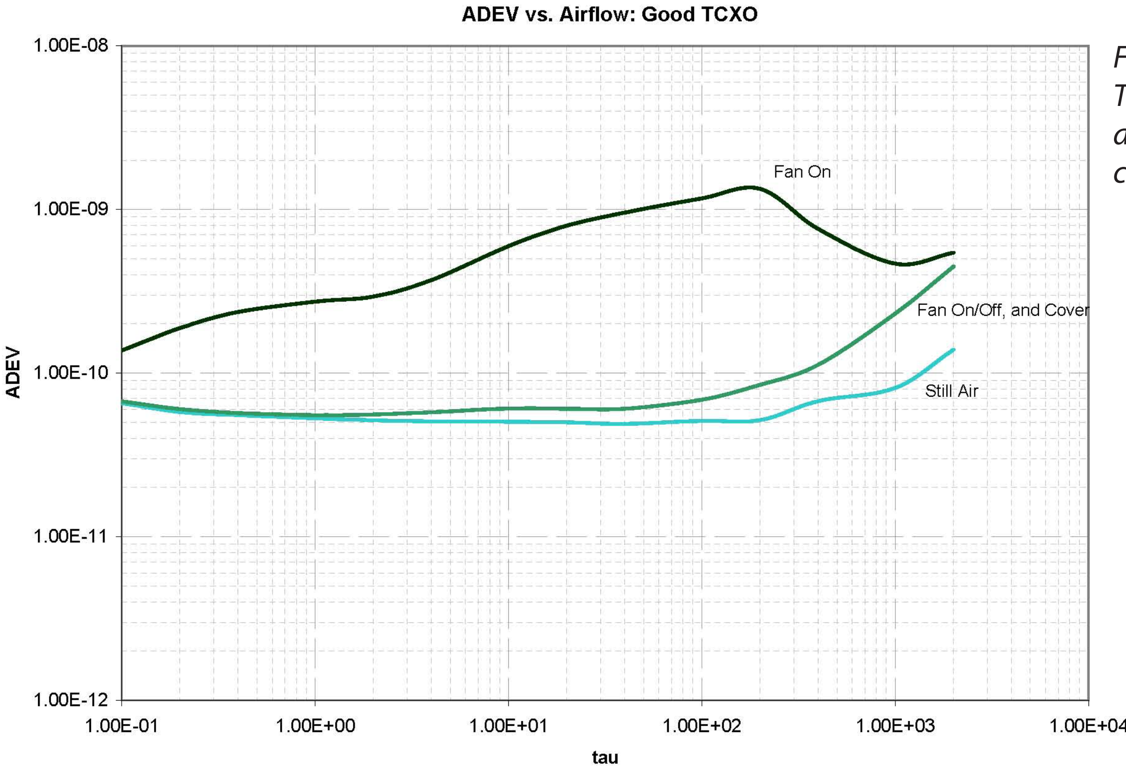

Figure 4. TCXO with Fan On, and additional cover.

So, even at relatively fixed temperatures the flow of air around an oscillator can have a detrimental effect on the performance of the oscillator.

We repeated the experiment for a small form factor OCXO and a 1" x 1" square OCXO, the results for all three cases for both oscillator types are shown below.

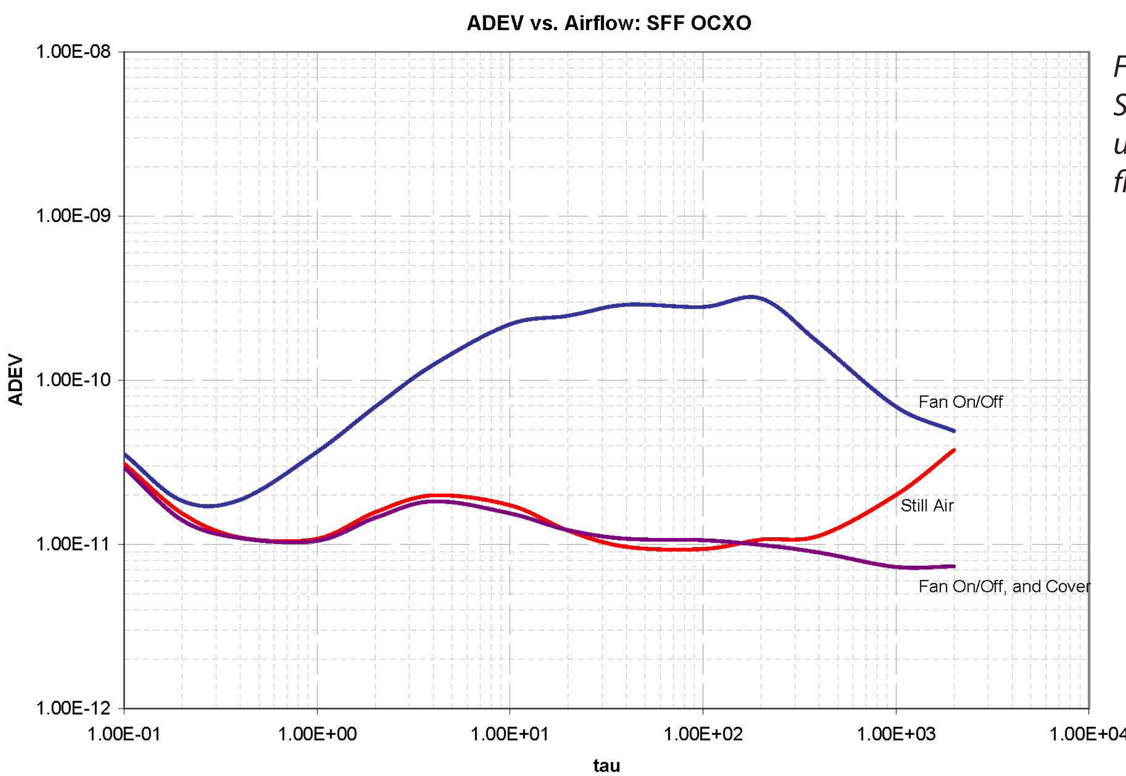

Figure 5. Small form factor under varying air-flow conditions.

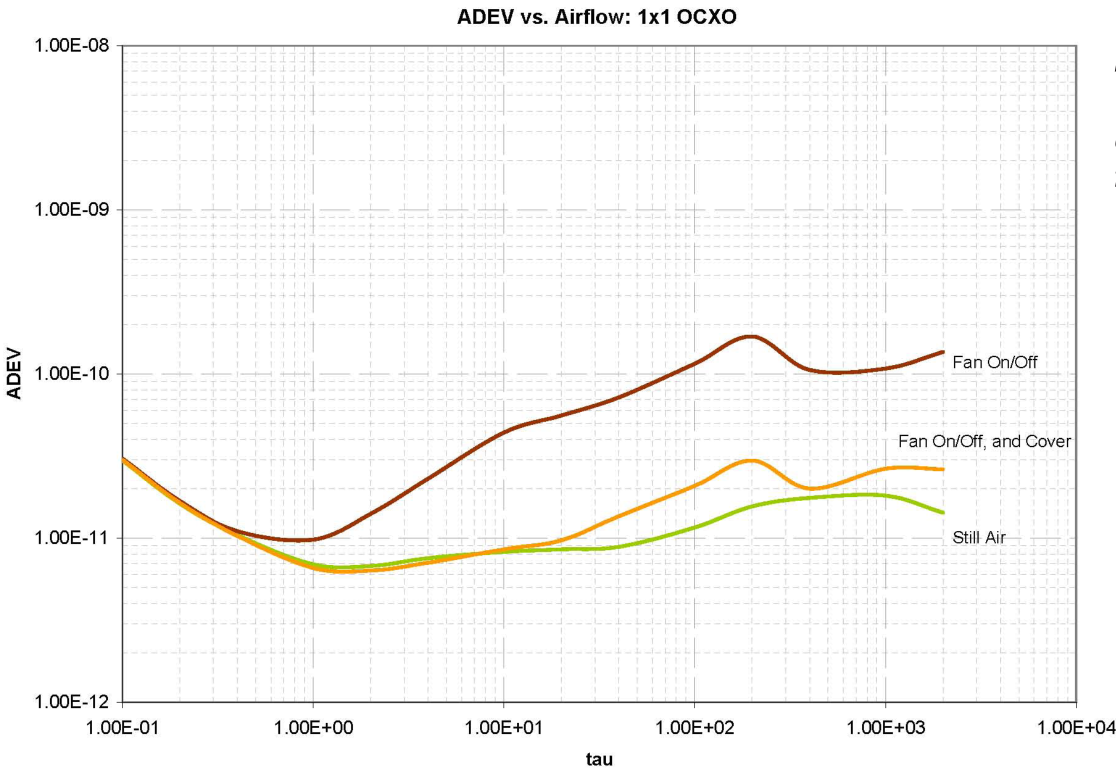

Figure 6.
1" Square OCXO under varying airflow conditions.

Looking through Figures 4, 5 and 6 we can observe that of all the oscillator types the TCXO is the most affected by airflow, and the 1" square OCXO is the least affected. Figure 7 summarizes this.

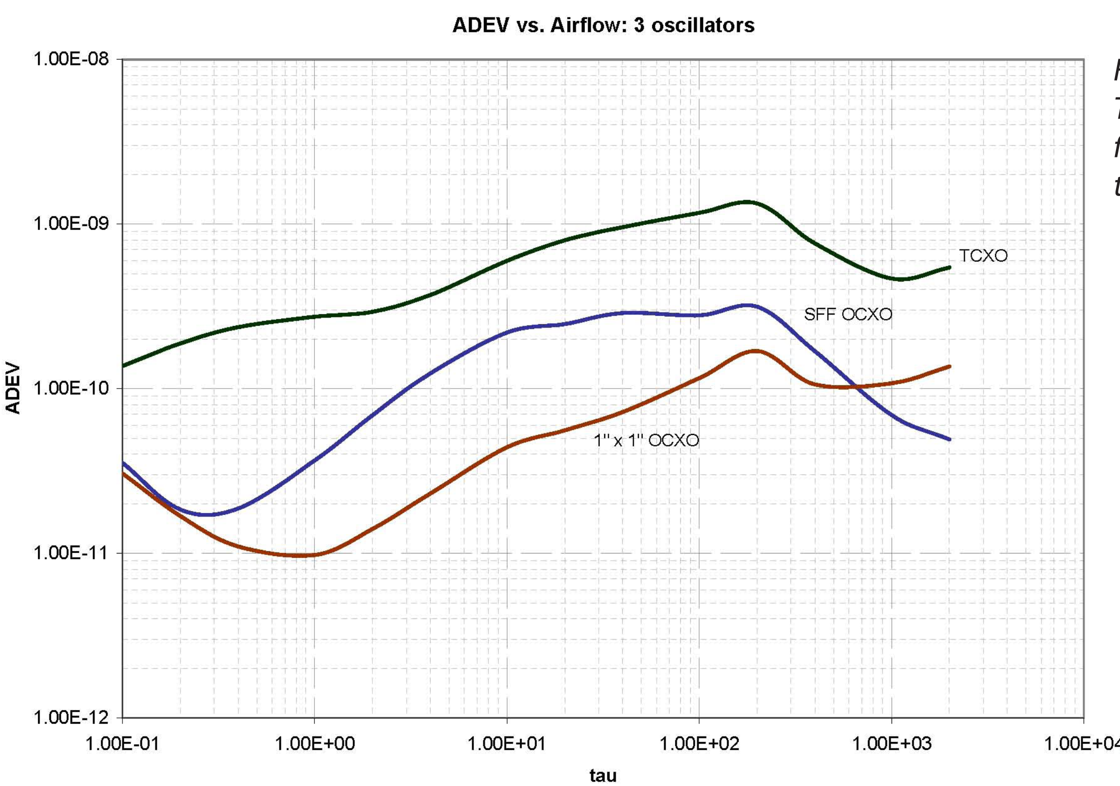

Figure 7.
The effects of airflow on 3 oscillator types summarized.

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From this simple exercise we can make the following observations:

1, Regardless of oscillator choice, taking some measure to protect a precision oscillator from turbulent airflow is important.

2, In instances where it is not possible to do this an oscillator built to minimize such influences (such as the 1" x 1" OCXO tested here) is a good alternative.

3, A compromise is the small form factor OCXO, as its stability when exposed to airflow exceeds that of a TCXO and when protected from airflow its stability is comparable with that of the 1" square OCXO.

It should be noted that we chose a 'worst case' scenario with a fan being pulsed on an off during operation. While this reflects the typical operation in some systems another scenario would be to have the fan on constantly - we anticipate that under these conditions the temperature instabilities would not be as significant and hence the ADEV behavior would be improved.

The real world effects of ambient temperature changes, the influence of heat sources (such as high power consumption devices) and stability changes due to cooling fans will all play an important role in deciding the effectiveness of the frequency reference in your design. It is important to discuss the thermal attributes of your design in advance with the oscillator supplier to see if they can help resolve some of the complexities that arise.

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