THE NECESSITY FOR USING OSCILLATING SYSTEMS
FOR SAMPLING OPTOELECTRONIC SIGNALS

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Abstract. Usually filtering and sampling devices for optoelectronic signals consist of low-pass filters represented by an asymptotically stable system (of first or second order), many times an integration of the filter output over a certain time interval is added. However, such a structure is very sensitive at the random variations of the integration period. This paper will show that for obtaining a robust structure based on an integrator we have to use a filter represented by an oscillating system. Mathematical aspects connected with the number of state-variables (see [1], [2]) are also presented.

1. Introduction

As it is known, the analog signal given by optoelectronic detectors usually presents a noise overlapped upon the useful signal. Because fluctuations and disturbances caused by this noise appear under the form of fast variations of the measured quantity around a mean value, low-pass filters are widely used. These must as possible allow the access of the continuous component of the input only towards the blocks for information processing. The influence of the input alternating component must be as possible rejected.

Usually, these filters are represented by delaying systems of first or second order, having the transfer function

\[ H(s) = \frac{1}{T_0s + 1} \]

(for a first order system) and

\[ H(s) = \frac{1}{T_0s^2 + 2B_0s + 1} \]

for a second order system. They attenuate an alternating signal of angular frequency \( \omega \gg \omega_0 \) about \( 1/T_0 \) times (for a first order system) or about \( (\omega/\omega_0)^2 \) times (for a second order system). The response time of such systems at the useful continuous signal is about \( 4-6 \ T_0 \) (5 \( T_0 \) for the first order system and 4 \( T_0/b \) for the second order system). If the signal given by the first or second order system is integrated over such a period, a supplementary attenuation for the alternating signal of about 4-6 \( \omega/\omega_0 \) can be obtained. For a useful signal represented by a unity step-input (represented in figure 1) the output signal of the integrator has the form represented in figure 2.
However, such structures are very sensitive at the random variations of the integration period (the signal which is integrated is equal to one at the sampling moment of time). Even if we use oscillators with a very high accuracy, such random variations will appear due to the fact that the integration is performed using an electric current charging a capacitor. This capacitor must be charged at a certain electric charge Q necessary for further conversions; this electric charge can't be smaller than a certain value $Q_{\text{min}}$, while it has to supply a minimum value $I_{\text{min}}$ for the electric current necessary for conversions on the time period $t_{\text{conv}}$ required by these conversions (the relation $Q_{\text{min}} = I_{\text{min}} t_{\text{conv}}$ being valid). So the minimum value $I_{\text{min}}(\text{min})$ for the electric current charging the capacitor in the integrator system is determined by the relation $I_{\text{min}}(\text{min}) = Q_{\text{min}}/t_{\text{int}}$, where $t_{\text{int}}$ is the integration period required by the application. Knowing the sampling frequency $f_s$, we can approximately establish $t_{\text{int}}$ using the relation $t_{\text{int}} = 1/f_s$. So the current charging the capacitor can't be less than a certain value; thus random variations of the integration period will appear due to the fact that random phenomena are generated when a nonzero electric current is switched off. These random variations can't be avoided if we use asymptotically stable filters.

2. The advantage of using oscillating systems for filtering the photoelectric signal

Much better results have been obtained using for filtering an oscillating system having the transfer function

$$H_{\text{osc}} = \frac{1}{T_0^2 s^2 + 1}$$

and if we integrate its output on the time interval $[0, 2\pi T_0]$. For initial conditions equal to zero, the response of the oscillating system at a step input with amplitude $A$ will have the form

$$y(t) = A(1 - \cos(t/T_0))$$

(represented in figure 3). By integrating this result on the time interval $[0, 2\pi T_0]$ we obtain the result $2\pi T_0 A$, and we can also notice that the quantity which is integrated is equal to zero at the end of the integration period (the function $\int y(t) dt$ is represented in figure 4). Thus the influence of the random variations of the integration period (generated by the switching phenomena for the photodetection current) is practically rejected.

Analyzing the influence of the oscillating system upon an alternating input, we observe that the oscillating system attenuates such an input about $(\omega/\omega_0)^2$ times; the use of the
variations of the integration (moment of time). Even if oscillations will appear due to the charging a capacitor. This for further conversions, this has to supply a minimum time period $t_{\text{min}}$ required by the minimum value $I_{\text{min}}(\text{min})$ system is determined by the required by the application with $t_{\text{int}}$ using the relation $t_{\text{int}}$ certain value, thus random that random phenomena are random variations can't be

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interval $[0, 2\pi T_0]$ we obtain this integrated is equal to zero (presented in figure 4). Thus the generated by the switching

on an alternating input, we $t(\omega T_0)^2$ times; the use of the
integrator leads to a supplementary attenuation of \([1/(2\pi)](\omega/\omega_0)\] times. The oscillations having the form

\[ y_{out}(t) = a \sin \omega_0 t + b \cos \omega_0 t \]

generated by the input alternating component, have a lower amplitude and give a null result after an integration over the time interval \([0, 2\pi T_0]\).

As a conclusion, such a structure provides practically the same performances as a structure consisting of an asymptotically stable second order system and an integrator (response time of about \(6 T_0\), an attenuation of about \((1/6)(\omega/\omega_0)^3\) times for an alternating component having frequency \(\omega\) moreover being less sensitive at the random variations of the integration period. The existence of some null values for state variables at certain moments of time is similar to the mathematical aspects connected with acausal pulses presented in [1].

It has to be also noticed that the electrical scheme presented in figure 1 (where the time constants \(T_0\) for oscillating system - and \(T_i\) for the integrating system - have the form \(T_0 = R_0 C_0\), \(T_i = R_i C_i\), \(R_0 = R_1, R_0, C_0 = C_1, C_2, R_i = R_{10}, C_i = C_3\)) is a robust structure as related to the variation of temperature. The result of the integration has the form

\[ A(2\pi T_0)/T_i = A(2\pi R_0 C_0)/(R, C) \]

If the resistors \(R_0, R_i\) and the capacitors \(C_0, C_i\) are made of the same material, the coefficient for temperature variation will be the same for resistors and will be also the same for the capacitors. Thus the ratio \(A(2\pi T_0)/T_i = A(2\pi R_0 C_0)/(R, C)\) (the result of the integration) is insensitive at temperature variations.

The presented scheme will be improved in two main directions: by adding some elements for decreasing the output of the oscillating system at the time moment \(2\pi T_0\) and by replacing the operational amplifiers with active elements working at higher frequencies, for increasing the working frequency.

References
