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The Usage of the Linear Interpolating Filter for an Accurate Fluctuation Fading Time Measuring Activated in LC-circuit

***Abstract**. The availability of detector with linear interpolating filter for oscillations attenuation time sensitive measurement is considered in article. The necessity of such approach for sensitive measurement is proved. The functional structure of detector with linear interpolating filter and schematic circuit based on it is proposed. Model-based analysis was carried out; expediency of employing such type of detectors is proved.*

***Streszczenie.** W artykule rozważa się oraz uzasadnia się możliwość zastosowania liniowo interpolującego filtru dla dokładnego pomiaru zanikania swobodnych drgań generowanych w układzie LC. Zaproponowano schemat detektora z takim filtrem i wykonano teoretyczne modelowanie. (**Możliwość zastosowania liniowo interpolującego filtru do dokładnego pomiaru zanikania swobodnych drgań w układzie LC**)*

Keywords: LC-circuit, linear interpolation filter, time measurement.
Słowa kluczowe: układ LC, filtr liniowo interpolujący ,pomiar czasu

Introduction

On the modern stage of measuring technique development, receipt of measuring information is necessarily accompanied by an analog-to-digital conversion. Despite that not only a voltage can be an analog value, today an analog-to-digital conversion is being understood exactly as a conversion of voltage into a digital code. The accuracy of conversion depends on the resolution of the analog-to-digital converter that is why the basic method of rise the accuracy of conversion is the increase of number of bits. But the increase of number of bits is accompanied by the growth of conversion error in consequence of hindrances action in the process of conversion, that is why the resolution of modern analog-to-digital converters is limited, and a necessity to search new approaches and improve other methods of conversion and the receipt of measuring information arises.

As an alternative of voltage conversion into a digital code there are the high-precision analog-to-digital converters built on the principle of converting into the code of time intervals duration [1]. Such converters provide the measuring of time intervals with the accuracy of order of 22 - 250 ps, that is equivalent to voltage conversion in a digital code with a number of bits of 30, and the increase of resolution in such converter is limited only by the measuring time.

It is suggested to apply such analog-to-digital converter at measuring of dielectric coverings thickness of metallic surfaces [2] for determination of transient process duration activated in the oscillatory circuit of primary measuring converter.

Operation principle

Duration of transient process (fading time of the excited vibrations t_f) in an oscillatory circuit is determined as a time for which amplitude of free vibrations will diminish in e times. So for determination of transient process duration it is necessary to assign envelope curve of a signal and compare the amplitude value of envelope curve with exemplary voltage U_0/e, where U_0 is maximal voltage in a circuit (fig. 1). The selection of envelope curve of such signal is not a trivial task because the application of the known methods does not provide the necessary accuracy of recreation, and a measuring error grows accordingly. Applications of the simplest low pass filters circuits do not give satisfactory results as the envelope curve has a complicated form which is far from harmonious one with a wide spectrum which does not allow to reproduce a modulating signal by the simplest methods [3].

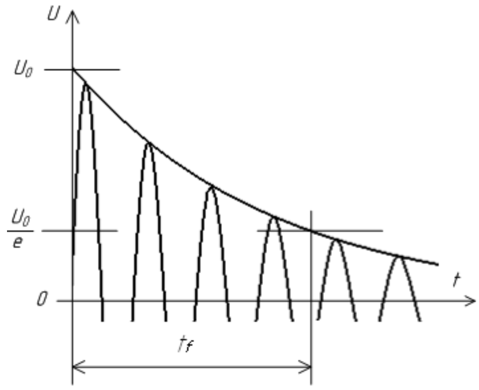

Fig.1. The determination of transient process duration

Application of more difficult schemes, for example a peak detector [4] provides a signal recreation close to the ideal only in the certain area of AB (fig. 2), as far as nominal values of circuit driving elements remain permanent. And as a change of transient process duration is substantially larger than the period of vibrations, and accordingly larger than the area of "ideal" recreation of AB (fig. 2), so such approach does not allow to provide the minimum error of recreation on all range of measuring.

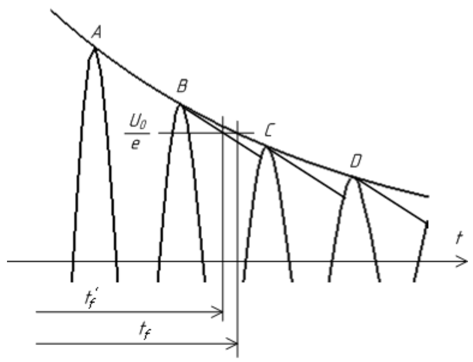

Fig.2. The non-ideal recreation of the envelope curve of signal

For expansion of the "ideal" recreation area it is suggested to use the detector with the linear interpolating filter described in [5]. The basic idea of precise recreation of the envelope curve is the application of the linear interpolation on the local maximums of harmonious signal. The functional circuit which explains the work of the detector with the linear-interpolating filter is given on fig. 3.

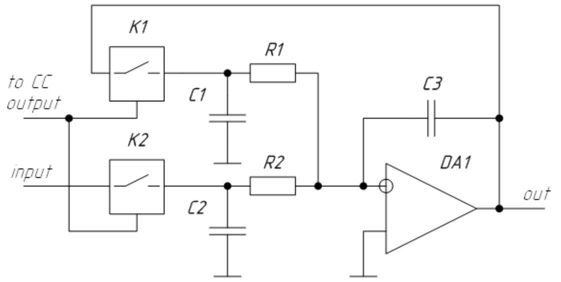

Fig.3. The functional circuit of the detector with the linear interpolation filter

In the detector with the linear interpolating filter two condensers of C1 and C2 are used. On the condenser C2 the amplitude of the impulse which is supplied to it at the moment is "memorized", and on the condenser C1 the amplitude of the previous impulse is "memorized". The voltage from the condensers is supplied to integrator (R1, R2, DA1, C3) the parameters of which are chosen so that at the moment of the another impulse receipt, the voltage on its output reaches the amplitude of the previous impulse. The control circuit (CC) output is connected to the analog keys control inputs (K1, K2) which are closed in the moments of achievement of incoming voltage amplitude local maximums.

The detector circuit with the linear interpolating filter was simulated in the environment of Multisim 11 from National Instruments (fig. 4). According to the results of simulation the signal rejection from the exemplary on the detector output was defined.

The reference signal was got on the output of RC circuit with such parameters, which provide the same time constant, as for the oscillatory circuit.

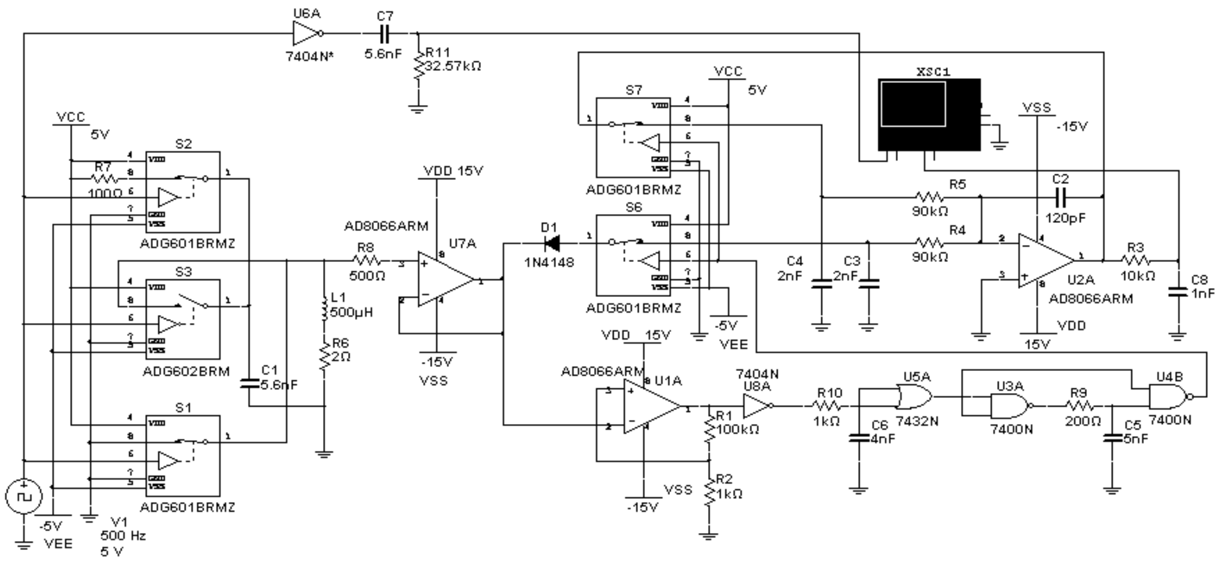

Fig.4. A principal detector circuit with the linear interpolation filter

For the research of the detector circuit were chosen the following parameters of circuit elements: oscillatory circuit (C1 5.6 nF, L1 500 mH, R6 2.0 Ω) which is periodically activated by the current impulses in 5 V with frequency 500 Hz and porosity in 2. On the output of the repeater collected from the operating amplifier U7A one will get periodically going out oscillations with frequency 94.34 kHz. RC circuit (C7 5.6 nF, R11 32.57 kΩ) has the same time constant as well as the oscillatory circuit, and is used as an exemplary signal.

According to functional circuit (fig. 3) the ADG601 SPST low ON resistance CMOS analog keys [6] used in detector. Less than 2.5 Ω typically value of on resistance and 110 ns typically switch ON time allow to use such type of analog keys in detector circuit up to 4.5 MHz carrier frequency.

The main task of control circuit is generate impulses in determined time moments which responds local maximum of harmonious fading signal. The basis of control circuit is Schmitt trigger assembled on U1A AD8066 fast FET operational amplifier [7] with pass band up to 145 MHz. While voltage on invert input of operational amplifier is remain positive output state of Schmitt trigger is remain negative saturation. Moments in which Schmitt trigger output change state from positive saturation to negative saturation is basis for time delay circuit assembled on logical element U5A and R10, C6. Since the frequency not changing during transient process simply time delay scheme with integration circuit is applied. Time delay value set by nominal of R10-C6 circuit and, as long as we use CMOS components with threshold voltage U_{tr}=0,5·V_{cc}, where V_{cc} – logic supply voltage, can be calculate as 0,7·R10·C6 [8]. For 94 kHz carrier frequency time delay from input voltage zero level crossing to leading edge of control impulse is approximately 2.65 μs.

Monostable multivibrator assembled on U3A, U4B logical elements and R9, C5 generate given duration impulse for analog key control. Duration of output impulse determined by nominal R9, C5 and set enough for C3, C4 capacitors charge enable.

The results of the circuit work are given on fig. 5. On the oscilloscope screen the signals from an oscillatory LC-circuit output, and from the linear interpolating filter output and control circuit output are represented.

For estimation of the approaching degree of the reproduced signal to exemplary the package of character mathematics of Maple was used. The data from a digital oscilloscope was stored in a digital form and downloaded in Maple for subsequent treatment. In particular the values of absolute voltage error were got on the output of linear interpolating filter. On fig. 6 the dependence of the absolute error of the filter recreation is presented in time on the interval of 1.50 - 1.55 ms from the beginning of transient process.

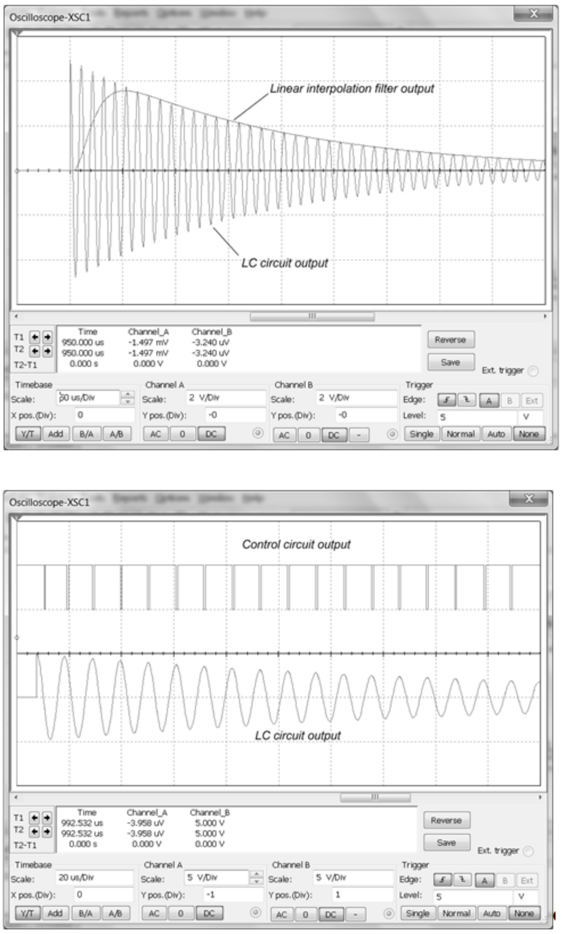

Fig.5. The result of linear interpolation filter work

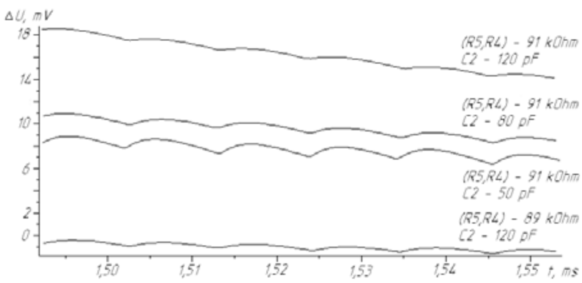

Fig.6. The absolute error of signal envelope curve recreation

As it is evident from fig. 6 the additive constituent of error grows with growth of the capacitance nominal, when the error of integrator work diminishes with growth of the capacitance nominal. At a value of capacitance nominal 120 pF the error of integration is 0.2 mV and the additive constituent is approximately 17 mV. And at the value of the capacitance nominal 50 pF the error of integration is 1 mV and an additive constituent is approximately 8 mV. The optimum element nominal's were determined for these terms C2 – 120 pF, R4, R5 – 89 kΩ.

On condition of ideal comparator application at the optimum values of the chart elements, an absolute fluctuation fading time measuring error will be 5 ms.

REFERENCES

[1] http://www.acam.de/products/time-to-digital-converters/tdc-gp1
[2] Shabatura U.V. Research of measuring converters of metallic surfaces dielectric coverings thickness with time presentation of information. The National University Bulletin "Lvivska Politekhnika": Automation, measuring and management. - №551. – L.2006. – p.63-69
[3] Pat.2365910 Russian Federation, MPK G01N27/90. The Vortex-current Control Method and Device for its Realization/ Kibrik G.E., Naldaev N.D.; a declarant and a patent holder. Limited Liability Company. Scientific and Production Enterprise "TIK" (LLC SPE "TIK"). - 2007103265/28; declarated 26.01.2007; published 27.08.2009. – 3 p.: illustr.
[4] Semiconductor circuit technology: Reference Guide. Transl. from German. – M.: Mir, 1982. – 512 p. with illustr.
[5] Kartsev E., Chulkov E. Stereodecoder with a Quartz Resonator. Radio. 1986, №2, p.38-42
[6] http://www.analog.com/static/imported-files/data_sheets/ADG601_602.pdf (data dostępu:04.94.2013)
[7] http://www.analog.com/ru/high-speed-op-amps/fet-input-amplifiers/ad8066/products/product.html (data dostępu:04.04.2013)
[8] Information-measuring technique and electronics: Rannev G.G. and other. – M.: Publishing center "Academy", 2006. – 512 p.

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