Using RF Power Transistors in Industrial Applications

50 V LDMOS Revitalizes the Industrial Markets

Taura Gardner
Agenda

- Who is Freescale RF?
- Basic 50 V LDMOS Structure
- Using RF in Industrial Applications
- Session Wrap-up and Q & A
Cellular Infrastructure Key Player

- Dedicated, performance-optimized portfolio for all popular frequency bands
- Leader in reliability, performance and consistency
- Advanced multi-stage IC portfolio
- Only vendor offering high-power, cost-effective over-molded plastic packaging
- Leveraging history of leadership and experience to deliver innovative products to new markets
- Competitive line of General Purpose Amplifiers (GPAs) that can be used in any application needing RF Power

*Sources: Gartner Dataquest, Strategy Analytics
Freescale RF Products – Frequency and Power

60 dBm = 1000 W

50 dBm = 100 W

40 dBm = 10 W

30 dBm = 1 W

24 dBm = 1/4 W

14 dBm = 25 mW

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RF Power Market Focus

Industrial, Scientific, Medical
- CO$_2$ Laser Applications
- Magnetic Resonance Imaging (MRI)
- Semi Mfg. Equipment
- Alternative Energy

Broadcast
- Analog & Digital FM & TV
- HF/VHF Communication Equipment

Microwave (Aerospace)
- Air Traffic Management
- Automatic Dependent Surveillance Broadcast
- Weather Radar
One Freescale Advantage: Packaging

Industry Leader in RF Power Packaging

- Most comprehensive portfolio of over-molded plastic and air-cavity packages
- Industry leader in RF power over-molded plastic packaging
- Automated assembly manufacturing for consistency
- Dedicated packaging design center for system level application support
- Multiple assembly locations for secure supply
- Offer IC (integrated circuit) solutions in both package options
- Compatibility with high temperature re-flow Pb-free solders
Supporting Customers at Every Step of the Design Process

Device Evaluations
- Custom Circuit Tuning
- Loadpull
- Ruggedness
- Digital Pre-Distortion
- Temperature Characterization

Integrated Devices
- MD7IC21080N
- MD7IC21270H
- MD7S21300H
- MD8IC21200HS

Reference Designs
- Line-Up Demonstrations
- Symmetrical Doherty
- Multi-stage Doherty
- Asymmetrical Doherty
- Smart Demo Boards / Reference Designs

Integration Strategy
- 2-Stage Devices
- Dual-Path Devices
- Asymmetric, Dual-Path
- Integrated Doherty Splitting / Combining
LDMOS Development Trends

1. Operation up to 3.8 GHz

2. Multi-stage power IC’s

3. Cost effective over molded plastic packaging

4. 50 V LDMOS device technology
In-depth study of the LDMOS Structure
Basic 50 V RF LDMOS Device Structure

- P+ Sinker
- WSi/Poly Gate
- WSi Faraday Shield
- Metal-1 + Metal-2 Drain
- Metal-1 Source
- N+ Source
- PHV
- NHV
- N+ Drain
- P- Epi
- P+ Substrate
- Backside Metal / Source
VHV6 LDMOS vs. Competing Technologies

Higher RF performance:

- Gain: Up to 27 dB - best performance in the industry
- Efficiency: Up to 70% - best performance in the industry
- Linearity: Based upon a platform designed for linear operation
- Fmax: Superior harmonic gain enables high efficiency architectures
- Ruggedness: VHV6’s 120 V breakdown voltage creates devices capable of handling extreme impedance mismatches
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► RF plastic packaging
  • Tighter mechanical tolerance
  • RoHS compliant, no BeO
  • Reduced cost
The advantage of 50 V LDMOS in ISM Applications
- Power Density and Gain

► 50 V
► 500 MHz ISM Device
  • 300 W peak power output
  • 25 dB gain
  • 68% Efficiency
  • $\theta_{JC} = 0.24^\circ$C/W

► 50 V
► 500 MHz ISM device
  • 150 W peak power output
  • 16 dB gain
  • 55% Efficiency
  • $\theta_{JC} = 0.6^\circ$C/W
### Benefits of Higher Gain

#### Example lineup - ISM pulse

## Benefits of Higher Gain - ISM Pulse Example Lineup

<table>
<thead>
<tr>
<th>Standard Solution</th>
<th>Freescale Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.0 kW line-up</strong></td>
<td><strong>1.9 kW line-up</strong></td>
</tr>
</tbody>
</table>

**45 dB of gain**

- **in 3 stages**
- 8:1 combining losses (0.7 dB)

**52 dB of gain in 2 stages**

- Smaller, cheaper, over-molded plastic driver
- More compact design
  - Decreased part count
  - Better device thermal resistance numbers → smaller heatsinks
  - 2:1 combining losses (0.2 dB)
New, wider range ESD structure are designed for better overdrive capability and deeper Class C operating ranges
Section Overview

Device Design Methods Overview
• To learn more about the device design methods, go to the Freescale web site and download

Freescale ISM Solutions
50 V LDMOS
Evolution of Freescale’s 50 V LDMOS

- VHV6 is a 50 V extension to Freescale’s widely accepted 28 V LDMOS technology
- Key technology enhancement tailor-made for the Broadcast, Industrial, Scientific, Medical (ISM) & now Commercial Aerospace markets
- Performance levels exceed those of competitive products
  - High gain and efficiency figures
  - Low thermal resistance lessens the overall cooling capacity needed by the transmitter
  - Multiple technology innovations produce extremely rugged device
- Higher power density means more power per device... so less devices per system!
- Significant cost and board space savings
Main applications in ISM Market

- Plasma, CO2 laser
- MRI
- Synchrotron
- Lighting, Heating
- Miscellaneous RF

- CW
- CW / pulse
- CW
- CW
- CW

- 80MHz
- 64MHz, 130Mhz
- 352MHz, 500 MHz, 1.3Ghz
- 2.45GHZ
- < 700MHz
LDMOS Part Nomenclature

**Device Status**
M - Production  
P - Prototype

**Design Characteristics:**
RF – Radio Frequency Device  
HV – High Voltage Device  
E – Enhanced Ruggedness  
W – Wideband Device  
MG – Monolithic GaAs  
D – Dual Path Device

**Generation of LDMOS**
5 – 5th Gen LDMOS  
6 – 6th Gen  
7 – 7th Gen  
8 – 8th Gen  
3 – TV Broadcast

**Device Type**
H – HFET  
S – Single Ended  
P – Push Pull  
IC – Integrated Circuit  
G – GaAs  
V – Very High Voltage

**Freq Band**
38 – 3800 MHz  
35 – 3500 MHz  
27 – 2700 MHz  
24 – 2400 MHz  
21 – 2100 MHz  
19 – 1900 MHz  
18 – 1800 MHz  
9 – 900 MHz  
4 – 400 MHz  
2 – 200 MHz

**P1dB Output Power Capability**
(in watts)
10 – 10 W  
100 – 100 W  
1K – 1 kW

**Tape and Reel Information**
T1 – (500 or 1,000)  
R1 – 500  
R2 – 1,500  
R3 – 250  
R4 – 100  
R5 – 50  
R6 – 150  
R7 – 25

**Package Details**
G – Gull Wing Surface Mount  
H – Low Rth Ceramic  
N – RoHS Compliant Overmolded Plastic  
B – Bolt Down Overmolded Plastic  
S – Earless Package  
L – Low Gold

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50 V LDMOS ISM Portfolio
HF/VHF/UHF to 600MHz

RF Power ISM Portfolio

>1 kW
- MRF6VP41KH
  1 kW Pulsed, NI-1230/S
  10-450 MHz

>600W
- MRF6VP21KH
  1 kW Pulsed, NI-1230
  10-235 MHz
- MRF6VP11KH
  1 kW Pulsed, NI-1230
  10-150 MHz
- MRF6VP2600H
  600W, NI-1230
  10-250 MHz

500W to 100W
- MRF6V2300N
  300W CW, TO-270/2
  10-600 MHz
- MRF6V2150N
  150W, TO-270/2
  10-450 MHz

<100W
- MRF6V2010N
  10W, TO-270/2
  10-450 MHz
### 50 V LDMOS ISM Device Performance Table

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Operating Frequency (MHz)</th>
<th>Voltage (V)</th>
<th>Rated Power (W)</th>
<th>Technology</th>
<th>Package</th>
<th>$\theta_{JC}$ °C/W</th>
<th>Typical Gain (dB)</th>
<th>Typical Efficiency (%)</th>
<th>Demo Board Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRF6V2010N</td>
<td>10-450</td>
<td>50</td>
<td>10</td>
<td>VHV6</td>
<td>Over-molded</td>
<td>3(5)</td>
<td>23.9</td>
<td>62</td>
<td>27, 64, 130, 220, 450 MHz</td>
</tr>
<tr>
<td>MRF6V2150N</td>
<td>10-450</td>
<td>50</td>
<td>150</td>
<td>VHV6</td>
<td>Over-molded</td>
<td>0.24(5)</td>
<td>25</td>
<td>68.3</td>
<td>27, 64, 130, 220, 450 MHz</td>
</tr>
<tr>
<td>MRF6V2300N</td>
<td>10-600</td>
<td>50</td>
<td>300</td>
<td>VHV6</td>
<td>Over-molded</td>
<td>0.24(5)</td>
<td>25.5</td>
<td>68</td>
<td>27, 64, 88-108 CW, 130, 170-230 Analog, 220, 450 MHz</td>
</tr>
<tr>
<td>MRF6V4300N</td>
<td>10-600</td>
<td>50</td>
<td>300</td>
<td>VHV6</td>
<td>Over-molded</td>
<td>0.24(5)</td>
<td>22</td>
<td>60</td>
<td>450 MHz</td>
</tr>
<tr>
<td>MRF6VP2600H</td>
<td>10-250</td>
<td>88-108</td>
<td>600 CW</td>
<td>VHV6</td>
<td>Air Cavity</td>
<td>0.20(5)</td>
<td>25/OFDM 20/CW*</td>
<td>28.5/OFDM 72/CW*</td>
<td>170-230 Analog, 225 MHz 88-108 MHz (CW)</td>
</tr>
<tr>
<td>MRF6VP11KH</td>
<td>10-150</td>
<td>50</td>
<td>1000(7)</td>
<td>VHV6</td>
<td>Air Cavity</td>
<td>0.03(5)</td>
<td>26</td>
<td>71</td>
<td>27, 81 CW**, 130 CW**, 130 MHz</td>
</tr>
<tr>
<td>MRF6VP21KH</td>
<td>10-235</td>
<td>50</td>
<td>1000(7)</td>
<td>VHV6</td>
<td>Air Cavity</td>
<td>0.03(5)</td>
<td>24</td>
<td>67.5</td>
<td>225 MHz</td>
</tr>
<tr>
<td>MRF6VP41KH</td>
<td>10-450</td>
<td>50</td>
<td>1000(7)</td>
<td>VHV6</td>
<td>Air Cavity</td>
<td>0.03(5)</td>
<td>20</td>
<td>64</td>
<td>352 CW, 450 MHz</td>
</tr>
</tbody>
</table>

(1) Peak power  
(2) Thermal resistance is determined under specified RF operating conditions: 220 MHz @ CW rated power. MRF6V4300N: 450 MHz @ CW rated power  
(3) Thermal resistance is determined under specified RF operating conditions: 225 MHz @ 125 W Avg.  
(4) Preliminary thermal resistance is determined under specified RF operating conditions: 130 MHz @ 1000 W peak, 100 μsec pulse width, 20% duty cycle  
(5) Preliminary thermal resistance is determined under specified RF operating conditions: 225 MHz @ 1000 W peak, 100 μsec pulse width, 20% duty cycle  
(6) Preliminary thermal resistance is determined under specified RF operating conditions: 450 MHz @ 1000 W peak, 100 μsec pulse width, 20% duty cycle  
*Preliminary Data  **Coming Soon
Typical ISM Applications: MRI

- Suggested Freescale RF Devices for MRI applications:
  - MRF6VP11KH
  - MRF6VP2600H
  - MRF6V2010N
Typical ISM Applications: Lighting

- Suggested Freescale RF Devices for Lighting applications:
  - MRF6V2300N
  - MRF6V2010N
  - MRFE6S9060N
Support & Documentation

► DOCUMENTATION
  - Product summary pages available online: www.freescale.com/rfpower
  - Data sheets for all devices available – Now
  - 50 V RF LDMOS White Paper

► SAMPLES / BOARDS
  - Samples of all devices are available – Now
  - Application demo boards available – Now
  - Production quantities available – Now

► MODELS
  - Large-signal product models – External model library recently updated!
New Website and Reduced Time For Model Delivery

► http://www.freescale.com/rf/models (main page)
► All new models are released as individual design-kits as soon as they are completed: single product design-kits (SPDKs)
  • No waiting for a new library containing many parts
Summary

• 50 V LDMOS is a proven technology with multiple RF performance advantages.

• 50 V LDMOS is expanding into several market RF applications.

• Freescale is the technology leader in all forms of high power RF.

Download more info at…

www.freescale.com/rfpower
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