# Open Source SPM Controller & PLL
Model Mk3-PLL

The *Open Source SPM Controller & PLL* can be used as:
- ✓ a SPM controller
- ✓ a controller with an embedded PLL, or
- ✓ a stand alone PLL

This *MK3-PLL model* is fully compatible with the SPM control software developed by the GXSM Group. This model has more computational power and memory than the MK2-A810 model for further developments and improvements of the next generation of the GXSM control code.

One of the great innovation of this model is an embedded PLL function.
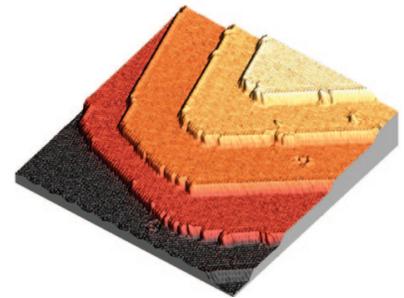
"Ultrathin Bi(111) film on a Si(111)-7x7 substrate Images provided by, C.A. Bobisch, M.C. Cottin, J. Schaffert and R. Möller"

KEY FEATURES OF THE PLL MODULE

This highly optimized software PLL module is based on an innovative phase/amplitude detector. This module is embedded in the SPM controller firmware code.
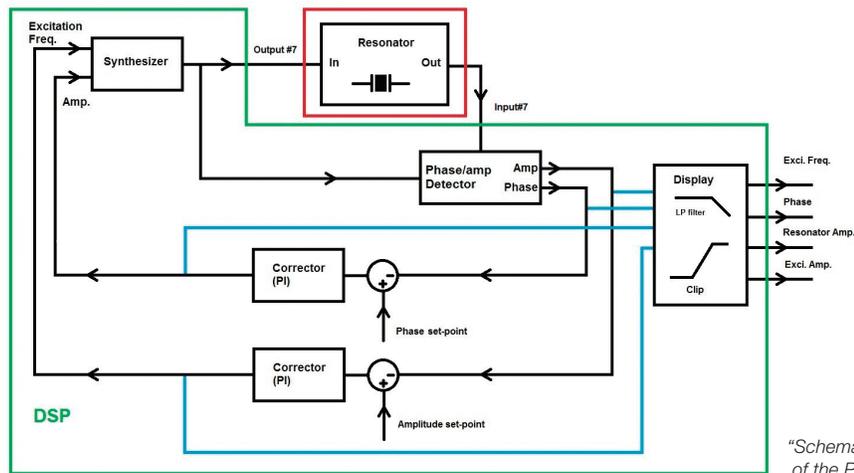
"Schematic Diagram of the PLL"
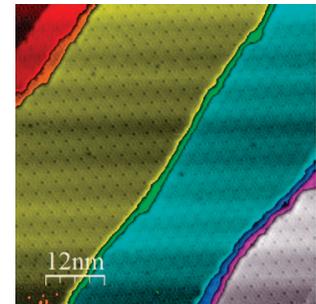
"Si(111)-7x7 reconstruction Image provided by, D.v.Vörden, M.Lange and R. Möller"

The analog I/O board of this *SPM controller Mk3-PLL model* also includes a TCXO (temperature compensated crystal oscillator), which greatly improves the PLL's thermal stability and reduces its noise at low frequencies.

KEY FEATURES OF THE PLL MODULE

- The PLL module is based on an innovative (patent-pending) phase/amplitude measurement technique. This technique does not rely on narrow-band filtering like traditional demodulation techniques. The result is signal capture and tracking capabilities that encompass the whole frequency range, with better noise and precision/time-constant trade-offs that are independent of frequency range.

- Allows the control of both the phase and amplitude of the resonator signal.

- Implemented as a module of the SPM controller's firmware. This way, high resolution input and output signals are directly accessible in digital form. No DAC/ADC conversions take place between the PLL and SPM controller, as is the case with a stand-alone PLL. This provides greater precision and lower group-delay for a faster loop response.

- Includes a function to automatically measure the resonator-frequency response and characteristics:
  - ✓ Frequency and phase at resonance
  - ✓ Q factor
  - ✓ Gain at resonance

- Includes a special auto-set feature to simplify the loop-gain set-up. With the auto-set feature, the user only needs to specify the desired closed-loop response for both controllers. The module automatically sets the loop gains to achieve the desired response.

- Includes a unique step-response function that allows the in-circuit measurement of the closed-loop response for both the phase and amplitude loops.

- The PLL module generates the excitation frequency, the excitation amplitude, the resonator phase and amplitude signals.

- Both phase and amplitude loops have an additional output low-pass filter to reduce the noise on all PLL signals. This filter is automatically adjusted to reduce noise without altering controller bandwidth.

- The PLL module includes a function for long-term analysis of PLL signals. This can be used to assess thermal drift and low frequency noise.

STAND-ALONE PLL

The *SPM controller Mk3* unit can also be used as a stand-alone PLL. Soft dB provides an open source Windows/LabVIEW-based interface to run the *SPM controller Mk3* unit as a stand-alone PLL with four output signals:

✓ Excitation frequency ✓ Excitation amplitude ✓ Resonator phase ✓ Resonator amplitude
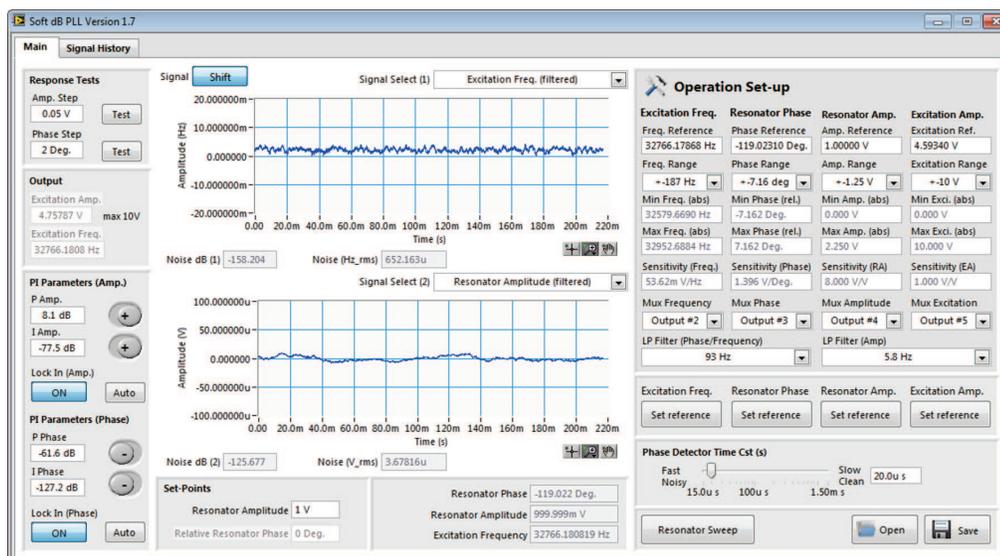
"PLL stand-alone user-interface"

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PLL MODULE SPECIFICATIONS			
Input Range	±10V		
Output Range	±10V (external 1/100 and 1/1000 attenuators provided)		
Frequency Range	3.2 kHz to 75 kHz		
Resonator Test Board	An active resonator board is included with the SPM controller for easy testing and setup of the PLL module		
PLL Output Signal Ranges (Stand-Alone Operation)	**Excitation Frequency** **Excitation Amplitude** **Resonator Phase** **Resonator Amplitude**	±2.85 mHz ±1.19 µV ±6.83 µ degree ±1.19 µV	to ±23.9 kHz to ±10V to ±57.3 degree to ±10V
PLL Signal Noise Levels*	**Excitation Frequency** **Resonator Phase**	**Phase Controller Bandwidth: 1 kHz** 60 mHz RMS 4 m degree RMS	**Phase Controller Bandwidth: 5 Hz** 20 µHz RMS 200 µ degree RMS
	Excitation Amplitude **Resonator Amplitude**	**Amplitude Controller Bandwidth: 7.5 Hz** 400 µV RMS 5 µV RMS	**Amplitude Controller Bandwidth: 1.5 Hz** 50 µV RMS 2 µV RMS
Phase/Amplitude (PAC) Detector Bandwidth	100Hz to 10kHz. The bandwidth is automatically adjusted when the loop auto-set function is used		
Software Features	• Resonator frequency sweep for automatic measurement of resonator frequency characteristics • Loop-gain auto-set for amplitude and phase controllers. Gains are set according to desired closed-loop bandwidth • In-circuit closed-loop step response measurement function validates the setup of both controllers • Adjustable low-pass filter on PLL signals: Excitation amplitude/frequency and Resonator phase/amplitude. These filters can be adjusted from 1.5 Hz to 16 kHz or bypassed. • Real time monitoring of all PLL signals • Long term monitoring of PLL signals to assess the low frequency stability and noise		
Temperature Coefficient	• TCXO Stability 140 ppb over a temperature range from -20°C to 70°C • TCXO Precision 2 ppm		

* Note: Noise levels are measured using the resonator board included with the SPM controller (gain –13 dB at the resonance) and the auto-set of loop gains for both controllers. The new PLL technique ensures that the noise levels are independent of measurement ranges.