



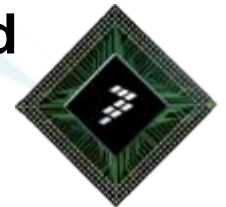
# Freescale Technology Forum

Design Innovation.

November 2008

## Highly Reliable 50 V RF Power LDMOS Devices Designed Specifically for Broadcast and ISM Applications

PN118



**Antoine Rabany**

Chengdu Design Center Development Manager

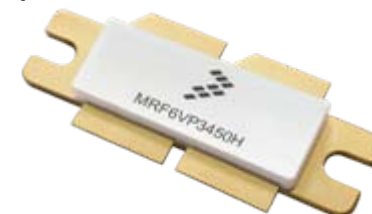
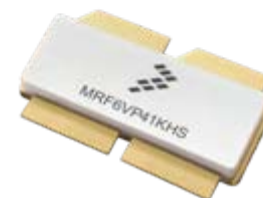
# New 50V LDMOS Devices for Industrial and Broadcast Applications



- ▶ **Freescale breaks new ground with 50V RF power LDMOS**
- ▶ *New standards set for RF power transistors designed specifically for industrial, broadcast and pulsed applications*
- ▶ MUNICH, Germany – (Freescale Technology Forum) – Oct. 16, 2007 – Freescale Semiconductor has expanded its portfolio of 50 V LDMOS RF power transistors with three new devices that set new standards for efficiency, gain, and thermal resistance when compared to competing bipolar and MOSFET devices.
- ▶ The introduction provides competitive advantages for Freescale’s growing roster of industrial customers, while creating entirely new RF power opportunities for the company in broadcast, scientific, medical, radar and pulsed applications markets.

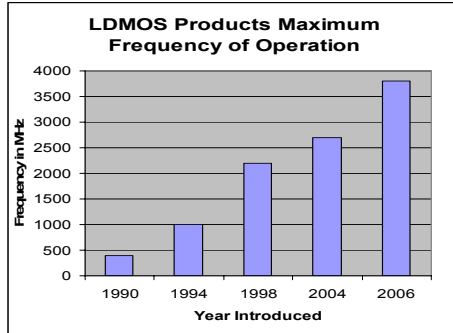
# Evolution of Freescale's 50 V LDMOS – Supporting ISM and Broadcast Applications

- ▶ **Phase I:** June 2006 – IMS/MTTS, San Francisco
  - **50 V VHV6 LDMOS technology introduction (*MRF6V2300N*)**
    - A key technology enhancement, tailor-made for Broadcast and ISM markets
    - Over-molded plastic packaging – a first in ISM, the most cost-effective solutions available
    - Performance levels exceed those of competitive products
- ▶ **Phase II:** June 2007 – IMS/MTTS, Hawaii
  - **Industry's first 1 kW rated RF Power Amplifier for ISM (*MRF6VP11KH*)**
    - First 50 V LDMOS 1 kW device, suitable for pulsed applications requiring high output power
    - Best-in-class drain efficiency of 65% at 1kW peak in Class C
    - Significant cost and board space savings
- ▶ **Phase III:** October 2007 – Freescale Technology Forum, Munich
  - **50 Volt RF Power Amplifiers for HF/VHF/UHF markets (*MRF6VP41KH, MRF6VP2600H*)**
    - Unprecedented power levels covering the HF/VHF broadcast band
    - Industry's first air-cavity packaged device optimized for solder-down mounting
    - Portfolio supports Broadcast and Pulsed Radar applications
- ▶ **Phase IV:** April 2008 – National Association of Broadcasters (NAB), Las Vegas
  - **50% more power than leading competitor for UHF markets (*MRF6VP3450H*)**
    - Unprecedented power levels covering the UHF broadcast band
    - Multiple technology innovations produce extremely rugged device
    - Portfolio supports analog and digital Broadcast applications

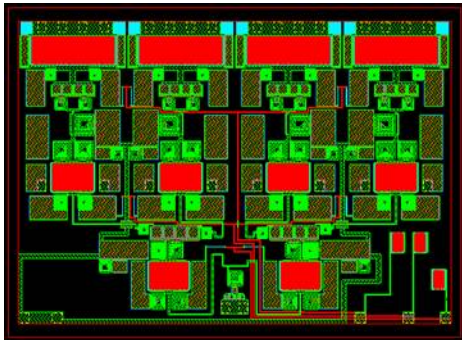


# LDMOS Development Trends

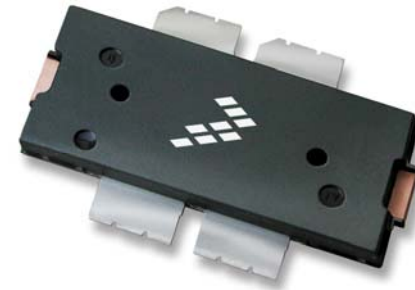
## 1) Operation up to 3.8 GHz



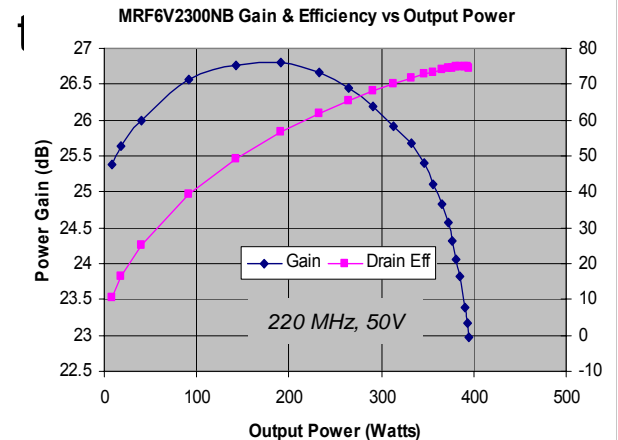
## 2) Multi-stage power IC's



## 3) Cost effective over-molded plastic packaging



## 4) 50V LDMOS device



# Technology Comparison Matrix

Attribute	Si VMOS	28V RF-LDMOS	50V RF-LDMOS
CW eff. at P1dB	3	5	5
Power Gain	3	5	5
Thermal resistance	3	4	5
CW Power Density	3	3	4
High Intrinsic Zin / Zout (wideband)	3	3	4
On-Die Passives Integration	2	4	4
Variability / Performance spread	2	4	4
Technology Maturity	5	5	4
Reliability	4	5	5

# Freescale Introduced 50 Volt LDMOS to ISM Market

June, 2006

- ▶ Key technology enhancement tailor-made for HF/VHF/UHF markets
  - Utilizing long history of RF experience and innovation, Freescale introduced a 50 V extension to the widely accepted 28 V LDMOS technology – VHV6 LDMOS
  - Performance levels exceed those of competitive ISM products
    - Highest gain figures in the industry - up to 27 dB!
      - Less gain stages needed – saves cost and board space
    - Exceptional efficiency - up to 70%
  - Today - Proven, mature technology with production data for >1 year
- ▶ Over-molded plastic packaging – **A first** in ISM, the most cost-effective solutions available!



# MRF6VP3450H Key Messages

**50% more peak power than the nearest competitor.**

Revolutionizing the Broadcast industry with unprecedented combination of power, ruggedness and efficiency.

## Unprecedented Power

**50 V VHV6 LDMOS:**  
A key technology enhancement, tailor-made for Broadcast & ISM markets

- 23 dB Gain @ 90 W Avg. (DVB-T OFDM Signal, 64 QAM)
- 23 dB Gain @ 450 W PEP (Two-tone Test)

Unprecedented power levels covering the UHF broadcast band

Less gain stages needed – saving cost and board space and improving reliability

## Extremely Rugged

Multiple technology breakthroughs enable the MRF6VP3450H to handle stringent mismatched and PAR conditions

Operating at 50 V with 450 W Peak Power, 10  $\mu$ sec Pulse Width, 2.5% Duty Cycle, the MRF6VP3450H can survive 10:1 VSWR at all phase angles

Incorporates protection against electrostatic discharge (ESD), making it manufacturing friendly

Higher range of negative gate-source voltage improves RF overdrive capability

## Ultra Efficient

Careful attention to the device's thermal design to maintain a low operating junction temperature

Exceptional efficiency:

- 28% (DVB-T OFDM Signal, 64 QAM)
- 45% (Two-tone Test)

Low thermal resistance lessens the overall cooling capacity needed by the transmitter

Leading efficiency and low thermals decrease operating cost for TV broadcasters

# Standard 250 W Line-up



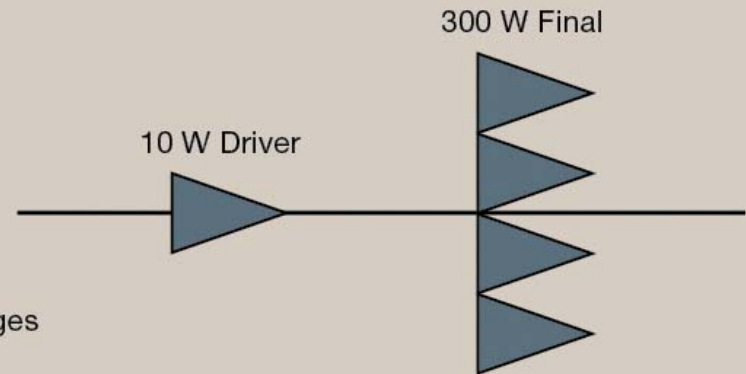
## Analog and Digital UHF TV - Output Transistor

This industry standard line-up provides 250 W Avg. output power with two stages and five devices.

### Standard Solution

250 Watt Avg.  
Line-up

- 250 W Avg.  $P_{out}$
- 29 dB of gain in 2 stages



Devices	Standard Driver	4xStandard Final	Totals
Typical Gain	15 dB	15 dB	29 dB
$P_{out}$	10 W	70 W	250 W Avg.
Drain Efficiency	10%	30%	24%

*5 total parts, DVB-T OFDM signal, 10 PAR dB, 0.5 dB splitting and combining loss*



# Freescale 320 W Line-up

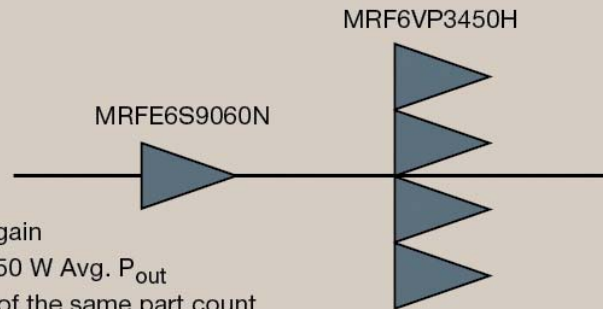
## Analog and Digital UHF TV - Output Transistor

The MRF6VP3450H's high level of gain (23 dB) and high output power capability (90 W Avg. DVB-T OFDM) allows for very compact line-ups, providing 320 W Avg. output power with only two stages and five devices. This class-leading RF performance is 8 dB higher in gain and 30% higher in output power capability than the current standard solution.

### Freescale MRF6VP3450H

320 Watt Avg.  
Line-up

- 42 dB gain vs. 29 dB gain
- 320 W Avg.  $P_{out}$  vs. 250 W Avg.  $P_{out}$
- 30% more power out of the same part count
- 8 dB higher gain on the output device
- 6 dB higher gain on the driver



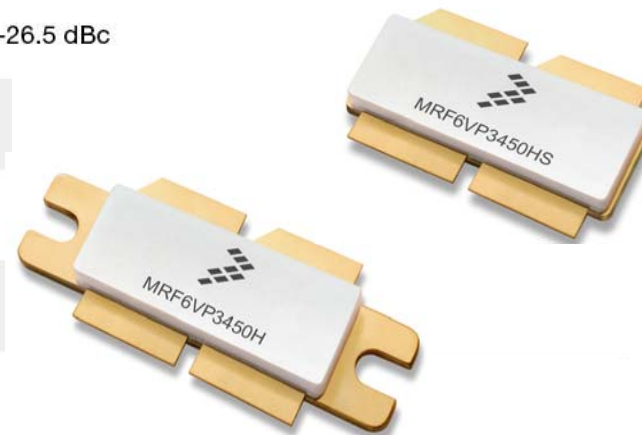
Devices	MRFE6S9060N	4xMRF6VP3450H	Totals
Typical Gain	21 dB	23 dB	42 dB
$P_{out}$	2.8 W	90 W	320 W Avg.
Drain Efficiency	10%	28%	24%

*5 total parts, DVB-T OFDM signal, 10 PAR dB, 0.5 dB splitting and combining loss*



# MRF6VP3450H/HS Technical Features

	Typical Worst Case in Broadband Fixture, 470 to 860 MHz	Typical Values @ 860 MHz measured in Broadband Fixture
RF Output Power (at 860 MHz)	90 Watts Avg. DVB-T, 450 W PEP Two-tone	90 Watts Avg.DVB-T, 450 W PEP Two-tone
Drain Efficiency	26% (DVB-T OFDM Signal, 64 QAM) 40% (Two-tone Test)	28% (DVB-T OFDM Signal, 64 QAM) 45% (Two-tone Test)
Gain	21.5 dB @ 90 W Avg. (DVB-T OFDM Signal, 64 QAM) 21.5 dB @ 450 W PEP (Two-tone Test)	23 dB @ 90 W Avg. (DVB-T OFDM Signal, 64 QAM) 23 dB @ 450 W PEP (Two-tone Test)
ACPR	-61 dBc (4 MHz Offset, 4 kHz Bandwidth)	-62 dBc (4 MHz Offset, 4 kHz Bandwidth)
Third Order Intermodulation Distortion	-26 dBc	-26.5 dBc
Maximum Tolerable VSWR (at 450 W Peak Power output, 50 V supply) @ 470 MHz	10:1 VSWR with 10 μsec Pulse Width, 2.5% Duty Cycle	
Package	NI-1230, NI-1230S Air Cavity Ceramic Packages	
Operating Voltage, Current	50 Vdc, 1400 mA	
Features	Internal Input Impedance Matching Integrated ESD Protection RoHS Compliant	



# RF Power HF/VHF Broadcast Products

## MRF6VP2600H 600 W CW, NI-1230

Analog and Digital FM  
VHF TV

*Designed primarily for wideband applications with frequencies up to 250 MHz*

- Typical DVB-T OFDM performance at 225 MHz:  $V_{DD} = 50$  volts,  $I_{DQ} = 2600$  mA,  $P_{out} = 125$  watts
  - Power gain = 25 dB
  - Drain efficiency = 28.5%
  - ACPR @ 4 MHz offset = -61 dBc in 4 kHz bandwidth
  - $\theta_{JC} = 0.20^{\circ}$  C/W
- Capable of handling 10:1 VSWR, @ 50 Vdc, 225 MHz, 600 watts peak power, pulse width = 100  $\mu$ sec, duty cycle = 20%

## MRF6VP21KH 1 kW Pulsed, NI-1230

Digital VHF TV

*Designed primarily for pulsed wideband applications with frequencies up to 235 MHz*

- Typical pulsed performance at 225 MHz:  $V_{DD} = 50$  volts,  $I_{DQ} = 150$  mA,  $P_{out} = 1000$  watts peak, pulse width = 100  $\mu$ sec, duty cycle = 20%
  - Power gain = 24 dB
  - Drain efficiency = 67.5%
  - $\theta_{JC} = 0.03^{\circ}$  C/W
- Capable of handling 10:1 VSWR, @ 50 Vdc, 225 MHz, 1000 watts peak power, pulse width = 100  $\mu$ sec, duty cycle = 20%

## MRF6V2300N 300 W CW, TO-270 WB

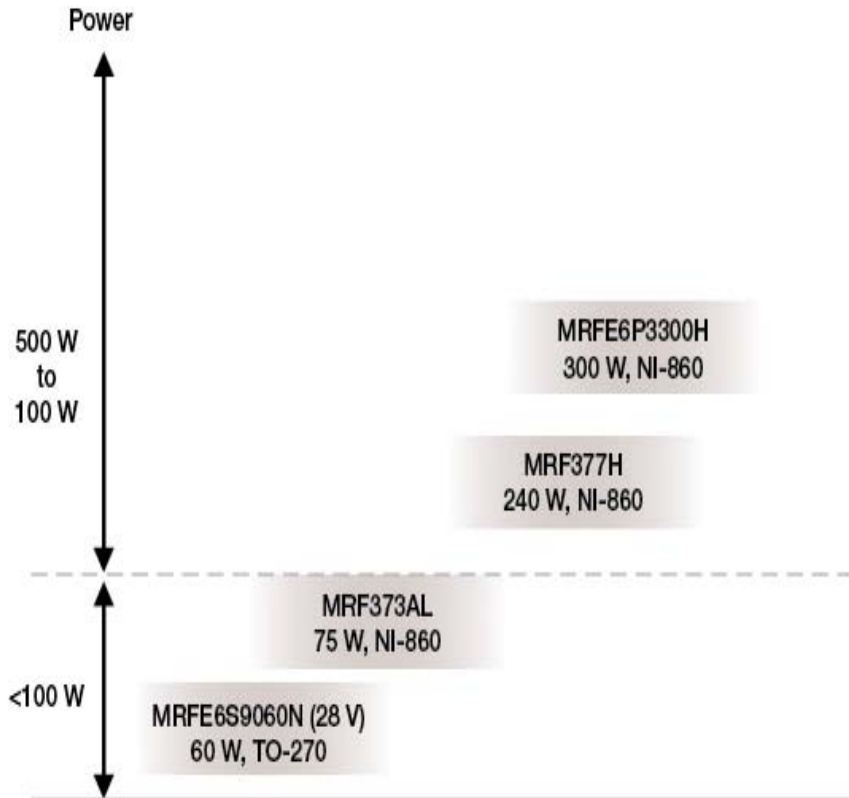
Analog and Digital FM  
VHF TV

*Designed primarily for CW large-signal output applications with frequencies up to 600 MHz.*

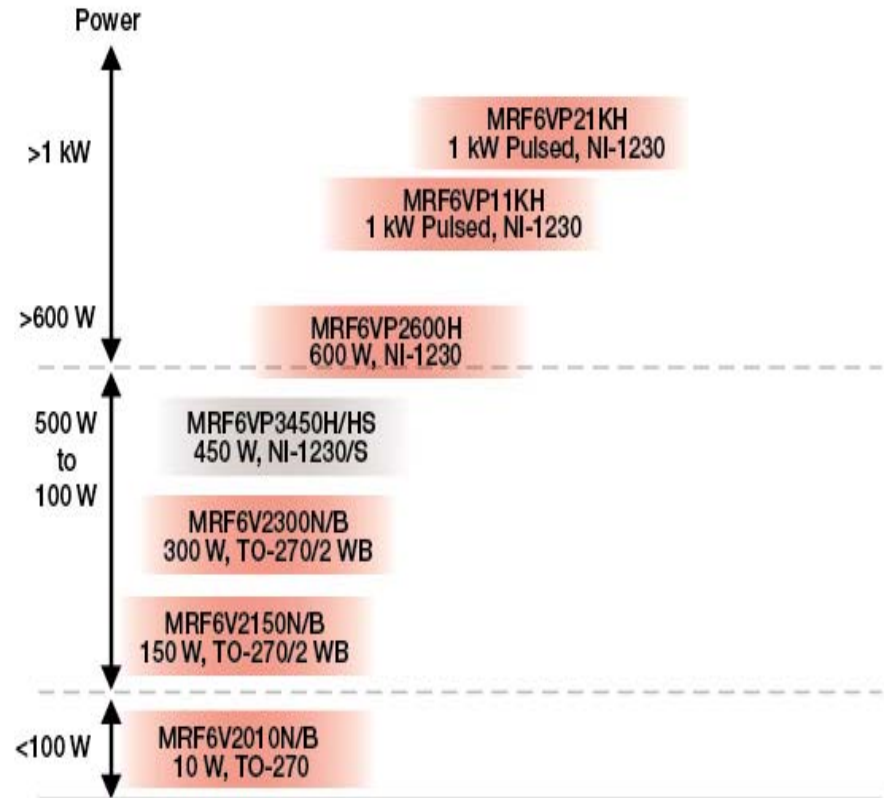
- Typical CW performance at 220 MHz:  $V_{DD} = 50$  volts,  $I_{DQ} = 900$  mA,  $P_{out} = 300$  watts
  - Power gain = 25.5 dB
  - Drain efficiency = 68%
  - $\theta_{JC} = 0.24^{\circ}$  C/W
- Capable of handling 10:1 VSWR, @ 50 Vdc, 220 MHz, 300 watts CW output power

# Complete Broadcast Portfolio

## RF Power 32 Volt UHF Broadcast Portfolio



## RF Power 50 Volt FM/VHF/UHF Broadcast Portfolio



UHF  VHF/FM

# HF/VHF RF Power Portfolio

for applications up to 450 MHz

## MRF6V2300N/NB



TO-272 WB-4



TO-270 WB-4

### Highlights

Single-ended part operating at **50 V**:

**300 W**

Rated P1dB

**27 dB**

Gain at 220 MHz

**68%**

Efficiency at CW P1dB

**0.24 °C/W**  $\Theta_{jc}$

RoHS compliant upgrade of the MRF151G

Production qualified

# HF/VHF RF Power Portfolio

for applications up to 450 MHz

## MRF6V2150N/NB



TO-272 WB-4



TO-270 WB-4

### Highlights

Single Ended part operating at **50 V**:

**150 W** Rated P1dB  
**25.5 dB** Gain at 220 MHz  
**69%** Efficiency at CW P1dB  
**0.3 °C/W**  $\Theta_{jc}$

RoHS compliant upgrade of the MRF151

Production qualified

# HF/VHF RF Power Portfolio

for applications up to 450 MHz

## MRF6V2010N/NB



**TO-272-2**



**TO-270-2**

### Highlights

Single Ended part operating at **50 V**:

**10 W**

Rated P1dB

**25 dB**

Gain at 220 MHz

**68%**

Efficiency at CW P1dB

RoHS compliant, driver

**Production qualified**

# Freescale Broadcast – Beyond Silicon

## ▶ **COLLATERAL**

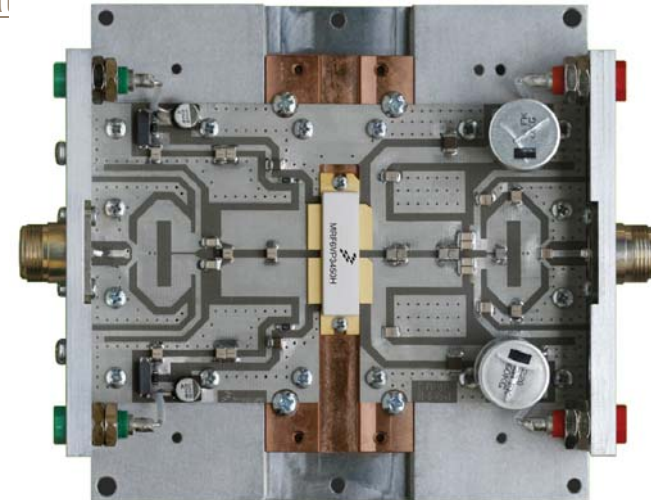
- ▶ Product summary pages available online:  
[www.freescale.com/rfbroadcast](http://www.freescale.com/rfbroadcast)
- ▶ Data sheets for all devices in production, contact Taura/Jeannette for prelim data sheets.
- ▶ Promotional brochure (Doc# BR1607 Rev. 1)
- ▶ MRF6VP3450H Fact Card (Doc# BRDCAST50V Rev. 0)
  - Above documentation is available through Freescale's Literature Distribution Center [www.freescale.com/documental](http://www.freescale.com/documental) Literature" under Related Links.

## ▶ **SAMPLES / BOARDS**

- ▶ Samples of all devices are available now
- ▶ Application demo boards available now
- ▶ Production NOW!

## ▶ **MODELS**

- ▶ Large-signal product models available in Q4, 2008



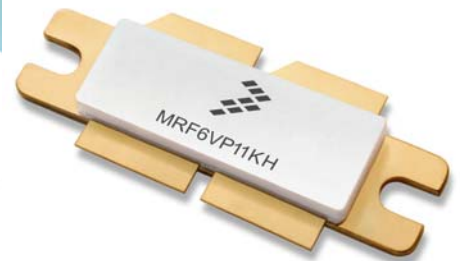


# Freescale Technology Forum

## Design Innovation.



## ISM Portfolio Overview



# HF/VHF ISM Portfolio

## for ISM and Broadcast Applications up to 450 MHz

Performance Table for New ISM Devices

Part Number	Operating Frequency (MHz)	Voltage (V)	Rated Power (W)	Technology	Package	$\theta_{Jc}$ °C/W	Typical Gain (dB)	Typical Efficiency (%)
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**HF/VHF/UHF ISM – To 450 MHz Devices** – Freescale’s new line of VHV ISM devices offer high gain and efficiency and can be used up to 450 MHz at 50 V supply voltage. Superior gain in the harmonic frequencies makes them highly suitable for higher classes of amplifier operation.

<b>MRF6V2010N</b>	10-450	50	10	Very High Voltage LDMOS (VHV6)	Single-ended Plastic	3 <sup>(2)</sup>	23.9	62
<b>MRF6V2150N</b>	10-450	50	150	Very High Voltage LDMOS (VHV6)	Single-ended Plastic	0.24 <sup>(2)</sup>	25	68.3
<b>MRF6V2300N</b>	10-450	50	300	Very High Voltage LDMOS (VHV6)	Single-ended Plastic	0.24 <sup>(2)</sup>	25.5	68
<b>MRF6VP11KH</b>	10-150	50	1000 <sup>(1)</sup>	Very High Voltage LDMOS (VHV6)	Push-pull Air Cavity	0.03 <sup>(3)</sup>	26	71
<b>MRF6VP21KH</b>	10-235	50	1000 <sup>(1)</sup>	Very High Voltage LDMOS (VHV6)	Push-pull Air Cavity	0.03 <sup>(4)</sup>	24	67.5
<b>MRF6VP41KH</b>	10-450	50	1000 <sup>(1)</sup>	Very High Voltage LDMOS (VHV6)	Push-pull Air Cavity	0.03 <sup>(5)</sup>	20.5	64

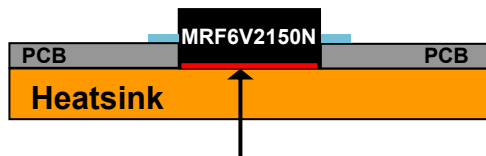
**ISM Band – 2.45 GHz Devices** – Derived from Freescale’s industry-leading cellular infrastructure portfolios, the MW6IC2420NB, MRF6S24140H and MRF6P24190H devices operate at 28 V and achieve high levels of performance for 2.45 GHz applications.

<b>MW6IC2420NB</b>	2450	28	20	28 Volt LDMOS	Single-ended Plastic	1.8 1	19.5	27
<b>MRF6S24140H</b>	2450	28	140	28 Volt LDMOS	Flanged Air Cavity	0.29	13.2	45
<b>MRF6P24190H</b>	2450	28	190	28 Volt LDMOS	Flanged Air Cavity	0.22	13.2	46.2

# Over-molded RF Plastic Packaging A Freescale Success Story

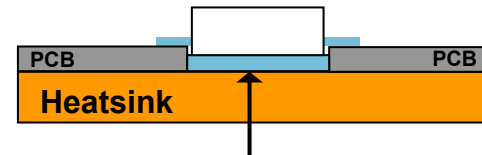
- ▶ Over 20 million devices delivered in RF over-molded plastic packages.
  - Excellent reliability record
  - RoHS compliant,
  - Low thermal resistance:  $0.3^{\circ} \text{C/W}$

## Freescale



With 68% efficiency at 150 W:  
T<sub>j</sub> is increased by **+21° C**

## Competitive Products



With 55% efficiency and  $0.6^{\circ} \text{C/W}$  at 150 W:  
T<sub>j</sub> is increased by **+73° C**

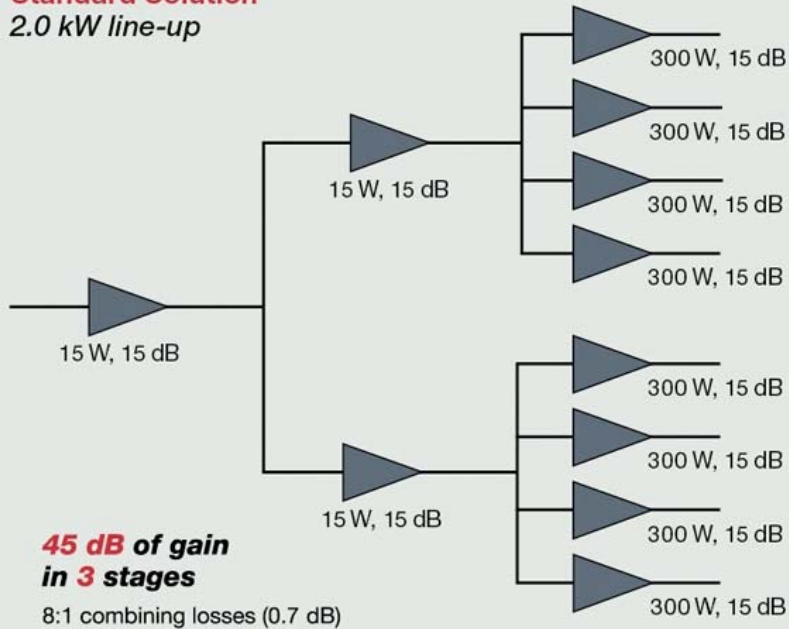
- Lower junction temperature means increased reliability and lifetime

# Benefits of Higher Gain

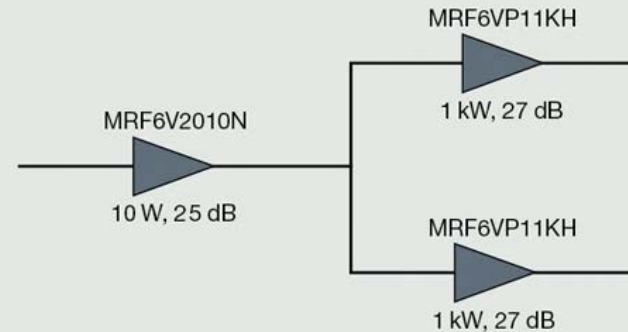
## ISM pulse example line-up

### Benefits of Higher Gain – ISM Pulse Example Lineup

#### Standard Solution 2.0 kW line-up



#### Freescal Solution 1.9 kW line-up



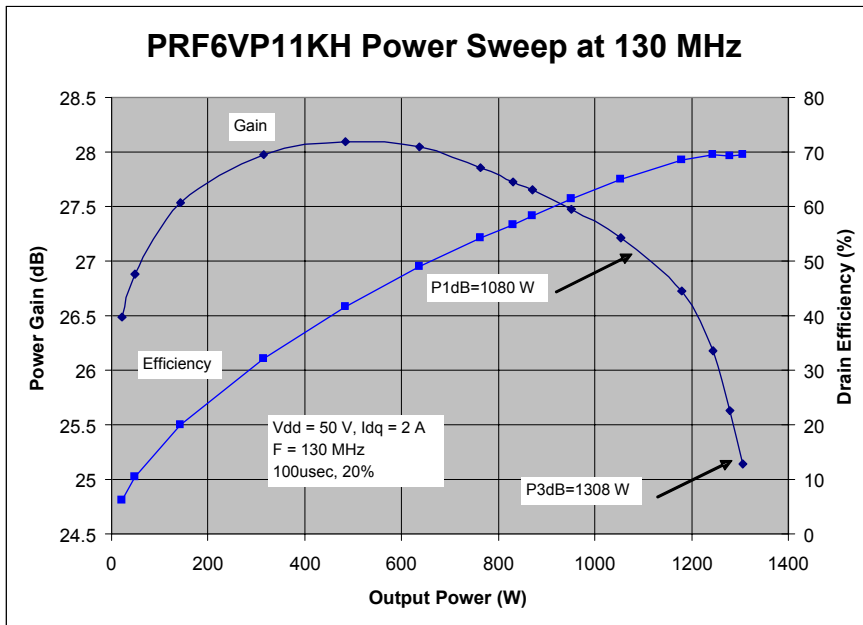
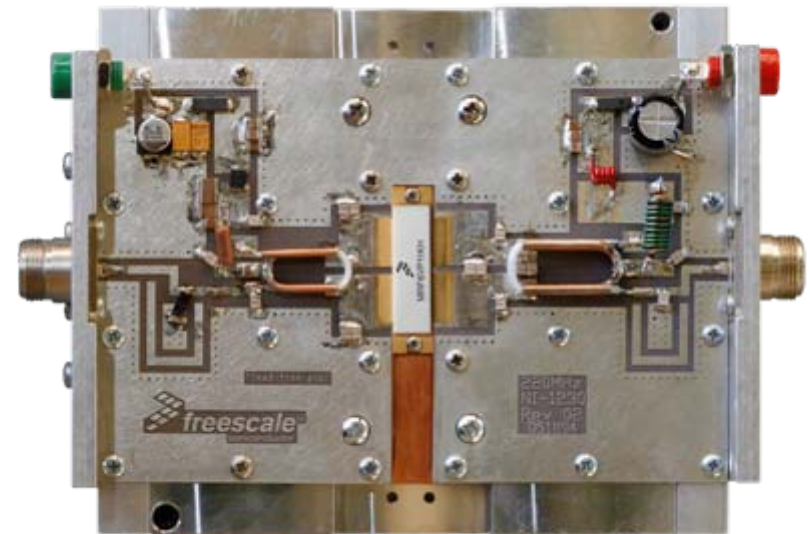
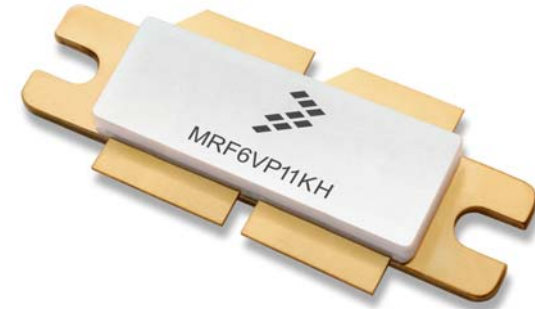
#### 52 dB of gain in 2 stages

- 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)

# MRF6VP11KH 1 kW Peak Push-Pull HF/VHF Device

## ► First 1 kW Peak rated LDMOS device

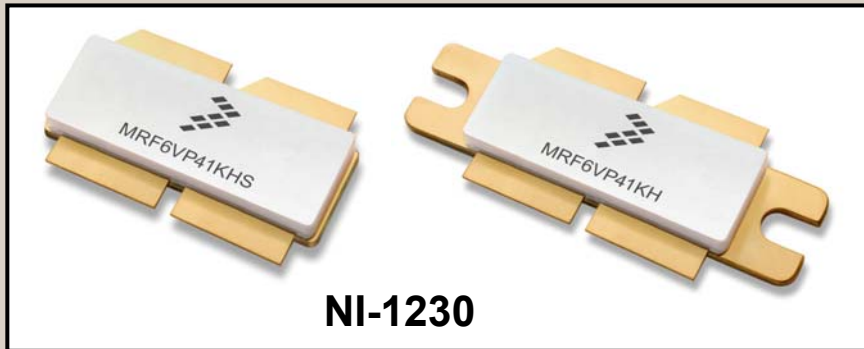
- P1 dB – 1080 W, Efficiency – 65%
- P3 dB – 1308 W, Efficiency – 70%
- $\theta_{JC}$  –  $0.03^{\circ}$  C/W (preliminary, pulsed conditions)



# MRF6VP41KH/HS

for pulsed ISM and Broadcast Applications up to 450 MHz

## MRF6VP41KH/S



### Highlights

Push-pull part operating at **50 V**:

**1000 W**

Pout peak

**20.5 dB**

Gain at 450 MHz

**64%**

Drain Efficiency

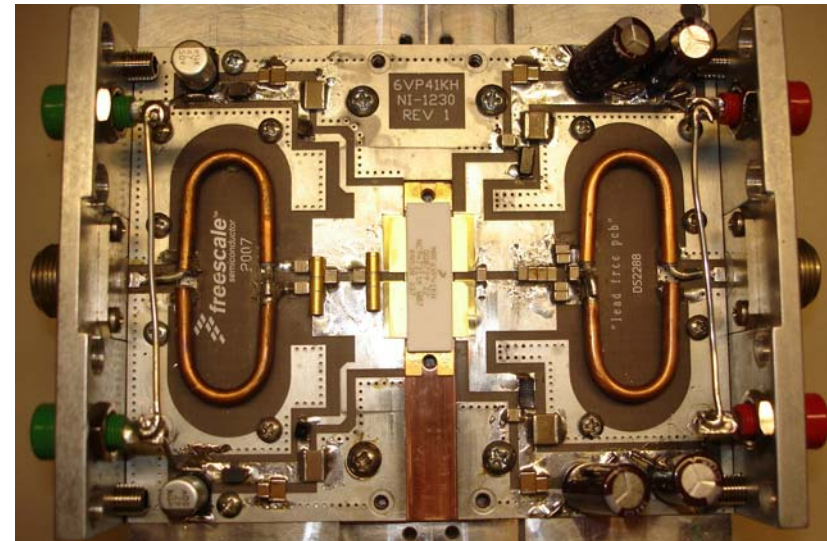
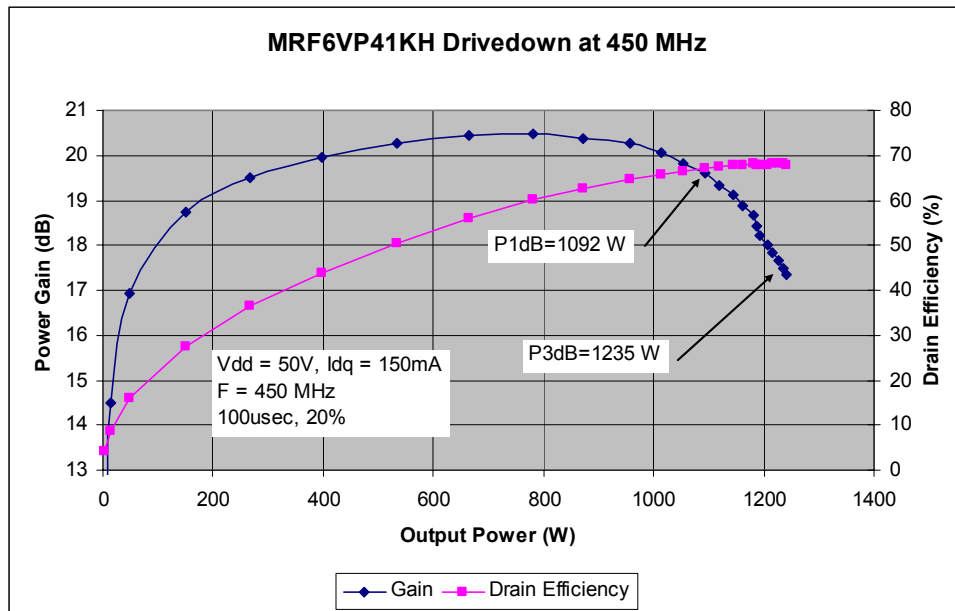
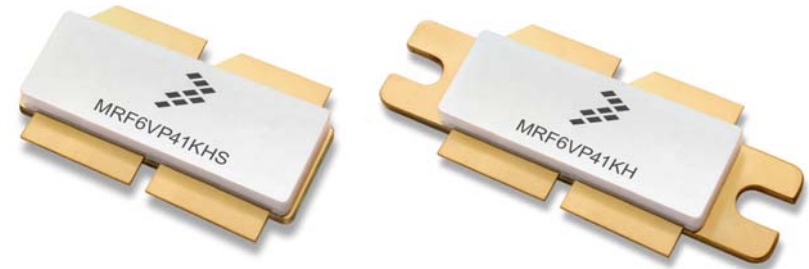
RoHS compliant air cavity ceramic package

# MRF6VP41KH/HS

## 1 kW Peak Push-Pull HF/VHF Device

### ► First 1 kW Peak rated LDMOS device

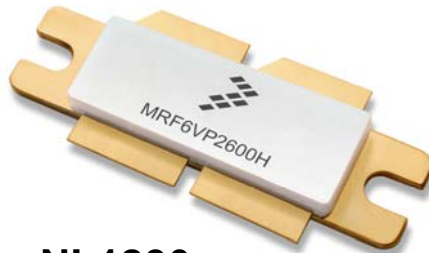
- P1 dB – 1092 W, Efficiency – 64%
- P3 dB – 1235 W, Efficiency – 69%
- $\theta_{JC}$  – 0.03° C/W (preliminary, pulsed conditions)



# MRF6VP2600H

for ISM and Broadcast Applications up to 250 MHz

## MRF6VP2600H



NI-1230

### Highlights

Push-pull part operating at **50 V**:

**600 W**      Rated P1dB

Typical DVBT OFDM performance at 225 MHz

**26 dB**      Gain at 225 MHz

**29%**      Drain Efficiency

**-61dBc**      ACPR

RoHS compliant air cavity ceramic package

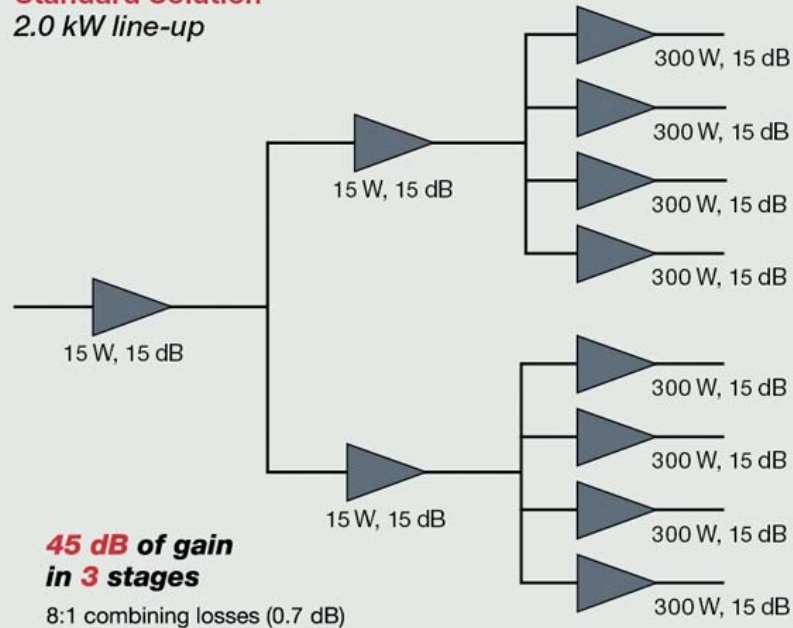


# Benefits of Higher Gain

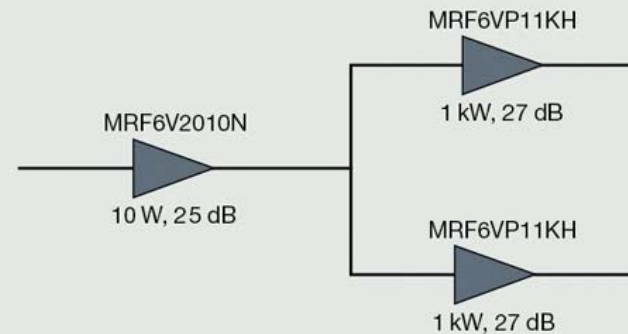
## ISM pulse example line-up

### Benefits of Higher Gain – ISM Pulse Example Lineup

#### Standard Solution 2.0 kW line-up



#### Freescal Solution 1.9 kW line-up



#### 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)

# Freescale Technology Forum

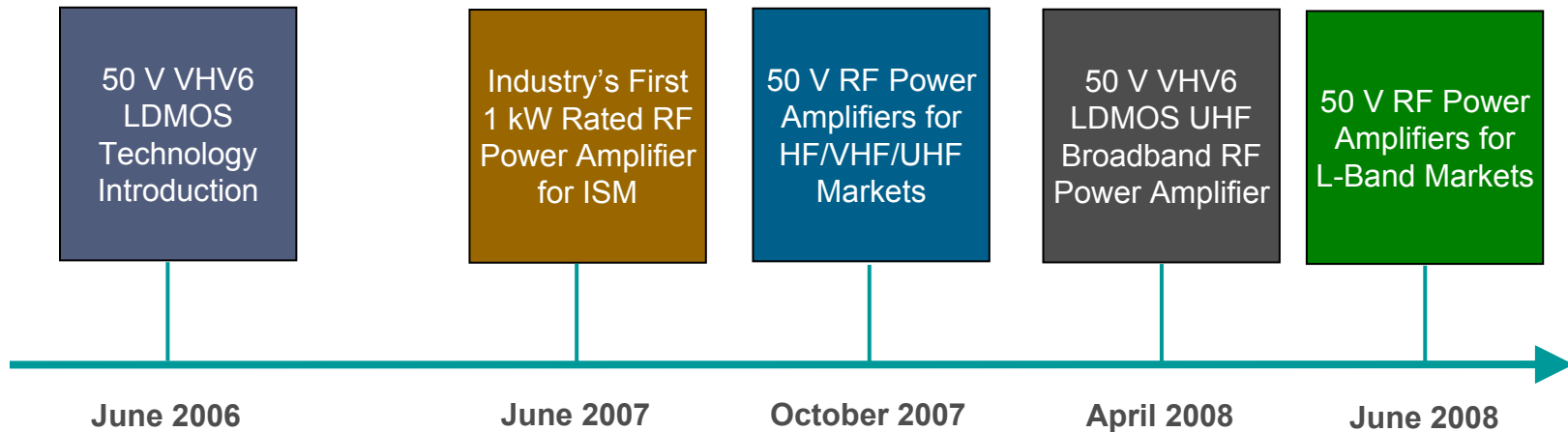
Design Innovation.



## Freescale RF Power Avionics – MRF6V14300H and MRF6V10010N



# Evolution of Freescale's 50 V LDMOS



- VHV6 is a 50 V extension to Freescale's widely accepted 28 V LDMOS technology
- This key technology enhancement is tailor-made for the Broadcast, Industrial, Scientific, Medical (ISM) & now pulsed Radar & Avionics 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

# Avionics Portfolio Key Messages

## First 50-volt LDMOS power transistor line-up for L-Band radar applications

High-performance line-up designed to offer industry-leading efficiency, gain and thermal resistance

### Unprecedented Power

**50 V VHV6 LDMOS:**  
A key technology enhancement, tailor-made for pulsed Radar and Avionics markets

**Unprecedented power levels covering the L-band**

**•17 dB Gain**

**Less gain stages needed – saving cost and board space and improving reliability**

### History of Innovation

Combining our history of experience, innovation, reliability, and cost-consciousness, Freescale enables designers to accelerate their designs to succeed in a dynamic market.

**Experience and expertise in Design, Modeling, Characterization, Packaging, and Applications support drive innovation to multiple markets.**

**Incorporates protection against electrostatic discharge (ESD), making it manufacturing friendly**

**Higher range of negative gate-source voltage improves RF overdrive capability**

### Ultra Efficient (Thermals)

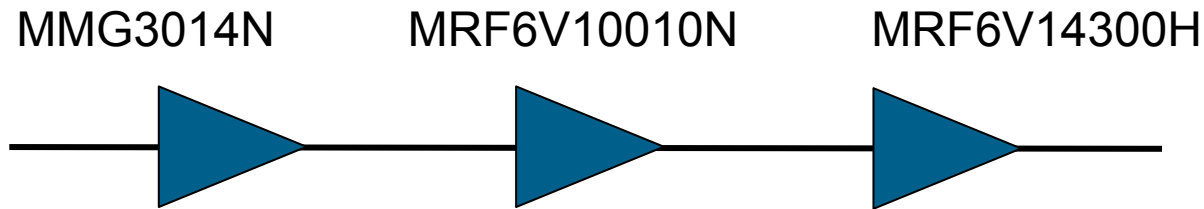
Careful attention to the device's thermal design to maintain a low operating junction temperature

**Exceptional Efficiency: 60%**

**Low thermal resistance lessens the overall cooling capacity needed by the transmitter**

**Leading efficiency and low thermals decrease operating cost**

# Freescale L-Band Line-up



	<u>MMG3014N</u>	<u>MRF6V10010N</u>	<u>MRF6V14300H</u>	<u>Totals</u>
<b>Typical Gain</b>	19.5 dB	25 dB	17 dB	<b>62 dB</b>
<b>P<sub>out</sub></b>	25 dBm	8 W	330 W	<b>330 W Peak</b>
<b>Drain Efficiency</b>	N/A	70%	60%	<b>58%</b>
<b>Current Draw</b>	5 V @ 160 mA	.2 A	11.0 A	<b>11.2 A</b>

**V<sub>dd</sub> = 50 V, 1400 MHz, 300 μSec on 12% duty cycle pulsed mode, 0.5 dB splitting and combining loss**

# L-Band Portfolio: MRF6V14300H

- RF Power transistors designed for applications operating between 1200 and 1400 MHz, 1% to 12% duty cycle
- Devices are suitable for use in pulsed applications

## Highlights

Single-ended device operating at 50 V

1400 MHz, 300  $\mu$ sec pulse width, 12% duty cycle

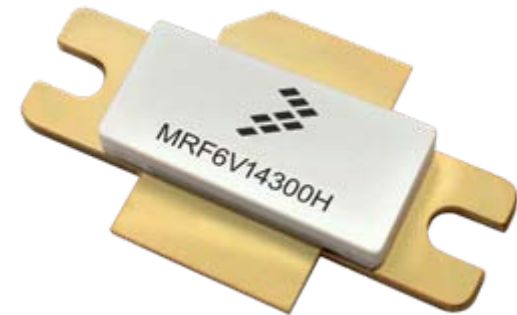
330 W Peak Output Power

17 dB Gain

60% Drain Efficiency

<0.12  $^{\circ}$ C/W  $\Theta_{jc}$

RoHS compliant air cavity ceramic NI-780 package



**Samples available today !**

**Production qualified today!**

# L-Band Portfolio: MRF6V10010N

- RF Power transistors designed for applications operating between 1030 and 1400 MHz, 1% to 20% duty cycle
- These devices are suitable for use in pulsed applications

## Highlights

Single-ended part operating at **50 V**

**1400 MHz, 300  $\mu$ sec pulse width, 12% duty cycle**

**8 W**      **Peak Output Power**

**22 dB**     **Gain**

**60%**      **Efficiency**

**RoHS compliant over-molded plastic PLD-1.5 package**



**Samples available today!**

**Production qualified today!**

# MRF6V14300H and MRF6V10010N Features

- ▶ VHV6 (Very High Voltage, 6<sup>th</sup> generation)
  - Enhancement to Freescale widely accepted 28 V LDMOS
  - Qualified for operation at 50 V
- ▶ Industry leading RF figures of merit
- ▶ The final stage device MRF6V14300 is available in industry standard air-cavity ceramic package
- ▶ The driver is designed in innovative over-molded plastic package
- ▶ Internally matched for Ease of Use
- ▶ Integrated ESD Protection, with greater Negative Gate-Source Voltage Range for improved Class C Operation
- ▶ Commercial Off The Shelf Product (COTS)
- ▶ RoHS Compliant



# Freescale L-Band – Beyond Silicon

- ▶ Samples / Boards
  - Samples for both devices available now
  - Test fixtures available upon request
  
- ▶ Large-signal product models:
  - ADS compatible large-signal models are currently under development and are expected to be available in Q4 2008
  
- ▶ Direct application support by Freescale RF Power experts
  
- ▶ Detailed plastic and ceramic package mounting available

# Related Session Resources

## Session Location – Online Literature Library

<http://www.freescale.com/webapp/sps/site/homepage.jsp?nodeId=052577903644CB>

## Sessions

<i>Session ID</i>	<i>Title</i>

## Demos

<i>Pedestal ID</i>	<i>Demo Title</i>



[www.freescale.com/rfpower](http://www.freescale.com/rfpower)