Adaptation to Nonlinear Piezo Amplifier Chain

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Abstract

The MIDI engineering GUI to control the DAC that steers the two piezo mirrors of the internal delay line is upgraded to implement a nonlinear (quadratic) term in the conversion formula.

1 Implementation

An option to work with a nonlinear, quadratic dependence between piezo surface motion ("mechanical path length") x and applied DAC output (of the VMEbus) voltage U has been added to the `lmidlei` engineering interface which now looks like shown in Fig. 1. The two parameters α and β of

$$x_i = \alpha U_i + \beta U_i^2$$

are selectable in the first lines of the two DAC channels. The units of α and β are μm/V and μm/V^2, respectively, as indicated. For MIDI applications, β is small and negative. The new interface does not add any nonlinearity to the amplifier chain, but is only a commodity that incorporates a pocket calculator in the Tcl/Tk script, plus automated use of the inverse formula

$$U = -\frac{\alpha}{2\beta} \pm \sqrt{(\frac{\alpha}{2\beta})^2 + \frac{x}{\beta}} \tag{1}$$

in real time when the LCU calculates/emits U on request of moving to x. The current implementation is (1) on the LCU and chooses the branch of the square root that is closer to the origin $U = x = 0$. Later on, the assumption will be that β is small, and the Taylor expansion

$$U = \frac{x}{\alpha}\left(1 - \frac{x\beta}{\alpha^2} + 2(\frac{x\beta}{\alpha^2})^2 - 5(\frac{x\beta}{\alpha^2})^3 \ldots\right) \tag{2}$$

will be used to third order (because this automatically incorporates the correct branch of the square root, might be faster than evaluation of the square root, and the original formula is also only correct up to second order in U).

Fig. 2 shows the usual application and Fig. 3 a case where the parameter β has been chosen large and negative such that a local maximum of the curve falls within the range of U from 0 to 10 V. The Tcl/Tk script rejects the editable range of piezo locations x outside the interval $[0, x_{\max}]$ and also rejects setting β to a value that would invalidate the stroke value currently selected.

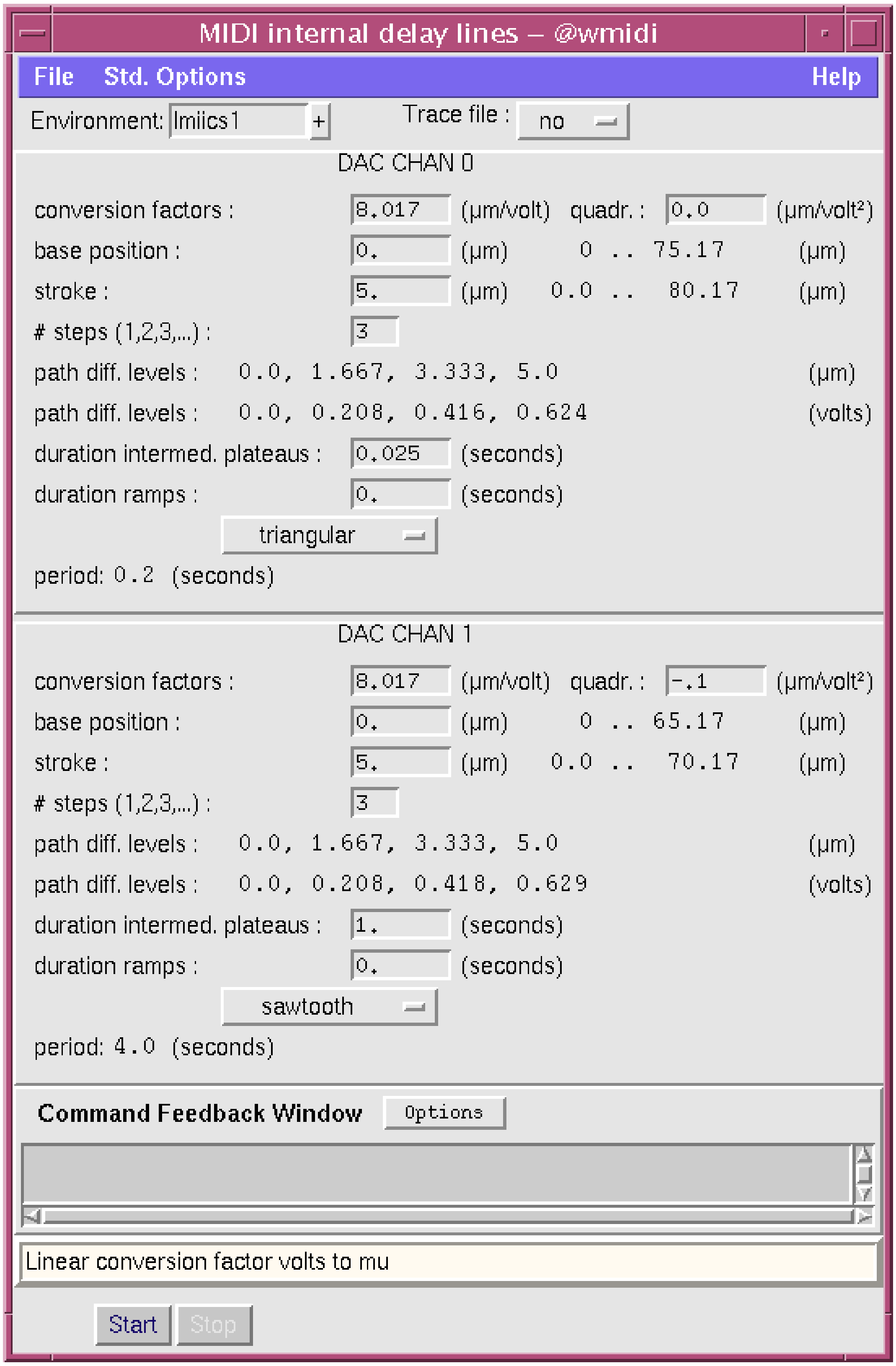

Figure 1: The GUI that appears on the call `lmidlei`. It differs from the one shown in VLT-TRE-MID-15824-0128 (issue 2.0) by the two additional entry fields in the upper right corners of the two sub-panels, different voltage levels if $\beta \neq 0$ and so on.

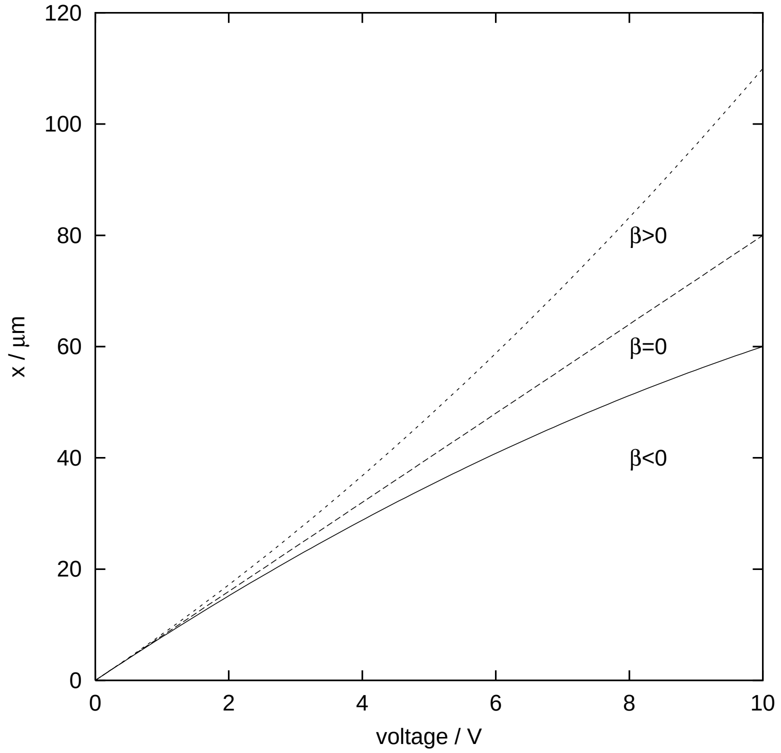

Figure 2: The actual dependence of $x(U)$ assumed for different signs of β.

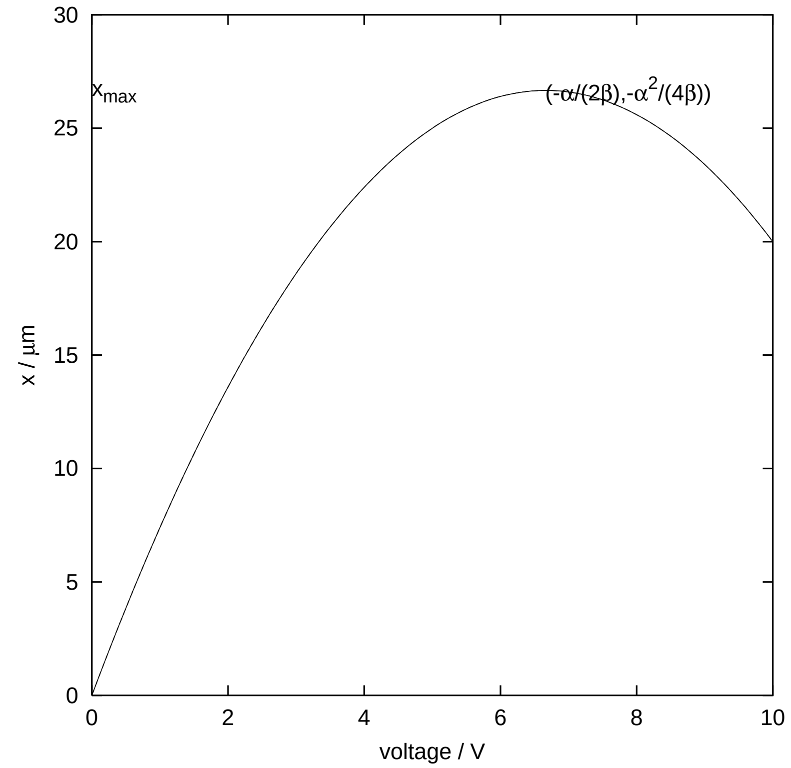

Figure 3: For large negative β (here: $\alpha = 8$, $\beta = -0.6$) a local maximum shows up at $U = -\alpha/(2\beta)$, $x = -\alpha^2/(4\beta)$. Only the left branch of the parabola up to the maximum is accepted by the GUI.

2 Appendix

The nonlinear least squares fit of a set of $i \geq 2$ points (U_i, x_i) to the function

$$x_i = \alpha U_i + \beta U_i^2$$

is given by the expressions

$$\alpha = \frac{B_0 A_{11} - B_1 A_{01}}{A_{00} A_{11} - A_{01}^2} \quad (3)$$

$$\beta = \frac{B_1 A_{00} - B_0 A_{01}}{A_{00} A_{11} - A_{01}^2} \quad (4)$$

with

$$A_{00} \equiv \sum_i U_i^2 \quad ; \quad A_{01} \equiv \sum_i U_i^3 \quad (5)$$

$$A_{11} \equiv \sum_i U_i^4 \quad ; \quad B_0 \equiv \sum_i U_i x_i \quad ; \quad B_1 \equiv \sum_i U_i^2 x_i \quad (6)$$

which minimizes $\sum_i (x_i - \alpha U_i - \beta U_i^2)^2$.