

Measurements of Propagation Delay Times of High-speed Logic Ics

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Abstract: The new tester for the measurement of the propagation delay times in high-speed IC logic by the use of multichannel sample converter is considered. The multichannel sample converter is a rather simple device with a small level of internal noise and was developed on the basis of peak detecting sample converter with two quartz generators. The two models of the tester is developed and researched. The measurement error of propagation delay times does not exceed $\pm 5\%$.

1. Introduction

The propagation delay times in the high-speed IC logic circuits, triggers, registers, counters etc. are equal to fractions of a nanosecond and their measurement is the difficult technical task. For these purposes testers with sampling converters of the signal time scale are frequently used.

During the IC manufacturing the check and certification of tens of propagation delay times between several tens inputs and outputs can be required. Usual sampling converters have from two to four inputs and are usually supplied with special high-frequency commutator, which consist of many high-frequency coaxial cables segments and high frequency, tunable with a wave resistance of a cable, reed-relays or mercury relays. By the means of a relay commutation of IC outputs and of a sampling converter inputs is provided. Application of the high-frequency channel commutator results in the significant reflections, distortion and, as consequence, in deterioration of accuracy of measurement. The electromagnetic relays considerably reduce productivity measurement because of small speed of switching. The measuring systems of this kind are complex, expensive and bulky devices.

2. Subject and Structure

The new construction of a propagation delay time tester for high-speed logical IC is proposed. To eliminate the high-frequency commutators were design [1]. The new converters work in a peak detecting mode [2, 3] with the small level of internal noise [4] and are the most suitable devices for propagation delay time tester with the commutator on an input (Fig. 1). The sample converters in the peak detecting mode have a transmission factor more than 0.5, and the measurement signal comes to capacity C1 in the transformed time scale. Therefore it is possible to include the low-frequency commutator DA2 between C1 and capacity discharge resistance R4. The n channel transforms the time scale, when the n input of a commutator DA2 is on (when resistance between this input and output of DA2 is small). For the other channels, working in the ideal peak detecting mode, the resistances of the closed inputs of the commutator are very large. The voltage on capacities C1 is also large enough and the

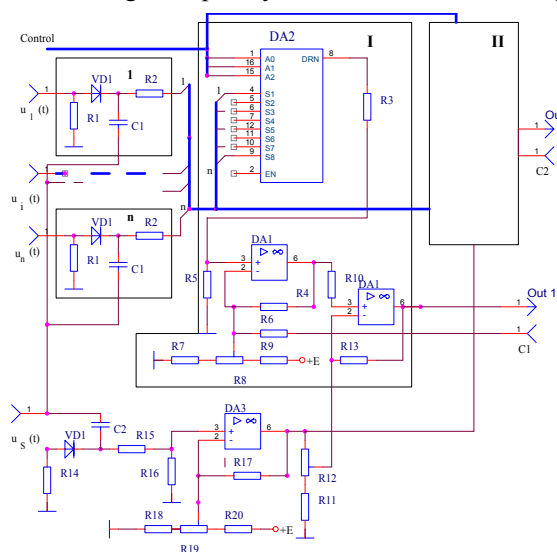


Fig. 1. Multichannel sampling converter with the commutator on an input

energy of sample impulses is not spent. The analysis has shown that in such converter simultaneous only two time scale transformation channels and the compensating mixer working simultaneously. Other channels remain in the mode of ideal peak detecting. Therefore, irrespective to a number of entry channels the generator of sampling pulses practically is loaded only with three working channels. The increase of entry channels up to 20 has not resulted in decrease of amplitude of sampling pulses. Therefore, the number of entry channels of a sampling converter may be much large.

On the basis of these reasons the original circuit of the tester for the measurement of propagation delay times in logical IC (Fig. 2) was developed.

The work of the tester consists in the following. The output pulses with the given frequency f_1 of quartz generator KG1 starts multichannel generator TPG. The number of outputs of the generator corresponds to a maximum number of tested inputs of a tested IC. It is possible to establish a sequence of test pulses with duration t_i and durations of a fronts t_f , or levels of logic zero U^0 or units U^1 on each output TPG changing a code of the control circuit CC. Outputs TPG are connected to inputs contactor inclusions of a tested IC. Thus, the control circuit establishes such code TPG that on inputs IC measurements required on the program levels of a voltage or a sequence of test pulses are established. Besides outputs TPG are connected to inputs of multichannel sampling head MSH.

Other information inputs MSH are connected to information outputs of IC (outputs of contactor). Thus, the number of inputs MSH should make to the greatest number of information inputs and outputs in series IC for which will be measured propagation delay times. Short sampling pulses on MSH act from the generator of sampling pulses SPG. Frequency f_2 of sampling pulses is determined by frequency of signal KG2. Thus transformation ratio of time scale is

$$q = \frac{f_1}{f_1 - f_2}, \quad (1)$$

where f_1, f_2 - frequencies of signals of the quartz generators KG 1 (TPG), KG 2 (SPG).

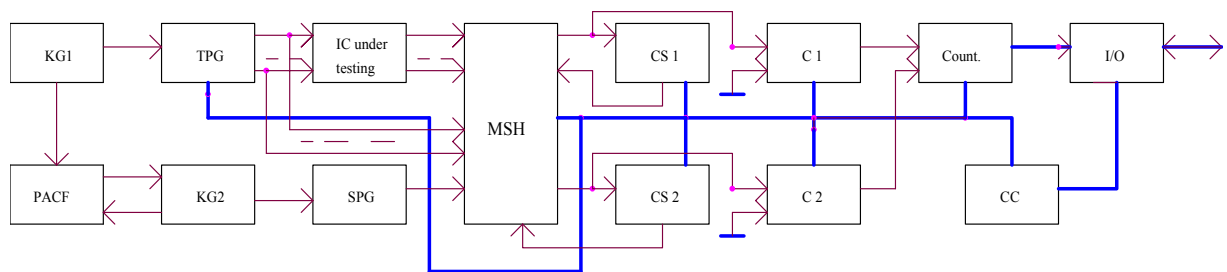


Fig.2. The block diagram of a multichannel tester of propagation delay times
 KG 1, KG 2 - quartz generators, PASF - the block of automatic phase frequency trim, TPG - the multichannel generator of test pulses, SPG - the generator of sampling pulses, MSH the multichannel sampling head, CS 1, CS 2 - circuits of adjusting of levels, C1, C2 - comparators, Count. – time interval counter, I/O - input - output circuit, CC - the control circuit

The code of management CC establishes two switchboards MSH so that on outputs tested signals in the transformed time scale between which acted will be measured propagation delay time. Target signals move on two circuits of installation of levels CS 1, CS 2 and two comparators C1 and C2. In CS 1, CS 2 levels of logic zero and units of tested signals on outputs MSH are determined and is developed voltage of management by levels of target signals MSH. These levels are adjusted so that the level of 0.5 amplitudes of output signals would be equal to zero. After that it is included measurements of propagation delay time. For decrease of random errors the result of the measured hold time averages from multiple measurements. Usually, at design of the tester it is not possible to receive identical delay between

different inputs and outputs of IC and inputs of channels of a sampling converter. In the tester digital correction of a systematic error originating at it is stipulated. The measured propagation delay time code from counter through an input/output circuit I/O moves on PC.

3. Results

Sources of errors of propagation delay times measurement are:

1. An inaccuracy and instability of installation of coefficient of transformation of a time scale;
2. Finite time of increase of a transient response of sample converters;
3. Inaccuracy of installation of levels of researched signals;
4. Drift output power of converters;
5. Reflections and disturbances generated in a measuring path;
6. Internal noise of converters;
7. Errors of the digital block.

Let's consider influence of these errors.

The measurement error of delay time is [3]

$$\delta t_T = \sqrt{\left(\frac{K_V f_1 \mathcal{J}_1}{(f_1 - f_2)}\right)^2} + \mathcal{J}_1^2, \quad (2)$$

where \mathcal{J}_1 - instability and an inaccuracy of frequency installation in quartz generator KG1, K_V - coefficient of influence.

In the tester quartz generators the use of the phase circuit of automatic frequency trim allows reducing this making error up to $\pm 0.1\%$.

The measurement error of propagation delay time because of finite increase time of a transient response arises only at different lengths of fronts of researched signals or different increase times of channel's transient responses. On fig. 3 dependences of measurement errors from fronts times and a transient response of converters [3] are shown. Apparently, this error of measurement does not exceed 2%.

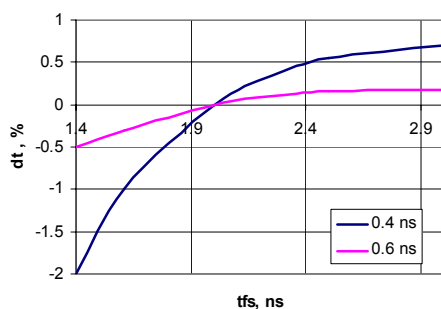


Fig.3. Dependence of an error of measurement on front time of output impulse IC

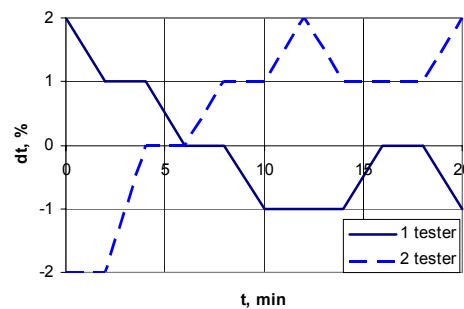


Fig.4. Short-term stability of measurement of times of delays of distribution

The error of measurement because of an inaccuracy of installation of levels of researched signals and drift of an output signal of a converter in the tester will depend on accuracy of operation of circuit CS. As shows the analysis, the error because of this component will not exceed 0.2%. As it was marked above, application of a multichannel converter has allowed to refuse measuring paths and to eliminate components of errors because of reflection and interference in a signal path.

In the tester multichannel compensating sample converters a level of internal noise 60...100 μV [4], and therefore the error because of internal noise is very small.

Two models of testers of measurement of logic circuits, triggers, registers, counters of a series 1590 are constructed and researched. Error of measurement of the calibrated segments of coaxial cables with delays times from 0.4 ns up to 18 ns did not exceed $\pm 3\%$, a difference the indications of researched models does not exceed $\pm 3\%$. On fig. 4 - 5 results of measurement of short-term and durable stability of results of measurement are shown. Apparently, the random error does not exceed $\pm 2\%$.

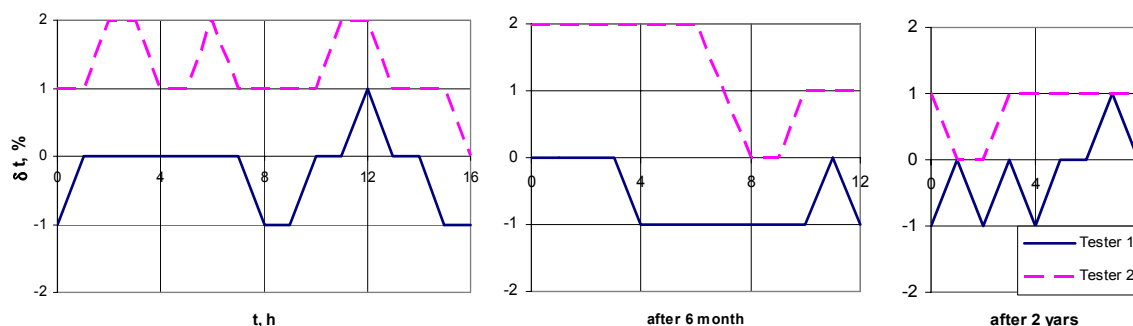


Fig.5. Long-time stability of measurement of propagation delay times

4. Conclusions

1. The application of multichannel sampling converters allows to design the simple testers of a fast speed logic circuits, registers, counters, amplifiers, etc. and to avoid the use of the high-frequency commutators.

2. The experimental results show, that the developed multichannel tester guarantees the measurement accuracy $\pm 5\%$ for a delay times of 1 ns duration.

3. The developed tester can be applied for measurements of propagation delay times of other fast logic circuits, for example, series 74AC, 74F, fast operational amplifiers etc.

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