Freescale RF Technology and Product Overview (Non-NDA)

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Freescale RF

Cellular Infrastructure market share position #1

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

*Sources: Gartner Dataquest, Strategy Analytics

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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

Zigbee
Wi-Fi

TD-SCDMA
Unmatched Medium Power Class AB (PHEMT)

Additional LDMOS Markets
Additional GPA Markets (Femtocells)

ISM
Radar, FM/TV and Broadcast
Air Traffic Management
L Band Radar
Cellular Basestation
WiMAX-BWA LDMOS & PHEMT
S-Band Radar

Frequency (MHz)

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LDMOS Development Trends

1) Operation up to 3.8 GHz

2) Multi-stage power IC’s

3) Cost effective over-molded plastic packaging

4) 50V LDMOS device technology
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

May 2010: Freescale’s latest innovation: Introducing 50V High Ruggedness Technology : MRF6VP6300H
RF Power transistors designed for applications operating at frequencies between 1.8 and 600 MHz. These devices are suitable for use in high VSWR industrial, broadcast and aerospace applications.

**Highlights**

- Push pull device operating at 50 V
- 1.8 - 600 MHz
- 300 W Peak Output Power
- 25dB Gain
- >70% Drain Efficiency
- RoHS compliant
- air cavity ceramic NI-780-4 package

- Capable of handling 65:1 VSWR at all phase angles @ 50 Vdc, 300 Watts CW Output Power
RF Power (50 V LDMOS) Market Focus

### Industrial, Scientific, Medical
- CO₂ Laser Applications
- Magnetic Resonance Imaging (MRI)
- Semi Mfg. Equipment
- Alternative Energy

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

### Commercial Aerospace (Avionics & Radar)
- Air Traffic Management
- Automatic Dependent Surveillance Broadcast
- Weather Radar
10 to 500+ MHz ISM Portfolio

With proper cooling, all parts are fully CW capable, even the 1000 W parts

Standard and Enhanced ESD ckt
DC I-V curves are shown on next slide

10 – 500 MHz
Enhanced ESD Structure

-2 $\times 10^{-2}$
-1 $\times 10^{-2}$
-5 $\times 10^{-3}$
0 $\times 10^{0}$
5 $\times 10^{-3}$
1 $\times 10^{-2}$
2 $\times 10^{-2}$

Vgs (V)

I ESD (A)

better for class-C and pulsed;
-2 Vdc bias turns device hard off

older 30 V LDMOS families;

first few 50 V LDMOS devices

newest 30 V and 50 V LDMOS

Enhanced ESD
RF Power Broadcast Portfolio

RF Power 32 Volt UHF Broadcast Portfolio

500W to 100W

MRFE6P300H
300W, NI-860

MRF377H
240W, NI-860

< EOL >

<100W

MRFE6S9060N (28 V)
60W, TO-270

Also E6s9045N

RF Power 50 Volt FM/VHF/UHF Broadcast Portfolio

>1 kW

MRF6VP21KH
1 kW Pulsed, NI-1230

MRF6VP11KH
1 kW Pulsed, NI-1230

>300W

MRF6VP2600H
600W, NI-1230

500W to 100W

MH-FV-3450H/HS
450W, NI-1230/S

MRF6V2300N/E
300W, TO-270/2 WB

MRF6V2150N/B
150W, TO-270/2 WB

<100W

MRF6V2010N/B
10W, TO-270

MRF6V3000NB
90W PEP, TO-270/2WB-4
Avionics Transistors

Nominal CW devices:
- 7s15100H – optimized for 1500 MHz / workable 1400 to 1900 (?)
- 7s16150H – 1500 to 1700 MHz

Consider also the 3.5 GHz WiMAX devices
Devices for Wideband Amplifiers

1) General Purpose Amplifier (GPA) 50-ohm gain blocks
2) GaAs pHEMT, e.g. MRFG35010AN
   100(?) to >5000 MHz; 12 Vdc (and negative gate bias)
3) HF/ VHF ISM, e.g. MRF6V2150N
   10 to 500 MHz; 50 Vdc
4) Land Mobile, e.g. MRF15xx series
   50 to 500+ MHz; 12.5 Vdc; some 7.5 Vdc
5) UHF broadcast parts, e.g. MRF6VP3450H, MRF6V3090N
   470 to >980 MHz; 50 Vdc
6) Certain RF Integrated Circuits, for example
   MW5IC970N  2-stage RFIC with off-chip inter-stage match
   tunable across 130 to 960 MHz; 30 Vdc
   MHV5IC2215N: usable 1200 to 2300 MHz; 30 Vdc
   MW7IC2725N: usable 2200 to 2700 MHz; 30 Vdc
   (other choices shown later)
7) Low-Power (4 and 10 W) LDMOS
   MW6S004N: 1 to 2000 MHz; 30 Vdc
   MW6S010N: 450 to 1500 MHz; 30 Vdc
   MRF6S20010N: 1600 to 2200 MHz; 30 Vdc
Key 1GHz Driver Products

MW7IC008N
8W Wideband IC Driver

Performance
(CW, 100-1000MHz, 28 V, 50 ohm matched in/out, 39.0 dBm peak)
P1dB, CW: 39 dBm
Gain: 32.0 dB
Drain Efficiency: 32%
ACP: - 48 dBc

Timing
Prototype Samples: Available
Mature Samples: Available
Product Launch: Available

Key Features
High Performance HV7 Technology
High Gain Two Stage RFIC
Low Cost Overmolded Package

MW7IC915N
15 W IC Driver

Performance
(1 Carrier WCDMA, 28 V, 32.0 dBm Average)
P1dB, CW: 42.0 dBm
Gain: 37.8 dB
Drain Efficiency: 17%
ACP: - 50 dBc

Timing
Prototype Samples: Available
Mature Samples: Available
Product Launch: Available

Key Features
High Performance HV7 Technology
High Gain Two Stage RFIC
Low Cost Overmolded Package

MW7IC930N
30 W IC Driver

Performance
(1 Carrier WCDMA, 28 V, 35.0 dBm Average)
P1dB, CW: 45.0 dBm
Gain: 36.6 dB
Drain Efficiency: 16%
ACP: - 48 dBc

Timing
Prototype Samples: Available
Mature Samples: Available
Product Launch: Available

Key Features
High Performance HV7 Technology
High Gain Two Stage RFIC
Low Cost Overmolded Package

MW7IC008N
100 – 1000 MHz
Poor phase linearity

MW7IC915N and
MW7IC930N
600 – 1050 MHz
GPA Product Selector Guide

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Freescale 2010 GaAs MMIC Initiative

Leverage existing design and manufacturing capabilities to expand RF product offering beyond power transistor devices

Freescale GaAs MMIC’s are specifically designed for the cellular base station application

Products will be characterized and specified using realistic signal conditions encountered in base stations

Design Support
- Reference demo boards
- Product models

Offer the same level of service and support as for existing LDMOS products

Competitive pricing
Key New Product Features

Enhancement-mode pHEMT low-noise amplifier

- Covers 400 to 1400 MHz
- Broad bandwidth includes W-CDMA as well as high-data-rate networks in new 700 MHz band
- Small-signal gain of 21 dB at 900 MHz
- P1dB output power of 20 dBm
- Output IP3 of 32 dBm
- Isolation of -40 dBc

MML09211H

Very low noise figure: 0.5 dB

Two-stage InGaP HBT power amplifier

- Covers 1800 to 2200 MHz
  - Excellent choice for femto cell base stations, repeaters, and smart grid transceivers
- Icq = 65 mA
- P1dB RF output power of 31 dBm
- Small-signal gain of 26 dB.

MMA20312B

P1dB output of 31 dBm
Key New Product Features

**Versatile pHEMT amplifier**

- **MMG15241H**
  - Covers 500 to 2800 MHz
  - Can be used as driver amplifier in transmit chain or second-stage low-noise amplifier in receive chain
  - Covers 500 to 2800 MHz, Idc = 85 mA
  - Excellent linearity and lower current consumption than typical HBTs
  - Noise figure of 1.2 dB at 2.1 GHz
  - P1dB output of 24 dBm
  - Output IP3 of 39 dBm
  - Small-signal gain of 19 dB

- **MMG20271H**
  - Covers 1500 to 2700 MHz
  - Can be used as driver in transmit chain or second-state amplifier in receive chain
  - Covers 1500 to 2400 MHz
  - Idc = 175 mA, Adjustable Active Bias
  - Noise figure of 1.8 dB at 2.1 GHz
  - P1dB output of 27 dBm
  - Output IP3 of 42 dBm
  - Small signal gain of 15 dB
Freescale RF GaAs pHEMT Products

- 12 V pHEMT (Power listed is P1dB)
  - MRFG35002N6A (2 W, 6 V)* < EOL >
  - MRFG35003N6A (3 W, 6 V)*
  - MRFG35003AN (3 W, 12 V)*
  - MRFG35005AN (4.5 W, 12 V)*
  - MRFG35010AN / A (10 W, 12 V) (Plastic / Ceramic)*
  - MRFG35020A (20 W, 12 V) (Ceramic pkg; input matched) < EOL >

- * indicates devices are unmatched and thus suitable for wideband designs

- Designed for 3.5GHz operation; characterized (class AB S-parameters) from 500 MHz to 5 GHz

- Capable of 5.8 GHz performance
  - MRFG35003: 11 dB gain at 3.5 GHz, 7-8 dB Gain at 5.8 GHz
  - MRFG35010: 10 dB gain at 3.5 GHz, 6.5 to 7 dB Gain at 5.8 GHz
MRF15xx Series Unmatched LDMOS
Land Mobile Radio PAs

Tested at 175 MHz

**MRF1511**
8W, 7.5Vdd
11.5dB gain
55% Eff
PLD-1.5 pkg

**MRF1550**
50W, 12.5Vdd
12.5dB gain
50% Eff
TO-272 pkg

Tested at approx 500 MHz

**MRF1513**
3W, 12.5Vdd
11dB gain
55% Eff
PLD-1.5 pkg

**MRF1517**
8W, 7.5Vdd
11dB gain
55% Eff
PLD-1.5 pkg

**MRF1518**
8W, 12.5Vdd
11dB gain
55% Eff
PLD-1.5 pkg

**MRF1535**
35W, 12.5Vdd
10dB gain
50% Eff
TO-272 pkg

**MRF1570**
70W, 12.5Vdd
10dB gain
50% Eff
TO-272 pkg
2.4 GHz **ISM Portfolio** (and Zigbee)

**802.15.4 Transceivers**  
Flexibility with Proven Performance  
Freescale Semiconductor adds a 2nd generation to it's popular IEEE® 802.15.4 2.4GHz ...

**802.15.4 Platforms ICs**  
Integration brings reduced size and cost. Freescale has raised the bar 802.15.4 platform IC by ...

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**Low Noise Amplifiers**  
suitable for Zigbee –

- MBC13720, 13916, 13821
- RF BiCMOS process/  
  SiGe:C option

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**2400 MHz ISM Band**

- **MRF6P24190H**  
  190W, Ni1230

- **MRF6S24140H**  
  140W, Ni880

- **MW7IC2425N**  
  25W, TO-272 WB-16

- **MW6IC2420N**  
  20W, TO-272 WB-16

Consider also the MW7IC2725N  
23 dB gain / 2200 – 2700 MHz
WiMAX, Cellular Infrastructure, LTE

WiMAX Product Overview
Fact Sheet: “WiMAX RF Power Solutions” RFWIMAXFS

http://www.freescale.com/webapp/sps/site/taxonomy.jsp?nodeId=0106B975208362

for Cellular Infrastructure, WiMAX, and LTE device questions
contact Gene Heimbecher (geneh@freescale.com)
## Newest Driver Stage Products by Band

<table>
<thead>
<tr>
<th>Band</th>
<th>700 - 1000 MHz</th>
<th>1800 - 2000 MHz</th>
<th>2100 - 2200 MHz</th>
<th>2300 - 2700 MHz</th>
</tr>
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<tbody>
<tr>
<td><strong>50 W</strong></td>
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<tr>
<td>P1dB Output Power</td>
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<td></td>
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<tr>
<td>30 W</td>
<td>MWE6IC9080N</td>
<td>MD7IC2050N</td>
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<tr>
<td></td>
<td>80 W P1dB / TO-270WB-14</td>
<td>50 W P1dB / TO-270WB-14</td>
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<tr>
<td></td>
<td>2 Stage RFIC</td>
<td>2 Stage RFIC</td>
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<tr>
<td>10 W</td>
<td>MRFE6S9046N</td>
<td>MRF7P20040HS</td>
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<td></td>
<td>45 W P1dB / TO-270WB-4</td>
<td>40 W P1dB / NI-780-4</td>
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<td></td>
<td>Single Stage Discrete</td>
<td>Dual Path Single Stage Discrete</td>
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<td></td>
<td>MW7IC930N</td>
<td>MW7IC2040N</td>
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<td></td>
<td>30 W P1dB / TO-270WB-16</td>
<td>40 W P1dB / TO-270WB-16</td>
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<td>2 Stage RFIC</td>
<td>2 Stage RFIC</td>
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<td><strong>10 W</strong></td>
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<tr>
<td>P1dB Output Power</td>
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<tr>
<td>15 W</td>
<td>MW7IC915N</td>
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<td></td>
<td>15 W P1dB / PQFN 8x8</td>
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<td>2 Stage RFIC</td>
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</tbody>
</table>

**Device Naming Conventions**

- **D** = Dual Path
- **S** = Single Ended
- **H** = Air Cavity Low Rth
- **N** = Overmolded Plastic
Freescale RF Portfolio – Beyond silicon

Design Support

• Data sheets for production devices
• Test Fixtures and kits
• S-parameters for small signal devices
• Large-signal product models
• Application Notes

50 V RF LDMOS White Paper
RF Package Construction

Conventional Ceramic Package

- Cu laminate heat sink
- AuSi eutectic die attach (hard solder)
- Cavity style package
- Epoxy lid seal
- Air surrounding the wire bonds

Power Plastic Package

- Cu heat sink
- Pb based (soft solder) die attach
- Over-molded package
- Epoxy mold compound
- Mold compound surrounding the wire bonds

Tightest Mechanical Tolerances
Lowest Cost
RF Power Plastic Package Construction

Lead frame design with thicker heat sink for better thermal performance

LDMOS die with Al top metal and Al wire for a monometallic bond site eliminating the 150°C Tj barrier for device operation

Thermoset mold compound has been qualified to increase the Tj to 200°C (and recently, to 225°C in some devices)

Packages designs specifically for Power RF applications, not just a modification of a low frequency power package

Similar processes and materials used are also preferred for under-hood automotive applications
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

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

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

- **Level 0**: The model is based entirely on simulations with no comparison / optimization against measured data.
  - These models do not appear on our external website. They can be released to customers under NDA with agreement of applications and marketing teams.

- **Level 1**: Optimize the Level-0 model against S-parameters and RF test-fixture measurements (gain, efficiencies, IRL, etc.). Validates the model at single impedance presented to package leads.
  - Requires impedance probes or an accurate model for the PCB.

- **Level 2**: Optimize the model against a S-parameters and loadpull contours and drive-ups at various impedance points.

**Notes:**

- Validation reports are available for all Level 1 & 2 models.
  - Released only under NDA to customers.
- Level-1 and Level-2 models are considered validated. Desired level depends on application type, required accuracy, internal resources and delivery date.
App Notes on PCB-Attachment of RF Transistors and ICs

AN1908 “Solder Mounting Method for the MRF19090S and Similar Packages”
<soldering of ceramic air cavity packages>

AN1907 “Solder Reflow Attach Method for High Power RF Devices in Plastic Packages”
<soldering of plastic over-molded packages>

AN1949 “Mounting Method for the MHVIC910 (PFP-16) and Similar Surface Mount Packages”
<soldering of surface mount packages>

AN1923 “Mounting Method with Mechanical Fasteners for the MRF19090 and Similar Packages”
<bolt down of “eared” ceramic air cavity packages (package bottom not soldered)>

AN3263 “Bolt Down Mounting Method for High Power RF Transistors and RFICs in Over-Molded Plastic Packages”
<bolt down of “eared” plastic over-molded packages (package bottom not soldered)>

AN3789 “Clamping of High Power RF Transistors and RFICs in Over-Molded Plastic Packages”
<clamping of “earless” plastic over-molded packages (package bottom not soldered)>

AN2467 and AN3778 - PCB design guidelines for surface mount PQFN and QFN packages