Optimization of Analog Signal Filtration Process

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Abstract – The technique for designing the optimal value of the filter time constant for analog signal is presented. This technique is based on the objective function which takes into account the quality index of the filtration process and the dynamic error of the filtered signal.

Keywords – filter, time constant, optimization, analog signal, dynamic error, objective function.

Introduction

Analog signal filtration is often used in the up-to-date automated measurement and control systems. The main purpose of the filtration process is to eliminate the disturbances (noise) and to allow the useful signal to pass [1]. Setting a too small value of the filter time constant will lead to a low quality of filtration process because not all the disturbances (noises) will be filtered (removed). Setting a too big value of the filter time constant will provide a good quality of filtration, however it will lead to a significant delay of the filtered signal which, in turn, will lead to a big value of the dynamic error in the filtered signal. That is why there is a problem of defining such value of the filter time constant at which a good quality of the filtration process and a small dynamic error would be provided. To solve this problem the technique for designing the optimal value of the filter time constant was developed. This technique is based on the objective function which takes into account the quality index of the filtration process and the dynamic error of the filtered signal.

Design of optimal filter

It is proposed to design the optimal value of the time constant for the exponential filter in the following way:

1. Computation of the average analog signal by means of the non-causal moving average filter.

2. Computation of the mean square of the experimental samples deviation from the smoothed experimental points according to the formula

$$D = \frac{1}{N-4}\sum_{i=3}^{N-2}(y_i^e - y_{i-2}^a)^2 , \qquad (1)$$

where N is the number of registered experimental samples of the analog signal; y^e are experimental samples; y^a are smoothed experimental points obtained in clause 1.

3. Filtration of the experimental analog signal by means of the exponential filter with the time constant T_f=1s. The signal y^{f1} will be obtained as a result.

4. Computation of the average filtered signal by means of the non-causal moving average filter like it was made for the experimental signal in clause 1. The signal y^{a1} will be obtained as a result.

5. Computation of the mean square of the filtered points (y^{f1}) deviation from the smoothed filtered points (y^{a1}) according to the formula

$$D = \frac{1}{N-4}\sum_{i=3}^{N-2}(y_i^{f1} - y_{i-2}^{a1})^2 . \qquad (2)$$

6. Computation of maximum dynamic error of the smoothed filtered points with respect to the smoothed experimental points according to the formula

$$d_{\max} = \max(| y^{a1} - y^{a} | \times 100) . \quad (3)$$

7. Accomplish clauses 3-6 for the exponential filter time constant $T_f = 2, 3, 4, \ldots n$ s. The computation should be done until the maximum dynamic error does not exceed 10 %. The dependences of the mean square of deviation D and the maximum dynamic error δ_{max} on the filter time constant T_f will be obtained as a result of the computation.

8. Computation of the objective function for the obtained arrays of the mean square of deviation D and the maximum dynamic error δ_{max} according to the formula

$$I = D' + d'_{\max}, \quad (4)$$

where D' is the reduced mean square of deviation; δ'_{max} is the reduced maximum dynamic error.

Based on the calculated values of the objective function the optimal time constant of the exponential filter shall be defined as follows

$$T_f = T_f^{opt}\Big|_{I=\min(I)}. \qquad (5)$$

The optimal time constant of the exponential filter is the time constant value at which the objective function reaches its minimum.

The value of the mean square of deviation D represents the scattering of the filtered points around the smoothed filtered points. This value is taken as a quality index of the filtration process.

The example of the optimal filter design for the experimental transient processes presented in [2] is shown in Fig.1.

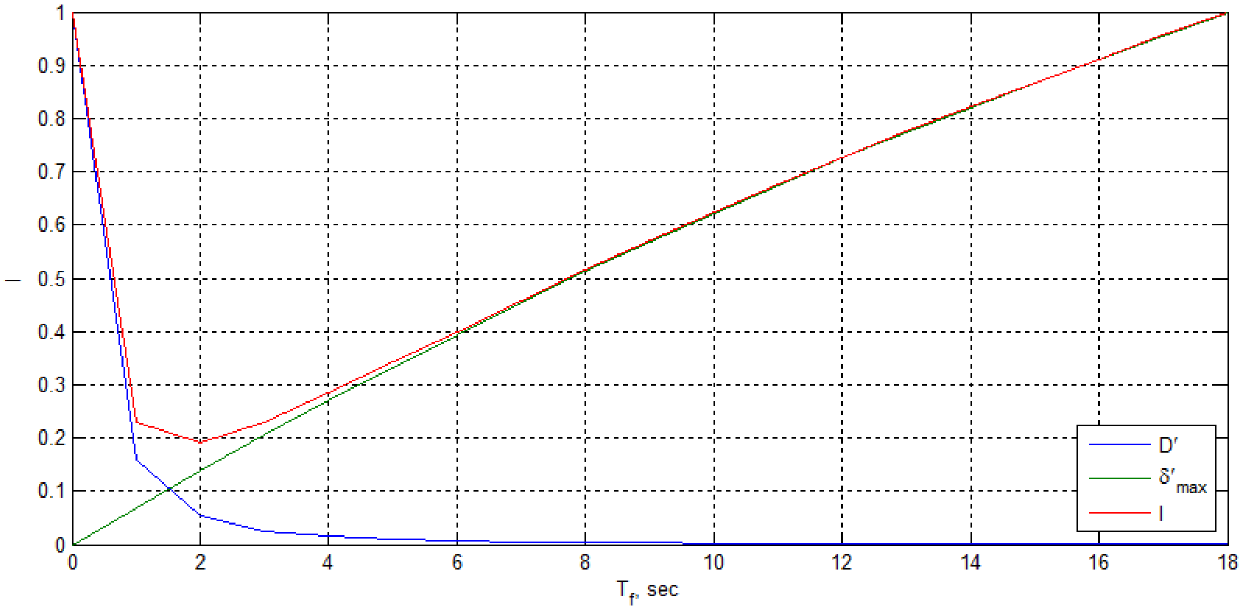

Fig.1. Curve of objective function versus filter time constant.

Conclusion

Application of the developed technique for designing the optimal time constant of the exponential filter in the automated measurement and control systems will provide high quality of the filtration process and small dynamic error of the filtered signal.

References

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