Radiation-Hardened SiGe BiCMOS Technologies for Analogue and Mixed-Signal ICs
RHBD SGB25RH (250nm) and SG13RH (130nm) PDKs

Maurizio Cirillo

2016-06-13
AMICSA 13 – 16 July 2016 – Gothenburg (Sweden)
# Outline

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IHP GmbH in Germany


- MPW and LVP SiGe BiCMOS Process Technologies (250nm, 130nm)
  - 1000m² Class 1 Clean Room / 100WSPW

- Approx. 310 (scientists, engineers, technicians, administration staff, etc.)
SiGe HBT BiCMOS vs RF CMOS

Technology node / effective emitter width (nm)

$f_T$ and $f_{max}$ (GHz) @ RT

Harame et al. IMS2015
Courtesy of Globalfoundries

(1) Boeck et al. BCTM2015
(2) Heinemann et al. IEDM2010 and Rücker et al. SiRF2012
(3) Fox et al. IEDM2008
(4) Heinemann et al. SST Journal 2007
**Commercially available IHP SiGe BiCMOS Technologies**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Parameters</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>250nm CMOS</td>
<td>$V_{DD}=+2.5V$; $T_{OX} = 5.8nm$</td>
<td></td>
<td></td>
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<tr>
<td>BEOL: 3 thin + 2 thick metal layers (TM1:2µm, TM2:3µm) + MIM Capacitor Layer</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SGB25V</td>
<td>npnVp 95/75/2.4 npnVs 90/40/4.0 npnVh 70/25/7.0</td>
<td>Stable</td>
<td></td>
</tr>
<tr>
<td>SG25H3</td>
<td>npnVp 180/110/2.3 npnVp 140/120/2.4 npnVs 140/45/5.0 npnVh 80/25/7.0</td>
<td>Early Access</td>
<td>EPPL submission 2016</td>
</tr>
<tr>
<td>SG25H1</td>
<td>npnVp 190/190/1.9 npnVp 220/180/1.9 (REPLACED by SG25H4)</td>
<td>In Development</td>
<td></td>
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<tr>
<td>SG25H4</td>
<td>npnVp 190/190/1.9 npnVp 220/180/1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGB25RH</td>
<td>npnVp 95/75/2.4 npnVs 90/40/4.0 npnVh 70/25/7.0</td>
<td>Under Development</td>
<td></td>
</tr>
<tr>
<td>130nm Dual Gate CMOS</td>
<td>$V_{DD}=+1.2V$, $+3.3V$; $T_{OX} = 2nm / 7nm$</td>
<td></td>
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<tr>
<td>BEOL: 5 thin + 2 thick metal layers (TM1:2µm, TM2:3µm) + MIM Capacitor Layer</td>
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<tr>
<td>SG13S</td>
<td>npnVp 340/250/1.7 npnV1 220/180/3.7</td>
<td>Phased-Out</td>
<td></td>
</tr>
<tr>
<td>SG13G2</td>
<td>npnVp 500/300/1.6</td>
<td>Speed-World-Record</td>
<td>EU-DotFive Project (2009-2012)</td>
</tr>
</tbody>
</table>

**Legend:**
- **Green**: Stable
- **Yellow**: Early Access
- **Blue**: In Development
- **Orange**: Phased-Out
- **Legend**: Technology device $f_{MAX}$ / $f_T$ / $BV_{CEO}$

**Status:** February 2016

**Modules**
- **-GD** n-LDMOS 18/48/22 p-LDMOS 8/28/-17
- **-H3P** pnp 120/90/-2.5
- **-PIC** SI-Photonic Devices Ge-PD, MZM, etc...
- **-RFMEMS** Capacitive Switches > 30GHz IL < 1.0dB / Pull-in ~50V / $C_{ON}/C_{OFF} > 10$

**LBE**
Selected MPW and LVP Customers

Microsemi
ROHDE & SCHWARZ
CISCO
Silicon radar
Keysight Technologies
Europractice IC Service
CSR
InnoSenT
IMST
Bosch
Airbus
Sivers
Sima
OHB
Space asics
Space Engineering
## Supported EDA Tools

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<thead>
<tr>
<th></th>
<th>cadence</th>
<th>Keysight Technologies</th>
<th>NI AWR Design Environment</th>
<th>Texeda Design GMBH</th>
<th>Sonnet</th>
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<tr>
<td>Schematic Capture</td>
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<tr>
<td>Spice Simulation</td>
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<td>Field Simulation</td>
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<tr>
<td>Layout</td>
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<td>Design Rule Check</td>
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<tr>
<td>LVS Check</td>
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<tr>
<td>Parasitic Extraction</td>
<td>✔️</td>
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<td>✔️</td>
<td>✔️*</td>
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</table>

* Third-Party Vendor
### Capability Domain for SGB25RH and SG13RH

<table>
<thead>
<tr>
<th>Device</th>
<th>SGB25RH Key Parameters</th>
<th>SG13RH Key Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HBT Devices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard HBT</td>
<td>npnVs $\beta \sim 190$ Peak $f_T = 45,\text{GHz}$, Peak $f_{\text{MAX}} = 90,\text{GHz}$, $BV_{\text{CEO}} = 4.0,\text{V}$</td>
<td></td>
</tr>
<tr>
<td>High Performance npnVp $\beta \sim 190$ HBT - Peak $f_T = 75,\text{GHz}$, Peak $f_{\text{MAX}} = 95,\text{GHz}$, $BV_{\text{CEO}} = 2.4,\text{V}$</td>
<td>High Performance npn13p /pl2 $\beta \sim 900$ HBT - Peak $f_T = 250,\text{GHz}$, Peak $f_{\text{MAX}} = 340,\text{GHz}$, $BV_{\text{CEO}} = 1.7,\text{V}$</td>
<td></td>
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<tr>
<td>High Voltage HBT npnVh $\beta \sim 190$ Peak $f_T = 25,\text{GHz}$, Peak $f_{\text{MAX}} = 70,\text{GHz}$, $BV_{\text{CEO}} = 7.0,\text{V}$</td>
<td>High Voltage HBT npn13v2 $\beta \sim 900$ Peak $f_T = 50,\text{GHz}$, Peak $f_{\text{MAX}} = 165,\text{GHz}$, $BV_{\text{CEO}} = 3.7,\text{V}$</td>
<td></td>
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<tr>
<td><strong>CMOS / MOS</strong></td>
<td></td>
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</tr>
<tr>
<td>nmos : Breakdown Voltage: typ. 4.8V</td>
<td>nmosLV : Breakdown Voltage: typ. 2.7V</td>
<td></td>
</tr>
<tr>
<td>pmos : Breakdown Voltage: typ. -4.1V</td>
<td>nmosHV : Breakdown Voltage: typ. 6.1V</td>
<td></td>
</tr>
<tr>
<td>Isolated_nmos : Breakdown Voltage: typ. 4.8V</td>
<td>Isolated_nmos : Breakdown Voltage: typ. 2.7V</td>
<td></td>
</tr>
<tr>
<td><strong>Resistors</strong></td>
<td>4-TYPES : Salicided N+ Poly, N+ Poly, P+ Poly, High Poly</td>
<td>3-TYPES : Salicided N+ Poly, P+ Poly, High Poly</td>
</tr>
<tr>
<td><strong>C-MIM</strong></td>
<td>typ. $1.0,\text{fF/\mu m}^2$, Breakdown Voltage typ. 30V</td>
<td>typ. $1.5,\text{fF/\mu m}^2$, Breakdown Voltage typ. 23V</td>
</tr>
<tr>
<td><strong>MOS Varicap</strong></td>
<td>typ. $2.7,\text{fF/\mu m}^2$ to $8.9,\text{fF/\mu m}^2$ (typ. from $-2.5,\text{V}$ to $+2.5,\text{V}, 1,\text{GHz}$)</td>
<td></td>
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<tr>
<td><strong>S-Varicap</strong></td>
<td>typ. $2.7,\text{fF/\mu m}^2$ to $8.9,\text{fF/\mu m}^2$ (typ. from $-2.5,\text{V}$ to $+2.5,\text{V}, 1,\text{GHz}$)</td>
<td>typ. $23,\text{fF/\mu m}^2$ to $39,\text{fF/\mu m}^2$ Q$\geq 40$ (typ. from $-2.5,\text{V}$ to $+2.5,\text{V}, 1,\text{GHz}$)</td>
</tr>
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Evaluation of SGB25RH

PDK SGB25RH based on:

- Qualified SGB25V Standard Commercial Process based on JEDEC JP001.01
  - Process stable and running since 2005
- RHBD Libraries
  - RH Layout Rules and derating factors
  - Analog Devices (nnp-HBT, MOS devices incl. ELT- RHBD version)
  - Digital Standard Cell and IO Libraries + RHBD (special layouts) core and IO cells.

Activity promoted by DLR and IHP

Project Partners: OHB (Prime), RHe-Cicor

Goal:

- Process Radiation Assessment
- Manufacturer Evaluation: IHP
  - Test Flow, Test Vehicles (TCV, DEC, RIC)
- Evaluation Testing based on ESCC 2269010 Microwave MMIC Flow
- Definition of Capability Domain
Evaluation of SGB25RH

Test Vehicles as requested by ESCC Basic Specification 2269010

- **TCV** all devices, min. size MOS and npn-HBT devices
  - **Endurance Testing (4000h, 150°C)** PASS
    - with predicted degradations and failures during stress tests
- **DEC-I**: CMOS-, HBT- Shift Registers and Ring Oscillators
  - **Endurance Testing (3000h, 150°C)** PASS
    - Dynamic testing, aging. Some failures after 3000h
    - F/A confirms handling issues
- **DEC-II CMOS- Ring Oscillators**
  - **Endurance Testing (2x 2000h, RT)** PASS
    - CMOS ROs for HCI degradation leading to Lifetime estimation (>18y)
    - HBT no degradation
- **RIC – VCO up to 24GHz, Divider, amplifier and SPI**
  - **Endurance Testing (4000h, 150°C)** PASS
    - **NO FAILURES**
    - VCO very small drift $f_{OUT} : +0.38$ppm/h
    - VCO no measurable PN drift
Evaluation of SGB25RH

TCV Endurance Testing (4000h, 150°C)

- MOS IDSAT drifts (NMOS ~ -2.0%, PMOS ~ -3.5%)
- HBT (npnVp, npnVs, npnVh): No measurable Current Gain drift! Highly stable.
- Diode pn-nw: No measurable Reverse Current drift! Highly stable.
- Resistor drifts (RHIGH ~ +4%, RPPD < 1%, RPND < 0.5%)
- CMIM capacitor drifts @ V=25V < +/- 0.2%
- Varactor capacitor drifts @ V=4.5V < -2.0%

![n npnVp Gain Graph](image)

![RPND Resistance Drift Graph](image)
Evaluation of SGB25RH

DEC-I Endurance Testing (3000h, 150°C)

- CMOS Ring Oscillators (VDD=+3.7V) drift < -9.0%
- ECL Shift Register VCO (Clock) Frequency drift < -0.6% (0V); higher for higher VTUNE

DEC-II Endurance Testing (2x2000h, 24°C)

- CMOS Ring Oscillators (VDD=+3.7V) drift < -16.0% (higher w.r.t. LLT @ 150°C) → HCl
- CMOS Inverter (minimum size) – Lifetime of ~20 years @ 300MHz & VDD=+2.7V
- HBT Ring Oscillators – no drift evidenced
Evaluation of SGB25RH

Radiation Assessment Results (Total Ionizing Dose)

Radiation Source: Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin. Gamma rays provided by Co\textsuperscript{60} source. Dosimetry performed by Farmer Ionization Chamber, nominal photon energy range from 60kV to 50MV.

Test Hardware: Keithley SCS-4200 Semiconductor Parameter Analyzer with Keithley 707B Switch Matrix Custom IHP Test Fixtures for measurements.
Evaluation of SGB25RH

Radiation Assessment (SEU/SEL) on Digital CMOS Std Cell Library

- No SEL detected up to tested 65MeV/cm²/mg @ +105°C
- Standard Cell CMOS Libraries will cover all applications with TID rated up to 300krad(Si)

Radiation Source:
Heavy Ion Facility - UCL - Université de Louvain-la-Neuve (Belgium)

Test Hardware:
Custom IHP + ARQUIMEA FPGA based Test Board & Fixtures for measurements.

DEC Test Vehicle
4 Shift Registers based on different D-FFs
Evaluation of SG13RH

PDK SG13RH based on:

• Qualified SG13S Standard Commercial SiGe:C BiCMOS Dual Oxide
  • BEOL 5 thin + 2 thick (TM1:2µm TM2:3µm) Al metal layers + MIM Capacitor Layer
  • SiGe HBTs npnVp ($f_{\text{MAX}}/f_T/BV_{\text{CEO}}$) : 340GHz/250GHz/1.7V ; npnV1 : 220GHz/180GHz/3.7V
  • CMOS Library Core Voltage +1.2V; IO Library +3.3V

• RHBD Libraries
  • Analog Devices (nnp-HBT, MOS devices incl. ELT- RHBD version)
  • Digital Standard Cell Core and IO Libraries  RHBD special cells (80 cells)

Activity promoted by DLR and IHP – Radiation Assessment

Goal:

- Design of Test Vehicles TCV, DEC
- Process Radiation Assessment i.a.w. :
  - ESCC N°. 25100 (SEE Testing)
  - ESCC N°. 22900 (Total Dose Steady State Irradiation Test Method) & MIL-STD-750E TM1019, MIL-STD-883H TM1019 Condition A and/or ESCC 22900 Window1
- Draft Definition of Capability Domain i.a.w. ESCC 24300
- Process Identification Document (PID) i.a.w. ESCC 22700

Further activities: proceeding into Evaluation Testing i.a.w. 2269010 (Endurance)
**Evaluation of SG13RH**

**Test Vehicles as requested by ESCC Basic Specification 2269010**

- **TCV** all single devices / elements of technology / min. size MOS and npn-HBT devices
  - TID, ELDRS Radiation Testing completed

- **DECs** – several defined comprising of analog and digital circuits
  - **CMOS Test Structures (Shift Registers, Ring-Oscillators, Latch-Up)**
    - Final Version currently in Manufacturing
    - Shift-Registers Test Structures based on IHP RHBD DFFs tested! Thresholds SEL/SEU > 40Mev/cm²/mg
    - Assembly and HI Testing – Fall 2016.
  - **Bipolar HBT Test Structures (Ring-Oscillators, ECL Shift Register, BGR + PTAT Stable References)**
    - TID, SEE Testing early 2016

- **RIC** – Integrated Low Phase Noise Programmable RF Synthesizer (VCO+PLL)
  - Design ready – manufacturing not planned in present activity
Evaluation of SG13RH

Radiation Assessment Results TCV (Total Ionizing Dose)

Radiation Source: Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin. Gamma rays provided by Co$^{60}$ source. Dosimetry performed by Farmer Ionization Chamber, nominal photon energy range from 60kV to 50MV.

Test Hardware: Keithley SCS-4200 Semiconductor Parameter Analyzer with Keithley 707B Switch Matrix Custom IHP Test Fixtures for measurements.
Evaluation of SG13RH

Radiation Assessment Results CMOS Test Structures

- IXC013RH CMOS Library and RHBD cells
- Intermediate Test Vehicle – RadHard13_1
  - 4 Shift Registers based on different D-FFs
  - Test Results (WK47 – 2015)

Radiation Source:
Heavy Ion Facility - UCL - Université de Louvain-la-Neuve (Belgium)

Test Hardware:
Custom IHP + ARQUIMEA FPGA based Test Board & Fixtures for measurements.
## IHP Processes and PDKs for Space Applications

### Summary I of II

<table>
<thead>
<tr>
<th></th>
<th>SGB25V/RH</th>
<th>SG13S/RH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process Description</strong></td>
<td>SiGe HBTs npn Peak $f_T / f_{MAX}$ 75/95GHz 250nm CMOS ($V_{DD}$=+2.5V; $T_{OX}$ = 5.8nm)</td>
<td>SiGe HBTs npn Peak $f_T / f_{MAX}$ 220/340GHz 130nm Dual Gate –Oxide CMOS ($V_{DD}$=+1.2V, +3.3V; $T_{OX}$ = 2nm / 7nm)</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Mixed-Signal MMIC/ASICs up to Ku Band</td>
<td>Mixed-Signal MMIC/ASICs up to W-Band</td>
</tr>
<tr>
<td><strong>Commercial Qualification</strong></td>
<td><strong>Re-Qualified 2010 active &amp; stable &gt; 10 years (2005)</strong></td>
<td><strong>completed 2014</strong></td>
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<tr>
<td>– Based on JEDEC Standard JP001.01</td>
<td></td>
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<tr>
<td>– QML/QPL (ESCC QPL, ESCC QML, MIL QPL, JAXA QPL)</td>
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<td></td>
</tr>
<tr>
<td><strong>Radiation Assessment (Analog)</strong></td>
<td><strong>completed</strong></td>
<td><strong>completed</strong></td>
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<tr>
<td>– HBT npn (all devices)</td>
<td>PASS TID 800krad(Si) incl. ELDRS TID &gt; 550krad(Si)</td>
<td>PASS TID &gt;1210krad(Si) no ELDRS TID &gt; 200 (HV) / 500 (LV) krad(Si)</td>
</tr>
<tr>
<td>– PMOS</td>
<td>PASS TID 100krad(Si) Characterized up to 500krad(Si) TID &gt; 550krad(Si)</td>
<td>PASS TID 50krad(Si) (LV) Characterized up to 500krad(Si) TID &gt; 900krad(Si)</td>
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<tr>
<td>– NMOS (WG=1µm)</td>
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<td></td>
</tr>
<tr>
<td>– ELT-NMOS (RHBD Device)</td>
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## IHP Processes and PDKs for Space Applications

### Summary II of III

<table>
<thead>
<tr>
<th>PDK Availability</th>
<th>SGB25V/RH</th>
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<td>Access Status</td>
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<td>In development</td>
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<tr>
<td></td>
<td>NDA – Unrestricted</td>
<td>NDA – Unrestricted (Early Access)</td>
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<td>Royalties on Dolphin Library</td>
<td>NO ROYALTIES</td>
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<table>
<thead>
<tr>
<th>CMOS Std Cell Core and IO Libraries</th>
<th>SGB25V/RH</th>
<th>SG13S/RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dolphin SESAME2-LP core cells + special RHBD cells (IHP) (80 cells)</td>
<td>IHP IXC013RH (~ 90 cells)</td>
</tr>
<tr>
<td></td>
<td>Saphyrion SAGL (25 cells) (Tested for SEU/SEL only)</td>
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<table>
<thead>
<tr>
<th>Radiation Assessment (Digital)</th>
<th>SGB25V/RH</th>
<th>SG13S/RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>100krad(Si) – 300krad(Si) SEU/SEL completed</td>
<td>100krad(Si) – 300krad(Si) SEU/SEL partially completed</td>
</tr>
<tr>
<td>CMOS Libraries</td>
<td>Threshold &gt; 65MeV/cm²/mg (RHBD IHP cells)</td>
<td>Threshold &gt; 65MeV/cm²/mg (RHBD IHP cells)</td>
</tr>
<tr>
<td></td>
<td>Threshold ~ 35MeV/cm²/mg (IHP DICE FF)</td>
<td>Finalization during Fall 2016</td>
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## IHP Processes and PDKs for Space Applications

### Summary III of III

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<tbody>
<tr>
<td>in acc. ESCC No. 2269010</td>
<td><strong>completed</strong></td>
<td>not yet performed</td>
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<table>
<thead>
<tr>
<th>Operation Temperature (max rated ( T_J ))</th>
<th>SGB25V/RH</th>
<th>SG13S/RH</th>
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<tbody>
<tr>
<td>-55°C to +125°C</td>
<td><strong>-55°C to +125°C (TBC)</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Test Vehicles</th>
<th>SGB25V/RH</th>
<th>SG13S/RH</th>
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<tbody>
<tr>
<td>in acc. ESCC No. 2269010</td>
<td>TCV, DEC-I/-II, RIC</td>
<td>TCV, DEC -I (CMOS) DEC-II (Bipolar) update in progress RIC in progress</td>
</tr>
</tbody>
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<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>TCV (Devices, analog)</td>
<td><strong>completed</strong></td>
<td>partially completed</td>
</tr>
<tr>
<td>DECs (Digital, Analog BiCMOS)</td>
<td></td>
<td>completed</td>
</tr>
<tr>
<td>RIC (Mixed-Signal IC)</td>
<td>DEC-I (SEU/SEL), Early structures TID + SEE LO RIC</td>
<td>partial planned</td>
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<tbody>
<tr>
<td>HBT npns devices</td>
<td><strong>passed</strong></td>
<td>not yet performed</td>
</tr>
<tr>
<td>HBT lifetime determination</td>
<td>very stable: no or low drifts characterization available</td>
<td></td>
</tr>
<tr>
<td>CMOS devices</td>
<td>drifts are measured and defined lifetime determination ~ 20 years</td>
<td></td>
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<tr>
<td>CMOS Core &amp; IO Std Cell Library</td>
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<thead>
<tr>
<th>Additional Tests (Reliability)</th>
<th>SGB25V/RH</th>
<th>SG13S/RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiGe HBT HCI &amp; Lifetime Estimation</td>
<td>SiGe HBT HCI &amp; Lifetime Estimation</td>
<td></td>
</tr>
</tbody>
</table>
Thank you for your attention!

Cirillo, Maurizio

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Outlook to possible Future fT/FMax Performance with SiGe

- Significant progress for fmax up to values ~ 600 GHz
- Only limited progress for fT over last years (often at the expense of fmax)
- Simulations shows that peak fT values close to 1 THz may be achievable

[Schröter et al. TED 2011]
Evaluation Test Plan - ESCC 2269010 - MMIC Flow

Test Flow - TCV

CHART IB - EVALUATION TEST PROGRAMME FOR CAPABILITY APPROVAL

CHART IB1 - GROUP 1 TCV EVALUATION

<table>
<thead>
<tr>
<th>INSPECTION Para. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Para. 5.4 Electrical Measurements (go-no-go) 100%</td>
</tr>
<tr>
<td>Para. 5.8 Hermeticity 100%</td>
</tr>
<tr>
<td>Para. 5.9 Serialisation and Traceability 100%</td>
</tr>
</tbody>
</table>

n = 134

INITIAL MEASUREMENTS Para. 6

<table>
<thead>
<tr>
<th>Para. 6.1 Initial Electrical Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Read and Record</td>
</tr>
<tr>
<td>Tables 2 and 3 of Test Document</td>
</tr>
<tr>
<td>Para. 6.2 Thermal Analysis (Note 1)</td>
</tr>
<tr>
<td>Para. 6.3 Specific Dynamic Measurements (Note 2)</td>
</tr>
<tr>
<td>Para. 6.4 Design System Assessment</td>
</tr>
</tbody>
</table>

n = 129

SUBGROUP 1A
Thermal Characterisation Para. 7.2.1.1

n = 3

SUBGROUP 1B
Storage Testing Para. 7.2.1.2

n = 24

SUBGROUP 1C
Endurance Testing Para. 7.2.1.3

n = 60

SUBGROUP 1D
Packaging/Atmosphere Testing Para. 7.2.1.4

n = 32

SUBGROUP 1E
Radiation Analysis Para. 7.2.1.5

n = 5

SUBGROUP 1E
ESD Testing Para. 7.2.1.6

n = 5

NOTES
1. 5 devices out of the initial 134 devices could be destroyed in thermal analysis.
2. To be performed on either TCVs or DECs.

source: ESCC 2269010
Evaluation Test Plan - ESCC 2269010 - MMIC Flow

Test Flow – DEC, RIC

CHART IB2 - GROUP 2 DEC EVALUATION

<table>
<thead>
<tr>
<th>INSPECTION</th>
<th>Para. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Para. 5.4</td>
<td>Electrical Measurements (go-no-go) 100%</td>
</tr>
<tr>
<td>Para. 5.8</td>
<td>Hermeticity 100%</td>
</tr>
<tr>
<td>Para. 5.9</td>
<td>Sealing and Traceability 100%</td>
</tr>
</tbody>
</table>

n = 74

INITIAL MEASUREMENTS Para. 6

| Para. 6.1 | Initial Electrical Measurements 100% Read and Record Tables 2 and 3 of Test Document |
| Para. 6.2 | Thermal Analysis (Note 1) |
| Para. 6.3 | Specific Dynamic Measurements (Note 2) |

n = 69

SUBGROUP 2A
Thermal Characterisation Para. 7.2.2.1

n = 3

SUBGROUP 2C
Radiation Analysis Para. 7.2.2.3

n = 5

SUBGROUP 2E
RF Compression Para. 7.2.2.5

n = 8

n = 48

SUBGROUP 2B
Endurance Testing Para. 7.2.2.2

n = 16

n = 2

Test 1

2B(i)

n = 16

Test 2

2B(ii)

n = 16

Test 3

2B(iii)

source: ESCC 2269010
SGB25RH PDK Elements and Applications

Basic structure elements:

- PMOS
- NMOS
- Isolated NMOS
- MOS Varactor
- RPND resistor
- RSIL resistor
- RPPD resistor
- RHIGH resistor
- MIM Capacitor
- npnVS bipolar HBT
- npnVH bipolar HBT
- npnVP bipolar HBT
- Inductor made by backend metal layer
- Antenna diode
- ESD clamp
- Digital standard cells
- Digital IO cells

Components in CMOS, bipolar and BiCMOS:

- Maximal application frequency up to 20 GHz
- as chip or packaged
- Mixed Signal Technology
- fast counters
- fast shift register
- FlipFlops
- Dividers
- Frequency-/Phase comparator
- Charge pumps
- VCOs
- Linear amplifiers
- Current sources
- PLLs (integer and fractional)
- Digital Analog Converters
- etc.

X-Band Local Oscillator Chip

12bit-1.5GHz Sample DAC
Silicon Photonics @ IHP

PDK Offerings in SG25-EPIC and -PIC Module on 250nm Technology

Waveguides

Coupler

Photonics

Silicon Photonics

Electronics

SiGe BiCMOS

Ge-PD

Modulators

WG-coupled Ge-PD on SOI

Ridge waveguide

Selectively grown Ge

ILD

AlCu

SiO₂
New in 2016

- Extended possibilities – IHP Solutions
- New SG25H4 as replacement for SG25H1 MPW access
- SG25H4_EPIC Si-Photonic/BiCMOS technology
- SG25InP1 Heterointegration of BiCMOS and InP HBTs (partnership FBH – IHP)
- TSV and RFMEMS module in SG13 technologies