DEVELOPMENTS OF MEASUREMENT DUE TO TENDENCIES OF MICROELECTRONICS AND A NEW OPTIMIZATION CRITERION

Eugen-Georg Woschni

Chemnitz University of Technology
D-09107 Chemnitz, Germany
Faculty of Electrical Engineering and Information Technology
Tel. 0049 177 5221562, Fax 0049 351 2684988
E-Mail: e.-g.woschni@infotech.tu-chemnitz.de

Abstract: The paper deals with problems of dynamic behaviour and shows especially how the development of microelectronics influences this field and how to teach this trends applying also heuristic methods and approximations. Using the results of information theory a new optimization criterion is introduced.

Keywords: dynamic behavior, trends, optimization criterion

1. TYPICAL TRENDS IN MICROELECTRONICS

As well-known from the last three decades every two to three years a new generation of technology is used leading to a reduction of the dimensions by the factor $1/\sqrt{2}$. This leads to the fact of an increasing of the degree of integration by the factor 2 and a decreasing of the areas by the factor 0,5, that means the capacities C are also reduced to half the values as Fig. 1 demonstrates. Because the time constants are $T=RC$ possible pulse frequencies are doubled from generation to generation [1]. So it follows the important result that every 7 years the processing speed is increasing by the factor 10 as given also in [1].

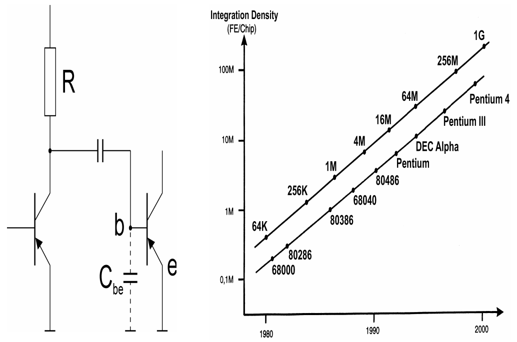

Fig: 1. Left hand side: Typical circuit (amplifier) with the decisive base-emitter-capacitance C_{be}
Right hand side: Development of the integration density

2. ALIASING ERRORS

The same tendency of higher sampling frequencies leads to decreasing aliasing errors [2]: Especially in digital measurement an antialiasing filtering before sampling often is not possible if sensors with direct-digital output are direct coupled to the process to be measured and – as in mechanical measurement – the necessary low-pass-filtering before sampling cannot be realized. Therefore only a high pulse frequency i.e. oversampling solves the problems. It may be noted on the other hand that the aliasing errors are depending of the signal processing after sampling [3].

3. COMPARISION OF ANALOGUE AND DIGITAL METHODS

As suitable quality criterion to compare both methods *Shannon´s* channel capacity is used [4]. In [5] the problem is already treated leading to the result of equal channel capacities

$$Tf_i = f_i / 2f_c = 1 / 2F = m - 1 \qquad (1)$$

with the number of distinguishable amplitude steps m, the relative amplitude error F, the pulse frequency f_i, and the critical frequency f_c [5]. The investigations show that due to the development of microelectronics because of the increasing pulse frequencies the limit between both methods will be shifted towards higher frequencies one order of magnitude every seven years [1].

4. ERROR CORRECTION

A general problem concerns the correction of the dynamic behaviour of a measuring system by means of a series-connected network or computer. As a criterion of optimization the well-known optimal filtering algorithm of minimizing the total mean-square error ε^2 is realized.

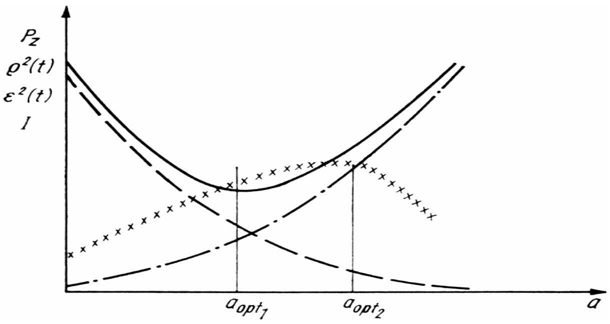

Fig. 2. Errors and information flow as a function of the degree of correction
- - - dynamic error, -.-.- noise error,
---- total error, xxxxx information flow

Fig. 2 shows as well the course of the error components and the total error [6],[7] as the information flow as a function of the degree of correction $a = f_c / f_o$ with the critical frequency of the corrected system f_c and of the original system f_o The advantages must be paid by increasing parameter sensitivity as demonstrated in the next chapter.

5. NEW OPTIMIZATION CRITERION USING INFORMATION THEORY

Because of the multiplication with the frequency f due to *Shannon`s* relation of the channel capacity [4] the optimal frequency $a_{opt\ 2}$ is higher than of the optimal filter due to *Wiener* and *Kolmogoroff* [4]. Because of this fact instead of the optimization criteria $\varepsilon^2 \rightarrow$ min now the new criteria of optimal information flow I [6]

$$I = f^2 log 1/\varepsilon^2 = -\ f^2 log\ \ \varepsilon^2 \rightarrow \max \qquad (2)$$

is to be used.

The optimal gain in I - e.g. the difference between $a_{opt\ 1}$ and $a_{opt\ 2}$ - is the higher, as the course of the mean-square-error ε^2 is the smoother. Therefore also under this point of view the gain is the higher the better the quality of the original system, the same result as in the next chapter – see Fig. 3.

6. LIMITATIONS OF ERROR CORRECTION

Now the question arises if it is still necessary to construct an original system with high quality because it is today possible using the instrument computer to improve the behaviour. Figure 3 shows the results of investigations: The better the quality of the original system the more efficient the correction!

Last not least another important effect should be mentioned limiting the degree of correction possible: To get an optimal correction the two time-constants of the measuring system and of the correcting system T_2 must be exact of the same value. In practice due to the parameter variations of the systems this is not possible. In this case the transient response will have a prolonged trail as shown in Figure 4 and so the advantage of the correction will be annihilated. This effect is called “parameter sensitivity”.

In special cases methods of adapted corrections using crosscorrelation functions to measure the time constant of the original system are used [6].

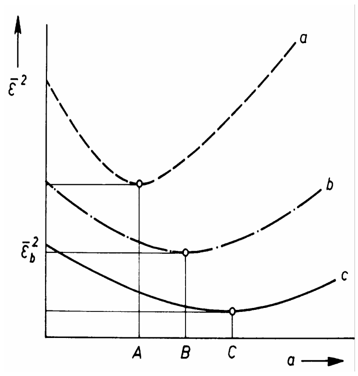

Fig. 3. Errors of three systems of different quality as in Fig. 1:
-------- High-quality original system
.--.--.-- Medium-quality original system
- - - - - Bad-quality original system

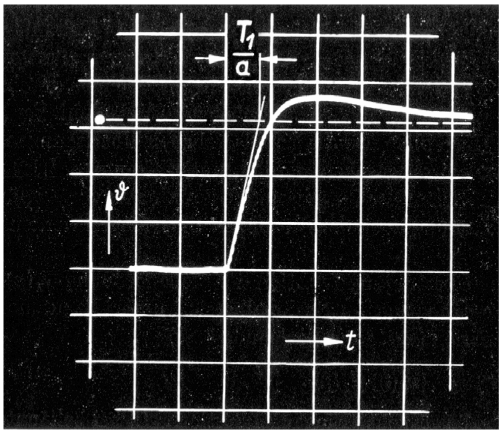

Fig. 4. Influence of a difference between the time constants of the original and the correcting system ΔT = +0.2 (parameter sensitivity

Last it may be pointed out that it is not possible to correct systems containing allpasses without an additional time delay [6].

Furthermore instead of only one sensor two ore more sensors with different behaviour can be used with the possibility of additional error correction by comparing the different outputs, e.g. application of the principle of decreasing the error by means of additional hardware. Here more investigations are necessary.

7. CONCLUSIONS

The investigations show results with great importance for practice and methods using approximations as also suitable for teaching:

- From the increasing integration density it follows that the time constants are decreasing by the factor 10 every 7 years.
- The comparison of both analogue and digital methods leads to the result, that due to the development of microelectronics the field of digital methods will be extended to higher critical frequencies one order of magnitude every 7 years.
- The total error consists of several components: The dynamic, statistic ore noise, aliasing ore cut-off and the approximation error. The investigations are showing that these components are depending on each other as well as especially in the digital field on the processing speed. Due to the development of microelectronics in future especially aliasing errors will play a decreasing role. So it will be possible to apply more efficient and powerful algorithms including also adaptive ones to minimize the errors.
- In general additional hardware – e.g. instead of one sensor two ore more – leads to better behaviour.
- Using the results of information theory instead of the classical criterion of minimizing the mean-square-error a new criterion of maximizing the information flow is introduced.

REFERENCES

[1] Diebold Research Program - Europe, “Report Nr. E 146”, 1976.

[2] Woschni, E.-G., “Cut-Off and Aliasing Errors - Exact Solutions and Approximations”, Proceedings XXIVth General Assembly of the International Union of Radio Science, Kyoto, 1993.

[3] Woschni, E.-G., “Signal Processing after Sampling - Today’s Problems and Solutions”, Proceedings Intern. Symposium Measurement and Technology ISIM II, Hayama, 1996.

[4] Shannon, C.E., “A Mathematical Theory of Communication”, BSTJ, vol. 27 , pp 379 - 423, 623 - 656, 1948.

[5] Woschni, E.-G., “Problems of Dynamic Measurements with Respect to the Development of Electronis and Signal Processing”, Proceedings Applied Electronics, Plzen, 2000.

[6] Woschni, E.-G., „Informationstechnik“, 4th ed., Verlag Technik, pp. 235 – 238, Berlin, 1990.

[7] Woschni, E.-G. “Signal Theory” and “Systems Theory”, in: Handbook of Measuring System Design, Vol. 1, ed. by P.H.. Sydenham and R. Thorn. Wiley, London, 2005.