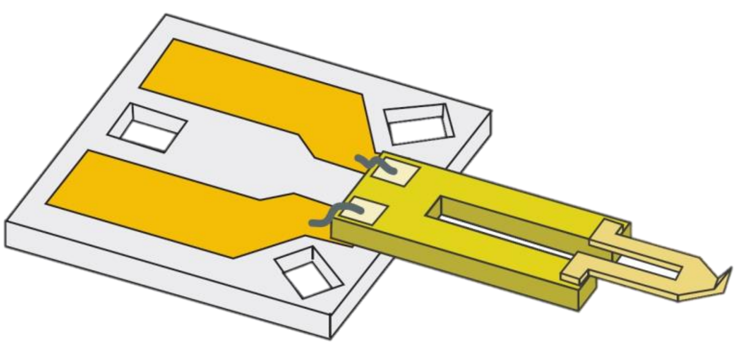
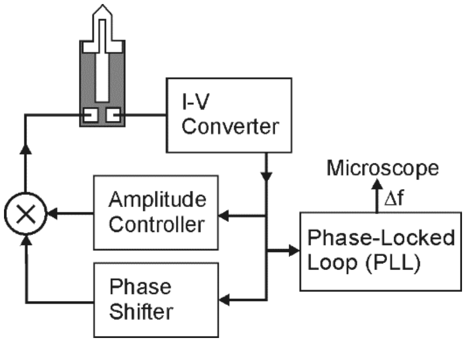
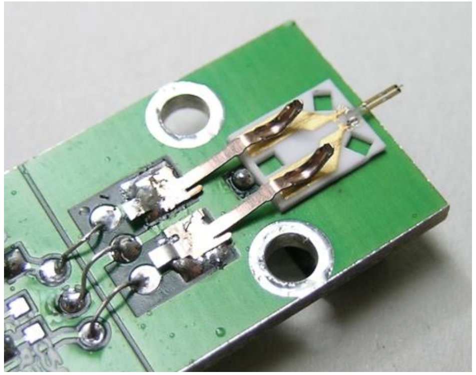
Akiyama-Probe (A-Probe)
technical guide

This technical guide presents:

how to make a proper setup for operation of Akiyama-Probe.







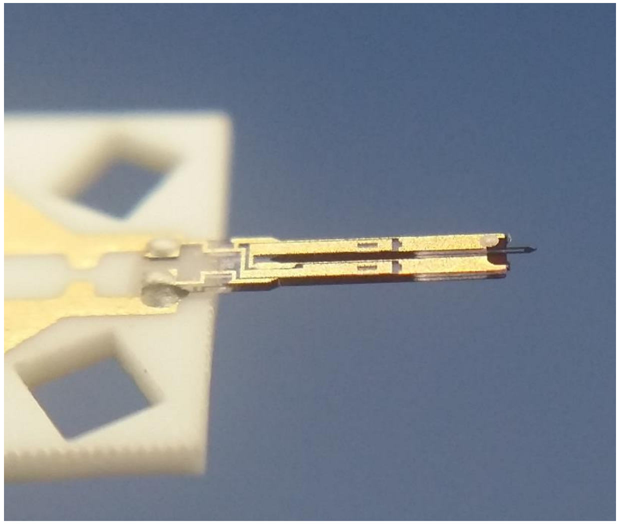
Version: 2.1

- To benefit from the advantages of Akiyama-Probe, a proper operation setup is required. In order to save some time and effort, a commercial instrument should be the first choice. One can obtain the best performance in a shorted time. An alternative to the commercially available/offered solution is building one's own setup. This technical guide is intended for those who prefer the latter. Many examples and suggestions in this guide will help to overcome common problems at the first step.

- The recommended operation mode for Akiyama-Probe is dynamic mode with the frequency modulation (FM) detection (self-oscillation). The amplitude modulation (AM) detection (fixed driving frequency) is also feasible, if one would accept a slower scan speed and compromise on spatial resolution.

- The following points have to be considered to build an own setup:
  - How to physically fix Akiyama-Probe with two electrical connections
  - Electrical configuration (self-oscillation, frequency measurement)
    - pre-amplifier
    - electronics for self-oscillation
    - phase locked loop (PLL)

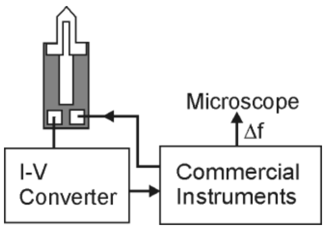
- Note that some contents in this guide may not apply to your specific setup. Please use this guide as a This is for general reference only.



Akiyama-Probe Since 2006

Akiyama-Probe is a patented technology.

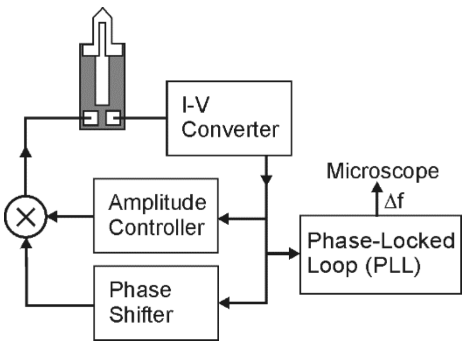
Operation setup



❑ Commercial instruments:

Many instruments and equipment (AFM, PLL, amplifiers and etc.) are commercially available for Akiyama-Probe operation. They are very reliable and highly recommended to use.

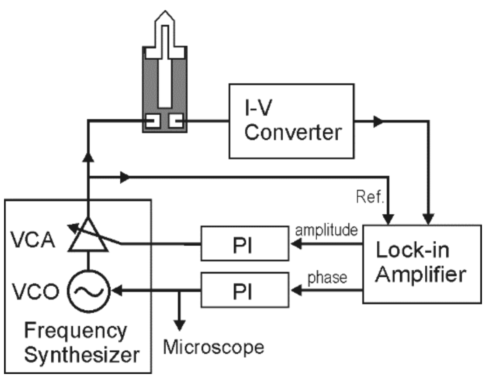
***E.g.*, Tuning Fork Sensor Controller** by NanoAndMore
http://www.nanoandmore.com/tuning-fork-sensor-controller.php



❑ Build your own setup with analog electronics:

A self-oscillation circuit can be built with some OP-amps. In a simple case, the PLL can be outside of the self-oscillation loop and works in a passive mode. If a single chip PLL (e.g., 4046) is used, a complete setup can be built with a low budget. If a higher resolution is required in this configuration, the simple PLL can be replaced with a more accurate commercial PLL without any major modification of the setup.

- M. Ferrara, Nanotechnology 14, 427–432 (2003)
- J. Jersch, *et al.,* Rev. Sci. Instrum. 77, 083701 (2006)
- H.-P. Rust, *et al.,* Rev. Sci. Instrum. 77, 043710 (2006)

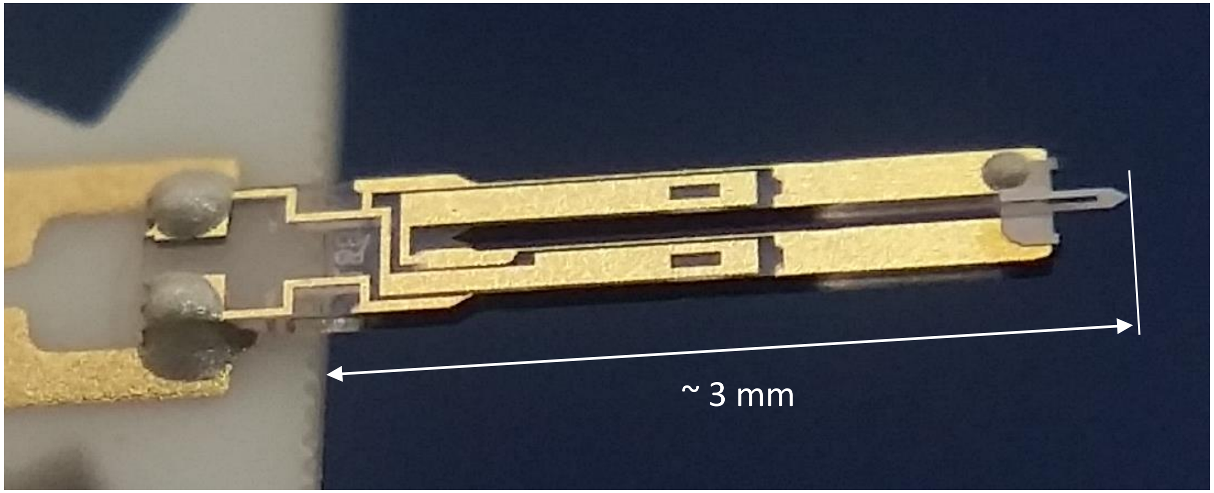


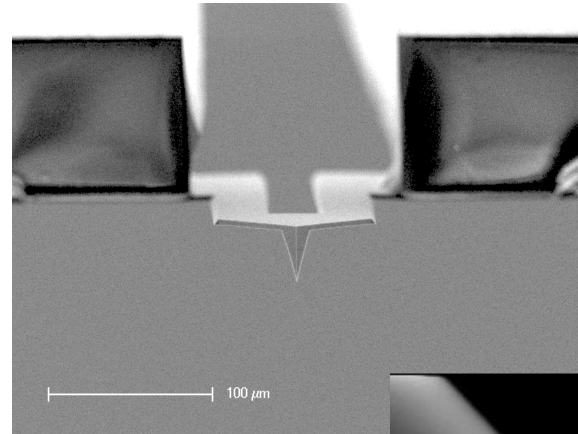
❑ Laboratory standard instruments + minimum analog electronics:

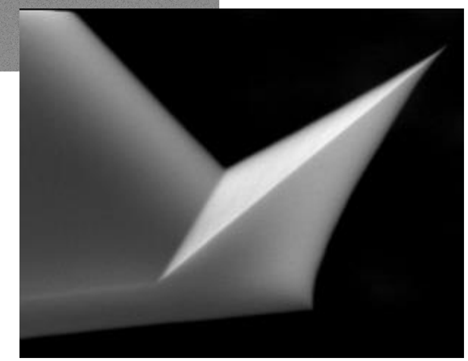
One can make a very high performance “self-oscillation + PLL” setup with two standard laboratory instruments (lock-in amplifier and frequency synthesizer) and a very simple analog circuit. The analog circuit with a few OP-amps forms a proportional-integral gain controller.

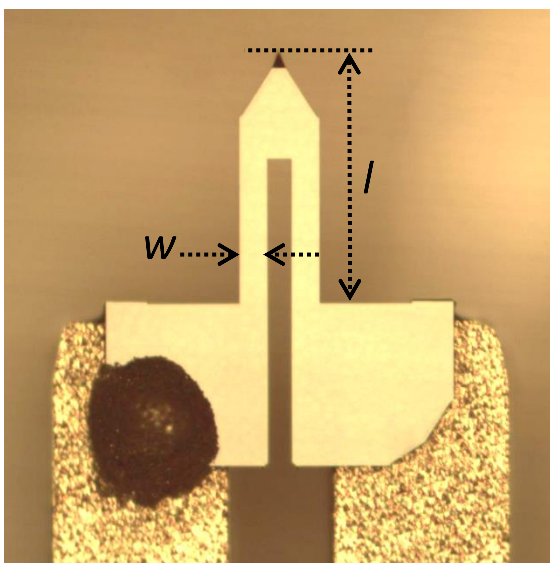
- J. Rychen, *et al.,* Rev. Sci. Instrum. 70, 2765 (1999)
- J. Jersch, H. Fuchs. IEEE Int. Freq. Cont. Symp. Forum, 483-487 (2007)

Akiyama-Probe specifications









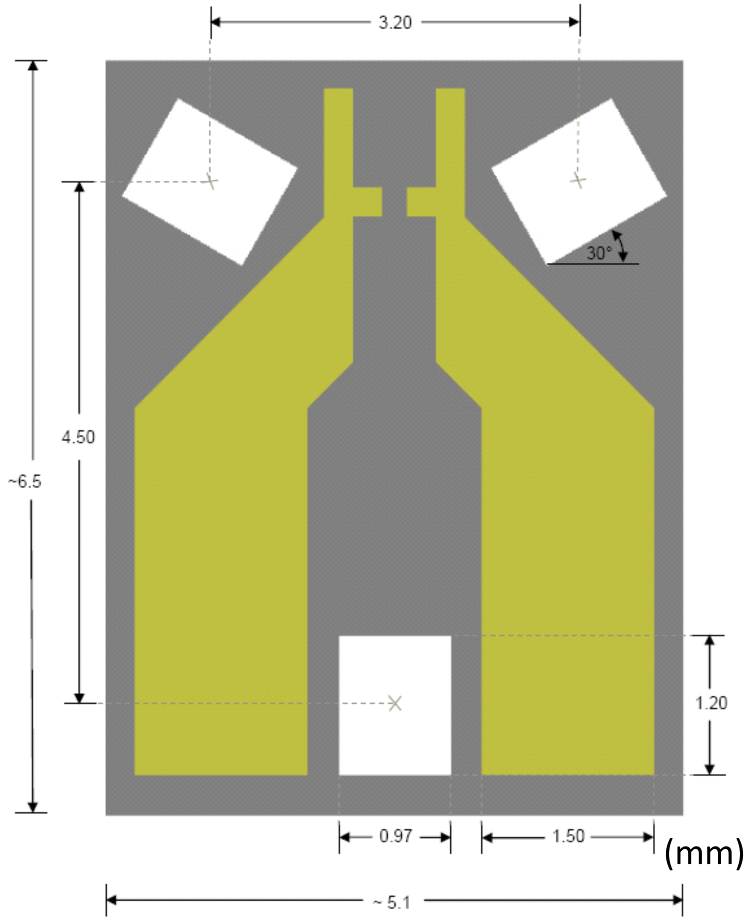
Specifications (typical values)

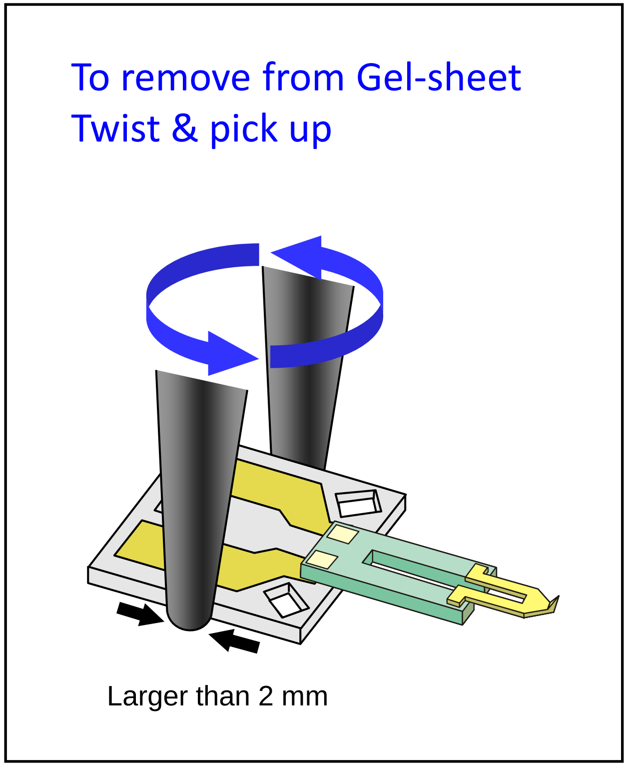
Cantilever	length: 310 µm, thickness: 3.7 µm, width: 30 µm each material: n^+ silicon (0.01 - 0.025 Ohm•cm)
Tip	AdvancedTEC™-like tip radius <15 nm, tip height 28 µm
Force constant	5 N/m (Si cantilever)
Resonance frequency	45 kHz (33 – 60 kHz)
Ceramic plate	approximately 6.5 mm x 5.1 mm x 0.4 mm

All values are subject to change without notice.

Ceramic plate

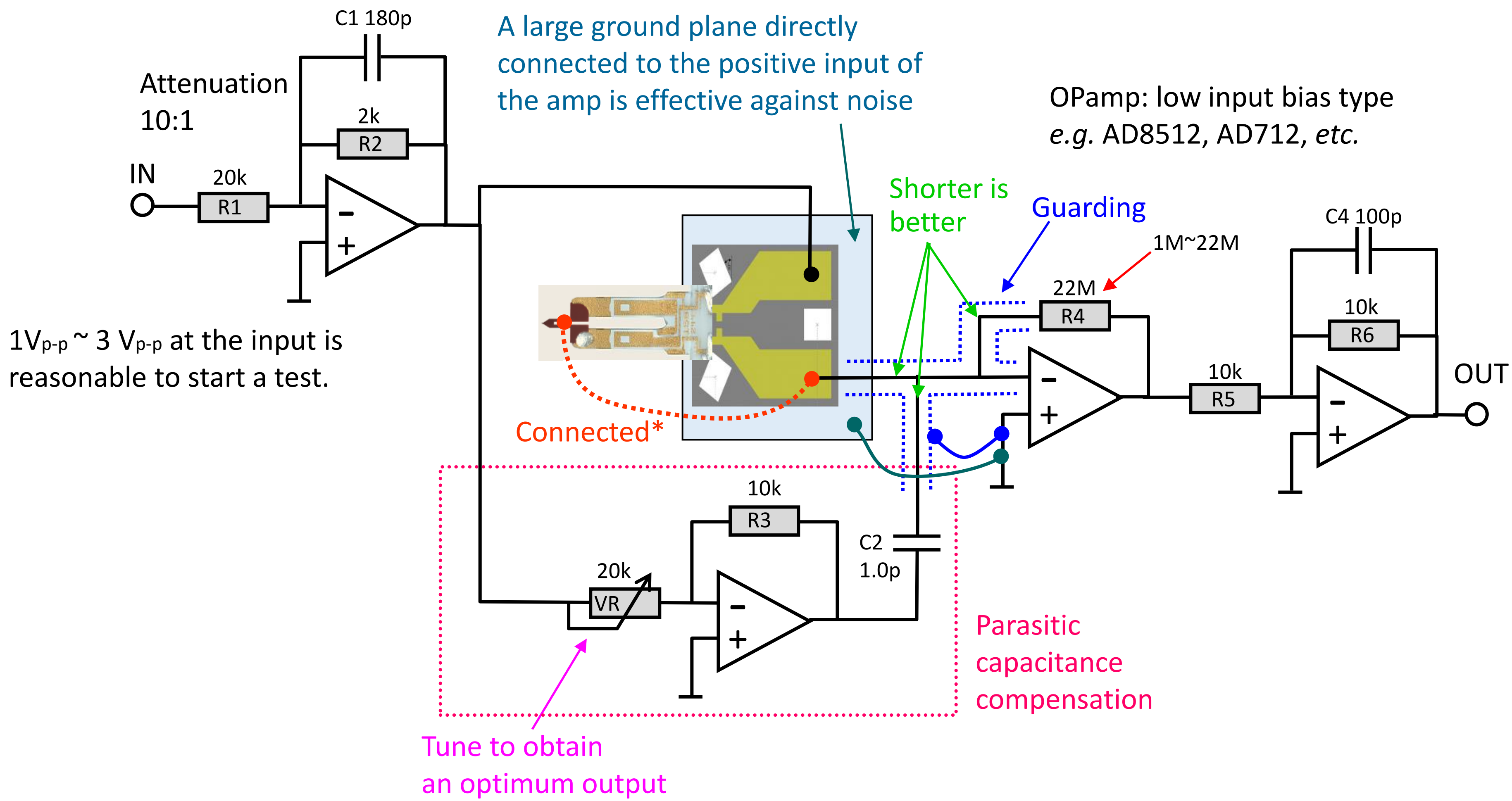
This side is electrically connected to the cantilever.





- NANOSENSORS™ original ceramic plate for Akiyama-Probe with two gold contacts and three through holes. All through holes have the same size and can be used for centering the plate on a counterpart that has three spheres. The thickness is approximately 0.4 mm.

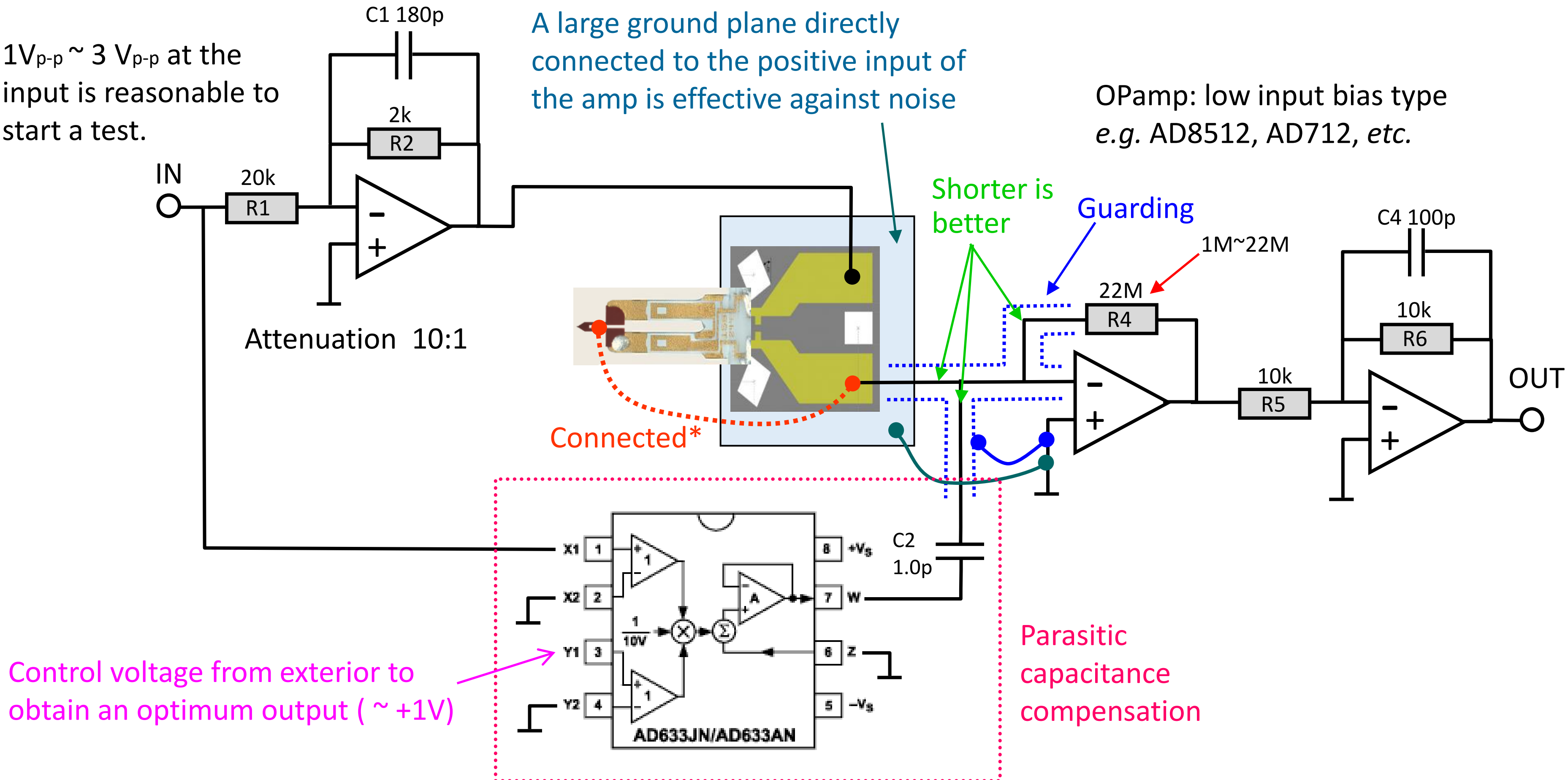
Amplifier circuit (1a)



*The silicon cantilever and tip is electrically connected to the left pad of the ceramic plate. In this configuration, the cantilever and tip should have the “virtual” ground potential.

All resistors and capacitors may have to be trimmed accordingly.

Amplifier circuit (1b)

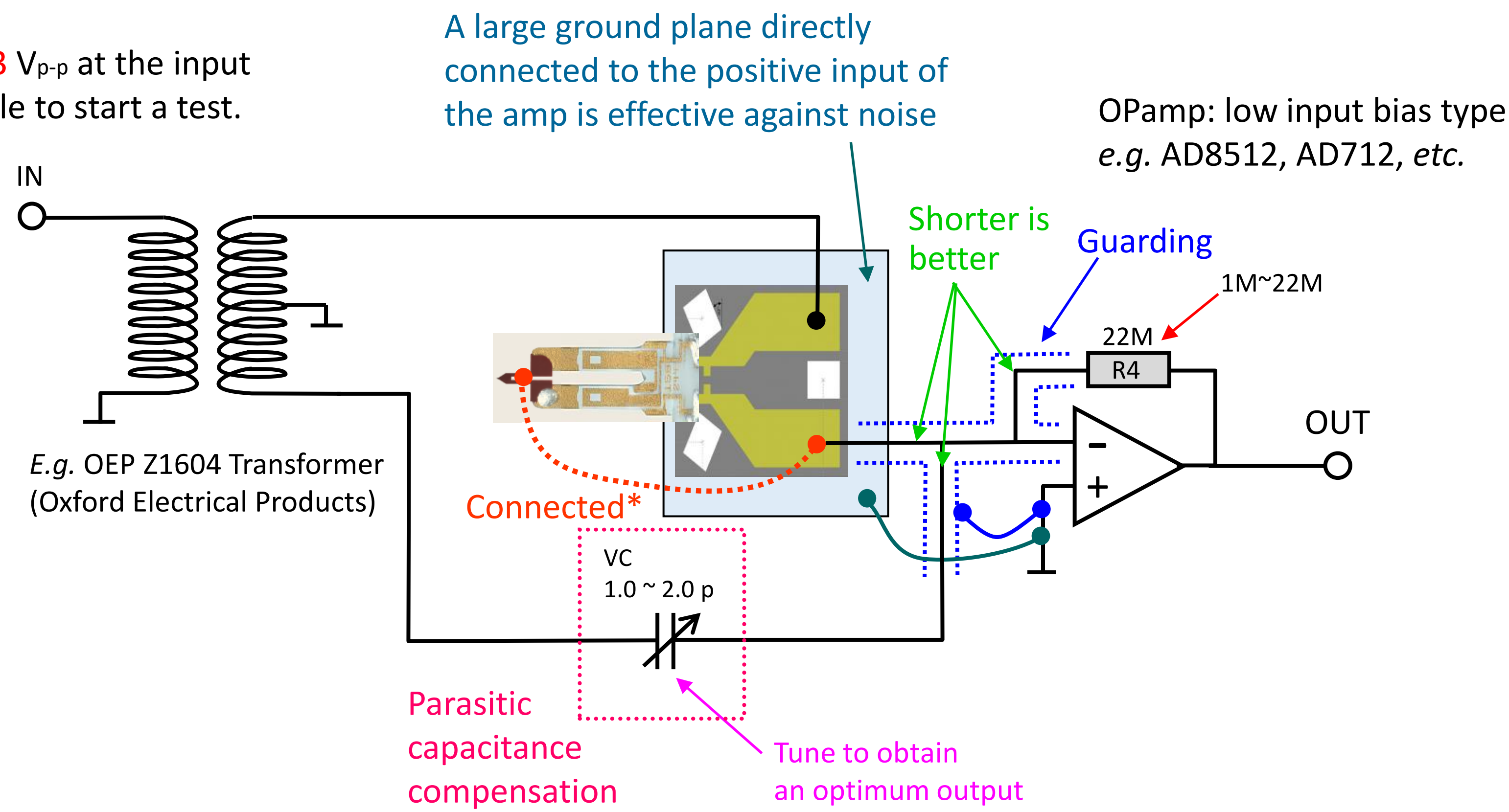


*The silicon cantilever and tip is electrically connected to the left pad of the ceramic plate.
In this configuration, the cantilever and tip should have the “virtual” ground potential.

All resistors and capacitors may have to be trimmed accordingly.

Amplifier circuit (2)

0.1Vp-p ~ 0.3 Vp-p at the input is reasonable to start a test.

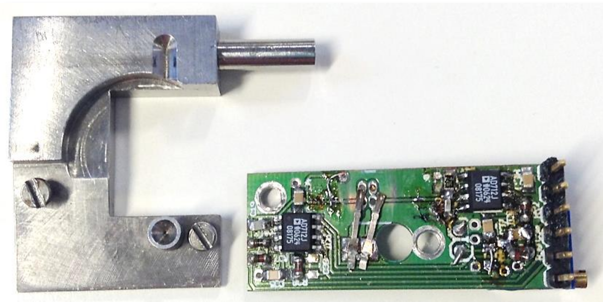


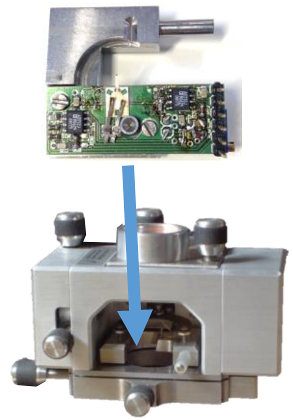
*The silicon cantilever and tip is electrically connected to the left pad of the ceramic plate. In this configuration, the cantilever and tip should have the “virtual” ground potential.

All resistors and capacitors may have to be trimmed accordingly.

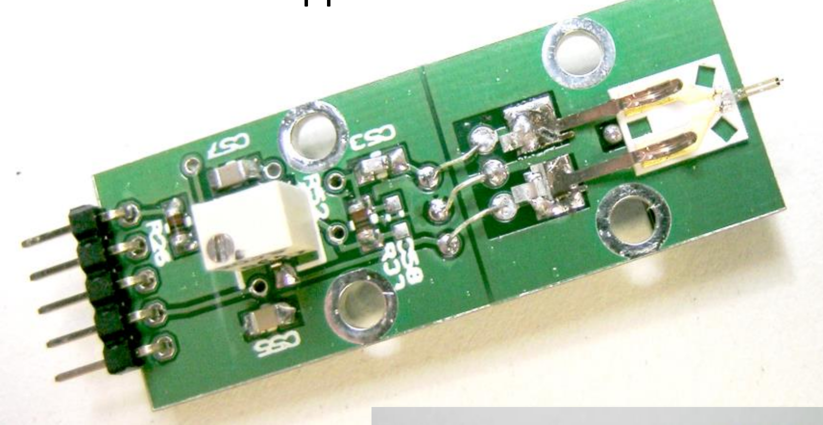
Prototype amplifier boards

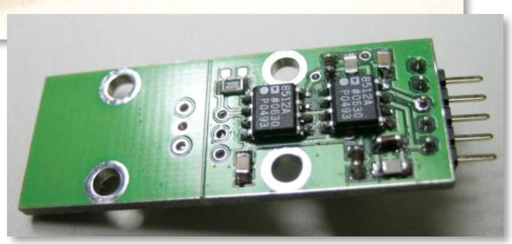
- For NanoScope Multimode AFM (Veeco/Bruker) with a custom made holder



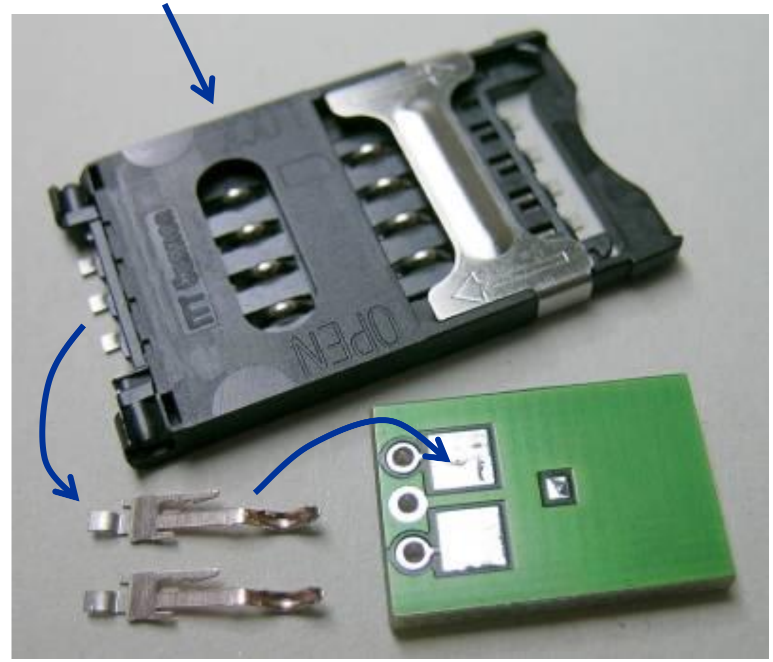


- For various applications



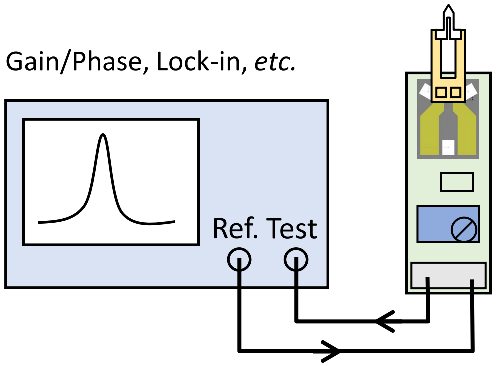


E.g., CONNECTOR, SMARTCARD, 8WAY CCM03-3003 LFT — ITT CANNON —



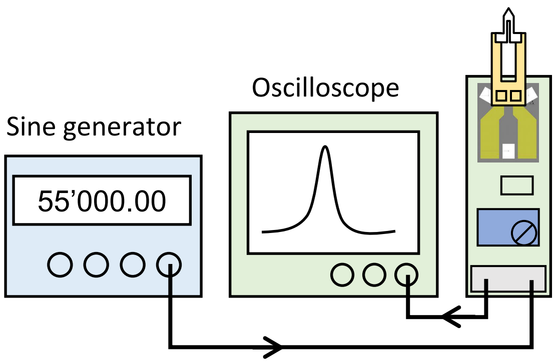
- Spring-pins from a memory card connector, which can be easily pulled out, are used. The metal pieces are soldered on a patterned PCB after cutting off excessive parts.
- As a stopper, a small solder bump is created.
- It is recommended to have a large ground plane to improve stability of the oscillation.

Adjustment of amplifier board (1)



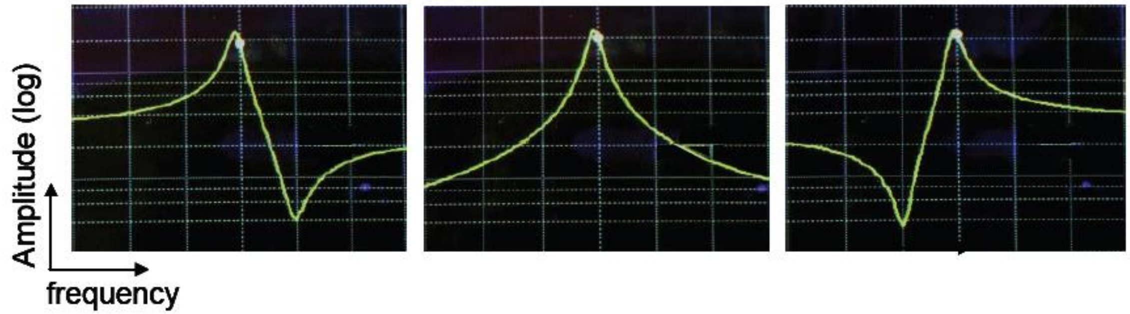
❑ If a parameter analyzer (Gain-phase, Lock-in amplifier, *etc.*) is available.

Find a peak by sweeping the frequency. Adjust the VR (or VC) on the board so that the peak becomes almost symmetric. In this condition, the parasitic capacitance around the probe is mostly compensated and only the piezoelectric current is amplified.



❑ If a sine wave generator **with frequency sweep function** and an oscilloscope are available.

Start a frequency sweep of the sine wave generator: *e.g.*, center frequency = resonance frequency of the probe, bandwidth = 2 kHz, amplitude = 1 V peak-peak, sweeping time = 5 seconds. Set the time axis of the oscilloscope, *e.g.*, 500 ms/div, so that one cycle of the frequency sweep can be monitored. If a peak is found, make the sweep range narrower, *e.g.*, 1 kHz, if not, slightly change the center frequency. Adjust the VR (or VC) on the board.



Adjustment of amplifier board (2)

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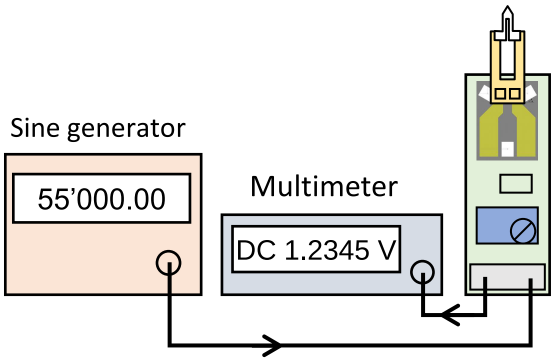
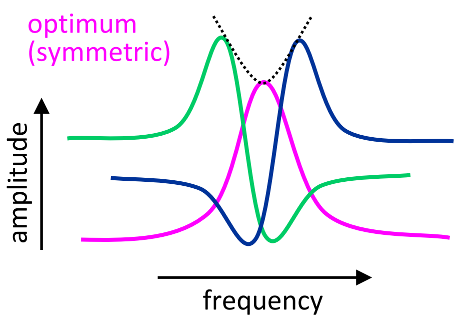




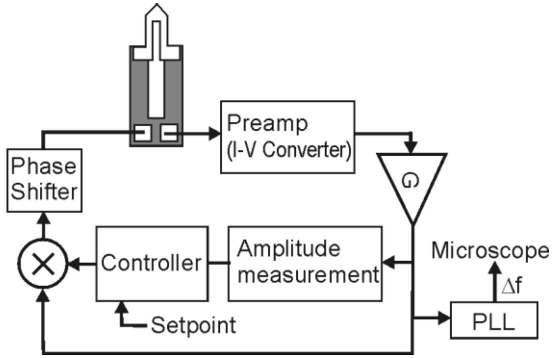
❑ If a sine wave generator **with NO frequency sweep function** and a multimeter (or an oscilloscope) are available.

- Set the frequency from the generator at the expected sensor resonance.
- Precisely adjust the frequency to obtain a maximum amplitude (measure on the multimeter). Take a note of the frequency and the amplitude.
- Slightly turn the VR (or VC) on the board to one direction.
- Adjust the frequency and find a maximum amplitude again. Repeat this step if you obtain a smaller amplitude than before. If the amplitude is increased, turn the trimmer to the other direction.

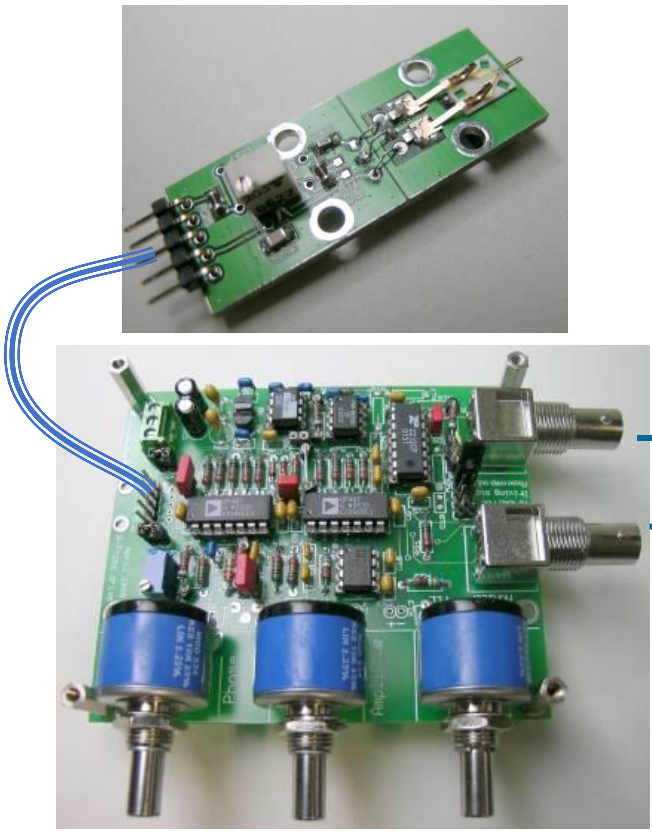
The optimum setting is at the point where the amplitude is at its minimum (see the figure below). Note that the amplitude change is usually very small.

Each time when a probe is exchanged, it is advised to readjust the tuning to obtain the best performance.

Simple and low-budget controller



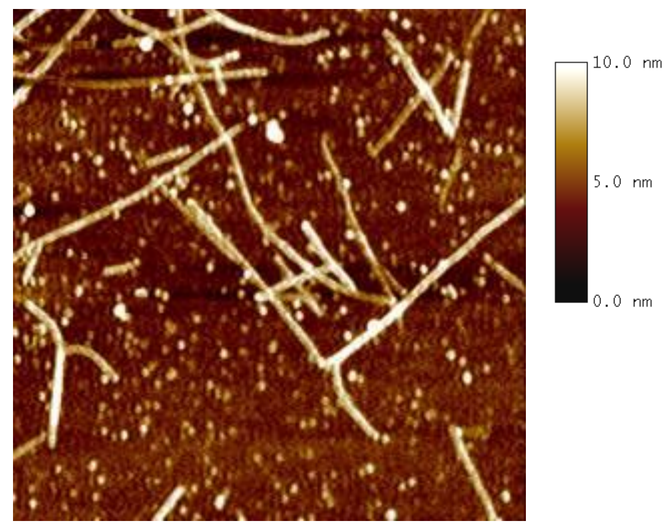
- NANOSENSORS has developed a simple and low-budget controller for operation of Akiyama-Probe.
- Detailed information of this controller is disclosed in another downloadable file for those who would like to make it by themselves.
- The controller uses a single PLL chip (XR2212) to reduce the total cost.
- For a higher resolution AFM imaging, it is highly recommended to use a crystal based PLL system.



Signal monitor

Frequency shift Δf
(to AFM feedback)

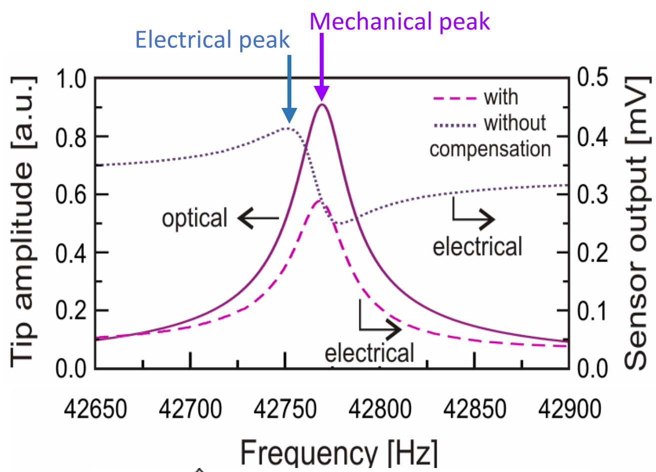
Self-Oscillation + PLL circuit board

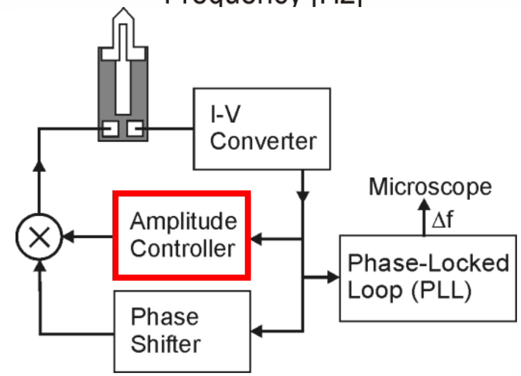


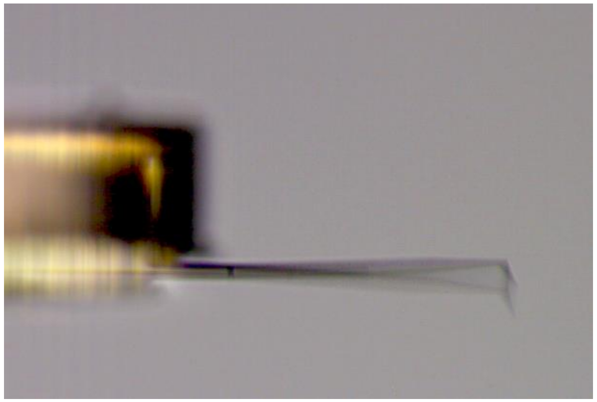
An image of carbon nanotube taken with the simple and low-budget setup, 3 µm x 3 µm

Suggestions for operation (1)

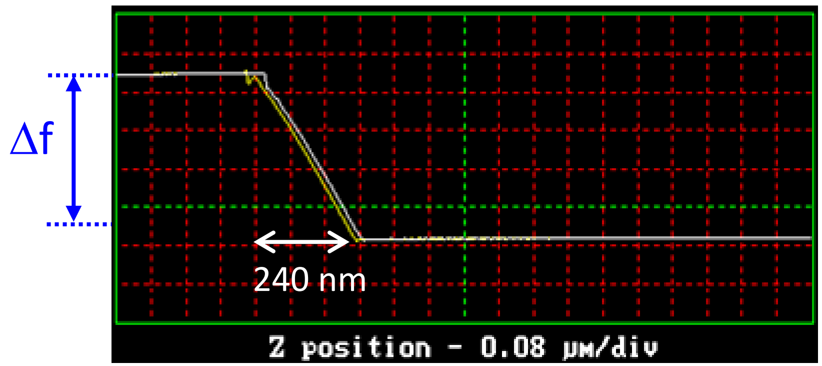
- The parasitic capacitance on the probe should be compensated so that only the piezoelectric current is extracted. If not, the electrical peak does not correspond to the real mechanical movement of the tuning fork. This is important for both FM and AM detections. Please refer to the electrical setup page.
- In FM detection mode, the amplitude of the electrical signal of the tuning fork should be maintained at a constant value with a feedback loop to obtain a higher spatial sensitivity (This does not mean that the mechanical vibration of the tip is kept constant).
- For measurements in ambient conditions, it is better to set a relatively large tip vibration amplitude. A real tip amplitude can be estimated from a full stroke approach curve.
- In an extreme case, the tip vibration can be more than 10 µm peak-to-peak.





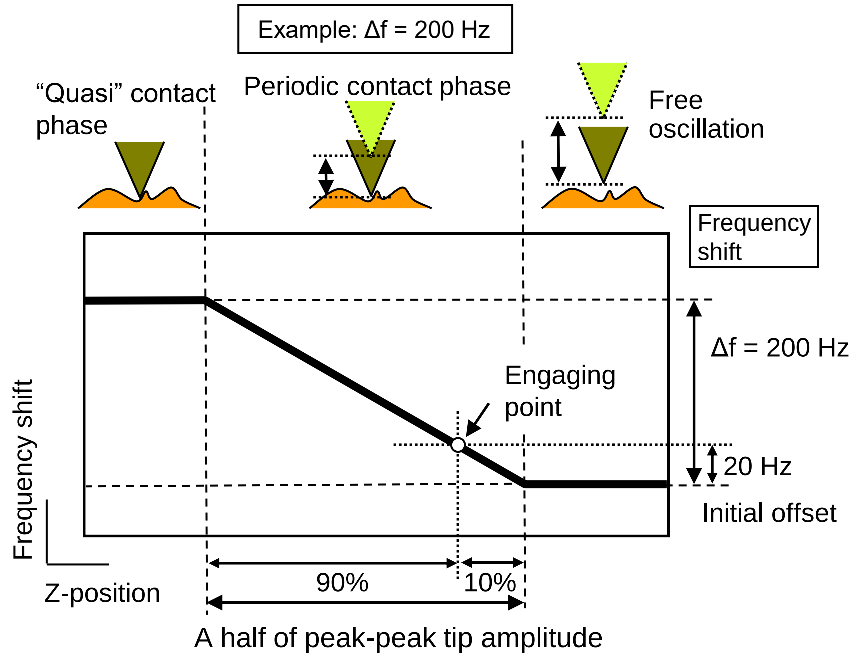


Peak-peak amplitude ≈ 2x 240 = 480 nm



Suggestions for operation (2)

- Shaking Akiyama-Probe by external piezo does not yield the oscillation correctly. Direct electrical driving of the probe is highly recommended.
- The Δf range is approximately 30 Hz ~ 400 Hz. This range is not guaranteed and subjected to change without any notifications. Δf varies depending on temperature and humidity.
- A reasonable frequency offset (setpoint) for “approach” is 5 Hz ~ 30 Hz, depending on Δf.
- Akiyama-Probe is designed for operation in ambient conditions. There are many publications which mention the use of Akiyama-Probe in other conditions, like vacuum, UHV, or low temperatures, *etc.* However, NANOSENSORS does not guarantee the functionality of the Akiyama-Probe in these applications. Please use the probe at your own responsibility.
- In AM detection mode, high Q factor of the probe limits the scan speed. It should be relatively slow.



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