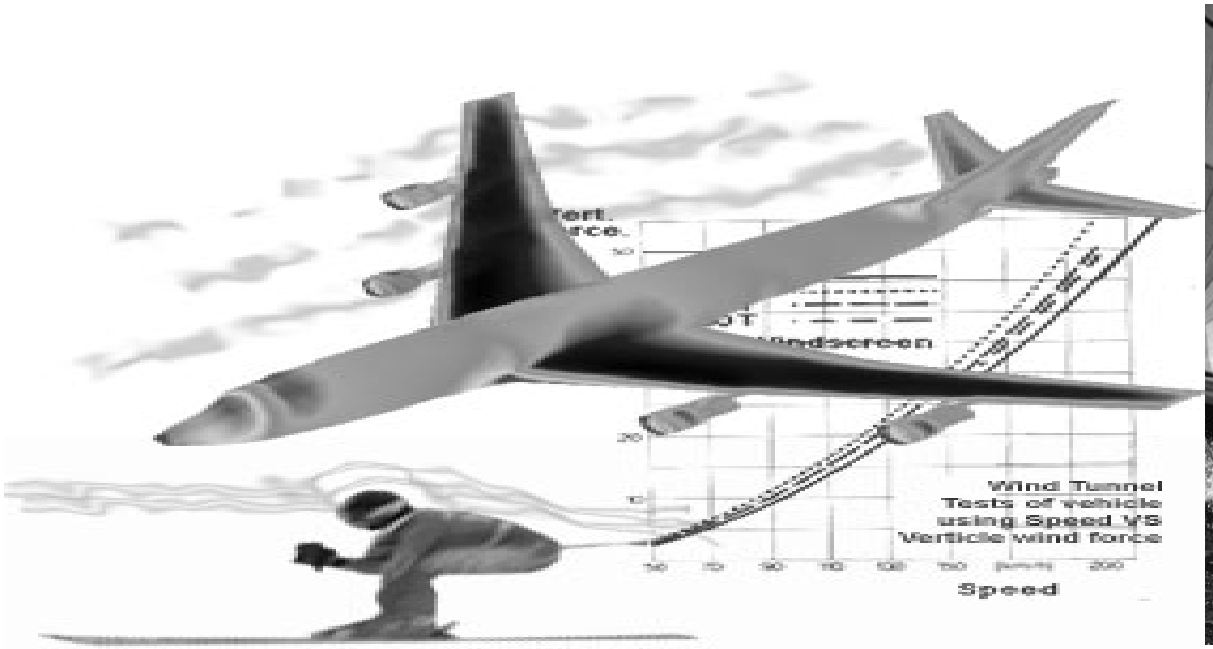
Wide Area Distributed Pressure Sensors

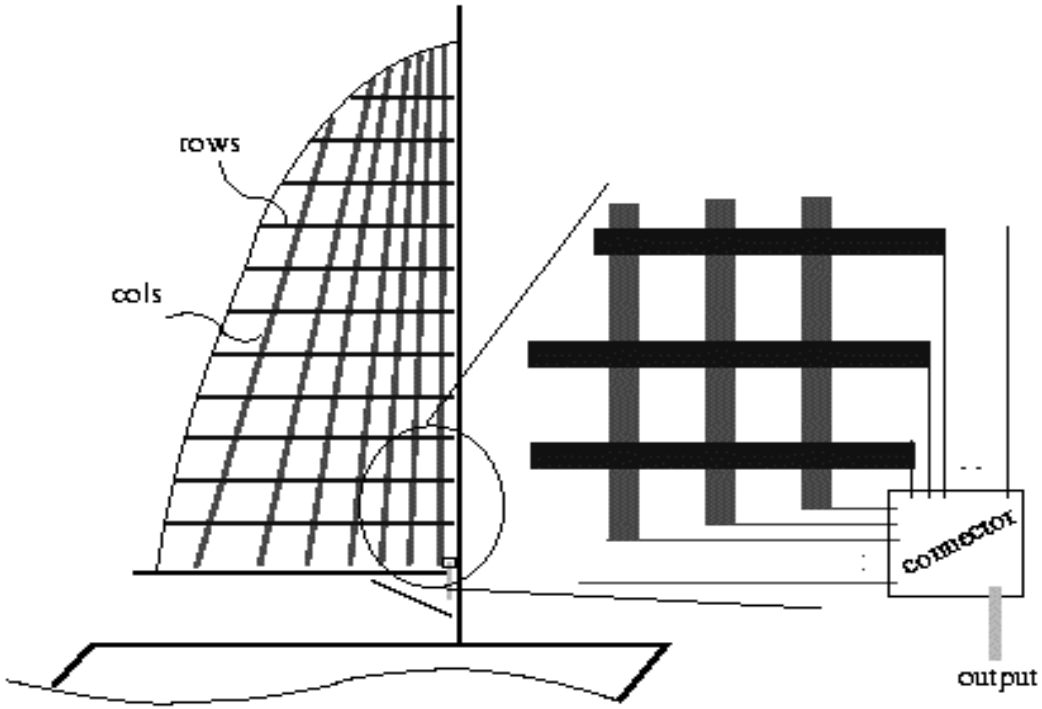
Bologna, May 24th 2002

Wide-Area Distributed Pressure Sensors



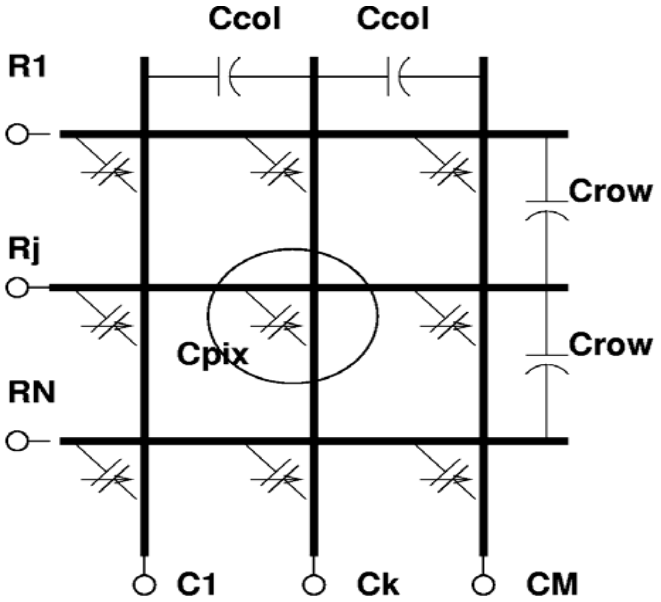
- Array of smart sensors for real-time monitoring of very large-area extended pressure fields

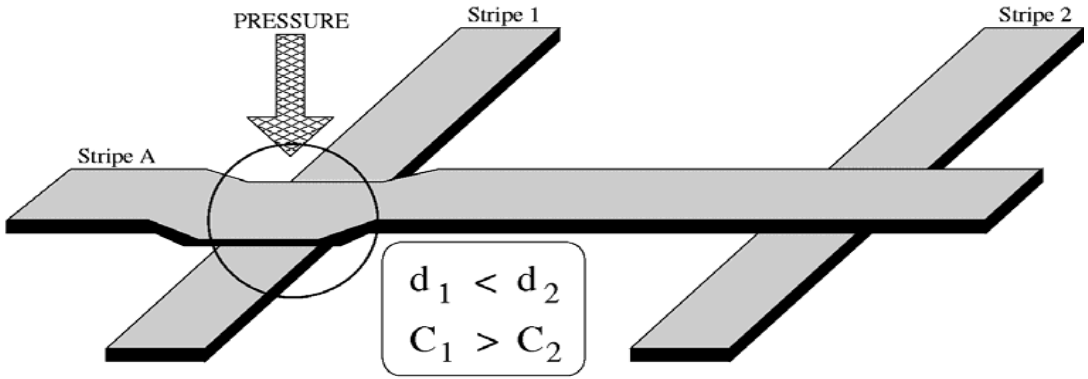
Possible Application: E-Sail Project



- Array of Capacitive Pressure Sensitive Sensors
- Sail Trimming for Best Performance

BASIC IDEA





$$C_1 = \varepsilon \frac{S_1}{d_1} \qquad C_2 = \varepsilon \frac{S_2}{d_2}$$

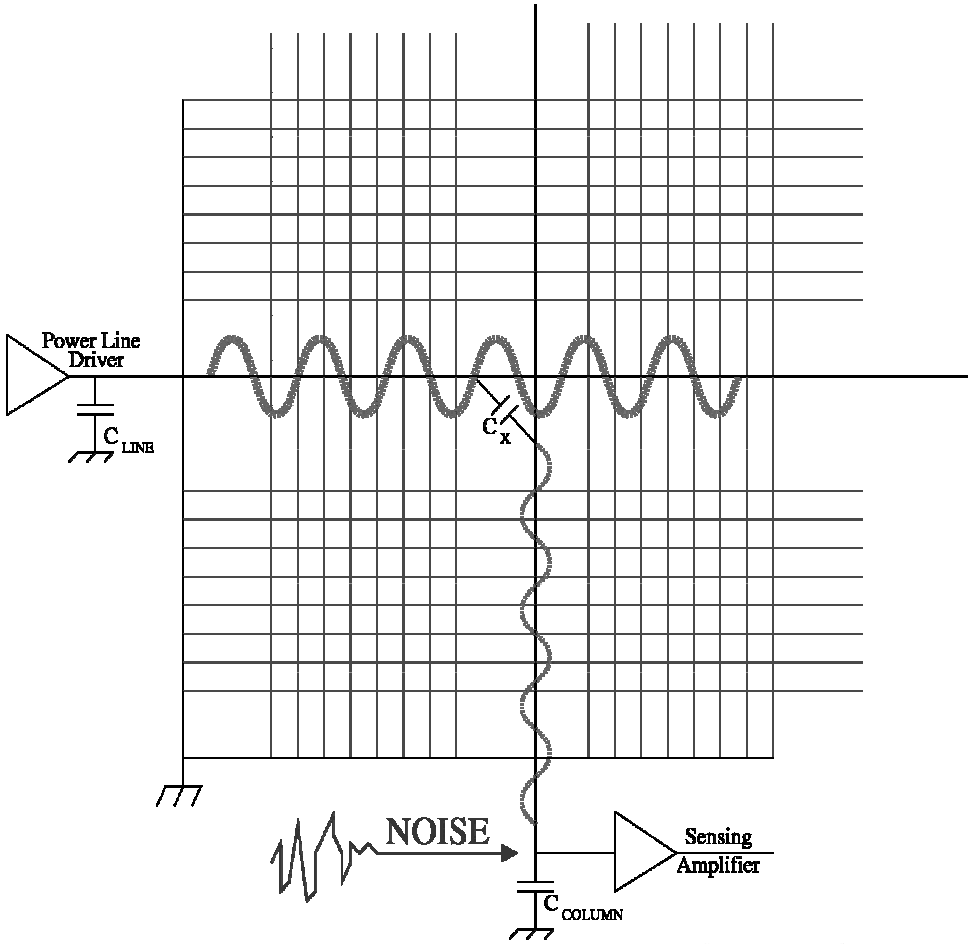
- Distributed array of passive sensing elements
  - Conductive threads separated by an elastic insulator
- Capacitive sensing
  - Charge/voltage conversion

SYSTEM LEVEL ISSUES

- Parasitic capacitances
  - 1-3 order of magnitude greater than sensed cap.
- Long distance
  - Transmission lines
  - Electromagnetic interferences
- Unobtrusiveness
  - Reduced number of I/O

FAR & SMALL CAPACITANCE MEASURE

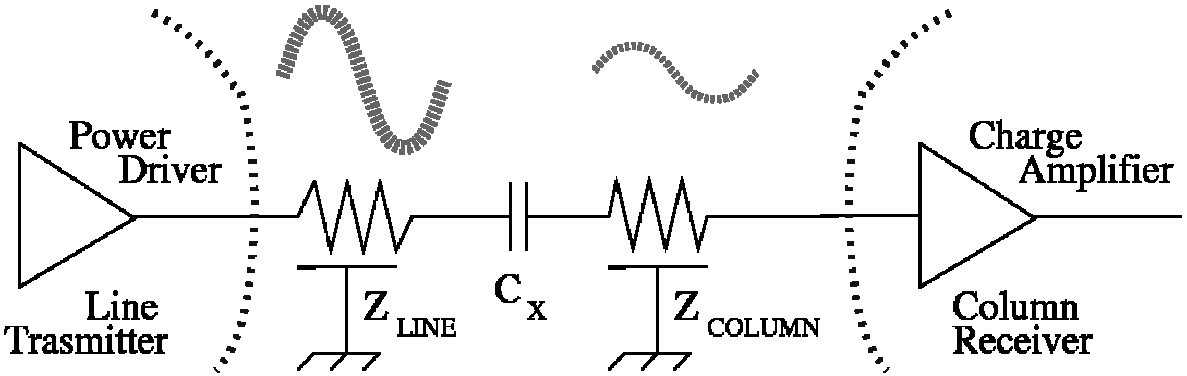
- Sensing strategies:
  - Sine function through C_X
  - Unselected lines grounded
- Sensing problems:
  - Heavy C_{ROW} driving
  - Long line propagation & R-C effects
  - Precise evaluation of $C_X << C_{COL}$
  - Crosstalk and noise effects

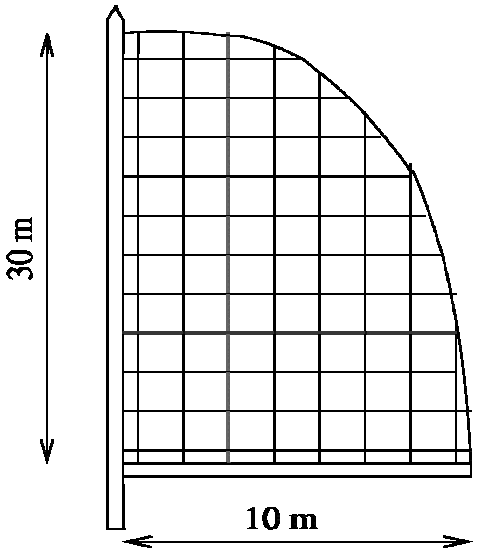


SIGNAL PATH MODEL

Simplified model:

- Wave Stationary
- Negligible L effects

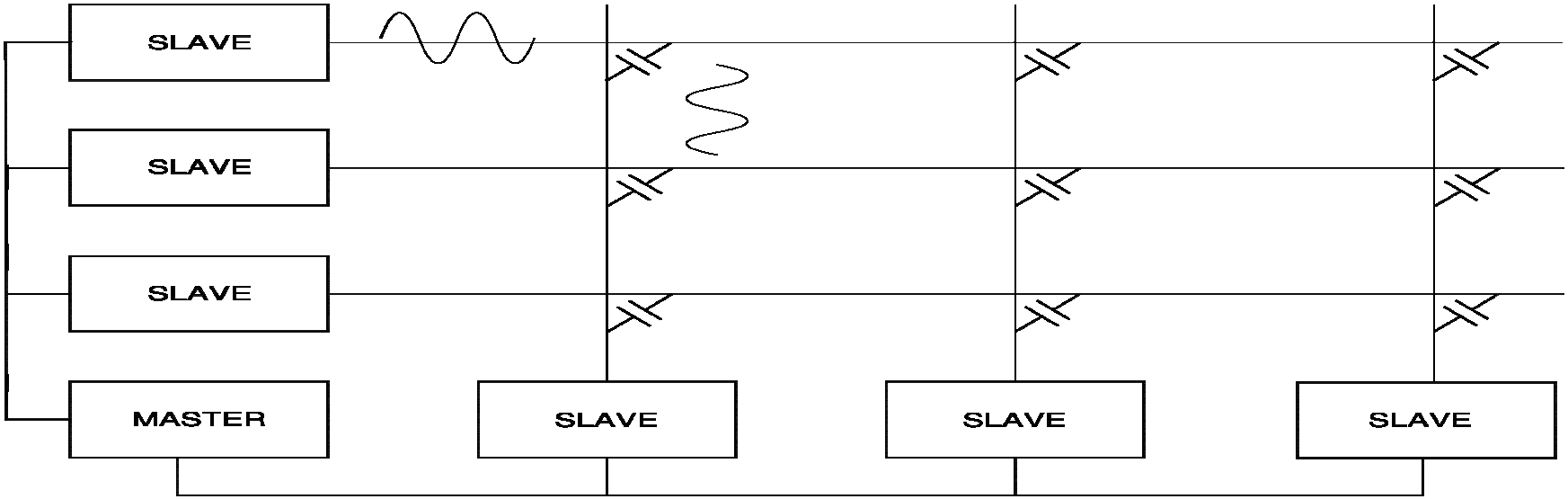




Target application: E-SAIL

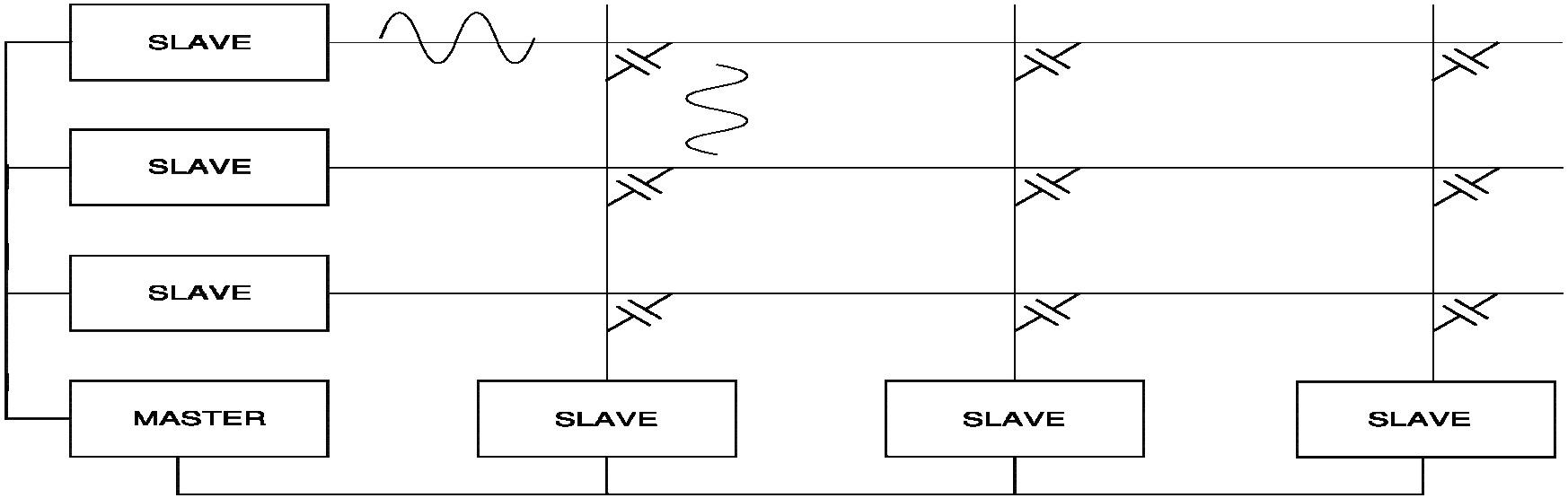
- Line length 10-30 m
  - quasi static conditions if freq. < 10 MHz
- Aluminium thin & large strips
  - R very small, C meanly concentrated

PROPOSED ARCHITECTURE



- Distributed addressing and sensing
  - Row modules: stimulus generation
  - Column modules: read-out & data processing
  - Digital bus: synchronization and data transfer

PROPOSED ARCHITECTURE



- Row-wise array scanning
- Master/Slave communication
- Autonomous modules based distributed computation

COMMUNICATION: BUS MODULE

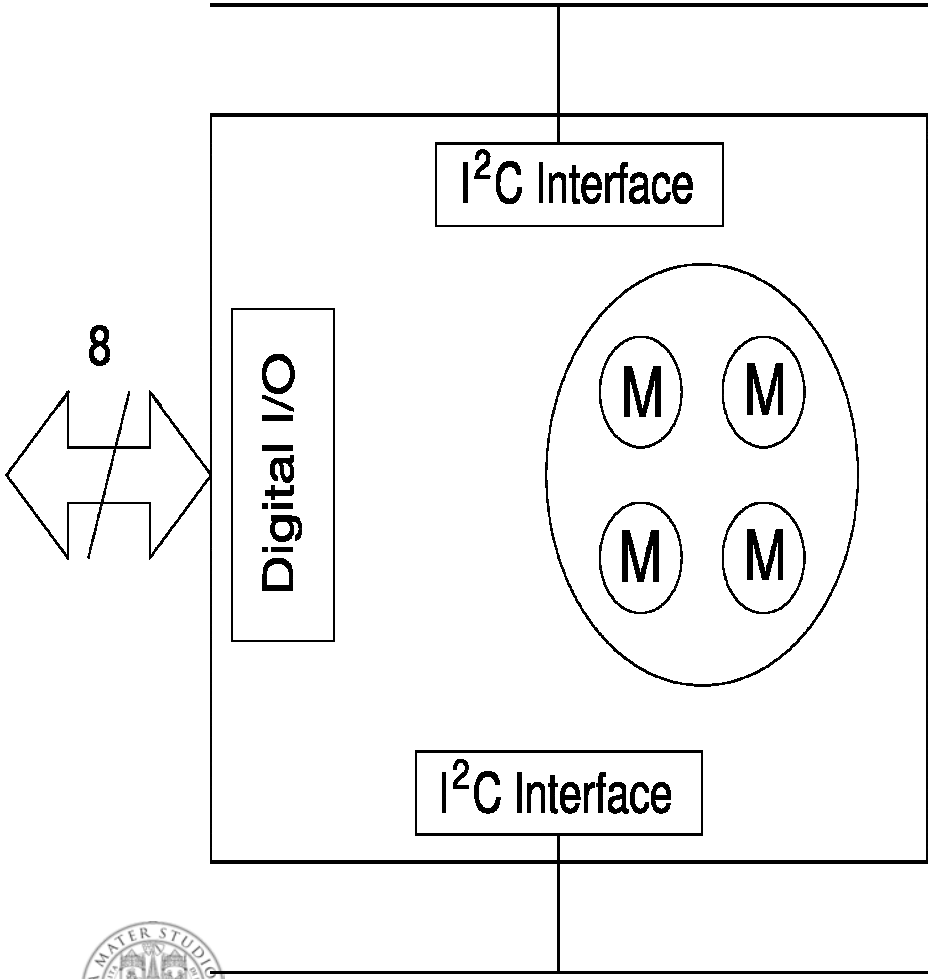
- I^2C-based 2-wire digital bus split in 2 different modules
  - Vertical bus: used to address each row block

  (Single direction communication, addressed mode)
  - Horizontal bus: used to collect data

  (Single direction communication, fast mode)
  - Horizontal & Vertical bus: System bootstrap

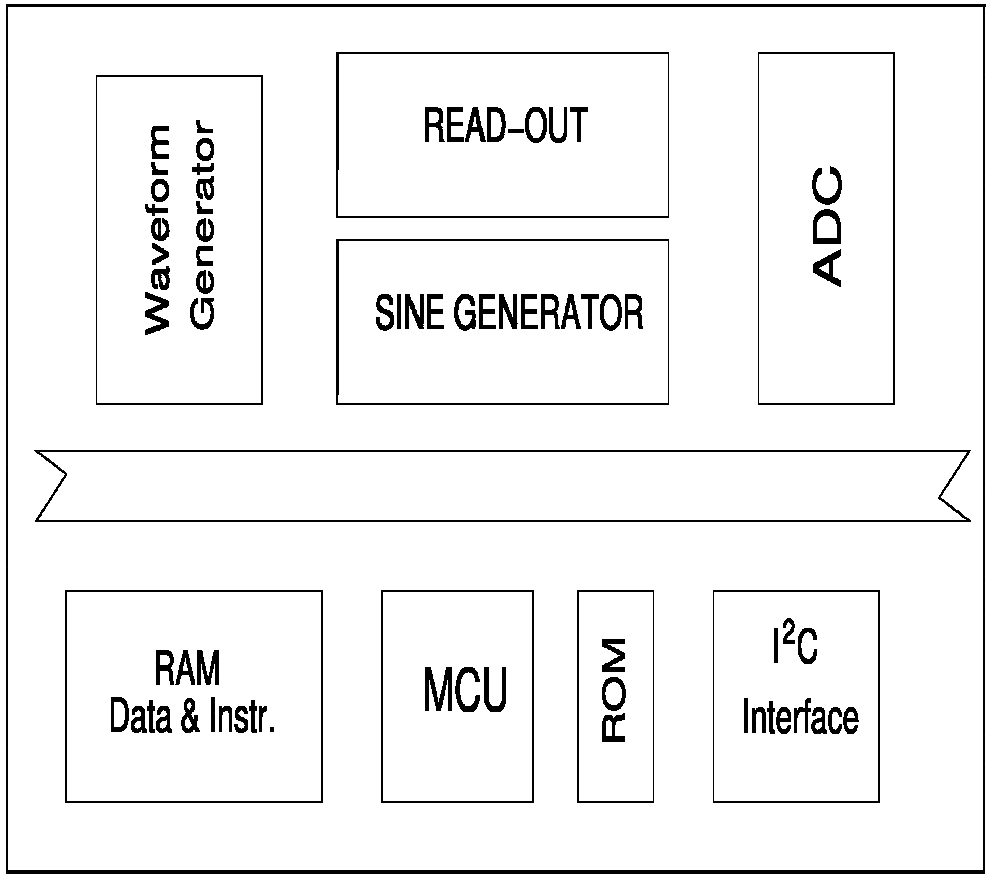
  (Broadcast communication)

MASTER MODULE



- Cluster of communication masters with static priority
- Two I^2C master interfaces
  - Internal data transfer
- 8-bit digital interface
  - External communication
- Microcontroller
  - Data elaboration
  - Protocol synchronization

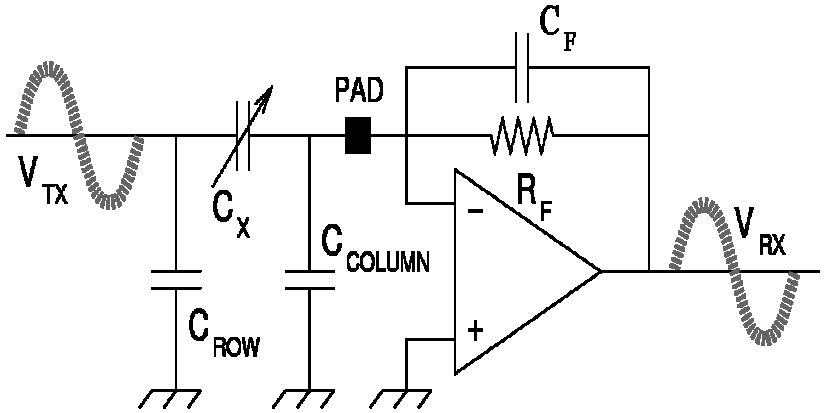
SLAVE MODULE

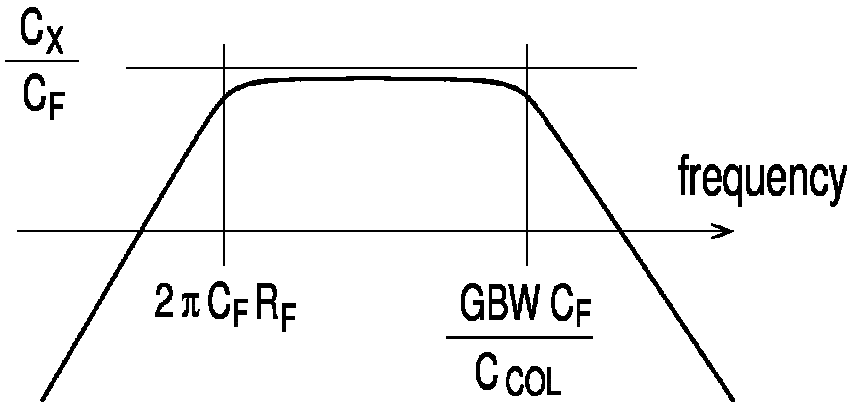


- Reduced pin number:
  - 3 I/0 (2 digital, 1 analog)
  - 2 power supply
- Analog core:
  - Sine wave generation
  - Sense – Filtering
  - Addressing
- Digital core:
  - Early data processing
  - Data transfer
  - Synchronization protocol

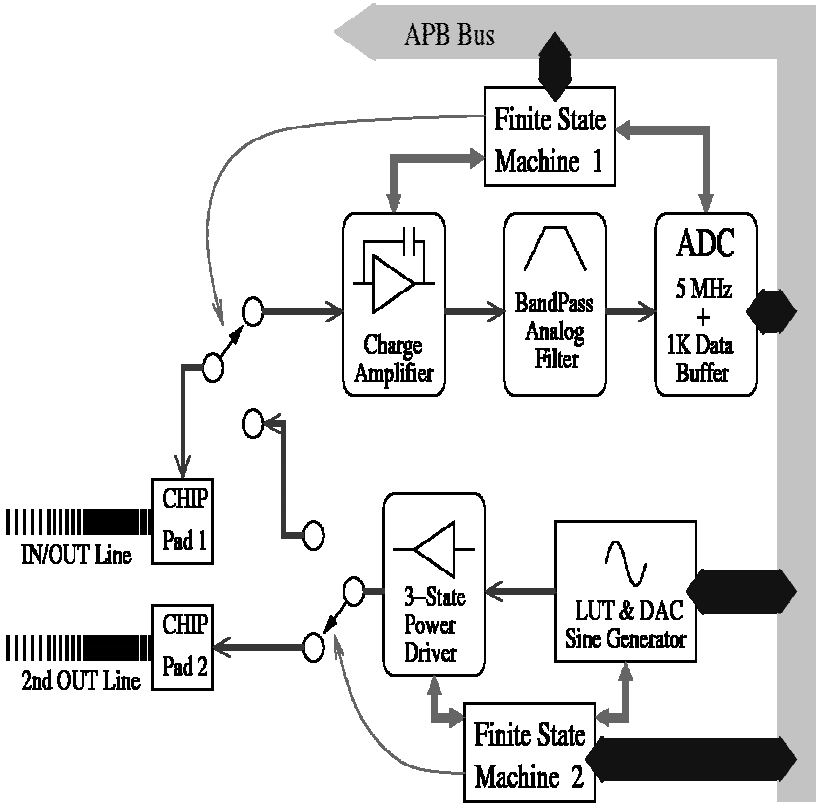
AC CHARGE AMPLIFIER

- C_F calculation (V_{TX} and V_{RX} full range)
- Op. Amp. $A_0 >> 1$ (C_{COLUMN} negligible)
- f_0 centered
- Further V_{RX} filtering



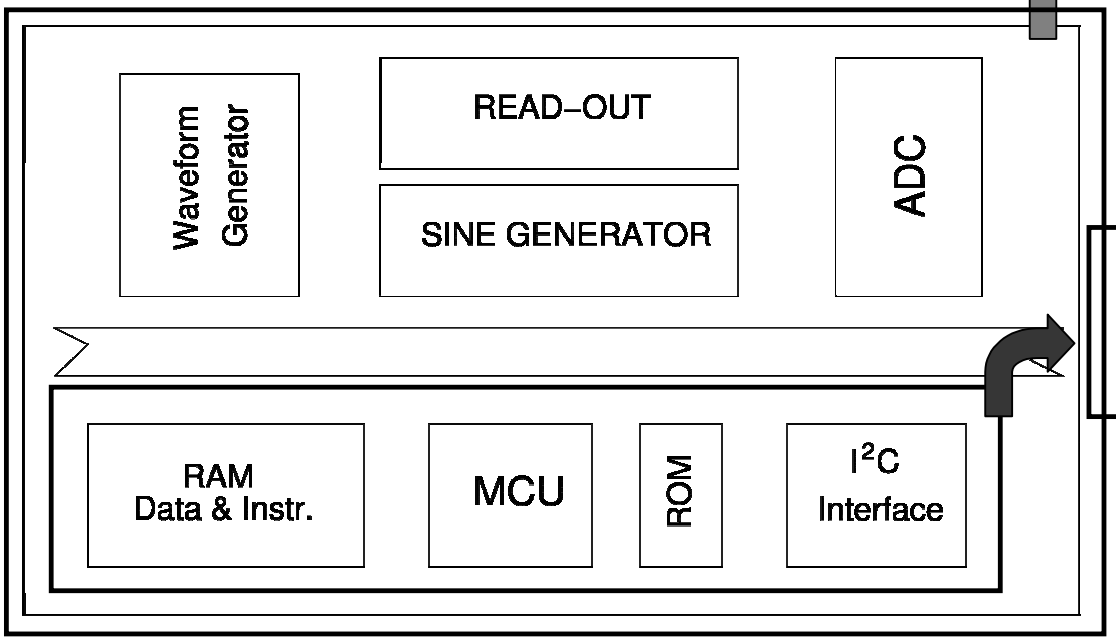


ANALOG CORE OVERVIEW



- Sine generation module:
  - Digital counter
  - Programmable lookup table
  - DA converter
- Signal driver & receiver:
  - Same chip for rows and columns
  - Stand alone sensor achievable

Digital platform for smart sensor



Schematic overview of the basic on-chip components

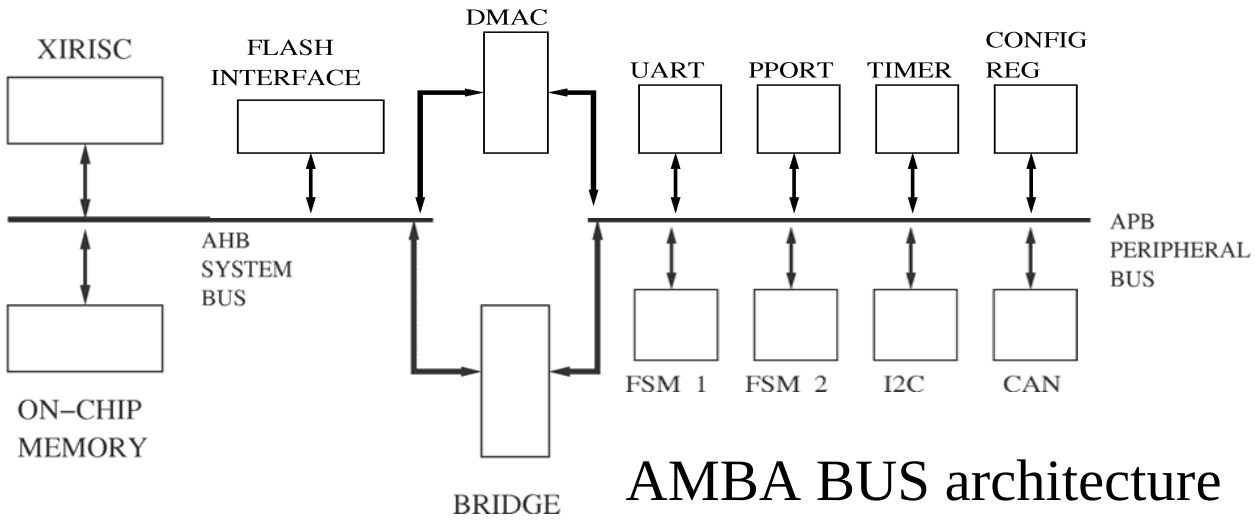
Schematic overview of the digital platform

Basic Components for smart sensor

Embedded elaboration unit	⇨	16-bit XiRisc processor
Two-wire interface (40m, 1Mbps)	⇨	I^2C Controller
Control of analog components (stimuli generation, A/D conversion)	⇨	On-chip dedicated FSMs
Boot load	⇨	Dedicated FSM inside the I^2C Unit

System-on-Chip Scenario
(easy-to-plug in peripherals)

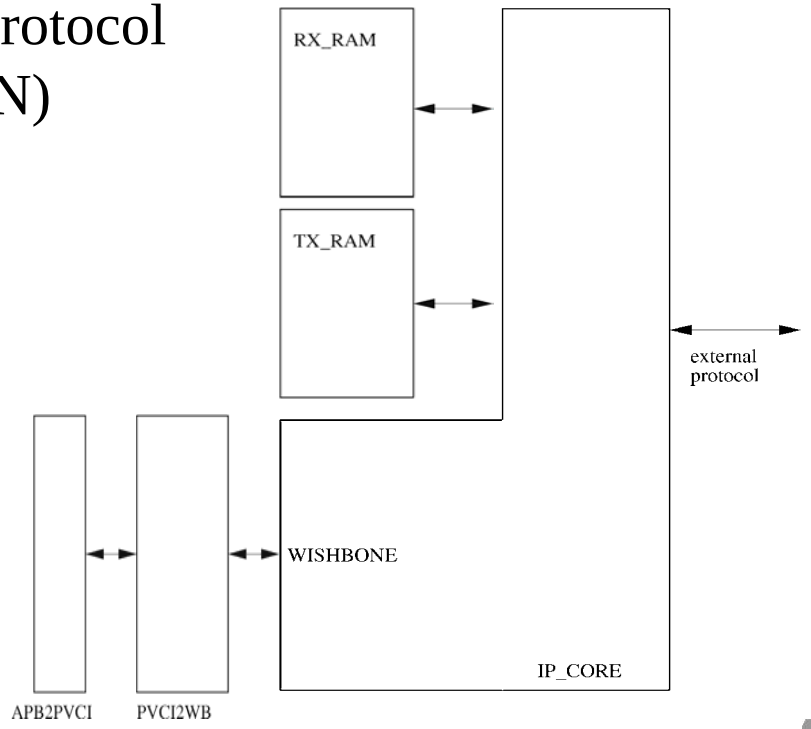
- (red boxes) basic components for a smart-sensor environment
- (black boxes) additional available general-purpose components



AMBA BUS architecture

IP CORE Structural Overview

- IP (Open Source) + external protocol (RS232, IEEE 1284, I^2C, CAN)
- VSIA standard interface
- APB AMBA wrapper
- RAM Fifo Buffer



SILICON INTEGRATION

- Digital Front to Back Design flow for HCMOS8
- Tape out: 3Q 2002
- Analog Core:
  - Reuse of hard blocks and custom layout
- Digital Core:
  - Soft macro internal library

PROJECT STATUS AND FUTURE DIRECTIONS

- Smart textile: Haptic interface
  - Gesture recognition: biometric identification
  - Biomedical devices: smart body cast
  - 3 papers accepted, 1 paper submitted, 2 patents pending

- Ultra wide area pressure sensors
  - Aerodynamic: real time pressure profile
  - 1 paper accepted, 1 patent pending