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Propagation Delay Times Measurements of High-speed Digital ICs

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1. Introduction

The propagation delay times in the high-speed IC gates, triggers, registers, counters etc. shares of a nanosecond [1] 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 digital IC (especially, registers, counters etc.) manufacturing the check and certification of tens of propagation delay times between several tens inputs and outputs can be required. Usual sampling head have from two to four inputs and are supplied with special high-frequency multiplexer, 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. The high frequency channel multiplexer application 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. Subjects and Structure

We construct new propagation delay time tester for high-speed digital IC (Fig. 1). In the given tester the multi-channel sampling head [2] and drivers of the test pulses are applied. The given approach has allowed excluding high frequency multiplexer from the established and to exclude occurrence of significant reflections, distortions of the signals. The work of the tester consists in the following. The output pulses with the given frequency f_1 of quartz generator KG1 starts multi-channel generator of test pulses TPG. The number of outputs of the generator corresponds to a maximum number of tested inputs of an IC under testing. It is possible to establish a sequence of test pulses with duration t_i and durations of a front's t_f, or voltage levels of signal no U^0 or signal yes U^1 on each output TPG changing a code of the microprocessor μP. Outputs TPG are connected to inputs contactor of IC under testing and multi-channel sampling head MSH (inputs group *a*). For measurement of number *i*- parameter on corresponding outputs TPG the program of measurement from μP establishes voltages U^0, U^1 or sequences of test pulses. All information outputs IC under testing (outputs of a contactor) are connected to group *b* of inputs MSH. 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.

The new multi-channel sampling head MSH (Fig.2) work in a peak detecting mode with the small level of internal noise [3 – 5] and are the most suitable devices for propagation delay time tester with the multiplexer on an input. This sample head have a big transmission factor, and the measurement signal comes to capacity C1 in the transformed time scale. Therefore it is possible to include the low frequency multiplexer DA2 between C1 and capacity discharge resistance R5.

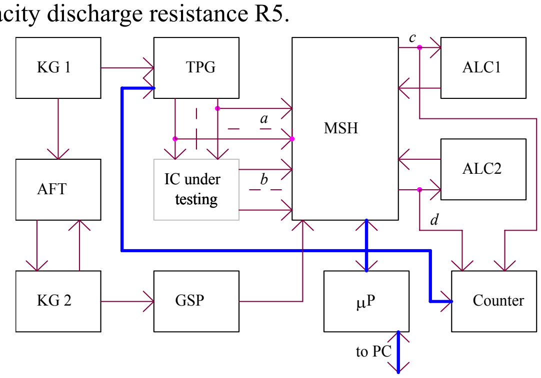

Fig.1. The block diagram of a multi-channel tester of propagation delay times. KG 1, KG 2 - quartz generators, AFT - the block of automatic frequency trim, TPG - the multi-channel generator of test pulses, GSP - the generator of sampling pulses, MSH the multi-channel sampling head, ALC1, ALC2 – level setting circuits, Counter – time interval counter, μP – microprocessor

The channel number *n* transforms the time scale, when the *n* input of a multiplexer 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 multiplexer are very large. The voltage on capacities C1 is also large enough and the energy of sample impulses is not employed. 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. Experimentally was established, that at connection to MSH 20 input channels yet it is not possible to measure reduction of amplitude sampling pulses. Therefore, the number of input channels of a sampling head may be much large.

Short sampling pulses on MSH act from the generator of sampling pulses GSP. Frequency f_2 of sampling pulses is determined by frequency of signal KG2. Thus transformation ratio of time scale is

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

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

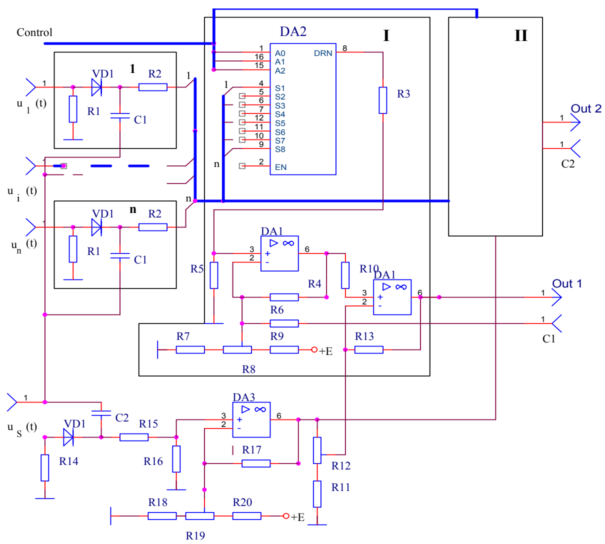

Fig.2. Multi-channel sampling converter with the multiplexer on an input

The code from µP establishes multiplexes DA2 in blocs I and II of a head (Fig.2) so, that on output there were two signals at the transformed time scale required for measurement of a propagation delay time.

Output signals transfer in two circuits of adjusting of levels ALC 1, ALC 2 [3] and Counter. In ALC 1, ALC 2 levels of signal no (U^0_{out}) and signal yes (U^1_{out}) of output signals MSH are determined and adjustment voltage move on MSH. These voltages it is adjusted MSH so that the level of output signals of equal 0.5 amplitudes would be equal to a zero. In the counter measurement of a time interval begins, when the level of signal c exceeds a zero and comes to an end when the level signal d is exceeded with a zero. For reduction of influence of random errors, measurement of delay time repeats 100 times. The measured result is remembered in memory µP, transmitted in PC, compared to the set norms of measurement. When the parameter does not correspond to the set norms measurement stops, µP gives out the information about not to validity IC. When the parameter corresponds to the set norms, µP generates a code of measurement of the following parameter. After measurement of all required delay times, µP gives out the information on validity IC.

Usually, at design of the tester it is not possible to receive identical delay between different inputs/outputs of IC and inputs of a sampling head. Digital correction of the systematic errors arising because of possible various delays of signals in measuring chain of a tester is stipulated.

Replacement of the contactor head, that simultaneously changes the program of measurement, allows passing easily from measurement of one type IC to another. Replacement of the measuring block allows passing from measurement gate IC to measurement IC of triggers, registers, etc., or IC others series.

The tester can be used for measurement of other dynamic parameters of IC. For this purpose only it is necessary to change circuits of adjusting of levels ALC 1, ALC 2 and to write the new program of measurement.

3. Results

Three types of testers for measurement ECL IC series 1590 (10H) have been constructed: for gates, for gates and decoders, and also for triggers, registers and counters. It has been constructed on two – three prototypes of each type of testers. Researches developed special contactor heads for IC under testing have shown good results. Maximal differences of researched signals delays in the heads did not exceed 0.5 ns. It is necessary to note, that the given differences of delays of signals during adjustment of a tester are measured, remembered in digital memory and at measurements of times of a propagation delay are automatically subtracted from the received results. Distortion of the researched signals caused by reflections and distortions in a line of transmission, past developed contactor heads to establish it was not possible.

The main sources of errors of propagation delay times measurement are:

1. An error of setting and instability of a coefficient of transformation of a time scale;
2. Final time of increase of a transient response of converters;
3. An error of setting of levels of test signals;
4. Drift of an output voltage of converters;
5. Reflections and disturbances generated in a measuring circuit;
6. Internal noise of sampling head;
7. Mistakes of the digital block.

Let's consider influence of these errors.

1. In circuits of sampling converters with two quartz generators, error of setting of a transformation coefficient and its instability depends on stability of quartz generators signals frequencies and, especially, from stability of a difference of these frequencies. The error of measurement of delay times

$$\delta t_T = \sqrt{\left(\frac{K_V f_1 \delta f_1}{(f_1 - f_2)}\right)^2 + \delta f_1^2 + \delta f_{1ina}}, \qquad (2)$$

where δf_1, δf_{1ina} – reduced instability and a reduced inaccuracy of frequency setting in quartz generator KG1, K_V - coefficient of influence.

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

2. For high-speed digital IC it is possible to accept, that front of a signal is linear, and character of change of the transitive characteristic – exponent. Dependence of an error of measurement of a delay time on final time of increase of the transitive characteristic, at duration of a test pulse front of 2 ns, durations of front of output pulses IC of 0.5 and 0.7 ns shown on figs. 3. It is obvious; that the error arises only in cases when duration of fronts of both signals it is various. The error of measurement of time of delay duration of 1 ns and duration of front of the transitive characteristic 0.2 ns, will make +2 %. It is necessary to note, that this error regular and can be excluded from result of measurement.

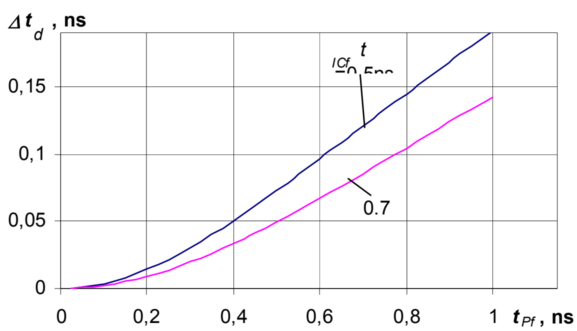

Fig. 3. Dependence of an error of measurement of a propagation delay time on time of increase of the transitive characteristic, when duration of fronts of the test pulse 2 ns

4. The error of measurement because of an inaccuracy of setting of levels of researched signals and drift of an output signal of a converter in the tester will depend on accuracy of operation and adjusting of circuit ALC. As shows the analysis, the error because of this component will not exceed 0.2%.

5. As it was marked above, application of a multi-channel converter has allowed to reduce measuring paths eliminate special high-frequency multiplexer, with coaxial cables segments and high frequency, tunable with a wave resistance of a cable, reed-relays or mercury relays and to eliminate components of errors because of reflection and interference in a signal path.

6. Used in a tester multi-channel sampling head have a level of internal noise 60...100 μV [4], therefore errors of measurement caused by internal noise will be small and they can be not taken into account.

7. Errors of a digital part usually a make 0.5 unit of the smallest bit and at it's correct designing usually does not bring appreciable errors of measurement.

Three types of testers for measurement of gate and triggers, registers, counters propagation delay times of IC series 1590 (10H) are constructed and researched. In testers frequency of test pulses 10 MHz, a range of measured propagation delay times are from 0.5 ns up to 50 ns is established. Experimental researches and pre-production operation of testers have shown good results. Accuracy of measurement of the calibrated segments of coaxial cables with delays times from 0.56 ns up to 18.3 ns did not exceed ±3%, a differences between the results of models does not exceed 3%. Work with testers has shown, that they have good reliability of measurements, and good accuracy and stability of results. On fig. 4 – 5 results of measurement of short-term and long-term stability of measurement results are shown. Apparently, the random error does not exceed ±2%. Time of measurement of one parameter makes 50 ms, without consideration IC installation time. Time of measurement of one IC, at measurement from 4 up to 32 parameters, makes from 0.2 ms up to 1.5 ms and can be in case of need reduced in 10 times.

Two types of pre-production models of testers have passed metrological certification and were used for reception control IC of a series 1590 before the end of their manufacture in firm "Venta". From figs. 4 it is visible, that the testers warm time does not exceed 3 – 5 min. From figs. 5 it is visible, that the automatic fine tunings of difference frequencies of quartz generators and levels of output signals of the sampling converter applied in testers have allowed receiving good long-term stability of measurement results.

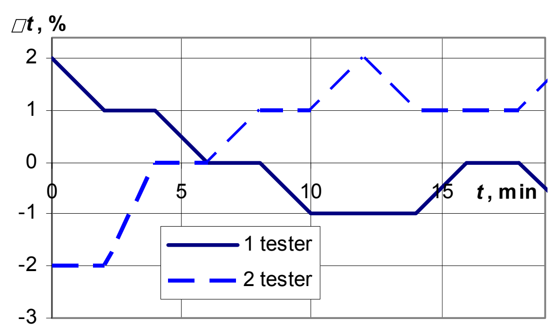

Fig. 4. Short-term stability of measurement of propagation delay times

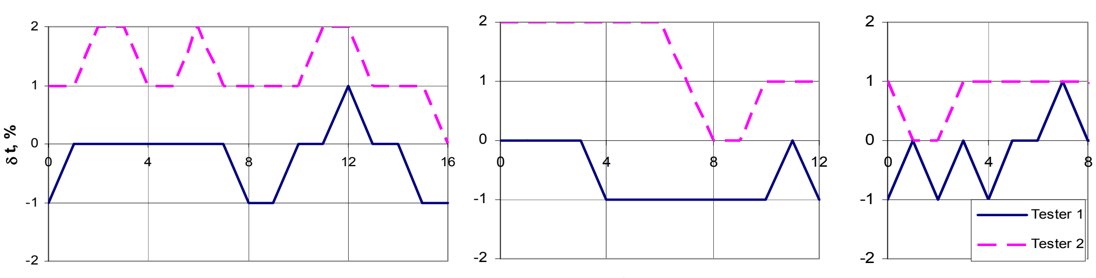

Fig.5. Long-time stability of measurement of propagation delay times

4. Conclusions

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

2. The experimental results show, that the developed multi-channel tester guarantees the measurement a propagation delay times a duration of 1 ns with accuracy no more ± 5 %.

3. The developed tester can be applied for measurements of propagation delay times of other fast digital circuits, for example, series 10H, 100E, 74AC, 74ALS and others fast gates, flip-flops, registers, counters, etc.

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V. Kvedaras, R. Kvedaras, Z. Jankauskas. Sparčių skaitmeninių IS sklidimo vėlinimo trukmės matavimas //Elektronika ir elektrotechnika. – Kaunas: Technologija, 2004. – 7 (56).-P. 33-36.

Nagrinėjamas naujas sparčiųjų skaitmeninių IS sklidimo vėlinimo trukmių matuoklis su daugiakanaliu stroboskopiniu keitikliu. Daugiakanalis stroboskopinis keitiklis – palyginti nesudėtingas įtaisas su žemo lygio savaisiais triukšmais buvo sukurtas naudojant stroboskopinio pikinio detektavimo keitiklio su dviem kvarciniais generatoriais schemą. Daugiakanalis keitiklis leido nenaudoti aukštadažnio komutatoriaus tarp tiriamosios IS ir matuoklio, supaprastinti matuoklio schemą ir padidinti jos tikslumą. Buvo sukurti ir ištirti trijų tipų testeriai. Testeriuose nustatytas bandomųjų impulsų pasikartojimo dažnis 10 MHz, matuojamos sklidimo vėlinimo trukmės nuo 0,5 ns iki 50 ns. Vienos IS matavimo trukmė priklausomai nuo matuojamų parametrų skaičiaus yra nuo 0,2 – 1,5 s ir gali būti sumažinta iki 10 kartų. Testerių eksperimentiniai tyrimai parodė gerus tikslumo ir matavimų trumpalaikio ir ilgalaikio stabilumo rezultatus. Sklidimo vėlinimo trukmių matavimo paklaida neviršija ± 5 %. Vieno parametro matavimo trukmė, neskaitant IS įstatymo trukmės, sudaro 50 ms. Il.5, bibl.5 (anglų k., santraukos lietuvių, anglų ir rusų k.).

V. Kvedaras, R. Kvedaras, Z. Jankauskas. Measurements of Propagation Delay Times of High-Speed Digital IC // Electronics and Electrical Engineering.-Kaunas: Technologija, 2004. – 7 (56).-P. 33-36.

The new tester for the measurement of the propagation delay times in high-speed digital IC by the use of multi-channel sample head is considered. The multi-channel 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. In testers frequency of recurrence the test pulses the equal 10 MHz, measured times of delays of distribution 0,5 – 50 nanoseconds is established. Time of measurement of one IC makes 0,2 – 1,5 s and depends on amount of measured parameters, and can be reduced up to 10 times. Experimental researches of testers have shown good characteristics of accuracy of measurement, shot-time and long-time stability of results of measurement. The measurement error of propagation delay times does not exceed ± 5%. Time of measurement of one parameter makes 50 ms, without consideration installation time IC. Ill.5, bibl.5 (in English; summaries in Lithuanian, English and Russian).

В. Квядарас, Р. Квядарас, З. Янкаускас. Измерение времен распространения задержки быстродействующих цифровых ИС // Электроника и электротехника. – Каунас: Технология, 2004.- №7 (56).- С. 33-36.

Рассматривается новый тестер для измерения времен задержки распространения быстродействующих цифровых ИС с применением многоканального стробоскопического преобразователя. Многоканальный стробоскопический преобразователь – довольно простое устройство с малым уровнем внутренних шумов был разработан на основе стробоскопического преобразователя работающего в режиме пикового детектирования с двумя кварцевыми генераторами. Разработаны и исследованы две модели тестера. В тестерах установлена частота повторения тестимпульсов равная 10 МГц, измеряемые времена задержек распространения 0,5 – 50 нс. Время измерения одной ИС составляет 0,2 – 1,5 с и зависит от количества измеряемых параметров, и может быть уменьшено до 10 раз. Экспериментальные исследования тестеров показали хорошие точностные характеристики и кратковременную и долговременную стабильность результатов измерения. Погрешность измерения времен задержки распространения не превышает ± 5 %. Время измерения одного параметра составляет 50 мс, не учитывая времени установки ИС. Ил. 5, библ.5 (на английском языке; рефераты на литовском, английском и русском яз.).

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