

USING LABVIEW FOR COMPUTER MODELLING OF CONVERSION METHODS IN ANALOG TO DIGITAL CONVERTERS

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Abstract: The applications designed in the LabVIEW environment for computer simulation of the operation principle and testing of two types of A/D converters (ADC): single-slope AD converter and dual-slope A/D converter are presented. Front panels contain graphical objects, permitting interactive communication with the user. Animation effects allow illustration of the ADC operation principle. The application permits performance of virtual experiments thanks to the possibility of control of the ADC parameters and the input signals parameters. The applications can be used for education and research purposes.

Keywords: LabVIEW, virtual instruments, computer simulation.

1. INRODUCION

Conditioning of the output signals from the sensors and measuring converters requires such operations as amplification, filtration and analog-digital conversion. Of key importance in the path of the signal conditioning is the A/D converter enabling communication with the microprocessor system. To be able to achieve the desired effects of signal conditioning of crucial importance is to know the operation principle of A/D converters and their properties. The information is provided in the courses at technical universities, in particular in specialisations related to electricity, in lectures and laboratory classes. Presentation of the operation principle of A/D converters and their properties in the classical way is time consuming and poses difficulties for the students because of the need to present considerable amounts of information in the graphical form. To illustrate the problems related to A/D converters functioning, many schemes, time courses of signals and characteristics describing relevant properties of the system are needed and have to be adapted for each new value of the parameters of the input signal or those of the path of the converter. A convenient solution seems to be the application of integrated programming environments for simulation of the measuring systems. In particular, the LabVIEW environment seems to be commonly used at the university level teaching process for realisation of specific programs for presentation of various problems. Many authors have

been interested in these problems and many applications dedicated to the simulation of the A/D converters and measuring paths employing different sensors and many examples of physical experiments have been published[1-4].

2. SIMULATION AND INVESTIGATION OF THE PROPERTIES OF A/D CONVERTERS

2.1. The single slope A/D converter

The single slope conversion method belongs to the simplest and oldest ones but in principle can be quite accurate. Fig. 1 presents the front panel of the application for simulation of performance of a single-slope A/D converter and illustrates the principle of operation of the single slope conversion technique.

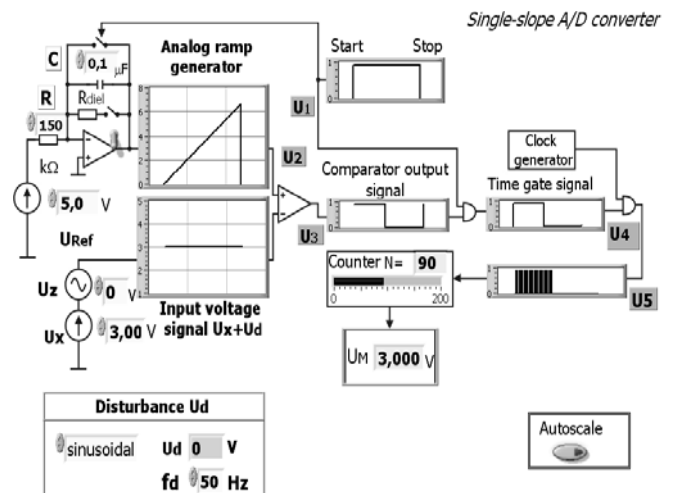


Fig. 1. View of the front panel of the application for simulation of a single-slope A/D converter.

Conversion process begins with a start signal, which resets the counter and initiates start of an analog ramp generator. In the same instant the counter begins to count pulses from the clock generator of the standard frequency. The comparator compares the voltage value of the ramp signal with measured signal V_x and at the moment in which voltage value of the ramp signal achieves value of measured

voltage signal, comparator changes the output state and stops the process of counting of pulses. The value of measured voltage V_x is directly proportional to the number N of counted pulses at the end of the conversion:

$$V_x = \frac{KN}{f_c} \quad (1)$$

where K is the slope of the ramp in volts/second, f_c is the frequency of the clock generator.

The front panel displays a block scheme of the A/D converter including its important subunits determining the activity and terminals permitting the selection of parameters of the input signal and the system. Besides, the front panel shows windows displaying the course of the signal at the important sites of the converter. The algorithms implemented in the application program allow presentation of the converting processes in the form of animation, which is particularly important as it permits observation of the dynamical states of the system. The graphically displayed courses of the signals can be magnified by using the bookmark "Plot magnification" (Fig. 2, Fig. 3, Fig 4, Fig 5).

The application permits preset of all important parameters of the A/D circuit including: the reference voltage U_R , time constant of the integrator responsible for generation of linearly increasing voltage, modelling of nonlinearity of by introduction of resistance R_{diel} simulating the leakage conductance of the capacitor in the integrator feedback.

Fig. 2 presents exemplary results of the simulation illustrating the process of conversion in the A/D converter for the DC voltage input signal of a constant value, while Fig. 3 gives the results of the simulation for the DC voltage input signal of a constant value exceeding the converter scale.

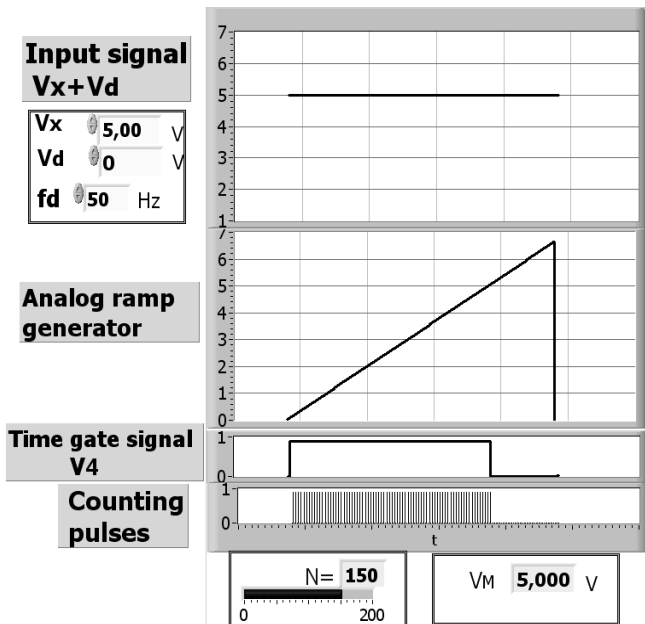


Fig. 2. Time diagrams of the signals in a single-slope AD converter for DC voltage input signal

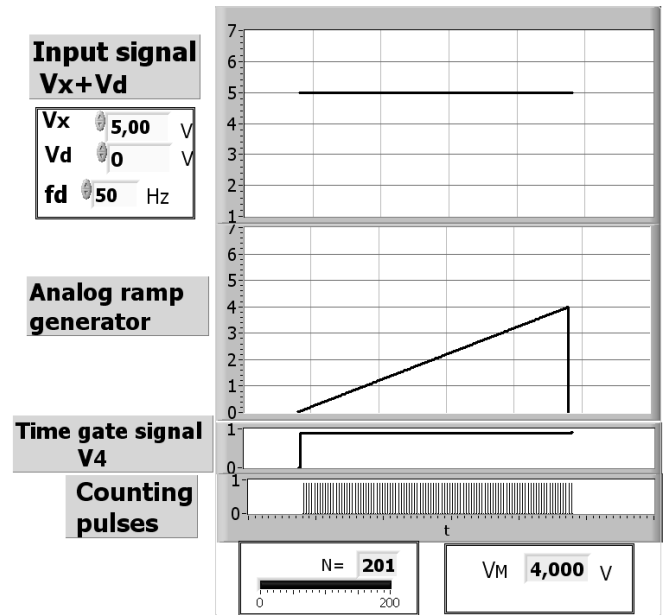


Fig. 3. Time diagrams of the signals in a single-slope AD converter for DC voltage input signal, whose value exceeds the range of AD converter.

An important feature is the possibility of introduction of a disturbing signal V_d adding to the utility signal V_x and the preset of such parameters of the disturbing signal as the amplitude, frequency and shape. A comparison of the results of simulation with the earlier predicted consequences of introduction of a new value of a signal parameter or an element of the converter can be used as a test checking the students knowledge of the A/D work.

Fig. 4 gives the results of the simulation for the DC voltage input signal of a constant value with a disturbing component of sinusoidal character.

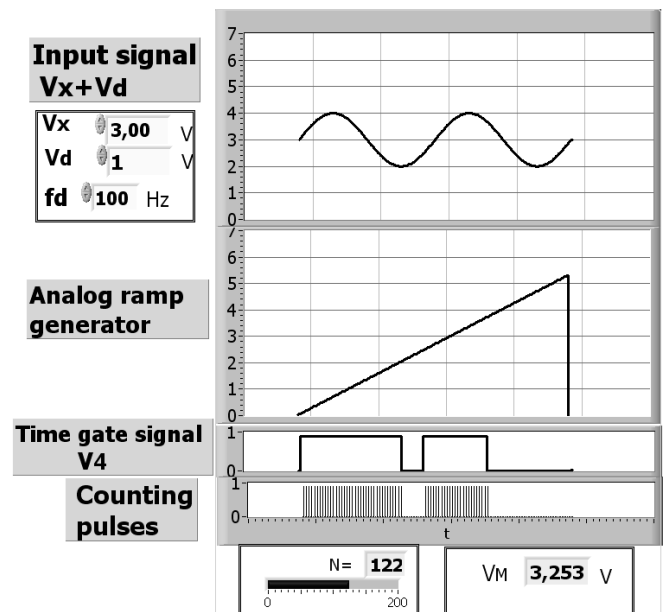


Fig. 4. Time diagrams of the signals in a single-slope AD converter for DC voltage input signal with sinusoidal disturbance component

Fig. 5 gives the results of the simulation for the DC voltage input signal of a constant value with a disturbing component of triangular character.

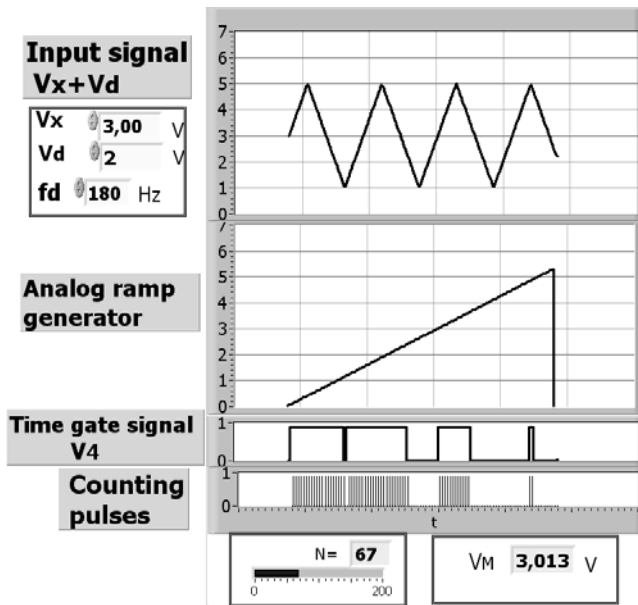


Fig. 5. Time diagrams of the signals in a single-slope AD converter for DC voltage input signal with disturbance component of triangular character.

2.2. Dual-slope A/D converter

Dual slope converter belongs to the family of integrating converters. Dual slope converters are commonly found in high-precision data acquisition and instrumentation systems.

Fig. 6 shows the front panel of the application with a basic block diagram of the dual-slope converter and illustrates converter operation.

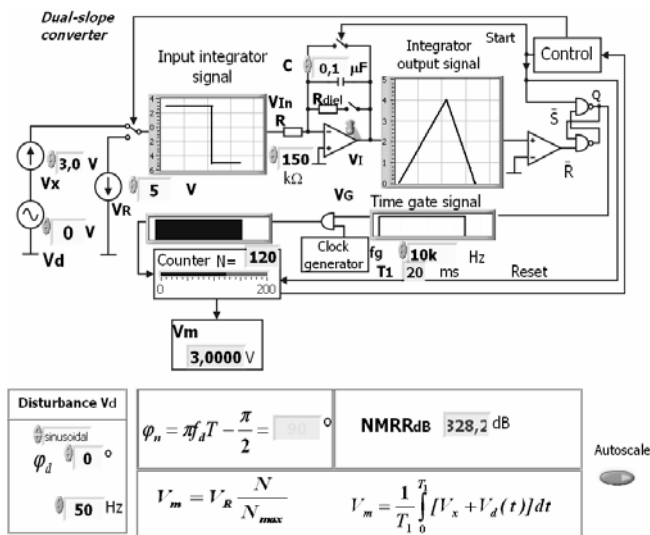


Fig. 6. The front panel of the application for simulation the principle of operation of a dual-slope A/D converter.

Similarly as for the single-slope converter, this panel presents a block diagram of the system, terminals permitting preset of the desired values of the signal or converter

parameters and graphic displays of the signal course at most important sites of the system. The graphically displayed courses of the signals can be magnified by using the bookmark "Plot magnification".

The conversion process consists of two separate integration cycles. At the first cycle the input voltage signal V_m is integrated for a known period of time T_1 . At the start of the first cycle the counter is enabled and begins to count clock pulses of frequency f_g . When the counter reaches its maximum count N_{max} , it will be reset and the control logic will switch the integrator input from voltage signal V_m to source of reference voltage V_R . At this instant begins the second cycle of integration. The polarity of the reference is determined during second cycle such that the integrator discharges back towards zero. The number N of clock pulses counted between the beginning of this cycle and the time when the integrator output signal passes through zero is a digital measure of the input voltage signal. The value of measured voltage can be expressed as:

$$V_m = V_R \frac{N}{N_{max}} \quad (2)$$

where V_m is average value of the input signal, which is defined by:

$$V_m = \frac{1}{T_1} \int_0^{T_1} [V_x + V_d(t)] dt \quad (3)$$

where: V_x is DC voltage signal and V_d is disturbance voltage signal.

Fig. 7 illustrates the principle of operation of the dual slope A/D converter.

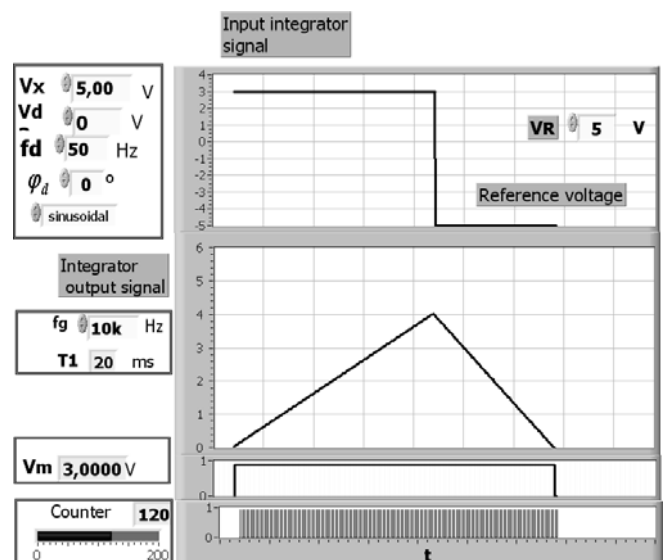


Fig. 7. The principle of operations of the dual slope A/D converter.

The dual-slope A/D converters are very attractive, because the theoretical accuracy depends only on the absolute value of the reference voltage U_R and the quality of

the individual clock pulses within a given conversion cycle. Long – time changes in the value of the other circuit parameters such as time constant RC of the integrator, frequency of the clock generator have no effect on the results of the conversion of measured voltage. These properties one can very easy to verify with using designed LabView application.

Particular care was taken to implement the procedures permitting investigation of the influence of series disturbances superimposed on the useful DC signal on the result of the conversion process. The program permits wide range changes in the parameters of the disturbing signal such as the amplitude, frequency and phase angle. The process of conversion is well illustrated by the time courses of the signals displayed on the graphic displays at the most important sites of the scheme. The graphic displays can be magnified by using the bookmark “Plot magnification”

Fig. 8 presents the front panel of the application and the results of simulation of conversion of the constant voltage with a superimposed disturbing signal of sinusoidal component.

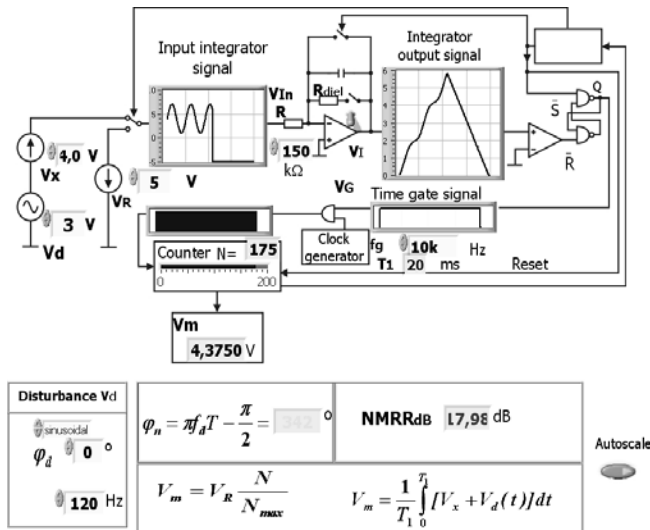


Fig. 8. Investigation of the converting process of the dual-slope A/D converter for the input DC signal with a sinusoidal disturbing component

It is good known, that the fixed input signal integration period results in rejection of disturbances signals on the analog input whose periods are equal to or sub-multiple of integration time T_1 . Proper choice of value of integration time can therefore results in excellent rejection of 50 Hz or 60 Hz disturbances independently of the phase value. The results of simulation presented in Fig. 9, Fig.10 and Fig.11 excellent confirm this feature. The results of investigations of dual-slope analog-to-digital converter with integration time equal to 20 ms show that disturbance signals of frequency 50 Hz or signals whose frequencies are an integral multiple of 50 Hz are completely rejected.

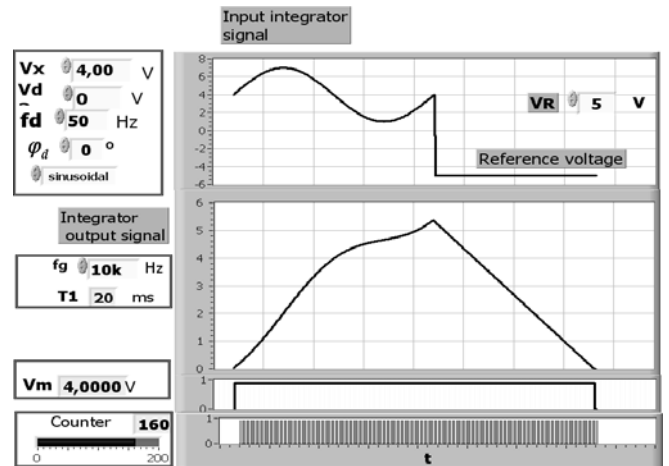


Fig. 9. Time diagrams of the signals in a dual-slope AD converter for DC voltage input signal with sinusoidal disturbance component of frequency equal to 50 Hz and of phase equal to 0° . Value of integration time is equal to 20 ms.

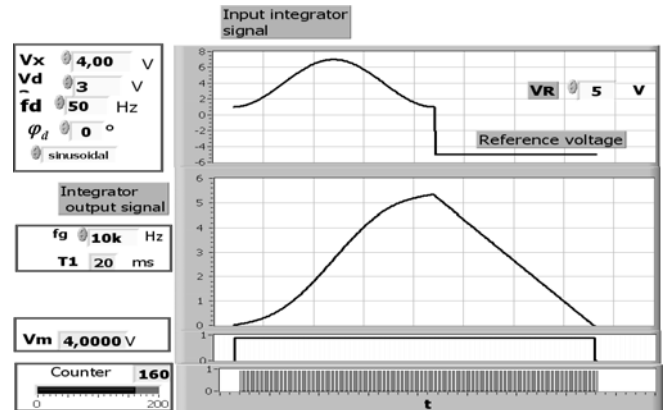


Fig. 10. Time diagrams of the signals in a dual-slope ADC for DC voltage input signal with sinusoidal disturbance component of frequency equal to 50 Hz and of phase equal to -90° . Value of integration time is equal to 20 ms.

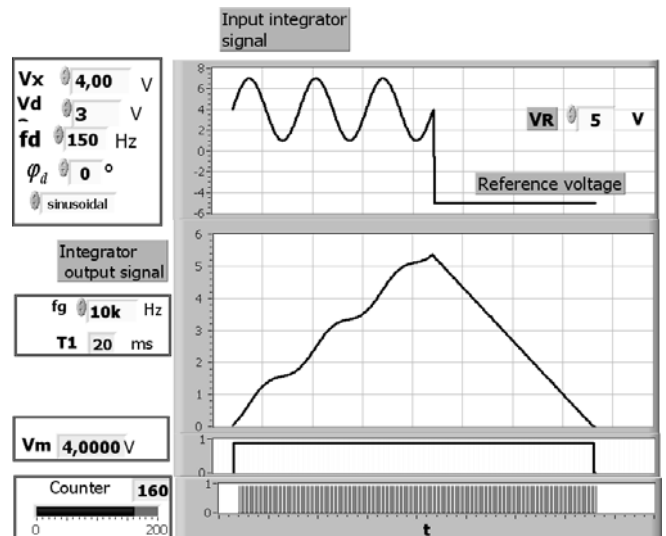


Fig. 11. Time diagrams of the signals in a dual-slope ADC for DC voltage input signal with sinusoidal disturbance component of frequency equal to 150 Hz. Value of integration time is equal to 20 ms.

It is also possible to choose a shape of the disturbing signal. Fig. 12 gives the results of the simulation for the DC voltage input signal of a constant value with a disturbing component of triangular character.

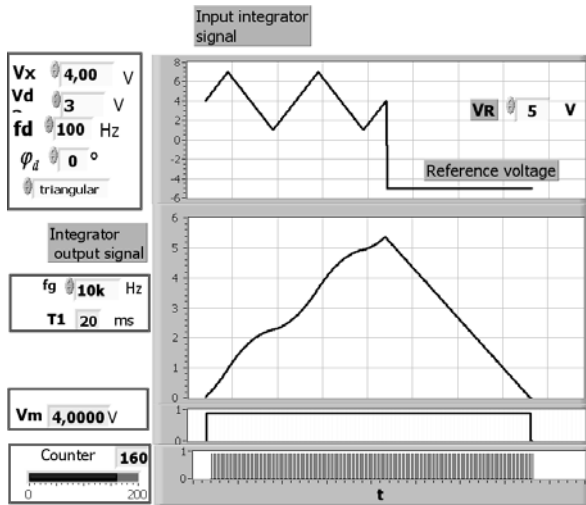


Fig. 12. Time diagrams of the signals in a dual-slope ADC for DC voltage input signal with triangular disturbance component of frequency equal to 100 Hz. Value of integration time is equal to 20 ms

The program is well suited for simulation investigation of the attenuation characteristics of disturbances obtained in the point-by-point experiment by introducing to the input of the A/D converter the sinusoidal signals of the amplitude of the constant component U_x of the input voltage and the appropriate phase angle φ_n , suggested in the window of a proper display. The display window also presents a result of the calculations of the attenuation coefficient of the series disturbances $NMRR_{db}$ for the preset parameters of the sinusoidal signal and the time T_1 of the first integration.

Fig. 13 and Fig. 14. present results of investigation for sinusoidal disturbances whose frequencies are not an integral multiple of 50 Hz.

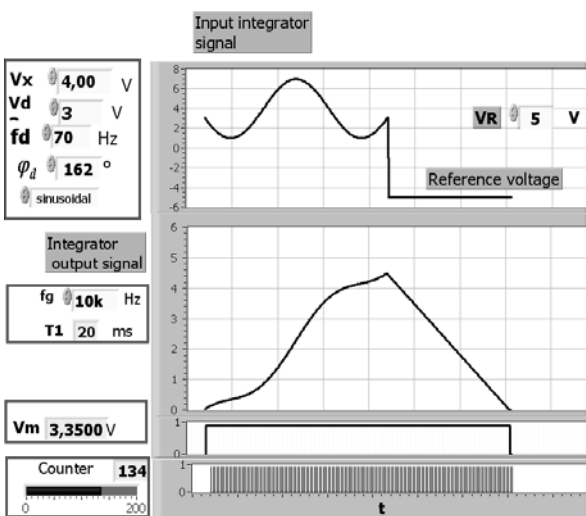


Fig. 13. Time diagrams of the signals in a dual-slope ADC for DC voltage input signal with sinusoidal disturbance component of frequency equal to 70 Hz. Value of integration time is equal to 20 ms.

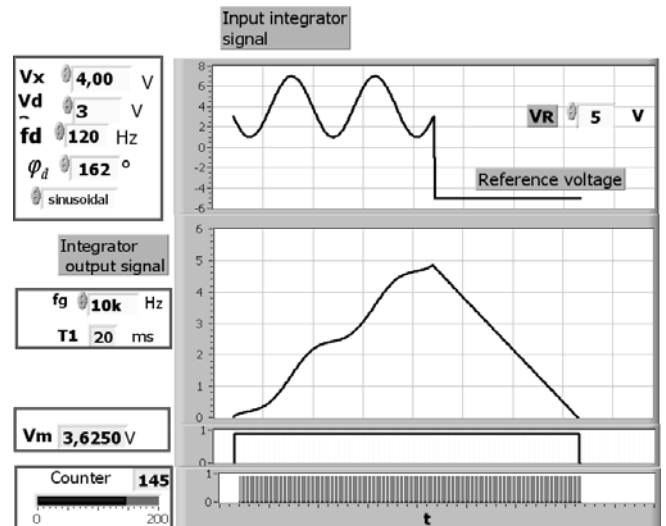


Fig. 14. Time diagrams of the signals in a dual-slope ADC for DC voltage input signal with sinusoidal disturbance component of frequency equal to 120 Hz. Value of integration time is equal to 20 ms. Value of phase is equal to 162° .

Fig.15 shows result of investigation for the same value of amplitude and frequency of disturbance as given in Fig. 14., but another phase value of sinusoidal disturbance is applied.

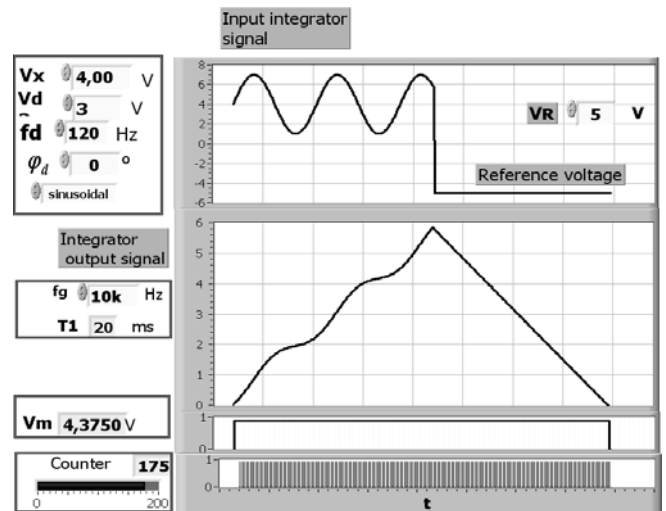


Fig. 15. Time diagrams of the signals in a dual-slope ADC for DC voltage input signal with sinusoidal disturbance component of frequency equal to 120 Hz. Value of integration time is equal to 20 ms. Value of phase of disturbance signal is equal to 0° .

The application permits the preset of all parameters of the A/D system determining the process of conversion such as the clock frequency and the related time of the first integration, reference voltage, simulation of the leakage of the capacitor in the integrator system. The pulse counter applied has a bar indicator and the mode of its work truly represents the well-known effect of the counter zeroing at completion of the first phase of integration. The result of conversion can be read off from the window of the counter as a number of counted pulses or directly as a value of the voltage.

3. CONCLUSION

The application program written permits presentation of the principles of operation of the A/D converters and performance of simulations of the conversion process thanks to the possibility of preset of the parameters of the input signal and those of the elements of the converter system. Students are not only able to learn about the work of the A/D converter but can analyse the effect of changes in the parameters of the signal or those of the system on the course of the process of conversion and the result of measurement. An important advantage of this application over similar ones presented in literature is the possibility of setting a large number of parameters of the system and of the signal over wide ranges. The solutions applied in the program ensure relatively high accuracy of simulations and permit collection of the data needed to make damping characteristics, the effect of changes in the present parameters on the error of conversion, etc. Thanks to the application of the animation effects illustrating the work of the converter in dynamic conditions the ideas behind the process of conversion and activity of A/D converters can be much easier understood. The analysis of the converter work and the effects of different parameters on its performance are conducted in the interactive mode and can be realised with the help of a PC unit only, so the results are achieved very fast.

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