A flexible evaluation platform for a novel X-ray detector

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**BRUCO INTEGRATED CIRCUITS**

*Short overview*

- Independent, privately owned fab-less IC design center
- Founded in 1988 – 31 years of Innovation!
- Turn key solutions and design services with own validation lab
- Customers from large multinational to **technology startups**
- End markets: Consumer Electronics, Industrial, and Automotive
- Design centers in Borne and Nijmegen
- Sales office in Taiwan
- Part of Dieco Electronics holding, ~50 highly educated and enthusiastic people

**Core competences**

- RF
- Analog / Mixed-Signal
OUR SERVICES
Designing, verifying and validating IC’s

IC Design services
Production Services
Application Development
OUR CUSTOMERS

We have designed IC's and application boards among others for the following companies:

- NXP
- Nexperia
- Dialog Semiconductor

- Ampleon
- Gray Medical
- Fluke
Switches & LNAs for WLAN, LTE, 5G high-end cell phones

Beam-forming Phased Array systems for satellite reception,
Ku band 11-13 GHz RF front-end

PLL for satellite receivers ~15 GHz

PAs including power and, bias circuitry 400 MHz - 2.7 GHz

Discrete, High-Power Doherty PA modules for Base Stations
Flexible power convertor controllers for LED and QL Lighting
Motor driver IC’s
High-side and low-side Driver IC’s

- High-voltage, dual-axis MEMS mirror array driver IC
- Analog front-end for a handheld Scope Meter
- Earth-fault circuit breaker
OUR BUSINESS

Automotive

- Smart power MOSFET and gate drivers
- Alternator Voltage Regulator (Chinese customer)
- Versatile Body Control
- Resonating mirror driver @ 80V with accurate position detection system (IP sold to Infineon)
## OUR BUSINESS

### EDA Tools, Technology and Foundries

<table>
<thead>
<tr>
<th>Match technical and commercial requirements</th>
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</thead>
<tbody>
<tr>
<td>Mostly 180-130 nm</td>
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<tr>
<td>CMOS</td>
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<tr>
<td>BiCMOS</td>
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<tr>
<td>SiGE (RF)</td>
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<tr>
<td>SOI (RF)</td>
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<tr>
<td>BCD (HV)</td>
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### Foundries

- Analog, Mixed-Signal, HV
  - UMC
  - TSMC
  - X-Fab
  - Tower-Jazz
  - SSMC
  - RF
  - NXP
  - GlobalFoundries

### EDA Tools

- Cadence
- Synopsys
- ADS
- LabView
- Altium Designer
OUR BUSINESS
Evaluation, Qualification and Production Test

Evaluation
- Own lab facilities including:
  - Dedicated RF measurement equipment
  - Thermo streamer
- Automated evaluation set-ups mostly LabView based
- Create Application / Evaluation PCB’s for Lab measurements

Qualification & Production Test
- 3rd parties
**OUR BUSINESS** **COMPONENTS**
Production and Supply

- Complete supply chain
  - Forecast
  - Packaging
  - Testing e.g.
  - Shipment (in split lots if needed)
- Wafer and component storage
  - in Nitrogen environment > 10 years
- Separated storage locations for safety reasons
Why work with start-ups?
The fun and the challenges

- Endless Can-Do-Mentality & big ego’s
- Coming from another field of expertise
- Build up knowledge about other domains
- Ever changing requirements and application
- No clue about electronics or IC
- Typically no SemiCon business experience
- Build trust – focus on the right stuff
- Getting money – Stop-and-Go
a Swiss start-up

- Build large, novel X-ray detector for mammography
- Low-temperature covalent wafer bonding
  - Realized at a 200 mm wafer scale
- Absorber materials
  - Si, GaAs, CdTe, epitaxial SiGe

- Advantages
  - CMOS compatible
  - X-ray direct conversion
  - Photon counting capability
  - Large-area detectors
  - No bump bonding
- Applications
  - Scientific, industrial, medical
- Needed
  - 2 new technological processes
  - X-ray sensor array
  - Readout electronics for the X-ray sensor
Sensor specification

- 2.4 x 3.0 cm² active area
- 100 µm pixel pitch
- 240 x 300 pixel array: 72'000 pixels
- Dark current compensation up to 1µA / pixel
- 2 discriminators with 12-bit counters per pixel
- Programmable charge amplifier sensitivity
- Parallel 12-bit interface for data readout
- Programmable region-of-interest for readout
- Sequential acquisition/ readout with 2 thresholds or continuous mode with 1 threshold
- 1.8V single power supply
- 587 wire bond pads
- Programmable shaping time: 40/70 ns
- 6-bit in-pixel DAC for threshold calibration
Readout Electronics
High Level Requirements

Customer
- Programmable – requirements change over time (typical for a start-up)
- Flexible – different sensors (absorbers)
- Demonstrator for customers (fool proof, easy to use)

Bruco
- Build re-usable evaluation platform
Evaluation boards 1
2006 – Versatile Body Controller IC

- Flexibility via relays and GPIB controlled instruments
- Test program and results via Labview
- Daughter board with test socket
Evaluation boards 2
2007 – 11M MEMS mirror array, 5.0x2.5 cm single die

FPGA with USB-IF

Company confidential
From system spec. to supply!

- **BCD technology**
- 200k gates on die
- Flip-chip, naked die, 254 pins
- 64 mirror drivers, 3 electrodes
- Operating @ 55V
- Die 19x4 mm
- 128 DACs, 12 bits @ 1.5 kHz
- Automated test set-up

Company confidential
Readout system
More detailed requirements

- 4x Controllable Power Supplies, 1.2 – 2.5V, two with remote voltage sensing
- 1x High voltage, low-current Power Supply, 4W: 0 - 1kV
- 8x Controllable reference current 0-5 mA, 0.1% full-scale
- External, isolated 12V Power Supply
- Power Supply monitoring on the sensor board

- 8 temperature and humidity sensors close to the X-ray sensor
- I²C EEPROM unique ID + calibration info
The resulting system
What we designed

Hardware:
- Use of standard Trenz module, TE0720 with Xilinx ZYNQ SoC featuring integrated FPGA + ARM core and 1GB ethernet
- Autonomous sensor acquisition
- Frame rate, acquisition window, shutter programmable
- Timing crystal based (RTC disabled)
- 120 pins IF between sensor and FPGA
- Hardware controls the Power Supplies based on sensor ID
- Defined our own interface between CPU and FPGA

Software:
- CPU: Application, command line
- Compiled PetaLinux (Xilinx) to run on the ARM core
- SFTP to read sensor images and to upload command scripts
- SSH for command handling – parallel sessions tested
- Virtual serial port via USB (PuTTY) – Service interface (log information)
Readout system

Functional overview
Readout system
Software/ hardware partitioning
Personal delivery...

... and a happily smiling customer
The results
X-ray Detector characterization

Pb-phantom with diverging lines: 5 lines/mm resolved
What is next?

- G-ray to sell the demonstrator kit to its customers
- Develop bigger sensors with new readout electronics
- Get onboard with IC Development
- Re-use the developed evaluation platform for other Bruco customers and applications