



### Lab Assignment #9

## Slope Calculation of Disturbed Measured Functions

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### Objective

To study slope calculations using Agilent VEE.

### Equipment

- Agilent VEE software

### A. Theoretical Introduction

Many physical parameters are defined as the slope of a function describing the dependence of one value from another. The determination of the parameter is very easy if the function is linear:

If the function is  $y = c \cdot x$ , the parameter (the slope)  $c = y/x$  is constant.

Well-known examples are

- the velocity  $v$ :  $v = \frac{s}{t}$  (with the distance  $s$  covered in the time  $t$ ),
- the resistance  $R$ :  $R = \frac{V}{I}$  (with the voltage drop  $V$  generated by the current  $I$ ) or
- the current amplification  $B$  of a transistor:  $B = \frac{I_C}{I_B}$  (with the collector current  $I_C$  generated by the basic current  $I_B$ ).

But this simple calculation gives an incorrect result if the function  $y = f(x)$  is non-linear. In

this case the correct value of the slope is defined as the first order derivative  $\frac{dy}{dx} = \lim_{\Delta x \rightarrow 0} \left( \frac{\Delta y}{\Delta x} \right)$

of the function  $y = f(x)$  at a point  $P$ . In practice often the quotient of differences is used to calculate the slope. Than the intervals of the variables must be very small to give a good approximation of the true value of the slope (see fig.1).

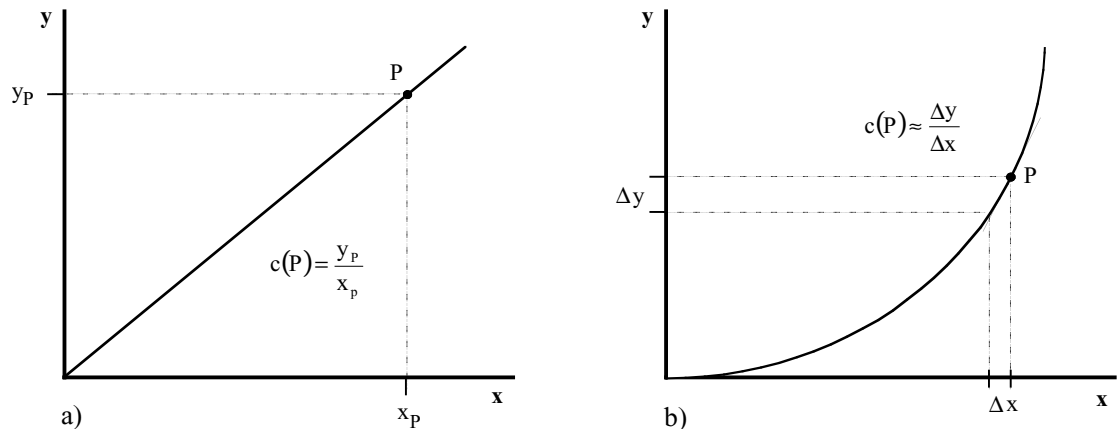


Fig. 1: Calculation of slope of a linear (a) respectively a non-linear (b) function

In practice measured functions often are not continuous but discrete, meaning the function consists of a number of discrete measured points. Using Agilent VEE the slope of such a measured function at a certain point P can be calculated using the mathematical function

“derivAt”. But a further complication takes place if noisy measured values are used. Because the result of the function “derivAt” strongly depends on the measured points in the neighbourhood of P the calculation will be extremely incorrect, if the random error  $\delta y$  of the measured value y is of the same order of magnitude than the undisturbed change  $\Delta y = f(\Delta x)$ . In this case the result can be improved by filtering the measured data. Using Agilent VEE this can be done with one of the functions “PolySmooth” or “MeanSmooth”. Supposing a linear approximation in a small interval fits very well, a further improvement of calculation will be possible using two very simple methods. The first one is the calculation of the quotient of differences using the first and the last value, the second one the linear regression method using all points in the measured interval. Especially the last method often yields the best approximation (see fig.2).

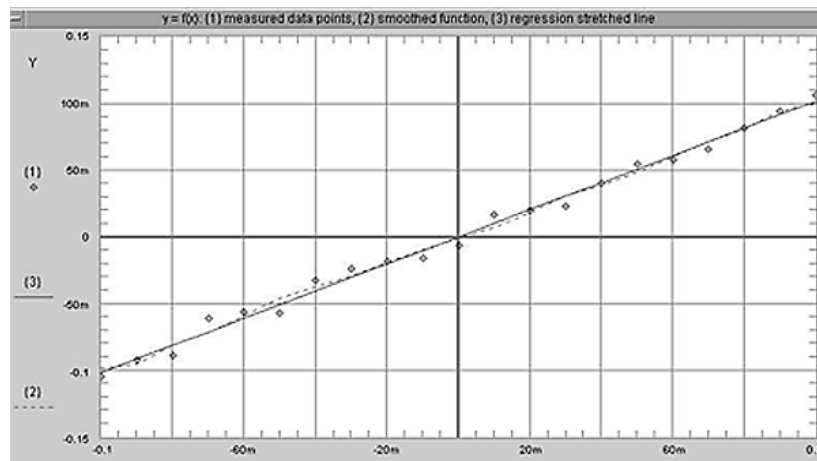


Fig 2: Slope calculation for noisy measured values of a non-linear function at  $P(x = 0)$ :

The display shows the measured values {1}, the function after filtering {2} and the result of linear regression {3}; expected value:  $c = 1.0000$ .

Numeric results :  $\frac{dy}{dx} = 1.852$  ,  $\frac{dy}{dx}(\text{smoothed}) = 0.8118$  ,  $\frac{\Delta y}{\Delta x} = 1.0554$  ,  $c = 1.0174$



### B. Simulation Experiments

For better understanding of the discussion use the simulation **SLOPE.VXE**. To run this program you need the run-time version of Agilent VEE (Version 6).

This program displays simulated noisy data points of a non-linear 5<sup>th</sup> order function in a small interval around zero and calculates the slope at the point  $x = 0$  using the four different methods discussed above.

Change the interval for the random errors and the number of data points and compare the different results.