RF & Microwave Capability & Roadmap

Microsemi Space Forum Russia – November 2013

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Senior Field Applications Engineer, RF Integrated Solutions Group
RF Integrated Solutions Space Heritage

- RF & microwave products
  - Si PIN, SRD, and varactor diodes
  - GaAs PIN and varactor diodes
  - Si bipolar power transistors
RF Integrated Solutions Space Heritage

Applications
- RF switching and attenuation
- Communication data links
- Conversion / Modulation
- Surveillance / tracking
- Telemetry / guidance
- Receiver protection
- Imaging / profiling
- Meteorological
- Broadcast
- Scientific
- Military
- Tuning
- GPS
RF Integrated Solutions – Diode Products

Si & GaAs
# RFIS Diode Products Overview

## Microsemi Lowell Frequency Range

<table>
<thead>
<tr>
<th>AM Radio</th>
<th>Mobile Radio</th>
<th>FM Radio</th>
<th>TV</th>
<th>Mobile Phone</th>
<th>VHF</th>
<th>Microwave</th>
<th>Millimeter Wave</th>
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<tbody>
<tr>
<td>DC</td>
<td>2 MHz</td>
<td>88 MHz</td>
<td>108 MHz</td>
<td>900 MHz</td>
<td>1.9 GHz</td>
<td>10 GHz</td>
<td>24 GHz 35 GHz 94 GHz</td>
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</table>

- **Power PIN Diodes**
- **Si Varactor Diodes**
- **Si Low/Medium Power PIN & Limiter Diodes**
- **Si Schottky Diodes**
  - **GaAs PIN Diodes**
  - **GaAs Varactor Diodes**
  - **GaAs Gunn Diodes**
  - **GaAs Schottky Diodes**
- **Control Devices (Modules)**
  - **Oscillators/Tranceivers**
  - **Isolators/ Circulators**
RFIS Diode Products Overview

- Silicon and GaAs diodes – Schottky, PIN, varactor

- Diodes available as die or packaged

- Package options include:
  - Microwave (higher freq) – ceramic, MMSM, stripline
  - Surface mount – MMSM, EPSM, MELF, GigaMite, SOT-23, thru-hole

- Diode based control components – switches, limiters, detectors

- Catalog and custom devices, components, & transceivers

- Military, commercial, semi-cap and ISM markets

- MIL-STD-750, MIL-STD-883, MIL-PRF-19500, Hi-Rel screening available, element evaluation sample testing for space qualification
RFIS Diode Products Overview

- **Silicon Diodes**
  - PINs
  - Schottkys
  - Varactors
  - Limiter
  - Multiplier
  - Noise
  - SPST Switch Element

- **GaAs Diodes**
  - PINs
  - Schottkys
  - Varactors
  - Gunn
  - Impatt
RFIS Diode Products Space Applications

- Switches
- Limiters
- Attenuators
- Detectors
- Phase Shifters
- Tunable Filters
- VCOs
- Mixers
- Up and Down Converters
- Phased Array Antennas
- Antenna Tuning Units
- T/R Switches
### Heritage/Current RFIS Diodes Space Programs

<table>
<thead>
<tr>
<th>Satellite / Program</th>
<th>Amazonas 3</th>
<th>EchoStar XI</th>
<th>Galileo</th>
<th>Nimiq 6</th>
<th>Viasat</th>
<th>ISDLA-1</th>
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<tbody>
<tr>
<td>Anik G1</td>
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<td>GPS Block III</td>
<td>QuetzSat</td>
<td>WildBlue 1</td>
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<td>Hispasat 1E</td>
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<td>NBNCo-1A</td>
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<td>SES Sirius 5</td>
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<td>DirecTV-9S</td>
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<td>Thor 7</td>
<td>Echostar XVIII</td>
<td>Jupiter 2</td>
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</table>
RF Integrated Solutions – Transistor Products

Si, SiC, GaN on SIC
RFIS Discrete Transistor Products Overview

- HF to C-band today, X & Ku band under development
- Si bipolar – HF to S-band, Pulsed/CW, Class A/AB/C, Vcc<52V
- SiC SIT – VHF & UHF, pulsed class AB, Vdd=100-125V
- GaN on SiC HEMT, class AB, Vdd=45-65V
  - L band through C-Band today, pulsed & CW
  - X & Ku band under development, pulsed & CW
  - Broadband CW under development
- VHF to UHF – <1W to 2200W
- L-Band – Up to 1100W
- S-Band – Up to 500W
- C-Band – Up to 100W
RFIS Discrete Transistor Products Overview

- Si bipolar proven device technology for space applications
  - Rugged, robust, radiation hard
  - Proper choice of package considering properties of materials, physical strength, electrical & thermal properties
  - Robustness assured by device processing, piece part selection, single metal configuration, and electrical testing
  - Hermetically sealed gold plated metal ceramic packages & all gold bond wire and wafer metallization
  - IR scan for thermal resistance measurements under RF conditions
  - 100% DC and RF electrical testing
  - MIL-STD-19500 JAN-S flow screening
  - Customer tailored device screening
  - ISO9001 registered
RFIS Space Power Transistor Applications

- Power Amplifiers – CW and Pulsed
- Communication data links
- Surveillance / tracking
- Telemetry / guidance
- Ground penetrating
- Imaging / profiling
- Scatterometers
- Meteorological
- Broadcast
- Scientific
- Military
- Clocks
- GPS
### RFIS Si Bipolar Space Heritage/Current

<table>
<thead>
<tr>
<th>Platform</th>
<th>Application</th>
<th>Freq Band</th>
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<tbody>
<tr>
<td>GPS III*</td>
<td>Navigation &amp; Communication</td>
<td>UHF</td>
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<tr>
<td>Classified govt satellite</td>
<td>Space based infra-red system (SBIR)</td>
<td>S</td>
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<tr>
<td>GPS III</td>
<td>Frequency standard clock in navigation system</td>
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<td>Galileo Constellation*</td>
<td>Maser Clock</td>
<td>UHF</td>
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<tr>
<td>Satellite (JPL)*</td>
<td>Power amp for on board radar- soil moisture measurements</td>
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<tr>
<td>Meteorological Satellite*</td>
<td>Data Transmission</td>
<td>S</td>
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<td>P142 classified govt. satellite*</td>
<td>Power amp line up for communication</td>
<td>UHF</td>
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<tr>
<td>Galileo Constellation*</td>
<td>Navigation and communication, clock signal</td>
<td>UHF</td>
</tr>
<tr>
<td>Aquarius Satellite*</td>
<td>SSPA on scatterometer for measuring sea water salinity</td>
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</table>

* Multiple RF power transistors
Wide Band Gap

SiC & GaN on SiC
## Wide Band Gap Material Property Advantages

### Material Property

<table>
<thead>
<tr>
<th>Material Property</th>
<th>Si</th>
<th>SiC</th>
<th>GaN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band Gap (eV) 3 Times Silicon</td>
<td>1.1</td>
<td>3.2</td>
<td>3.5</td>
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<tr>
<td>Critical Field (10^6 V/cm) 10 Times Silicon</td>
<td>0.3</td>
<td>3</td>
<td>3.3</td>
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<tr>
<td>Thermal Conductivity (Watt/cm^2-K) 3 Times Silicon</td>
<td>1.5</td>
<td>4.9</td>
<td>&gt;1.5</td>
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</table>

### Capability

- High operating temperature
- High breakdown voltage, higher power output, higher impedance
- Higher Power Per part

### System Benefit

- Increase reliability
- High operating temperature
- Higher power
- Wider bandwidth amplifier
- Reduce part size
- Minimize cooling requirements

2200W Single Ended UHF SiC SIT 125V

0405SC-2200M
125V, 406-450MHz, 300µs, 6%
### SiC Power Transistor Devices

**SiC RF Power Device Family**

<table>
<thead>
<tr>
<th>Band</th>
<th>0150SC-1250M</th>
<th>0405SC-100M</th>
<th>0405SC-500M</th>
<th>0405SC-1000M</th>
<th>0405SC-1500M</th>
<th>0405SC-2200M</th>
<th>1214SC-500M</th>
<th>0912SC-500M</th>
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<tbody>
<tr>
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<td>UHF</td>
<td>UHF</td>
<td>UHF</td>
<td>UHF</td>
<td>UHF</td>
<td>L-Band</td>
<td>Avionics</td>
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<td>1250 W</td>
<td>100 W</td>
<td>500 W</td>
<td>1000 W</td>
<td>1500 W</td>
<td>2200 W</td>
<td>500 W</td>
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<td>8.5 dB</td>
<td>8 dB</td>
<td>8 dB</td>
<td>8 dB</td>
<td>8 dB</td>
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<tr>
<td>Pulse Width:</td>
<td>300 μs</td>
<td>300 μs</td>
<td>300 μs</td>
<td>300 μs</td>
<td>300 μs</td>
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<tr>
<td>Duty Cycle:</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>6%</td>
<td>6%</td>
<td>10%</td>
<td>10%</td>
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<tr>
<td>Efficiency:</td>
<td>60%</td>
<td>50%</td>
<td>50%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>50%</td>
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<td>125V</td>
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<td>KT-FET</td>
<td>KT-FET</td>
<td>ST-FET</td>
<td>ST-FET</td>
<td>TW-FET</td>
<td>ST-FET</td>
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<td>all AU</td>
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</tbody>
</table>

- High breakdown voltage allows the benefits of high voltage operation > 100 Volts
- Vertical structure not dependant on dielectric field strength
- Vertical Structure = High Power Density
- SIT operation in Class AB → Wide dynamic range
- SIT device extremely rugged
- SIT has high breakdown to Vdd Ratio
GaN Devices Improve Size, Weight & Power

• One GaN replaces Five Si BJT transistors

Before

Driver

Output TR

Now

GaN Power

2729GN-500
GaN Technology Advantages

- Highest power per transistor than other solid state solutions - Si BJT, LDMOS, GaAs
- Highest power density – smallest transistor size
- Ability to cover higher frequency
- Excellent Temperature stability
- Better Efficiency
- Broad Band Application
GaN Temperature Stability Advantage Example

Less Than 1 dB Gain and Power Variation from -55°C to +85°C

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Pin (W)</th>
<th>Pout (W)</th>
<th>Gp (dB)</th>
<th>Δ Gain</th>
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<tbody>
<tr>
<td>-55</td>
<td>5</td>
<td>621</td>
<td>20.9</td>
<td>-0.7</td>
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<tr>
<td>+25</td>
<td>5</td>
<td>720</td>
<td>21.6</td>
<td>0</td>
</tr>
<tr>
<td>+85</td>
<td>5</td>
<td>621</td>
<td>20.9</td>
<td>-0.7</td>
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</tbody>
</table>

- Heavy Mode-S ELM pulsing
- High Power >700W
- High Gain > 21 dB
- Excellent Efficiency > 70%

Graph showing 1011GN-700ELM Gain over Temp:
Pin = 5W, Mode-S ELM

## 24+ New 2013 50V GaN Power Transistors

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Freq (MHz)</th>
<th>Pout (W)</th>
<th>Gain Typ (dB)</th>
<th>Efficiency Typ (%)</th>
<th>Pulse Width (µs)</th>
<th>Duty Cycle (%)</th>
<th>Vdd (V)</th>
<th>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1011GN-1000V</td>
<td>1030</td>
<td>1000</td>
<td>17.5</td>
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<td>10</td>
<td>1</td>
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<td>MDSGN-750ELMV</td>
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<td>750</td>
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<td>ELM</td>
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<td>700</td>
<td>19</td>
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<td>20</td>
<td>6</td>
<td>50</td>
<td>55KR</td>
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<td>0912GN-20V</td>
<td>960-1215</td>
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<td>17</td>
<td>55</td>
<td>128</td>
<td>10</td>
<td>50</td>
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<td>960-1215</td>
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<td>16</td>
<td>55</td>
<td>3000</td>
<td>30</td>
<td>50</td>
<td>55KR</td>
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<td>960-1215</td>
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<td>55KR</td>
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</tbody>
</table>
New Long Pulse 1214GN – 600VHE (High Efficiency)

1200 – 1400MHz, 300us, 10%, +50V

• 1.2 – 1.4 GHz
• High Output Power >600W
• High Gain > 17.5 dB typ
• Excellent Efficiency > 60%

Typical Performance

<table>
<thead>
<tr>
<th>Freq(GHz)</th>
<th>Pin (W)</th>
<th>Pout (W)</th>
<th>Id (A)</th>
<th>RL (dB)</th>
<th>Eff(%)</th>
<th>G (dB)</th>
<th>Droop (dB)</th>
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<tbody>
<tr>
<td>1.2</td>
<td>11.2</td>
<td>656</td>
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<td>63%</td>
<td>17.67</td>
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<td>1.3</td>
<td>11.2</td>
<td>644</td>
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<tr>
<td>1.4</td>
<td>11.2</td>
<td>647</td>
<td>1.94</td>
<td>-15.0</td>
<td>70%</td>
<td>17.61</td>
<td>0.3</td>
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✓ Power Matters
✓ 50V Matters
New Long Pulse 1214GN – 300LV

1200 – 1400MHz, 3ms, 30%, +50V

Prototype Performance

<table>
<thead>
<tr>
<th>Freq (GHz)</th>
<th>Pin (W)</th>
<th>Pout (W)</th>
<th>Gp (dB)</th>
<th>Effi (%)</th>
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</tbody>
</table>

- 1.2 – 1.4 GHz
- High Output Power >300W
- High Gain > 16 dB
- Excellent Efficiency > 60%

✓ Power Matters
✓ 50V Matters
✓ Long Pulse Matters
From Heritage to New Technologies
The challenges & benefits
Adopting New Technologies

- Development cycle can exceed 4 years before purchase of flight units
- From flight units purchase to launch can be another 3-5 years
- Requires solid long term engineering and production commitment by Microsemi
- Engage closely with space payload/satellite platform manufacturer(s) to collaborate on the consideration for use in space new technologies
- With all Microsemi divisions having products for space, participate in the industry trade shows/forums/conferences together to offer greatest benefit to the market and our customers offering many products vertically
- Seek to develop/acquire the best new technologies for new space products
- Overcome Recession/Sequestration and other funding issues

<table>
<thead>
<tr>
<th>Phase 1 – up to 4 years</th>
<th>Phase 2 – 3-5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Start</td>
<td>Sub systems assembly</td>
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<tr>
<td>Prototype Delivery</td>
<td>Test and Evaluation</td>
</tr>
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<td>Spacecraft Integration</td>
</tr>
<tr>
<td>Purchase Flight Units</td>
<td>Launch set mount and test</td>
</tr>
</tbody>
</table>
Adopting New Technologies

- Collaboration allows improved development cycle time

- Microsemi broad space products portfolio can reduce supplier count costs

- Microsemi commitment to leading edge space products technologies will increase performance and decrease development and operating costs

- Overcome Recession/Sequestration and other funding

- Where Power Matters, we can together outfit high-performance satellites and payloads to be more safe, secure, and reliable
Thank You