### 1. Introduction & Background

**WHAT IS SIGNAL INTEGRITY (SI)?**

**WHY DOES IT MATTER?**
- SI is a set of measures of the quality of an electrical signal
- Present problem:
  - High-speed digital systems with sufficiently high clock frequencies create SI problems & cause device malfunctions

**GOAL:**
- To ensure reliable high-speed data transmission

**TIMING:**
- Interconnections affect timing budget that divides out and allocates one cycle of a clock to all the various operations

**NOISE:**
- Electrical properties of interconnects affect the waveform of digital signals.

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### 2. Ongoing Research

- Signal integrity problems in the design of high-speed serial communication devices
- SDE-based variance simulation in transmission line models with random excitations.
- Approaches to derive and generalize approximate formulas of NILT methods for solving differential equations and nonlinear circuits.
- Analysis of interconnects and high-frequency circuits up to 20 GHz
- Analysis and optimization of high-speed serial links up to 16 Gb/s
- The project connects to research activities of the Analog and Digital Systems of the SIX research center, FEEC BUT in Brno.

### 3. Research Plan

- The aims of the research are divided into the following work packages

- **WP1**
  - Research of mathematical models of interconnects based on RLCG lumped elements and their solution
  - Laplace transform techniques will be improved including numerical inversion of the Laplace transform (NILT)
  - Innovative techniques including SDE approach for delay estimation, sensitivity and worst-case analyses.

- **WP2**
  - Research of mathematical models for distributed-parameter-defined interconnects and their solution
  - Innovative approaches to the solution of PDEs describing lossy coupled multiconductor transmission lines (MTL)
  - A new approach for interconnect parameters variability analysis based on partial SDE’s will be elaborated.

### 4. Expected Findings

#### 1. YEAR 1
- Improved novel techniques of lumped-parameter interconnect models solution
- Parameters variability assessment based on ordinary SDAEs
- Improved pre-emphasis, equalization techniques and orientation measurements.

#### 2. YEAR 2
- Improved or novel techniques of distributed-parameter interconnect models solution
- NILT and FDTD improved and/or novel techniques
- Initial results from the field of partial SDEs and fractional-order DEs and nonlinear interconnects analysis
- Improved CDR techniques for high-speed transmissions and its VHDL implementations

#### 3. YEAR 3
- Improved multivariable NILTs
- Nonlinear interconnects analysis based on Volterra series and n-dimen-sional LT approaches and evaluation of approaches based on partial SDEs and fractional order DEs
- Compare the theory with the real results of the measurements on interconnects and experimental verifications.

### 5. Research Objectives

#### 1. OBJECTIVE - MATHEMATICAL MODELS
- Research on RLCG lumped element models
- Using transmission-line theory for interconnects solution
- Research of MTL systems variability analysis based on stochastic ordinary and partial differential equations
- Further research on NTL using NILT with the use of Volterra series expansion

#### 2. OBJECTIVE - PRACTICAL MEASUREMENTS
- Simulation credibility by comparing the theoretical with the real results of the measurements on interconnects.
- Development of CDR algorithms that feature some unique parameters and are a perspective for the use in high-speed communication protocols
- Reduce the negative effects of dielectric losses or skin effect of interconnects