24th IMEKO TC4 International Symposium
22nd International Workshop on ADC and DAC Modelling and Testing
IMEKO TC-4 2020
Palermo, Italy, September 14-16, 2020

# Waveform recovery technique based on differential localization algorithm

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***Abstract –*** During the measurement of transmission delay time in Automatic Test System, influenced by the boundary condition, the echo was partially lost, which directly affected the measurement result. By using differential positioning algorithm and implementing a supplementary measurement, the lost echo signal can be recovered,and the result of transmission delay time measurement can be accurately given. Through experiments, this paper proved that the differential positioning algorithm is feasible, and the results are accurate.

## I. INTRODUCTION

The channel transmission delay time is an important contribution component of the measurement error of the integrated circuit AC parameters (time amount). Therefore, in the integrated circuit test process, the accuracy of the measurement results of all time parameters directly affects the measurement accuracy of the AC parameters of the test system[1-4]. At present, the most representative test channel transmission delay measurement technology is the time-domain reflectometry technology, which calculates the delay time caused by the test channel to signal transmission by measuring the arrival time of the reflected echo signal[5-7]. Therefore, the integrity of the echo signal is very important for the determination of the transmission delay time measurement result. In the actual measurement process, the boundary conditions of the test system will cause the signal in the 0~3ns interval of the initial stage of the test to be unable to be monitored. If the echo signal has arrived within this period of time, the first echo signal will be missed, and the arrival time of the second echo will be mistaken as the first echo, resulting in a serious deviation in the determination of the measurement result.

In the field of IC testing, the parameters of Digital IC are generally divided into DC parameters and AC parameters.The voltage and current parameters including logic level and power consumption current are classified according to DC parameters, while time parameters such as pulse width and delay time are classified according to AC parameters. The Automatic Test Equipment is usually used to test whether the parameters of IC meet the requirements of the datasheet, and to verify whether there are errors in logic and timing. When the number of pins of LSI reaches hundreds or more, it is difficult to design a multi-channel Automatic Test Equipment, the problem include the time synchronization and alignment of the multi-channel, which will affect the accuracy of IC AC parameter test, but DC parameter have no these problems. The main reasons for the time synchronization between multi-channel include the channel clock is not synchronized and the channel itself has transmission delay, among which the channel transmission delay is the main factor. Therefore, in the IC test industry, including Automatic Test Equipment manufacturers and IC testers, they attach great importance to the problem of transmission delay. After a lot of research, the problem of channel transmission delay of Automatic Test Equipment is finally solved, which makes the test rate of LSI test system break through from 200Mbps to 2gbps. This paper will describe the typical waveform loss and corresponding recovery technology in the process of measurement and correction of transmission delay time of test system.

## II. ECHO LOSS OF MEASUREMENT SIGNAL

The digital channel transmission delay measurement technology uses the existing resources of the digital channel of the integrated circuit test system. The drive end of the digital channel sends the test signal, and then reaches the end of the DIB channel after passing through the transmission path of the digital channel, producing a reflection with the same phase and amplitude. signal. The reflected signal returns along the original path and reaches the comparison end of the digital channel. The time interval between the incident signal sending out and receiving the reflected signal is the transmission delay time of the digital channel, and the digital channel completes its transmission delay time measurement[8,9]. The principle is shown in Figure 1:

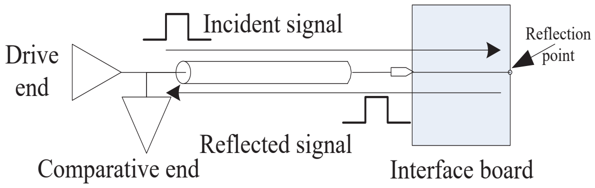

*Fig. 1. Schematic diagram of channel transmission delay measurement.*

For the selection of test signal, the best signal is the step signal, which has high signal energy and is not easy to decay in the process of transmission. The waveform of step signal is simple, and it is easy to separate the superimposed incident waveform from the reflected waveform. The pulse signal is the second best signal，the narrower the pulse, the higher the resolution. However, if the pulse is too narrow, it is easy to be attenuated and deformed. Automatic Test Equipment can not send and measure signals at the same time in one cycle, only one of them can be selected. This determines that the Automatic Test Equipment can only select the pulse signal as the test signal. Because if the step signal is selected, the test system can not receive the reflected signal.

The physical length of the digital channel of a general integrated circuit test system generally does not exceed 1m, and the use of a pulse signal with a pulse width of 2ns can meet the test requirements. The experiment uses Teradyne’s J750EX integrated circuit test system as a platform to measure the transmission delay of its test channel. Write the test program and configure the pulse high level to be 1.5V, the test period is 200ns, the pulse width is 2ns, the pulse start time is 198ns, and the fall time is 200ns; the echo signal is established by taking the test data points as shown in Figure 2:

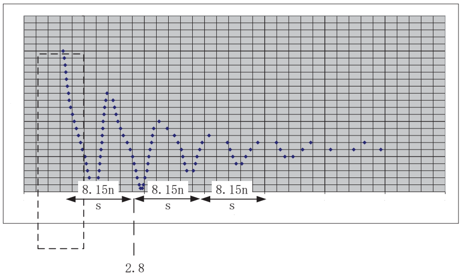

*Fig. 2. Waveform of echo signal.*

In the figure, there is obvious loss of waveform data in the dashed box on the left side of the echo signal. The lost data may contain the first echo or even the second echo. In the process of digital channel transmission delay time domain reflection measurement, the boundary conditions of the integrated circuit test system will cause the loss of echo data, which is called a blind zone, as shown in Figure 3. Due to the existence of the blind zone, a complete first echo pulse signal may not be received, leading to misjudgment of the measurement result.

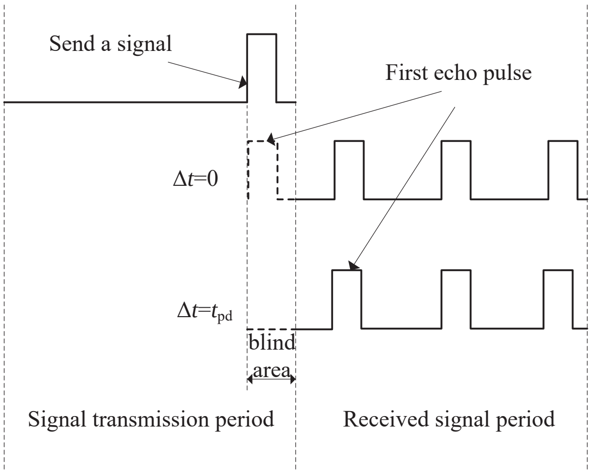

*Fig. 3. Blind area diagram.*

The test channel takes the test cycle as the unit, and the test channel in each unit can only complete one of the drive signal or comparison measurement signal functions, but cannot complete two functions in one cycle. This constraint depends on the test channel driving end and comparison end sharing the same time reference, as shown in Figure 4.

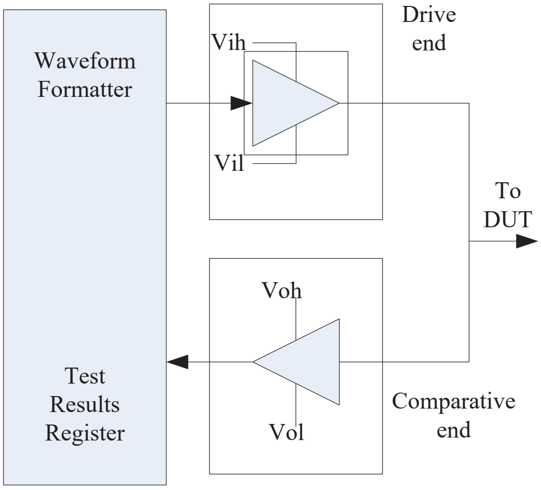

*Fig. 4. Digital channel driver / comparator architecture.*

Generally, for a test pulse signal, a signal time of at least 2ns is required to allow the pulse signal to rise to a certain amplitude and include enough capacity to meet the test requirements. This means that even if the test pulse drive time is arranged at the end of the cycle, until the next signal measurement cycle is entered, there will be at least 2ns that cannot receive the signal, that is to say, the dead zone time is at least 2ns. If the driving time of the test pulse is not arranged at the end of the cycle, it means a longer dead zone time, for example: 200ns test cycle, driving the pulse at the 196ns time, the last 4ns time period, the test channel comparison end cannot work, the dead zone The time lasts 4ns.

## III. DIFFERENTIAL POSITIONING ALGORITHM AND WAVEFORM RECOVERY

In order to solve the above problems, it is necessary to process the test data. The differential positioning algorithm is mainly used, which can make up the missing measurement signals[10-15], and extract useful signals from the multiple reflected signals for analysis to obtain the measurement results. The principle of differential positioning is shown in Figure 5, and the measurement of the channel transmission delay in the two states is performed respectively. The first state is that the test interface board of the integrated circuit test system to be calibrated is at no load, that is, in the state of open-circuit reflection at the terminal, the drive end (201) sends out a test pulse (207) at the set time t=t0, and the transmission and The reflection of the terminal, the echo signal (208) reflected multiple times is monitored by the comparison terminal (202). The time interval tPD1 between two pulses in the first group of echo signals (208) is the transmission delay value of the physical channel ; The second state is that the IC test system to be calibrated is connected to the delay line through the calibration adapter, and the delay line terminal is also in an open reflection state, the drive end (201) sends out a test pulse (207) at the same set time t=t0, The second group of echo signals (210) reflected multiple times are monitored by the comparison terminal (202). The time interval tPD1+tPD2 between two pulses in the echo signal (210) is the physical channel in the second state Transmission delay value.

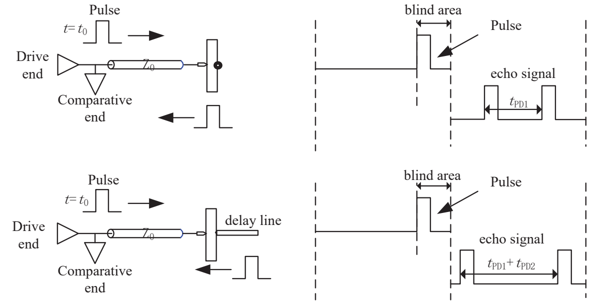

*Fig. 5. Differential positioning principle diagram*

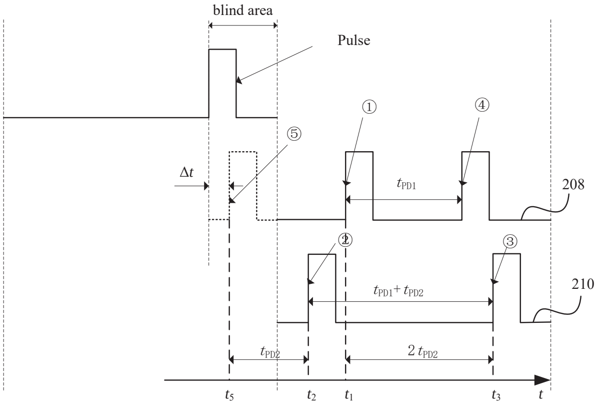

*Fig. 6. Schematic diagram of differential positioning algorithm.*

During the calibration process, the time to be measured is the arrival time Δt of the first reflected echo from the terminal reflection point. In fact, due to various reasons, the first pulse of the first group of reflected echoes measured cannot be The certainty is considered to be the first reflected pulse from the terminal reflection point. Through differential positioning calculation, it can be judged whether the first pulse of the first group of reflected echoes measured is the required first reflected pulse. If not, it can calculate and reconstruct the first reflected pulse. The calculation process is shown in Figure 6. Align the time coordinate axes of the first set of reflected echoes and the second reflected echoes obtained in FIG. 5. The time of the pulse ①in the first group of reflected echoes is t1, and it can always be found in each pulse of the second group of reflected echoes and only one pulse can be found. The time of this pulse just lags behind the pulse ①The time is an integer multiple of tPD2, namely tPD2 or 2tPD2, 3tPD2... Just find the pulse ③in Fig. 6, and the time t3 lags behind t1 is 2tPD2. At this time, it can be determined that both pulse ①and pulse ③are the second reflected pulses in their respective reflected echoes. Therefore, the time t1-tPD1 where the pulse ①is located is the time t5 where the pulse ⑤is first transmitted, and the time interval Δt between the pulse ⑤ and the test pulse is the actual channel transmission delay of the digital channel to be calibrated.

## IV. EXPERIMENTAL VERIFICATION ANALYSIS

According to the differential positioning algorithm, the waveform is restored, and the J750EX test system is used as the experimental platform. The parameters of the running test program are pulse start time d0=-6ns, pulse width 2ns, and amplitude VIH=3v. The receiving time starts from r1=0ns. The waveform shown in Figure 7 is obtained through two measurements:

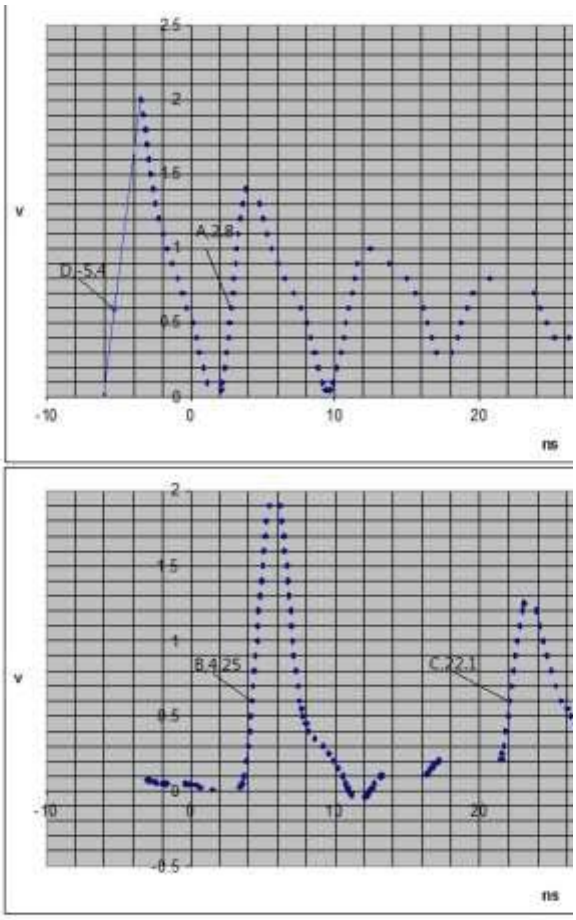

*Fig. 7. Differential positioning pulse waveform.*

The upper part of the waveform in Figure 7 is the No. 1 reflected wave, and the lower part of the waveform is the No. 2 reflected wave. Compared with the reflected wave of No. 1, the reflected wave of No. 2 is increased by a coaxial line with a delay of tpd2=9.7ns, which is connected to the channel through an SMA connector.

Due to the existence of the blind zone, it is uncertain whether the pulse at point A is the first echo signal pulse. By extending the channel tpd2, the first pulse of the reflected wave No. 2 travels by tpd2=9.7ns more than the reflected wave No. 1. The second pulse should be two tpd2 apart, 19.4ns, and so on... If point A and B are both the first pulse, the time of point B should lag point A by about 9.7ns, and the time between point A and B is 1.45 The time difference of ns indicates that the two points are not pulses in the same order. The difference between points A and C in the figure is 19.3 ns, and the pulse at these two points should be the second pulse. It can be deduced that the first pulses of the reflected waves of No. 1 and No. 2 are the previous pulse of point A and the pulse of point B respectively. Due to the existence of the blind zone, we can only take the part of the falling edge of the first pulse in the figure. The solid line part is the virtual waveform obtained through calculation. By comparing the entire waveform in the figure, it is easy to calculate that the 0.6V reference point corresponding to the first reflected pulse of the reflected wave in the figure should be the position of point D: -4.75ns.

## V. SUMMARY

In this paper, differential positioning algorithm is used to recover parts of the waveform of the lost reflecting echo signal due to the blind area, which solves the problem of inaccurate measurement of transmission delay time in the test channel of the test system affected by boundary conditions. The verification experiment is carried out in J750EX test system, and the experiment shows that the differential positioning algorithm can be realized in the test system, and the results basically meet the expectations.

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