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EMC ISSUES OF WIDE PCB BUSES

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A device under test with 17 coupled microstrip traces was constructed, built, and measured. It is shown that the near-end time-domain crosstalk waveform has a peak around the trailing edge, and the region of traces over which crosstalk must be considered extends over several adjacent traces.

1. INTRODUCTION

1.1. Crosstalk on multi-line interconnects

In terms of Electromagnetic Compatibility (EMC) concerns of digital equipment, one important limiting factor is crosstalk among coupled Printed-Circuit-Board (PCB) traces.

Digital systems today may have bus width of 64 bits and more. Crosstalk performance of PCB traces are usually described with only two signal traces. Assuming weak coupling and matched terminations on all four ports, the near-end and far-end crosstalk time-domain waveforms were described in the literature from the early years of computers [1], [2]. Investigation later covered also the frequency-domain description of crosstalk in two-wire and multi-wire digital interconnects [3], [4]. PCB interconnects and digital interconnects in Multi-Chip Modules, leadframes and packaging have much in common, their crosstalk description is similar [5], [6]. In multi-wire digital interconnects, the generalized description of time-domain crosstalk and coupling is based on the modal analysis [7].

Coupling and crosstalk among digital interconnects may be reduced in several ways. Besides to the obvious solution of increasing the separation between adjacent traces, it is possible to use divided dielectric layers in microstrip configurations [8], [9], adding grounded traces between active traces [10], [11], [12], and [13], or by making use of the additional periodical coupling and loading along digital bus systems [14], [15]. Other possibilities of crosstalk reduction includes the special shaping of microstrip traces, see e.g., [16].

1.2. Crosstalk behaviour of coupled microstrip traces

Crosstalk behaviour of microstrip and stripline buses differ mainly because of the different ratio in capacitive and magnetic coupling. Having homogeneous transmission medium in stripline configurations, the normalized capacitive and magnetic coupling have the same magnitude, hence far-end crosstalk in a two-wire matched interconnect is zero.

In coupled microstrip traces, however, the normalized capacitive coupling is less than the normalised magnetic coupling. This fact gives rise to non-zero far-end crosstalk in a two-wire matched interconnect. The nonhomogeneous propagation medium in microstrip interconnect also results in different velocities of the various propagation modes. The difference of the total propagation time of modes creates a time window around the trailing edge of the near-end time-domain crosstalk waveform, and the peak magnitude of the crosstalk waveform within this window can be significantly higher than the average crosstalk plateau. This phenomenon was described in [17].

This paper describes the measured results on a 17-line coupled microstrip bus structure in various configurations of active and passive lines both in the time domain and frequency domain.

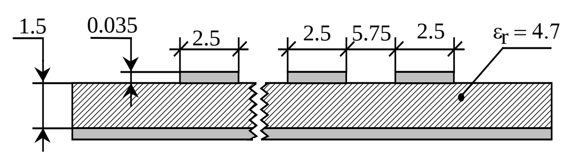

Fig. 1. Cross-sectional view of the Device Under Test with mechanical data.

1.3. Device Under Test

To measure the crosstalk performance of wide microstrip buses, a 17-trace printed-circuit-board test unit was built. The DUT was fabricated on FR4 material with an average low-frequency dielectric constant of 4.7. The two-sided PCB material had a thickness of 1.5 mm, and 35 microns of copper on both sides. The 2.5 mm wide traces result in an approximately 50-ohm trace impedance, which can be well matched to the measuring instruments. Edge-to-edge separation of the traces was 5.75 mm, which results in a low initial coupling between adjacent traces. The DUT can be considered as a 10-times scaled bus with a total length of approximately 2 meters. The scaled model makes it possible to investigate the crosstalk behaviour for both the near-end and far-ends below about 1000 MHz, where the losses and dispersion of the FR4 material are negligible.

To provide matched termination for all undriven traces, 51-ohm chip resistors were attached between the open ends and ground.

Figure 1 shows the cross-sectional view of DUT with dimensions given in mm. Figure 2 is the top view of DUT.

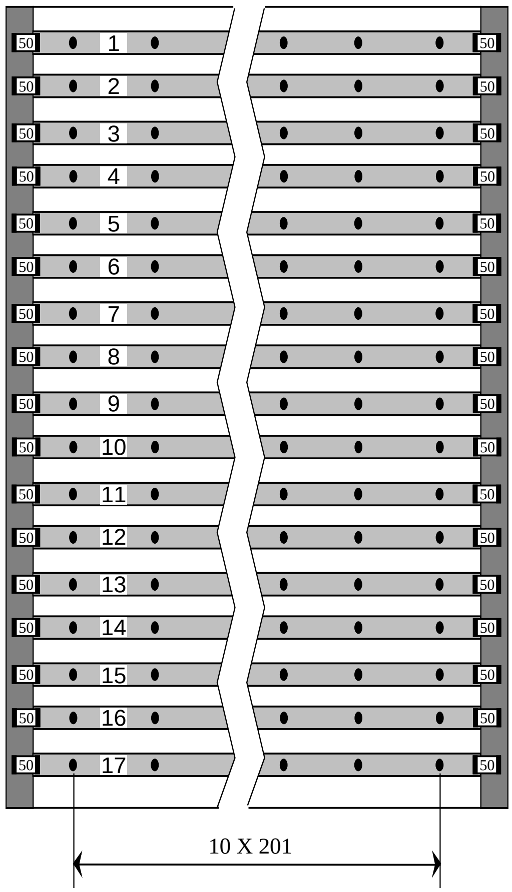

Fig. 2. Top view of the Device Under Test with mechanical data. At the end of each trace a 50-ohm leadless chip resistor was placed as termination.

2. MEASURED DATA

2.1. Crosstalk measurement with Vector-Network Analyzer

Figs. 3 through 8 show the crosstalk behaviour of the DUT measured with an HP8752A Vector-Network Analyzer (VNA). The VNA is suitable to measure the performance with one driven trace. The measurement setup is shown in Fig. 3. The driven line was #15 for all measurements with VNA. The equivalent time-domain stimulus at the input of DUT was a 1 V step with 1 nsec risetime. By connecting the input port of VNA to the near and far ends of traces, the transmission and crosstalk behaviour with one active line can be measured. Fig. 4 shows the reflection coefficient on line #15, with all nodes matched terminated. The measured reflection coefficient of +0.05 indicates that the trace impedance is approximately 55 ohms. The near-end crosstalk waveform of Fig. 5 has a plateau of about 12 mV, and a trailing peak of 16 mV. As it was reported in [17], the positive and negative peaks near the trailing edge of near-end crosstalk waveform are due to the different velocities of propagating modes. The far-end crosstalk waveform of Fig. 6 is according to the usual expectations. Note that the far-end crosstalk is large because the coupled section is very long. Fig. 7 illustrates the decay of crosstalk magnitudes in the time domain as we move the victim trace away from the active trace. The trace separation on the horizontal axis is shown in terms of line numbers, i.e., #1 refers to the line adjacent to the active line. The near-end crosstalk values show the level of waveform plateau, trailing peak is not included. Fig. 8 is an illustration of the time-domain trailing peaks and ringing in the frequency domain for four victim-line positions. Active (driven) line is #15. Note that the peak response around 500 MHz decays slower with line separation than the first peak at 19 MHz. The peak response at 19 MHz determines the time-domain plateau, the peak response at 500 MHz corresponds to the trailing peak in the time domain.

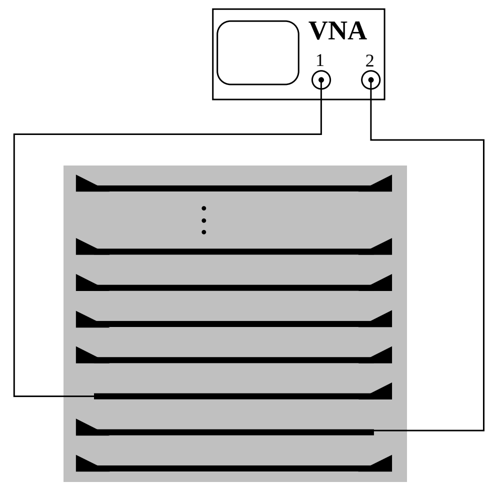

Fig. 3.: Measuring setup with VNA. Test port 1 of the VNA was connected to line 15 all the time, while the probe of test port 2 was moved to the near ends and far ends of measured traces.

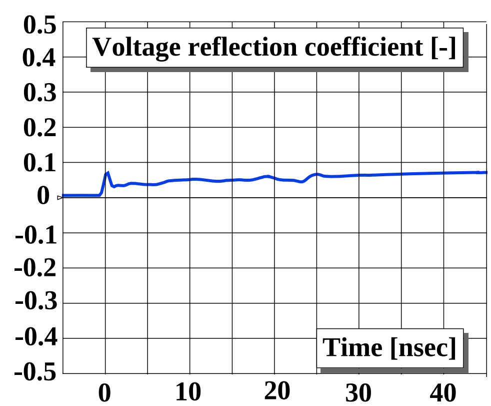

Fig. 4.: Voltage reflection coefficient on line #15.

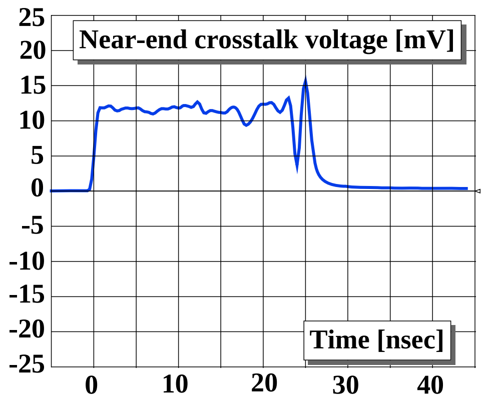

Fig. 5.: Near-end crosstalk waveform on line #14.

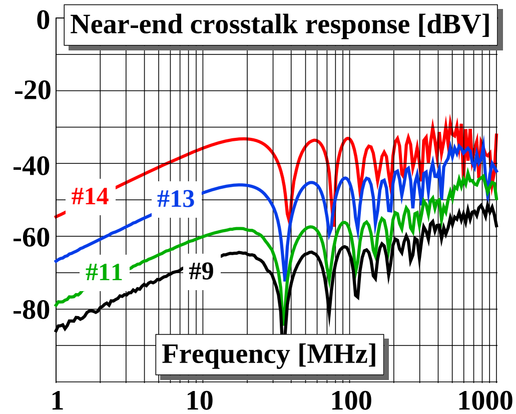

Fig. 8.: Illustration of trailing time-domain peaks in the frequency domain.

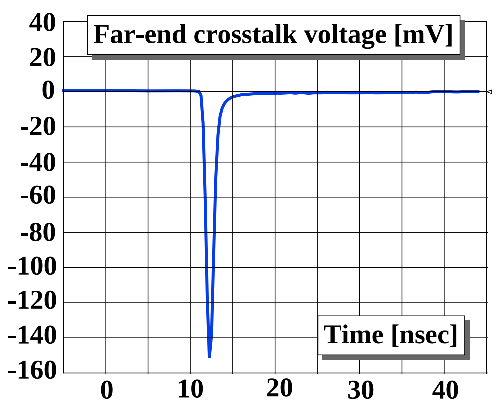

Fig. 6.: Far-end crosstalk waveform on line #14.

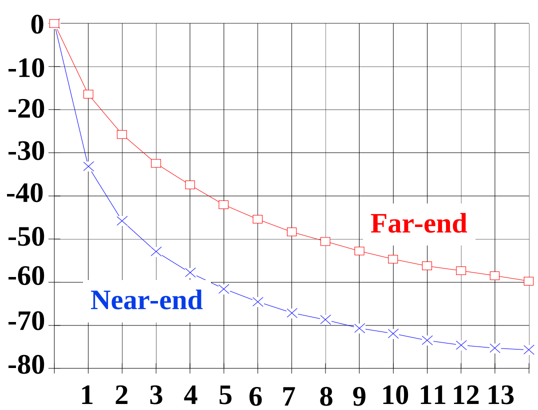

Fig. 7.: Decay of near-end and far-end crosstalk magnitude as a function of trace separation. Vertical scale: crosstalk magnitudes normalised to the input voltage (dB). Horizontal scale: trace separation between the active and measured passive lines in line positions.

2.2. TDT crosstalk measurement.

The actual usage of wide buses typically means that several of the bus lines may be active, and because of the low driver impedance, the driven ends of the lines are not matched. To investigate this Time-Domain Transmission (TDT) situation, a driver assembly was created, which contained a Texas Instruments 74BCT25245 octal driver. The driver has a specified low-state and high-state output current of 188 and 80 mA, respectively, which can generate a 2 V first-incident wave across a 25-ohm load. With the 50-ohm termination resistors connected to ground, the voltage swing on the active lines was 0.3 to 3 V. Driven lines were directly connected to the output of drivers, all other ports were terminated in 50 ohms. Two sets of measurements were carried out. For one set of measurements eight adjacent lines of the bus were driven, and the victim line was moved within the block of passive lines. The measurement setup is shown in Fig. 9. Another set of measurements used a fixed line position (#13) as victim line, and 2, 4, 6, and 8 active lines were driven symmetrically around the victim line. For this set up measurements, the measurement setup is shown in Fig. 10.

Figs. 11 through 13 show the crosstalk behaviour of the DUT measured with an HP54504A Oscilloscope. Measured output voltage swing with the given loads was 0.3-to-3V associated with a rise time of ten nanoseconds. Measured skew between any two driven traces was less than 0.25 nsec.

Figure 11 shows the crosstalk waveform with eight traces switching in one block, the victim line being the trace next to the block. All traces in the active block switch simultaneously, all traces terminated in 50 ohms.

Figure 12 shows the same arrangement, except the victim line is trace #2. Note that by moving the victim trace from next to the group of active traces to seven traces away, the peak near-end and far-end crosstalk magnitudes decrease by a factor of 18, and 13, respectively.

Figure 13 shows the near-end and far-end crosstalk waveforms with eight traces switching simultaneously symmetrically around trace #13.

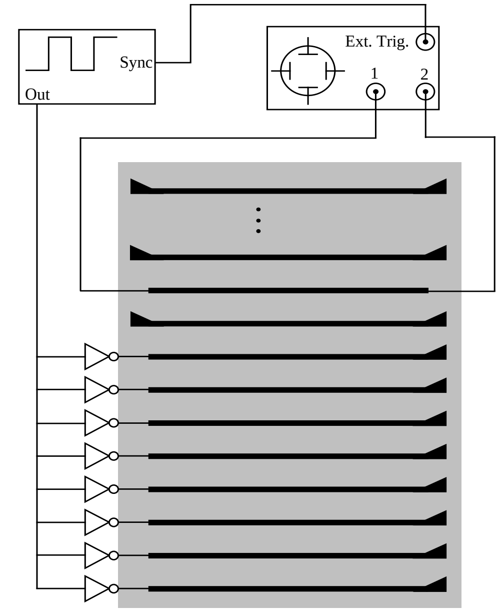

Fig. 9. Time-Domain Transmission measurement setup with eight adjacent traces driven simultaneously in one group. The victim trace was moved within the block of passive (undriven) traces.

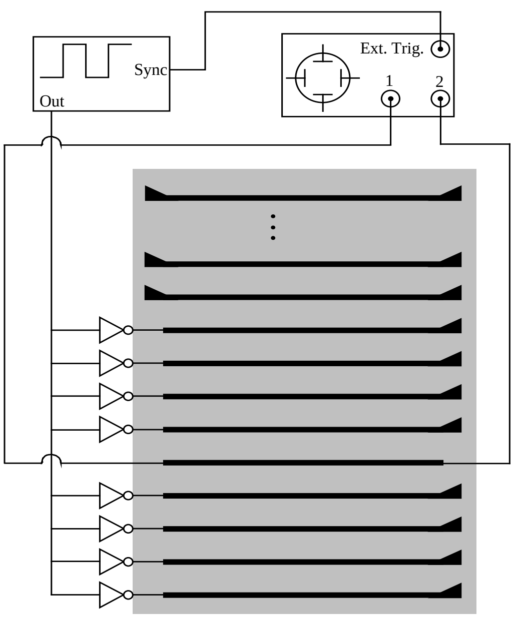

Fig. 10. Time-Domain Transmission measurement setup with fixed victim line. The octal driver enabled the measurements with two, four, six, and eight active traces driven simultaneously around the victim trace.

The peak near-end crosstalk voltage is 95 mV, peak far-end crosstalk voltage is -250 mV. For six, four, and two traces switching symmetrically around the victim line, the peak near-end crosstalk voltages are 95 mV, 80 mV, and 65 mV, respectively, the peak far-end crosstalk voltages are -250 mV, -250 mV, and -210 mV, respectively. When only one trace is active adjacent to the victim line, the near-end and far-end crosstalk voltages are 38 mV, and -160 mV, respectively. It can be concluded that for the given DUT, with reference to one adjacent victim line switching, the peak near-end, and far-end crosstalk voltages in a bus arrangement increase by a factor of approximately 2.5, and 1.6, respectively.

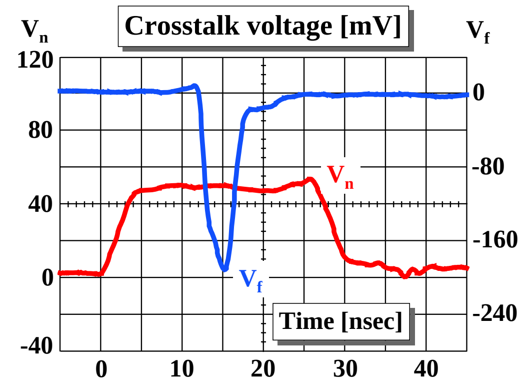

Fig. 11. Near-end and far-end crosstalk waveforms in the measurement setup of Figure 9. Active lines: traces 10 through 17. Victim line: trace #9.

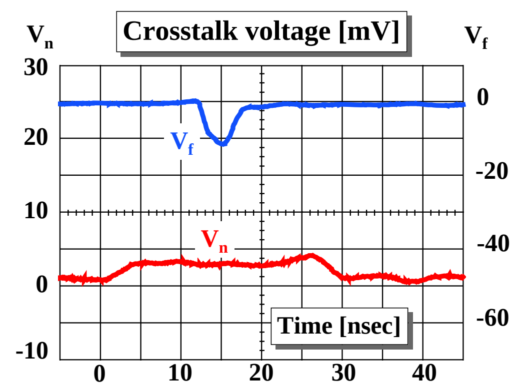

Fig. 12. Near-end and far-end crosstalk waveforms in the measurement setup of Figure 9. Active lines: traces 10 through 17. Victim line: trace #2.

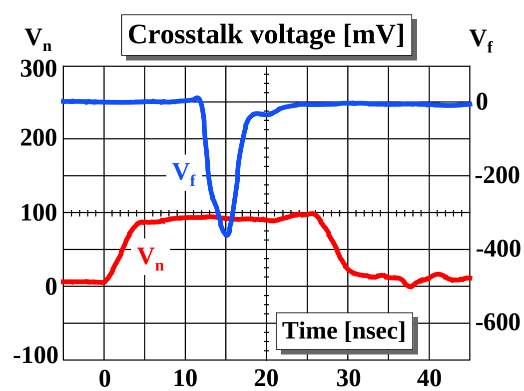

Fig. 13.: Near-end and far-end crosstalk waveforms in the measurement setup of Figure 10, eight active lines switching simultaneously.. Victim line: trace #13. Active lines: traces #9-12, and 14-17.

SUMMARY

It is shown that crosstalk in wide busses spread over several traces, and it is in general not sufficient to consider only a few adjacent traces for crosstalk analysis. A microstrip test device was constructed and measured in the time domain and frequency domain in various configurations.

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BIOGRAPHICAL NOTES

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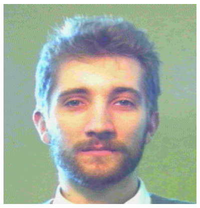

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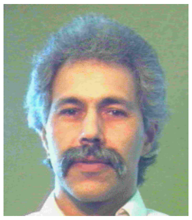

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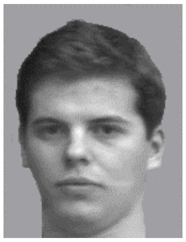

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