

DIAGNOSIS OF NON-SCAN EMBEDDED ANALOG CLUSTERS BY MEANS OF THE MIXED-SIGNAL TEST BUS

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Abstract: Analog clusters embedded within a larger design which is equipped with IEEE Std 1149.4 mixed-signal test bus are usually non-scan user-defined circuits. Diagnosis of them by means the test bus is a significant challenge.

Virtual probes created by analog modules of the bus impact on the results of measurement but it can be avoided by properly strategy of diagnosis. Possibilities of diagnosis by means of the bus are increased by different modes of the bus operation. They are particularly useful for diagnosis of extended clusters.

Test features of the bus can appear non-sufficient in the presence of variety, sensitivity and limitation of access to the nodes of extended nonlinear analog clusters. Application of analytical method of diagnosis is then necessary.

The paper presents and discuss the results of investigation of the virtual probes of the IEEE Std 1149.4 test bus and non-scan clusters by means of the test bus collaborated with the CIM 97 Multidiatest Measurement and Diagnostic System.

Keywords: diagnostics, mixed-signal test bus, analog circuit.

1 INTRODUCTION

In spite of the new testing tools and methods [1] the difficulties in diagnosis of analog circuit are still existing and are even bigger in complex devices where the access problem of the test equipment increase. One of the dominant solutions has used in technical diagnosis of the modern circuits is IEEE Std 1149.4 mixed-signal test bus ratified by IEEE Committee in June 1999. It provides a capability for diagnosis of analog parts of circuits.

The idea of the investigation of the mixed-signal circuit by means of the test bus is shown in fig.1. The IEEE Std 1149.4 (analog-digital) and IEEE Std 1149.1 (digital) compliant chips are used in design. They perform normal work mission and collaborate with the test bus.

Not all functions are integrated, so between the chips there are clusters of discrete components and devices. Clusters seldom include boundary-scan architecture due to the expense and complexity. They are non-scan embedded clusters. Diagnosis of them by the test bus is possible using the boundary-scan modules placed in the chips ("A" - analog and "D" - digital).

Clusters can be one or a few discrete components and also most complex and hard to testing circuits. Variety of analog circuits and sensitivity on introduction of a test probes into interior structure (possibility of the useful parameter destruction) cause that diagnosis of analog clusters by means of the test bus falls in some difficulties. Analytical diagnostic methods can support test bus.

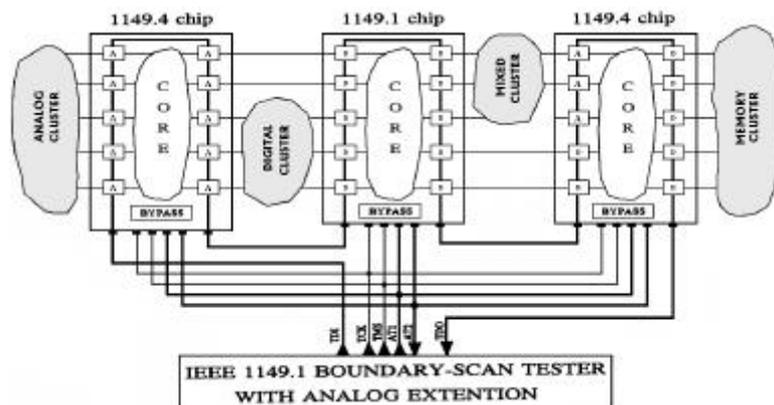


Fig.1. Mixed-signal circuit with test bus

2 ARCHITECTURE AND PERFORMANCE OF THE ANALOG VIRTUAL PROBES

The analog test structure of the bus built into the structure of chip is presented in the figure 2. It provides a link between the external AT1 and AT2 pins carrying signals to test equipment and pins of the chip.

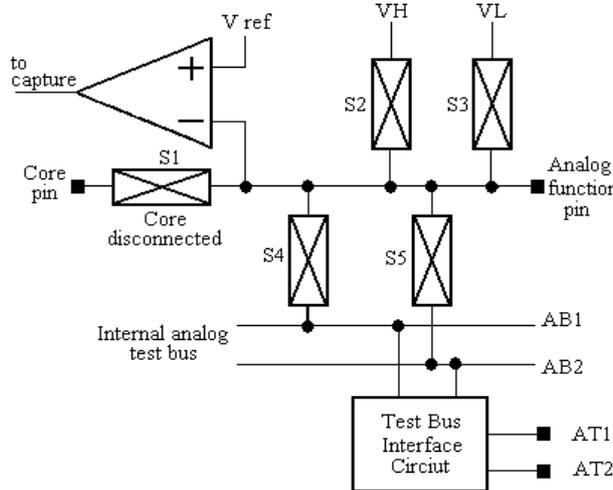


Fig.2. Conceptual view of the analog part of the IEEE Std 1149.4 mixed-signal test bus

The simplest analog test structure inside of chip consists of two internal bus lines (AB1, AB2). An optional extension (four lines) can be used for testing of differential signals. Test Bus Interface Circuit (TBIC) distributes analog signals passing through AT1 and AT2. The set of switches (S1 to S5) and comparator are placed between analog function pins and core of the chip. They are named Analog Boundary Module (ABM).

Switch S1 has core and analog function pin disconnect facility. S2 and S3 are associated with V_H and V_L corresponding to the two pins specific voltage levels. S4 and S5 provide the facility to use the internal analog lines: AB1 and AB2. One-bit digital information about the voltages appearing at analog function pins with respect to a reference voltage V_{ref} is captured and come in TDO signal.

Thanks to this structure AT1 and AT2 analog test ports of the bus can be connected to any analog function pin of the chip as the virtual probes.

Sometimes there are residual elements in structures of IEEE Std. P1149.4 compliant chip [2]. They stay connected to the analog function pins even while cores are disconnected by means of S1 switches of ABM. Structure, values and accuracy of the residual elements must be known for cluster investigations to correct results of tests.

Investigations of the probes in MNABST-1 IEEE 1149.4 test chips made by Matsushita Company [3] were done by means of CIM 97 Multidiatest Measurement and Diagnostic System designed in Technical University of Gdańsk [4].

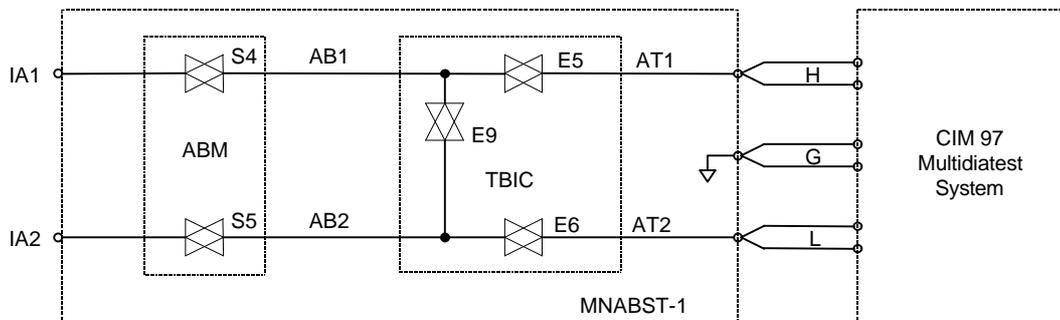


Fig.3. Diagram for investigation of the virtual probes

TBIC and ABM switches create two virtual probes presented in figure 3. E9 switch of TBIC is used for the bus calibration. IA1 and IA2 pins are analog function pins where cluster can be connected.

Resistance vs. voltage and frequency of these probes were measured in the two situations:

- "measurement" - E5, S4, S5, E6 switches are closed, E9 switch is open, A1 and A2 pins are shorted;
- "calibration mode" - E5, E6, E9 switches are closed, all others are open.

The results of measurements of resistance vs DC voltage are presented in Figure 4 and 5. TBIC and ABM switches of MNABST-1 are made as quad analog switches. S - two external signals control their resistance. Values of the switches' resistance gave by the producer are: S00-100 Ω, S01-400 Ω, S10-1.6 kΩ, S11-6.4 kΩ. Measurements were done for different control signals.

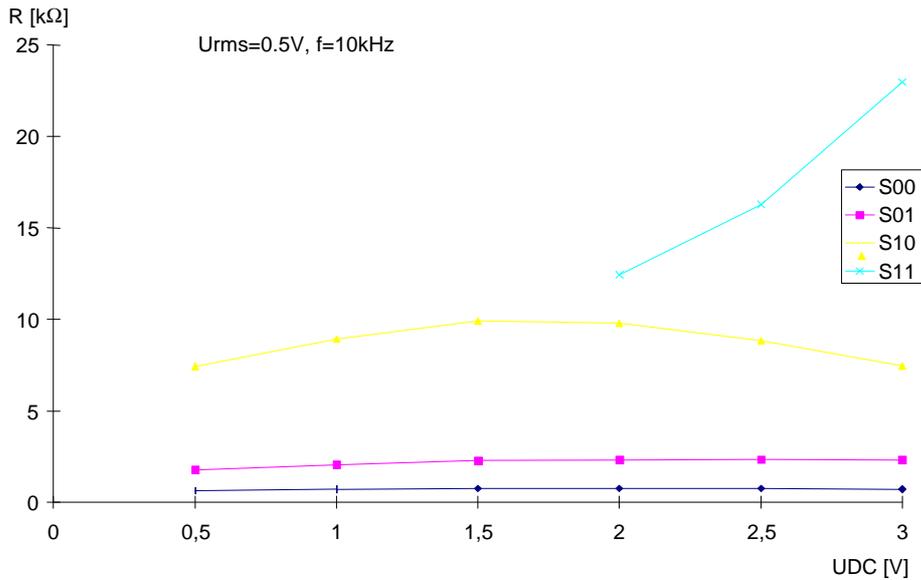


Fig.4. Resistance of the analog virtual probes vs DC voltage

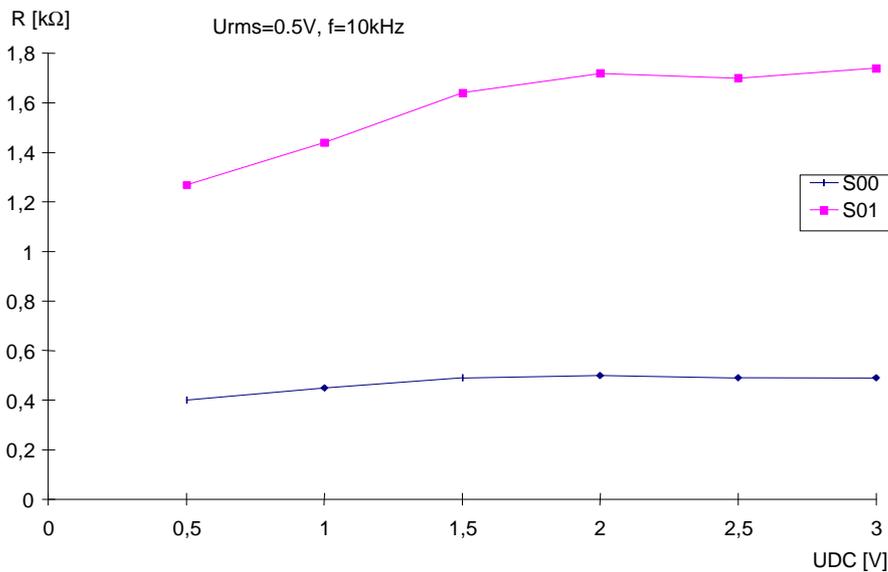


Fig.5. Resistance vs dc voltage of the analog test bus in calibration mode

The results of investigations have shown that the probes have resistance comparable with the resistance of clusters' components. Values of resistance depend on the DC voltage levels, which appear on the switches (dependence on AC voltage was not so visible). This situation needs special measurement method independent on changes of probes' resistances.

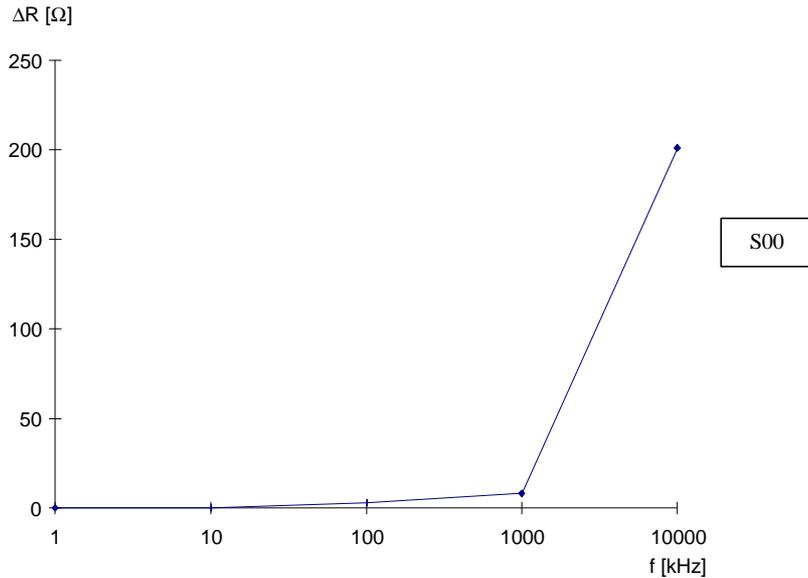


Fig.6. Change of resistance vs frequency of the analog virtual probes created by test bus

The results of investigation of probes' resistance vs frequency show that measurement frequency must be limited because parasitic inductance appears as dominant above some values of frequency.

3 DIAGNOSIS OF DISCRETE COMPONENTS

Testing for presence and value of discrete components is done in EXTEST mode of the bus operation where S1 switches of ABMs are open (cores are disconnected from clusters). Analog virtual probes created by TBICs and ABMs of the bus provide link between the Diagnostic System and Clusters. Location of clusters' components is determined by positions of boundary-scan cells used in tests.

Variations of resistance of bus probes with voltage have caused that the principle of discrete component's measurement is a current stimulus at AT1 and voltage measurement at AT2. Leakage and non-linear distortions of the probes are small [5]. In most practical cases, probes have resistance comparable with impedance of the CUT. It limits the stimulus current that can be forced in the CUT.

Investigations of discrete resistances have been done using MFC 1141.1-(A) Boundary Scan Tester Cascon with A/D and D/A unit (made by Goepel Company) which collaborated with programmable current source. Accuracy of measurement of the resistor values in the Multi Chip Model were 0.2% to 6.3%, according to the forced current (1mA to 0.125mA respectively) [5]. In spite of auto-correction of the bus by means of TBIC, accuracy of current force in investigated components was worse than accuracy of voltage measurement.

C and L discrete components were investigated by CIM-97 Multidiatest Measurement and Diagnostic System (designed in Technical University of Gdańsk) [3] which contain the HP4192A Impedance Analyser.

Substitute diagram of measurement circuit of Zx discrete component is presented in figure 7. Parasitic elements having impact on accuracy of measurement are visible. Input resistance of CIM-97 Multidiatest System is not shown because is eliminated by application of Kelvin contacts. Ccom is non-omit input capacitance of CIM-97. Z1 and Z2 are impedances between lines of the analog bus and ground of measurement circuit. Influence of them is eliminated during measurement by using of the special input stage of CIM-97 which opens the triangle of impedances created between H, L, G nodes.

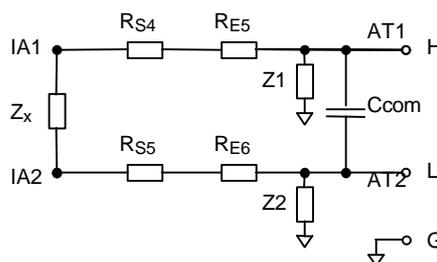


Fig.7. Substitute diagram for measurement of Zx discrete component

For example, the results of measurements of 10 nF capacitor are presented in figure 8. The results of measurements of 2,31 mH inductor are shown in figure 9. They are done in series and parallel substitute diagrams of Z_x .

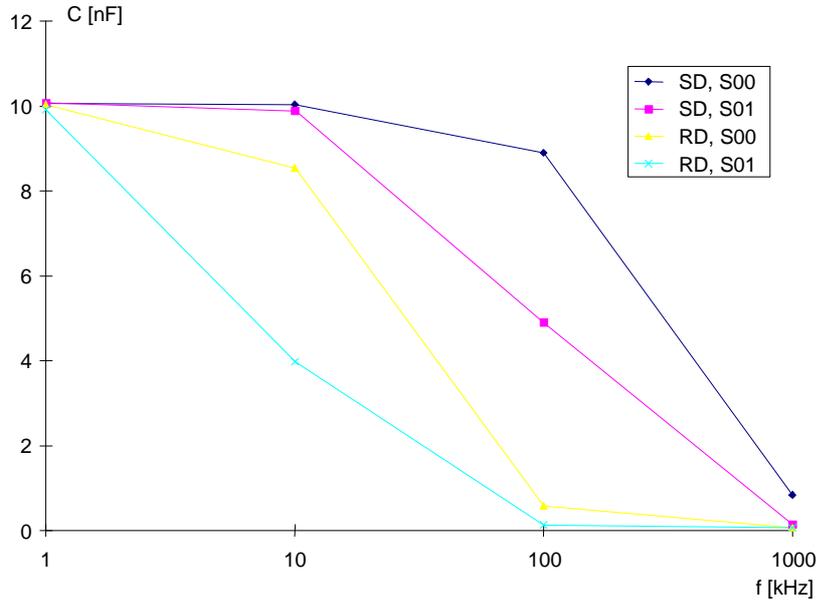


Fig.8. Results of measurement of $C = 10$ nF capacitor in series (SD) and parallel (PD) substitute diagram for different values of the analog bus switches (S00, S01)

The results have shown that measurement accuracy is better, if series substitute diagram of capacitance is chosen. In that case, the influence of switches' resistances of the bus is eliminated because imaginary part of impedance is separated in measurement process. Efficiency of the elimination depends on relation of Z_x impedance modulus to summarized switches' resistance (K coefficient). Advantageous situations are for $K > 1$.

Measurements in parallel substitute diagram are possible, if $K > 100$. For example, measurement results of 33 pF capacitor were correct for frequency of signal from 1 to 10 kHz, for series and parallel substitute diagrams and for all values of switches of the bus.

Optimization of K is possible by matching low measurement frequency and small resistance of switches. Lowering of frequency is limited because of disturbances have caused by control signals of the bus (analog and digital grounds of the bus are common).

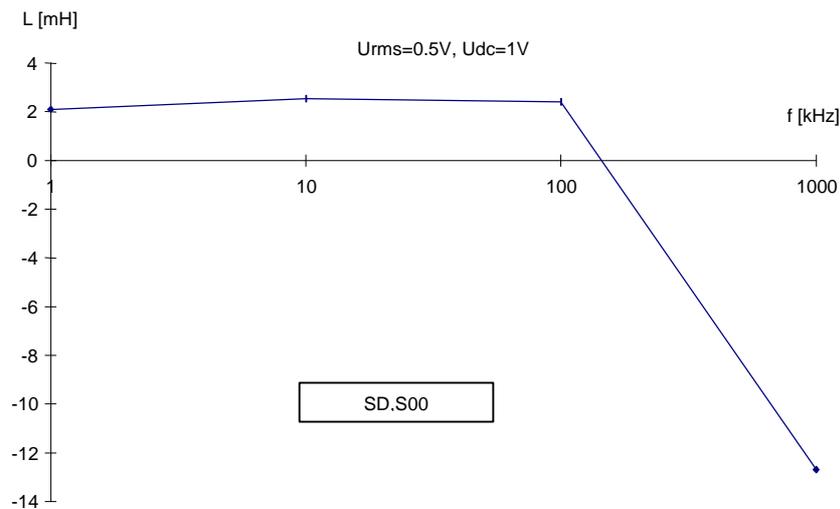


Fig.9. Results of measurement of $L = 2.31$ mH inductor in series (SD) substitute diagram

Above suggestions are correct for measurement of inductance (fig.9), except that measurement frequency should be matched as high as possible for increase of the K coefficient value. In practice, frequency of measurement signal is limited by value of the input capacitance of measurement equipment, what is visible in figure 9. Measurement frequency for CIM-97 System should be below 100 kHz.

4 DIAGNOSIS OF EXTENDED CLUSTERS

In order to shorten product development cycles for electronic systems, a growing trend is to use of pre-designed chips which are „fixed” and re-using. It is expected that IEEE Std 1149.4 conformant chips first of all will be of these types. The user-defined circuits are usually non-scan analog clusters.

Diagnosis of extended clusters by means of the mixed-signal test bus is difficult task because of a few reasons. On the first, in practice they are nonlinear, as the most of the analog circuits. On the second, access of the bus to their nodes is limited.

Apart from two (single or differential) analog measurement lines the mixed-signal test bus offers a few operation modes which help to solve these problems. BYPASS operation mode provides hierarchical approach to diagnosis and selection of the parts under testing. EXTEST operation mode gives possibility of partitioning of circuit on testable macros. In PROBE operation mode clusters can be test in their normal work configurations when are connected to cores. RUNBIST operation mode can be used for the co-operation of the bus with built-in self-test circuits placed in clusters.

Mentioned features of the bus in circuits' partitioning and a good accuracy of voltage measurements have been confirmed during investigations of the experimental models [5] lead to conclusion that verification method and the piecewise linearization (PWL) approach [6] should be elected for investigation of the extended nonlinear clusters. The research version of the CIM 97 Multidiatest Measurement and Diagnostic System possesses these possibilities [4].

5 CONCLUSIONS

Investigations have shown that structure of the bus impacts on the result of measurements but accuracy of measurements can be improved by proper strategy of diagnosis. Co-operation of the test bus with CIM-97 Diagnostic System gives possibilities of measurement impedance of discrete components in remarkable area of frequency. For diagnosis of extended clusters, partitioning of cluster on testable macros by modules of the test bus and co-operation with Diagnostic System using analytic methods appears necessary.

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