



ANALOG AND DIGITAL-TO-ANALOG TUNABLE INTEGRATORS

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ABSTRACT

The purpose and objectives of this work is to study circuits of analog and digital-to-analog tunable integrators, especially their construction and operation, the definition of the uniqueness of each scheme, both in circuit engineering execution, and by the process of restructuring, analysis. To solve the problem the analysis of domestic and foreign works, given the scheme of analog and digital-to-analog tunable integrators work has a review character. In a comparative analysis, in the article it revealed that, depending on the particular problem to be solved and the manufacturing process, any of the circuitry solutions integrators may be more effective than others.

Keywords: analog integrator, discrete analog integrator, tunable integrator restructuring, digital code.

1. INTRODUCTION

General trends in the development of modern electronic technology aimed at extensive use of digital signal processing that can be done in different ways: using microcontrollers, digital signal controllers, digital signal processors.

Efficacy of digital signal processing techniques is undeniable, as it provides the stability parameters of time and temperature, not only the ease of changing the parameters and algorithms changing coefficients of the transfer functions and adaptation techniques. However, experience has shown the development of various technical devices, there are still problems, for which the use of microcontrollers even impossible because of their high power consumption. Alternatively, an effective solution of such problems is the use of circuit decisions made on micropower op amps.

On the basis of schemes integrators to build various functional units: Regulators of automatic control systems, active analog filters, voltage-to-frequency converters, frequency-to-voltage analog-to-digital converters, pulse generators, etc. [18, 24-26]. Quite often, as the operation of the device in the circuit, the integrator parameters, namely, they realized a time constant must be changed, i.e. rebuild. One of the areas related to the solution of such problems is the use of programmable analog integrated circuits [9]. However, compared with digital programmable chips, due to a limited number of electronic structure and analog components they have little functionality.

Currently, the integration of the signal can be an analog, discrete analog and digital circuits.

In accordance with the above objective (minimization of power consumption) we restrict ourselves to the circuit design of analog and digital-analog circuits tunable integrators.

2. FUZZY LOGIC CONTROL

The analog integrator is made on the basis of the operational amplifier shown in Figure-1.

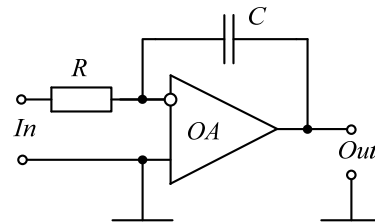


Figure-1. Diagram of the analog integrator.

Передаточная функция аналогового интегратора определяется по формуле

$$F(p) = -\frac{I}{pRC} = -\frac{1}{p\tau} \quad (1)$$

The only factor of its transfer function is determined by the product of the resistor R on the capacitance of the capacitor C , and is called the time constant τ . It should be noted that the transfer function of the integrator of the form (1) is valid only for an ideal operational amplifier, i.e. while neglecting the influence of parasitic parameters of the amplifier for realized transfer function [10, 27, 28].

Adjustment (change) the time constant of the integrator can be made by changing resistor or capacitance. Since the change in the capacitance of microelectronic circuits analog integrator is quite difficult, the only element whose value can be changed, there is a resistor.

Modern chip analog electronic keys have sufficiently low resistance in the conducting state (tenths of Ohm's) and very high resistance in the closed state (hundreds of MOhm). On the basis of such chips



containing sets of keys $S_1 - S_n$, as well as through a series of discrete resistors $R_1 - R_n$, can be implemented discretely tunable integrator circuit shown in Figure-2.

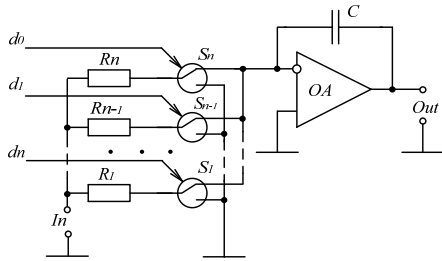


Figure-2. The analog integrator with discrete restructuring.

If the circuit of Figure-2 use resistors with nominal resistance, changing the law on the binary (similar to a digital-to-analog converter (DAC)), it is possible to construct a circuit of analog integrator with a time constant of restructuring with a digital code $d_n \dots d_0$. In accordance with weights positions binary values of resistors in the circuit must be related by

$$R_i = 2^{-i} R_1 \quad (2)$$

where i – the serial number of the resistor in the circuit and the resistance of the resistor R_1 – most significant bit (MSB).

The time constant integrator implemented under consideration, determined by the state of keys located in the ON state (in the diagram in Figure-2 in the up position), depending on the binary digital code D , state control keys.

Step integrator adjustment depends on the number of keys used, i.e. of n bit code D , and its time constant τ determined by the formula

$$\tau = R(D)C. \quad (3)$$

Resolved tunable integrator circuit solution rather difficult to implement in practice, since it requires the selection of precision resistors in accordance with (2). Alternative circuit solution can be obtained by the use in the circuit of the digital potentiometer integrated circuit included on a programmable resistor circuit as shown in Figure-3.

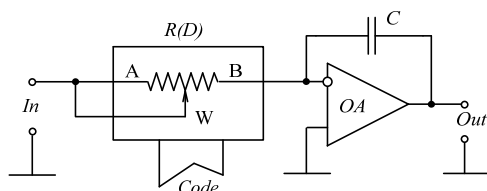


Figure-3. Analog integrator with a digital potentiometer.

Application IC digital potentiometer with SPI serial interface or I2C allows for comparison with the previous scheme to reduce the area occupied by the circuit on the circuit board and chip digital potentiometers with nonvolatile memory to receive the integrator circuit with the preset parameters. In accordance with the symbols in the diagram (Figure-3), the time constant of the integrator is determined by the formula

$$\tau = R_{AB} \frac{D}{2^n} C \quad (4)$$

where R_{AB} – initial resistance value chip digital potentiometer in – decimal code number, n – bit digital potentiometer.

Most digital potentiometers are available 8- and 10-bit [11 13]. However, there are a limited number of chips, which is guaranteed by the tolerance of resistors of 1% and only makes sense to use them in this scheme. The latter circumstance may serve as a limiting factor in the applicability of the digital potentiometer chip as a programmable resistor to implement tunable integrator.

The integrator circuit formed on operational amplifiers (OA), the differential voltage between its inverting and noninverting inputs close to zero up to where – gain of the amplifier. This property is used for constructing tunable integrator circuits in which the time constant is changed in an indirect way, i.e. not due to changes in the resistance of the resistor, and by changing the transmission ratio of the resistive voltage divider, installed at the entrance of the integrator, or by changing the gain of the amplifier is also mounted on the input of the integrator.

Using chip digital potentiometer, with its inclusion in the mode of controlling the digital code of the resistive voltage divider, also called a digital-to-analog converter (in the UK. Abbreviation RDAC), or by using a resistive matrix $R - 2R$, also included in the mode, multiplying digital-to-analog converter (UTSAP below), you can build an amplifier with programmable gain and, based on reconfigurable analog integrator circuit is shown in Figure-4.

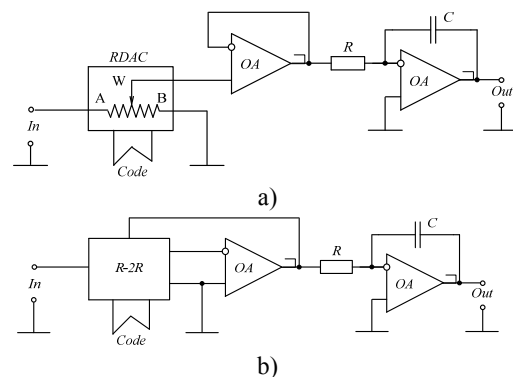


Figure-4. Tunable analog integrators VATSAP.



The time constant integrator implemented with VATSAP is determined not only by the resistance of the resistor R and the capacitance C , and the transmission coefficient $K(D)$ multiplying digital to analog converter, and is defined by the formula

$$\tau = \frac{RC}{K(D)} = \frac{2^n}{D} RC \quad (5)$$

Step (discrete) adjustment of the integrator is determined by bit DAC (resistive matrix $R - 2R$ or digital potentiometer). Chips containing resistive matrix $R - 2R$ produced 10, 12 bit or even higher, so they can be created based tunable integrators with a fine pitch adjustment, as compared with digital potentiometers.

The deviations from the nominal values of the resistive matrix $R - 2R$ in the integrated performance can reach 50% or more, as when performing more important, is not the resistor values, and their ratio, which is guaranteed to be 0.1%. Because of the large spread of nominal resistors even for one batch of chips including a resistive matrix directly instead of the resistor in the circuit of the integrator, for example, as in the circuit of Figure-2, it is inappropriate.

The discrete analog circuits integrators restructuring parameters is possible by changing the pulse ratio, electronic analog control keys, or by changing the frequency of repetition [14, 17, 29].

Figure-5 shows a diagram of a discrete-analog integrator, made on the basis of the switched resistor with an electronic key S . In the same figure shows the sequence of control pulses PWM.

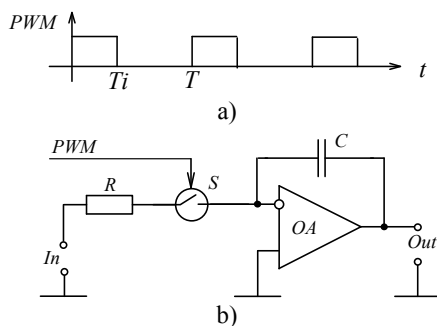


Figure-5. Discrete analog integrator based chain ARCS.

If the connection between the electronic key to select T is much smaller than the time constant integrator implemented, it is equivalent to the time constant determined by the formula

$$\tau_s = \frac{T}{T_i} RC = QRC \quad (6)$$

The time constant in this case can be varied by changing the ratio of the time placed in the OFF ($0 - T_i$)

and switched ($T_i - T$) the state of the electronic key, i.e., duty cycle pulse sequence Q .

The integrator circuit formed on the basis of a switched capacitor circuit (Figure-6), the time constant determined by the switching frequency electronic switches, which are controlled antiphase pulse sequence (Figure-6a) and the ratio of the capacitors C_d and C_i .

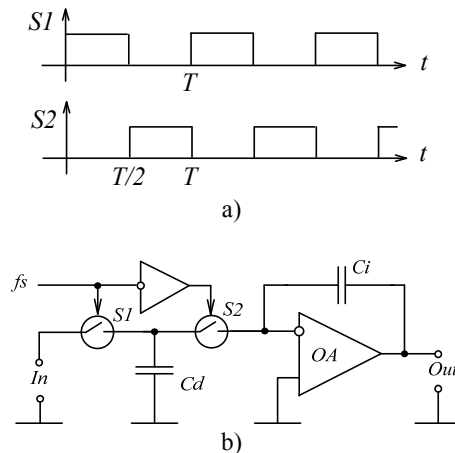


Figure-6. Discrete analog integrator based on the RC-circuit.

In accordance with the Figure-6 symbols, the equivalent time constant of the integrator based on the SC-circuit is determined by the formula

$$\tau_s = T \frac{C_i}{C_d} = \frac{1}{f_s} \frac{C_i}{C_d} \quad (7)$$

Here one should pay attention to the fact that the time constant of the integrator based on the SC-circuit is determined by the capacitance ratio of capacitors and is independent of their absolute values, which is very important when implementing a microelectronic circuit performance.

The circuit of the integrator shown in Figure-7, with properties closest to the digital integrator circuit [17, 19, 30]. Sampling-storage devices in this circuit are controlled by the same antiphase pulse sequence, as in the circuit formed on the switched capacitor [19, 20], as shown in Figure-6a.

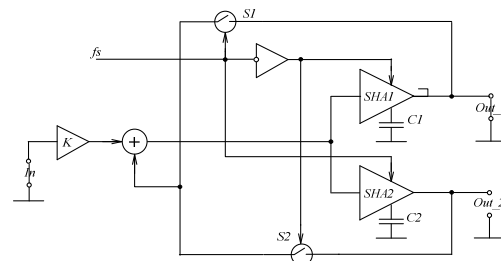


Figure-7. Discrete analog integrator based SHA.



The equivalent time constant of the integrator performed based on SHA, SHA determined sampling frequency and the transmission coefficient K divider (or amplifier) installed on the input of the circuit, according to the formula

$$\tau_s = 2TK = \frac{2}{f_s} K \quad (8)$$

An essential feature of the last viewed integrator circuit is implemented independent of the time constant equivalent value capacitors SHA. Because of this integrator circuit is made on the basis of the SHA, the stability of the parameters of the closest analogue to digital integrator.

3. CONCLUSIONS

The difference of this work from the prior art consists in the fact that the analysis performed, taking into account many criteria circuit solutions tunable integrators showed that each of the considered schemes of analog and digital-to-analog integrator has its own unique characteristics, both on the circuit engineering execution, and by the process of restructuring - by changing the control code, the frequency of the control pulses, or duty cycle. In this regard, one can not give preference to the use of some unique solution. Depending on the particular problem to be solved and the manufacturing process, any of the circuitry solutions integrators may be more effective than others. Stability parameters should be allocated by the integrator circuit formed by the SHA, because it is less sensitive to changes in the capacitors.

REFERENCES

- [1] Chaniyara P.M., Srivastava P.K., Suresha B. and Reddy A.S. 2015. Design of sampled analog wavelet processor architecture for cochlear implant application. *Analog Integrated Circuits and Signal Processing*.
- [2] Finaev V., Kobersy I., Beloglazov D., Shapovalov I., Kosenko E. and Soloviev V. 2015. Design of the neuro-like learning control system for a vehicle. *WSEAS Transactions on Systems and Control*. 10: 328-334.
- [3] Kobersy Iskandar S., Ignatev Vladimir V., Finaev Valery I. and Denisova Galina V. 2014. Automatic optimization of the route on the screen of the car driver, *ARPN Journal of Engineering and Applied Sciences*. 9(7): 1164-1169.
- [4] Drost B., Talegaonkar M. and Hanumolu P.K. 2012. Analog filter design using ring oscillator integrators. *IEEE Journal of Solid-State Circuits*. 47(12): 3120-3129.
- [5] Shah N.A., Iqbal S.Z. and Parveen N. 2011. Log-domain all pass filter based on integrators. *Analog Integrated Circuits and Signal Processing*. 67(1): 85-88.
- [6] Finaev Valery I., Kobersy Iskandar S., Kosenko Evgeny Y., Solovyev Viktor V. and Zargaryan Yuri, A. 2015. Hybrid algorithm for the control of technical objects. *ARPN Journal of Engineering and Applied Sciences*. 10(6): 2335-2339.
- [7] Yaguchi R., Adachi F. and Waho T. 2010. A low-power delta-sigma modulator using dynamic-source-follower integrators. 2010 IEEE International Conference on Electronics, Circuits, and Systems, ICECS 2010-Proceedings. p. 551.
- [8] Finaev Valery I., Beloglazov Denis A., Shapovalov Igor O., Kosenko Evgeny Y. and Kobersy Iskandar S. 2015. Evolutionary algorithm for intelligent hybrid system training. *ARPN Journal of Engineering and Applied Sciences*. 10(6): 2386-2391.
- [9] Santamaría G.E., Valverde J.V., Pérez-Aloe R. and Vinagre B.M. 2008. Microelectronic implementations of fractional-order integrodifferential operators. *Journal of Computational and Nonlinear Dynamics*. 3(2).
- [10] Zhou X.-, Jiang J.-, Liu J. and Wang J. 2014. High-accuracy and low signal distortion on-chip auto-calibrating architecture for continuous-time filters. *Analog Integrated Circuits and Signal Processing*. 80(3): 565-575.
- [11] Beloglazov Denis A., Finaev Valery I., Zargarjan Jury A., Soloviev Victor V., Kosenko Evgeny Y. and Kobersy Iskandar, S. 2015. Efficiency of genetic algorithms in intelligent hybrid control systems. *ARPN Journal of Engineering and Applied Sciences*. 10(6): 2488-2495.
- [12] Kobersy Iskandar S., Finaev Valery I., Zargarjan Jury A., Beloglazov Denis A. and Shadrina Valentina V. 2015. Model of the controller for output stream concentration in the mixer of a steam unit. *ARPN Journal of Engineering and Applied Sciences*. 10(4): 1637-1641.
- [13] Strube H.W. 1977. Synthesis Part of a Log Area Ratio Vocoder in Analog Hardware. *IEEE Transactions on*



- Acoustics, Speech, and Signal Processing. 25(5): 387-391.
- [14] Kobersy I.S., Ignatev V.V., Beloglazov D.A. and Kramarenko, E.R. 2014. An intelligent navigator with the control of the car technical condition. ARPN Journal of Engineering and Applied Sciences. 9(7): 1094-1098.
- [15] Yu T.-., Wu C.-. and Chang S.-. 1990. Realizations of IIR/FIR and N-Path Filters Using a Novel Switched-Capacitor Technique. IEEE Transactions on Circuits and Systems. 37(10): 1231-1247.
- [16] Kobersy Iskandar S., Ignatev Vladimir V., Finaev Valery I. and Denisova Galina V. 2014. Automatic optimization of the route on the screen of the car driver. ARPN Journal of Engineering and Applied Sciences. 9(7): 1164-1169.
- [17] Guo L., Ge T., Kang Y., He H. and Chang J. 2014. Analysis and design of PWM-in-PWM-out Class D Amplifiers. Midwest Symposium on Circuits and Systems. p. 254.
- [18] Kobersi I.S., Finaev V.I., Almasani S.A. and Abdo, K.W.A. 2013. Control of the heating system with fuzzy logic. World Applied Sciences Journal. 23(11): 1441-1447.
- [19] Shkurkin D., Novikov V., Kobersy I., Kobersy I. and Borisova A. 2015. Investigation of the scope of intellectual services in the aspect of virtualization and information economy of modern Russia. Mediterranean Journal of Social Sciences. 6(5S3): 217-224.
- [20] Matsumoto H. 2015. A simple switched-capacitor algorithmic digital-to-analog converter using sample/hold and divider. IEEE Asia-Pacific Conference on Circuits and Systems, Proceedings, APCCAS. pp. 45.
- [21] Kobersy I.S., Barmuta K.A., Muradova S.S., Dubrova L.I. and Shkurkin D. 2015. The system of the methodological principles of management of enterprise development. Mediterranean Journal of Social Sciences. 6(3S4): 25-30.
- [22] Knoll M. 2008. A self-writing smart label based on doping front migration. Electrochimica Acta. 54(2): 216-219.
- [23] Kader M.A., Mostafa S.M.G. and Das C.K. 2014. Speed up the conversion rate of integrator type Analog-to-Digital (A/D) converter combining it with flash type converter. 2014 9th International Forum on Strategic Technology, IFOST 2014. p. 503.
- [24] Kobersy, I. S., Shkurkin, D. V., Zatonkiy, A. V., Volodina, J. I., & Safyanova, T. V. (2016). Moving objects control under uncertainty. ARPN Journal of Engineering and Applied Sciences, 11(5), 2830-2834
- [25] Rylov, D. V., Shkurkin, D. V., & Borisova, A. A. (2016). Estimation of the probability of default of corporate borrowers. International Journal of Economics and Financial Issues, 6(1S), 63-67.
- [26] Gorbachenko, V. I., Kuznetsova, O. Y., & Silnov, D. S. (2016). Investigation of neural and fuzzy neural networks for diagnosis of endogenous intoxication syndrome in patients with chronic renal failure. International Journal of Applied Engineering Research, 11(7), 5156-5162
- [27] Kunelbayev, M., Auyelbekov, O., Katayev, N., & Silnov, D. S. (2016). Factor of catching of solar radiation of a tubular heat receiver with a cellular transparent covering. International Journal of Applied Engineering Research, 11(6), 4066-4072
- [28] Bolnokin, V. E., Storozhev, V. I., Vasilenko, S. V., Kobersy, I. S., Shkurkin, D. V., & Evtushenko, V. Y. (2016). Model for optimization elements system for screening of cylindrical hydroacoustic arials. International Journal of Applied Engineering Research, 11(4), 2879-2884.
- [29] Sergeevich, S. D., & Vladimirovich, T. O. (2015). Virus detection backdoor in microsoft security essentials. Information (Japan), 18(6), 2513-2520
- [30] Silnov, D. S. (2015). Security holes in manuscript management systems. ARPN Journal of Engineering and Applied Sciences, 10(18), 7994-7996