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Product Note 73

Vibration Tester for On-Wafer Tuner Operation

Introduction

This note describes a vibration tester for assessing vibrations inherent in any tuner with stepper motors. Vibrations can be seen in real time, registered and saved in a text file. This gives the ability to display the data and also understand them easily. It is also possible at the end of each acquisition to see what is the maximum distance that the tuner travels. Experience shows that vibrations in a wafer setup using electromechanical tuners originate almost entirely from inadequate mounting and assembling the tuners on the station.
The vibration tester is therefore extremely useful in order to optimize the load pull wafer setup for minimum tuner move and vibration sensitivity.

Description of the Tester

In order to measure the vibrations of the X, Y and Z axes of a tuner, we use three Hall Effect Sensors. As the amplitude of the vibrations is very small, an electronic circuit, which includes two low noise JFET inputs amplifiers (TL071) per sensor, allows adjusting the gain and the zero position middle of the dynamic range of the operational amplifiers before entering an 8-bit A/D acquisition box.
By connecting this acquisition box to a computer, it is possible to save the variation of the vibrations' amplitude versus time.
We use a LabView program to perform the acquisition, to display data (figure 1) and to save them as text file, which can be processed using spreadsheet programs like MS 'Excel'.

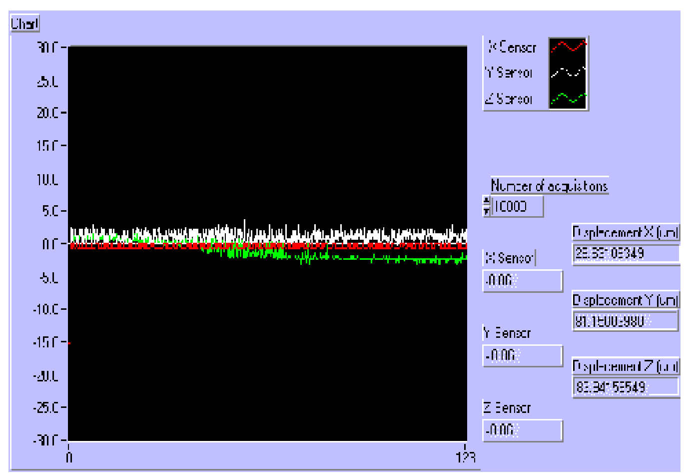

Figure 1: LabView platform used for the vibration tester

Description of the Sensors

The vibrations we are dealing with here are low amplitude phenomena (1µm - 100µm). In order to measure those on three axes, we use three 'Hall Effect' Sensors. Hall Effect sensors allow measuring the very low amplitude vibrations without friction.

A Hall Effect Sensor generates a magnetic field. A magnet, mechanically connected to the tuner, vibrates in this magnetic field, modifying the field properties. The Hall Effect Sensor outputs a voltage proportional to the perturbation of the field. As these perturbations are proportional to the vibration amplitude, the output voltage will be an image of the vibrations.

Figure 2 shows the sensor output voltage versus the air gap in millimeters between magnet and sensor. This characteristic is not linear, but as we need a very low range of air gap (maximum around few hundred µm), we need an amplifier in order to "zoom" in the characteristic. Figure 3 is a zoom of figure 2 in the area between 2 and 3 millimeter, and the characteristic is almost linear. So we will only need the slope of the zoomed characteristic for our further data processing.

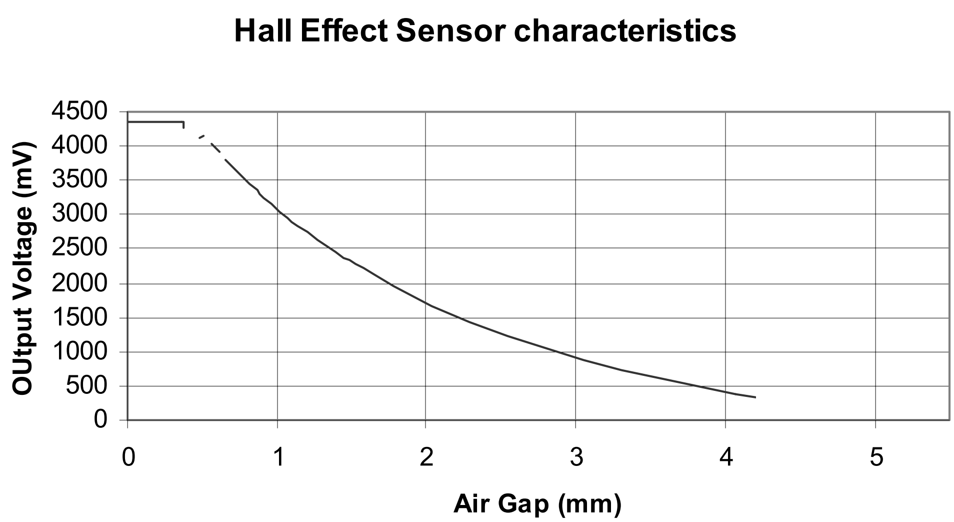

Figure 2: Hall Effect Sensor Characteristic.

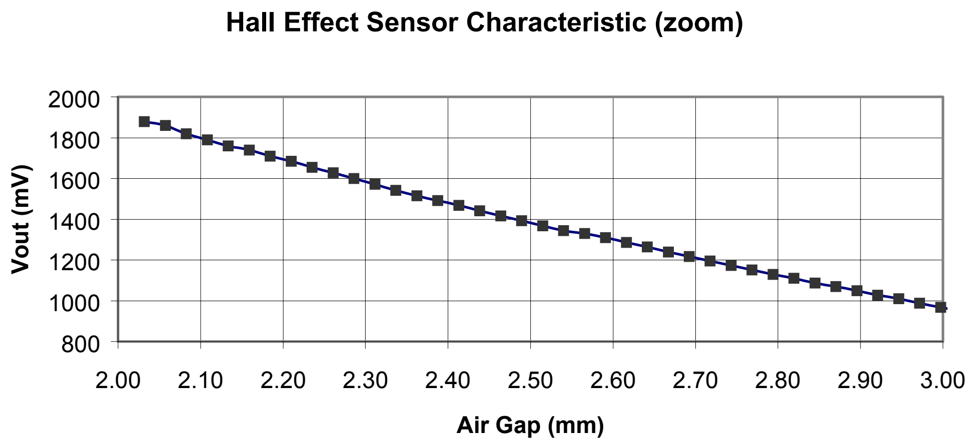

Figure3: Hall Effect Sensor Characteristic (zoomed).

Description of the Setup

Mechanics

The magnetic block (made of non-magnetic aluminum) is the enclosure for three magnets. One end of the block is equipped with a 3.5mm (SMA) adapter used to connect to the wafer probe (figures 4 a, b, c).

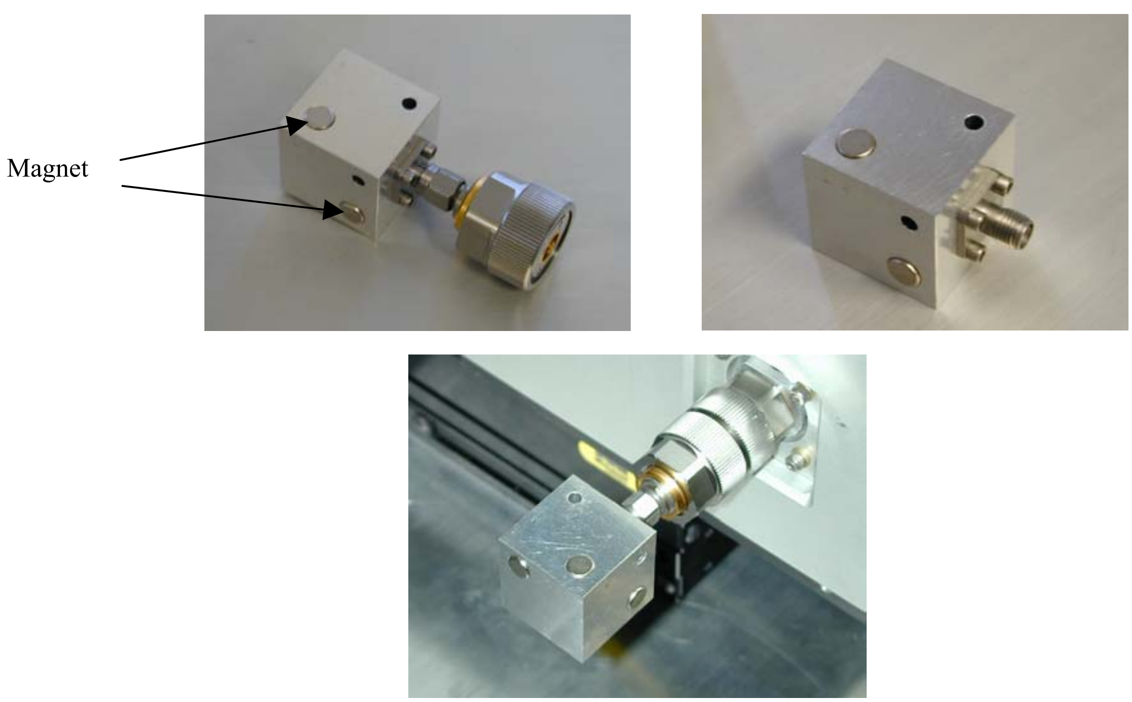

Figure 4 a, b and c: Connection of the magnetic block.

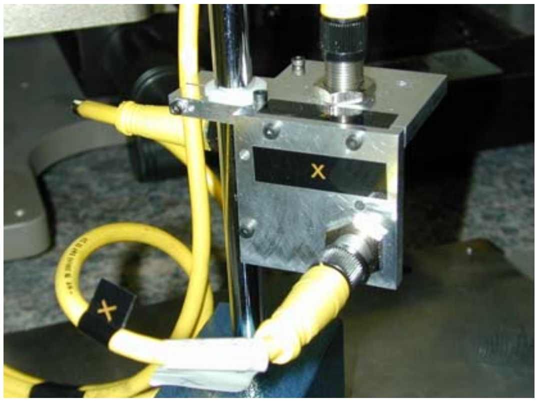

Figure 5: Mounting of the sensors on their support.

It is also possible to connect the magnetic block to the extremity of a 45º-bend line instead of cables for on-wafer measurements (figure 6).

Figure 6: Vibration test at the output of a 45º bend line.

Electronics

The following schematic shows the electronic circuit used to "zoom" the characteristic. Each channel amplifier is built using two TL 071, chosen for their low noise behavior (figure 7).

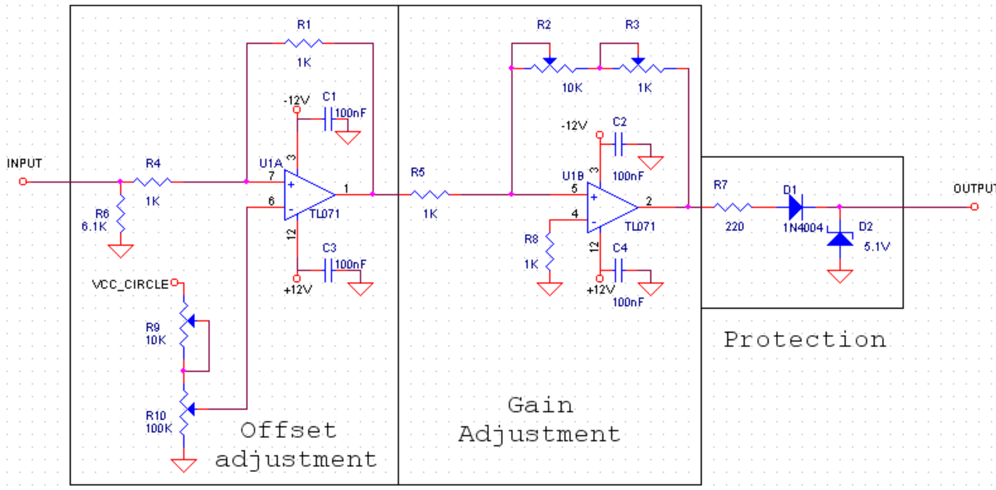

Figure 7: Schematic of the channel amplifier.

The first operational amplifier allows us to adjust the offset. By adjusting this we can set the zero value to the middle of the dynamic range of the circuit.
The second one allows adjusting the gain. The higher it is, the better is the sensitivity of each sensor. In our case, the gain is set by default to the maximum. If the gain is too high and if the amplitude of the vibrations measured is too large, the amplifiers will saturate.
The saturation voltage of the amplifiers is ±12V, which can damage the acquisition card as it can only support 0 to 5V on its input. So we use a protection circuit after the second operation amplifier. The diode D1 blocks all negative voltages and the Zener diode limits the output to less than 5.1V.

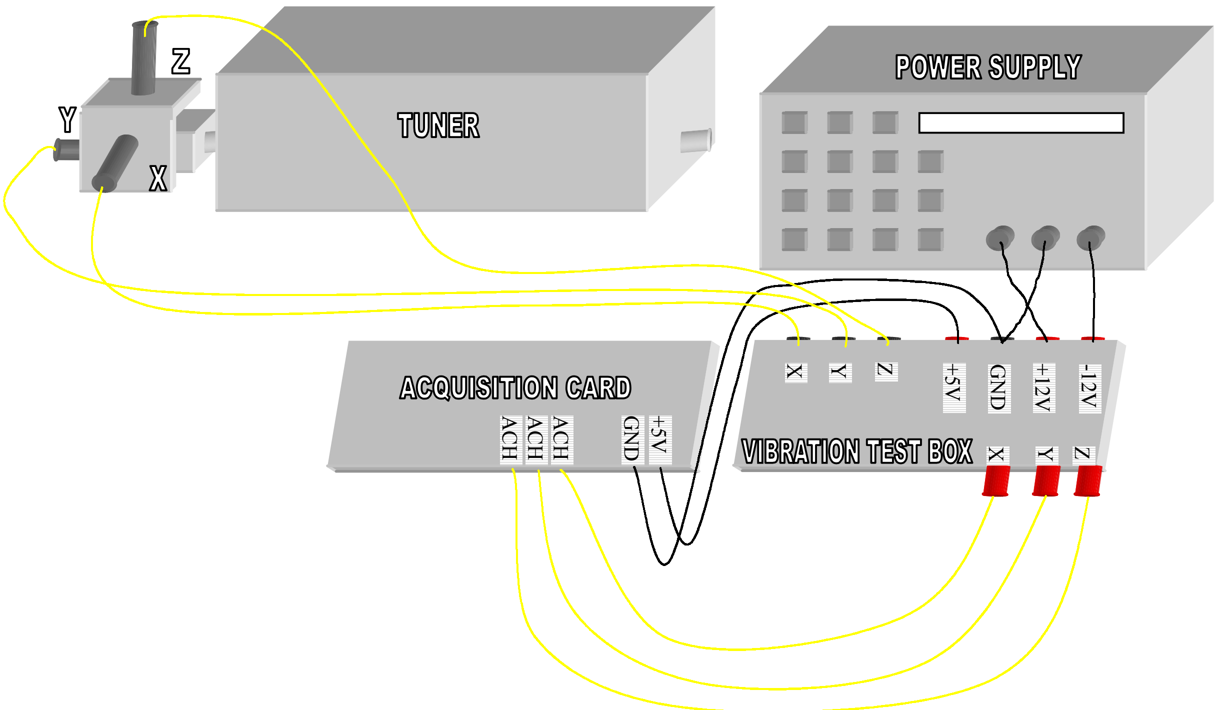

Figure 8: Setup of the Vibration Tester.

Figure 8 shows how all parts are connected together. The acquisition card is connected to the parallel port of a computer.

Software

The measurement software is designed using LabView. Figure 9 shows its main window.

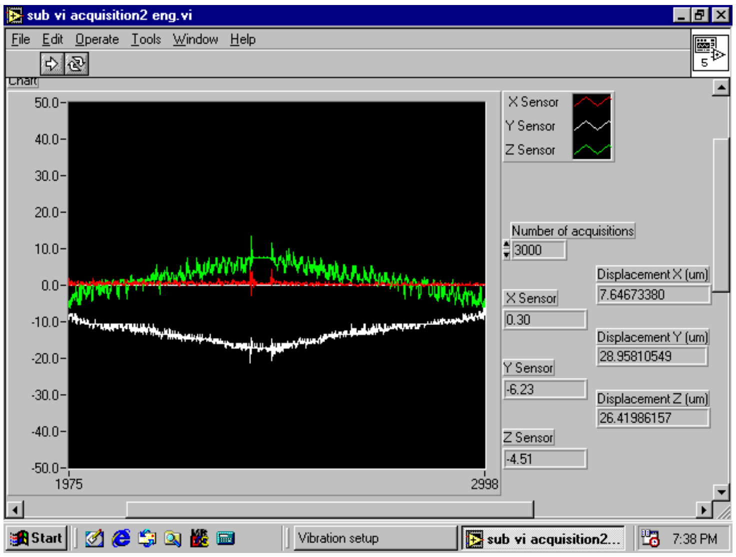

Figure 9: LabView main window.

The indicators "X Sensor", "Y Sensor" and "Z Sensor" display the actual position of the magnet and thus the ongoing vibration level in µm.
The horizontal axis shows the sequential readings, corresponding in fact to real time as the tuners move in various directions during initialization or a full load pull cycle, controlled by another application like manual tune or load pull software. Reading speed is approximately 20 to 60 samples per second. The vertical axis shows the displacement (vibration) readings themselves in a different color for each axis (X, Y or Z).
The "Displacement" indicators show the total maximum displacement of each sensor during the whole measurement cycle.

Measurement Results

At the end of the measurement, it is possible to save all data acquired in a text file. It is then possible to open it in a spreadsheet program ("Excel") and display data as charts (figure 10).

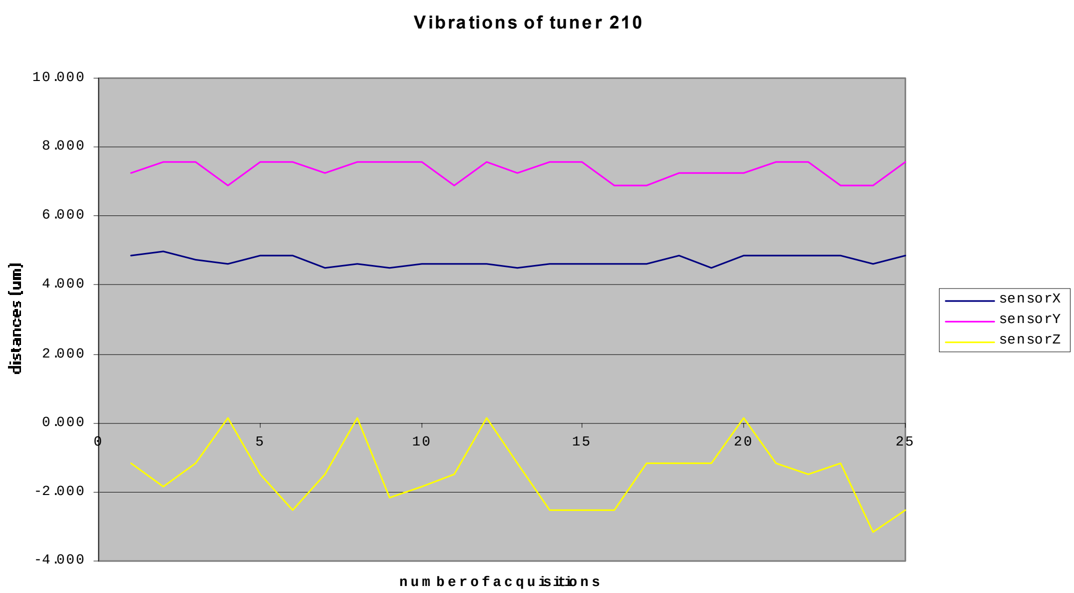

Figure 10: Data displayed in Excel.

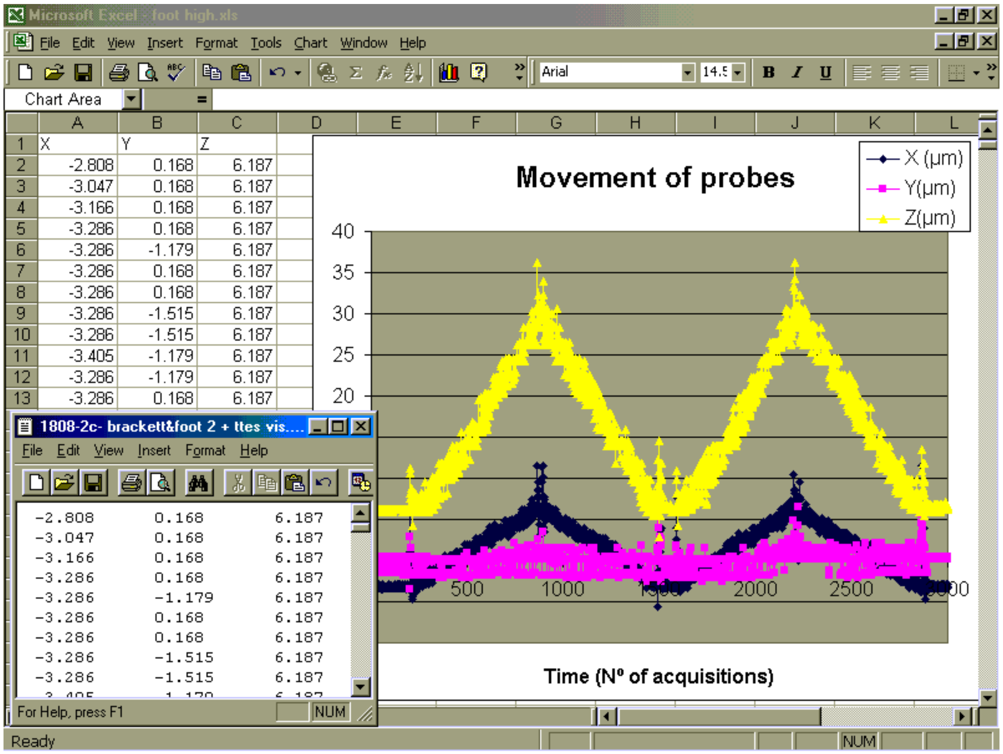

Figure 11: Vibration results displayed in Excel and text format

The graph on figure 11 represents the vibration results of a CCMT 1808 tuner, where the tuner was mounted on a 3-axis positioner. Vibrations were measured for a horizontal displacement of the carriage, which produces more vibrations than movement of the vertical axis.

We can steady vibrations with peak-to-peak amplitude of 2 µm on the Z-axis, due to the vibrations generated by the stepper motor.

The Z-axis also presents a slope, which is due to displacement of the carriage and the shift in weight of the tuner on the positioner; this way, the center of gravity of the tuner travels, and this phenomenon creates the total slope of the Z-axis. This total slope is around 25µm.