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.

**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.

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"
# Open Source SPM Controller & PLL
## Model Mk3-PLL

**PLL Module Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Range</td>
<td>±10 V</td>
</tr>
<tr>
<td>Output Range</td>
<td>±10 V (external 1/100 and 1/1000 attenuators provided)</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>3.2 kHz to 75 kHz</td>
</tr>
<tr>
<td>Resonator Test Board</td>
<td>An active resonator board is included with the SPM controller for easy testing and setup of the PLL module</td>
</tr>
</tbody>
</table>

### PLL Output Signal Ranges (Stand-Alone Operation)

<table>
<thead>
<tr>
<th>Signal Type</th>
<th>Frequency</th>
<th>Amplitude</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excitation Frequency</td>
<td>±2.85 mHz</td>
<td>±1.19 μV</td>
<td>±6.83 μ degree</td>
</tr>
<tr>
<td>Excitation Amplitude</td>
<td>±10 V</td>
<td>to ±23.9 kHz</td>
<td></td>
</tr>
<tr>
<td>Resonator Phase</td>
<td>±1.19 μV</td>
<td>to ±10 V</td>
<td></td>
</tr>
<tr>
<td>Resonator Amplitude</td>
<td>±57.3 degree</td>
<td>to ±57.3 degree</td>
<td></td>
</tr>
</tbody>
</table>

### PLL Signal Noise Levels*

<table>
<thead>
<tr>
<th>Signal Type</th>
<th>Frequency</th>
<th>Amplitude</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excitation Frequency</td>
<td>60 mHz RMS</td>
<td>20 μHz RMS</td>
<td></td>
</tr>
<tr>
<td>Resonator Phase</td>
<td>4 m degree RMS</td>
<td>200 μ degree RMS</td>
<td></td>
</tr>
<tr>
<td>Amplitude Controller</td>
<td>Bandwidth: 7.5 Hz</td>
<td>50 μV RMS</td>
<td></td>
</tr>
<tr>
<td>Bandwidth: 1 kHz</td>
<td>400 μV RMS</td>
<td>5 μV RMS</td>
<td></td>
</tr>
<tr>
<td>Bandwidth: 5 Hz</td>
<td>50 μV RMS</td>
<td>2 μV RMS</td>
<td></td>
</tr>
</tbody>
</table>

### Phase/Amplitude (PAC) Detector Bandwidth

- 100 Hz to 10 kHz. 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.*

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