RF MEMS To Enhance Telecommunications

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MEMS For RadioFrequency Systems

- Provide MEMS based devices for RF systems: antenna switch, tunable components, ..

- High RF Performances: ultra-low loss & stellar linearity

- Enable the simplification of RF architectures within Front-End Modules

- Decrease BOM, power consumption and improve integration

- Founded in 2006
- Fabless with strong foundry partners
- Based in France
- 7 key patents
World Wide DelfMEMS

- Headquarter + R&D in France / Foundries in USA & Europe (Q2)
- World Wide Network of representatives
- 15 people : 8 PhDs + 30y experience in foundry transfer + tens of people in foundries
- 4 more positions in a hiring process (Q2-3 2013)
- All CAD capabilities : HFSS, Ansys, Ansoft Designer, L-Edit, etc.
- All testing capabilities : lab for DC & RF
$10.5M Series B in December 2012

- One of the most promising semicon start-up in Europe
- Winner of the 2013 Red Herring top 100 in Europe
- One of the few well-funded RF MEMS teams in the world
- Going to low and very high volumes (2 sources)
- Experienced management in place

RF MEMS startup gains funds and veteran CEO

Peter Clarke
1/15/2013 2:03 AM EST

LONDON – DelfMEMS, a developer of MEMS-based switches for RF applications, has raised 8.2 million euro (about $10.5 million) in a venture capital funding round and announced the appointment of Guillaume d'Eyssautier as CEO.

DelfMEMS SAS (Lille, France) was founded in 2005 as a spinoff from the Centre National de la Recherche Scientifique (CNRS).

The latest round of funding comes from CDC Entreprises, Iris Capital, Capitalaria, Vives as well as previous investors A2D Invest, Alliansys, Finorpa, Innovam, Rhône-Alpes-Création, and angel investors. It brings the total invested in DelfMEMS to about $16 million.
Needs for RF Switches

- Switches are used for reconfigurable systems for multiband multimode radio front-end
- With a combination of switches and fixed caps, we achieve better performance and lower cost: Antenna & PA tuning
MEMS Switch Value Proposition

- Lower loss:
  - Increase Multi-Mode Tx Module performance
  - Improves Module PAE by up to 10%
  - Removes performance objection to converged architecture, i.e. enables FE reconfigurability

- MEMS RF switch has superior Isolation/Harmonics Performance (>15dB compared with solid state)

- Broadband technology: same size, cost & design from DC to 6GHz

- MEMS Technology is cost competitive with other RF solutions in multi-throw applications: it enables a better integration and performances at the same price (or below).

### MEMS Switch Technology Figure of Merit

<table>
<thead>
<tr>
<th>Process</th>
<th>Device</th>
<th>Ron [Ω-mm]</th>
<th>Cff [fF/mm]</th>
<th>Ron*Cff [fs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18um thick-film SOI</td>
<td>36NFET 4m0.6um 1.3m gate ox</td>
<td>1.9</td>
<td>285</td>
<td>485</td>
</tr>
<tr>
<td>0.18um thin-film SOI</td>
<td>56NFET 1.3m 35um 6.2nm gate ox</td>
<td>0.8</td>
<td>310</td>
<td>250</td>
</tr>
<tr>
<td>0.5um SOS</td>
<td>10NFET 10.4nm gate ox</td>
<td>2.8</td>
<td>270</td>
<td>758</td>
</tr>
<tr>
<td>0.25um SOS</td>
<td>10NFET 5.0nm gate ox</td>
<td>1.6</td>
<td>280</td>
<td>448</td>
</tr>
<tr>
<td>pHEMT</td>
<td></td>
<td>1.4</td>
<td>160</td>
<td>224</td>
</tr>
</tbody>
</table>

| MEMS Relay    | 1.0 or below | 8 | 10 |

« Lower is better »
MEMS Penetrates the RF Market

- CAGR: 20.3% from 2011 to 2017 for RF MEMS

Src: Yole Developpement
DelfMEMS : RF MEMS Switch

- Unique MEMS switch: patented push-pull anchorless membrane
- Unique Low cost Manufacturable Process: Transfer to 2 foundries for volume prod.
- Unique Wafer Level Thin Film Packaging
- Semi-Custom & Proprietary Designs
- Integration of capacitors within the process
A New Approach of Ohmic Switches

- Unique patented mechanical structure: anchorless membrane simply supported by 2 pillars

- Anchorless structure: no temperature & packaging dependency / ultra-fast switch / No stress concentration

- Push-Pull Device: small gap / high restoring forces / high contact forces / controlled state of the component
1st Source: Transfer in Foundry

- 1st run in 6" foundry / Tronic's Honeywell, based Texas, USA // Released Sept 2012
- Switches, Relays & Digital Caps with Silicon Wafer Level Packaging
Labs & Foundries Solutions are Totally Different
New: CMP for Feedthroughs

- 2 buried layers are used for interconnections & feedthroughs (under sealing ring for packaging)

- Low cost CMP is used to decrease the device size
Focus on Autoaligned Stoppers
Final Packaging: Thin Film Packaging

- Teflon layer is removed after sealing
- High yield process
- Standing overmolding for integration within RFFE modules
- Low profile (45-50µm) for bumping
Ex: Basic Building Block « Block D »

We have specific designs for customers, that we can not present. Next results will only concern a demonstrator block.

Block « D » is a general demonstrator for evaluation of the technology.

200x140µm² relay. Silicon WLP : 1 x 1 mm²
« Block D » : RF Performances

- ILO : -0.18dB @ 2GHz
- ISO : -52dB @ 2GHz
- Measurements on packaged switches produced in high volume foundry
- Losses will be decreased on next run
« Block D » : Very Fast Switch

- Very fast switch @ 35V
- Bouncing can be managed by using external electrodes
DelfMEMS has created a unique library for cellular switching and cellular tuning: Puzzle Approach on a same die

<table>
<thead>
<tr>
<th></th>
<th>Ohmic Switch</th>
<th>Capacitor</th>
<th>Resistor</th>
<th>Inductor</th>
<th>Varactor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Properties</strong></td>
<td>ILO: -0.18dB ISO: -52dB @ 2GHz</td>
<td>1pF Qmax: 121 @ 2GHz</td>
<td>Until 200kohm</td>
<td>Under Devlpt</td>
<td>Under Devlpt</td>
</tr>
<tr>
<td><strong>Working In Foundry</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>In Lab</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Substrate</strong></td>
<td>Si / Glass</td>
<td>Si / Glass</td>
<td>Si / Glass</td>
<td>Si</td>
<td>Si</td>
</tr>
</tbody>
</table>
Example of a system using 12 switches
Update

- First successfull transfer in foundry: packaged devices with good performances

- Launch of a second source for production

- From start-up to a business & industrial partner: the staff is strengthened with professionnal from semicon

- Backed by strong Vcs to accelerate the industrialization & company development

- Works in a collaborative ways with a limited number of customers
- We are the only company developing ultra-low-loss RF switch with stellar linearity with all specifications fitting with low cost & high integration

- We provide a broadband technology decreasing NRE for implementation of new designs

- DelfMEMS insures the supply chain for low & high volumes with 2 established sources

- We drastically enhance the simplification of RF architecture for multimode multiband to decrease the Bill of Material and Power Consumption

- Process & innovative design are patented and owned by DelfMEMS
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