CW Power Capabilities

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RFPP

Topics

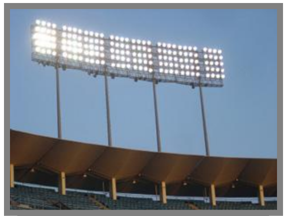
- LDMOS application and development trend
- LDMOS Ruggedness
- LDMOS Thermal characterization
- Reference design availability
- Design support

Industrial Applications

RF Heating

Microwave Furnace

Synchrotron



RF Lighting

UV sterilization

CO2 Laser

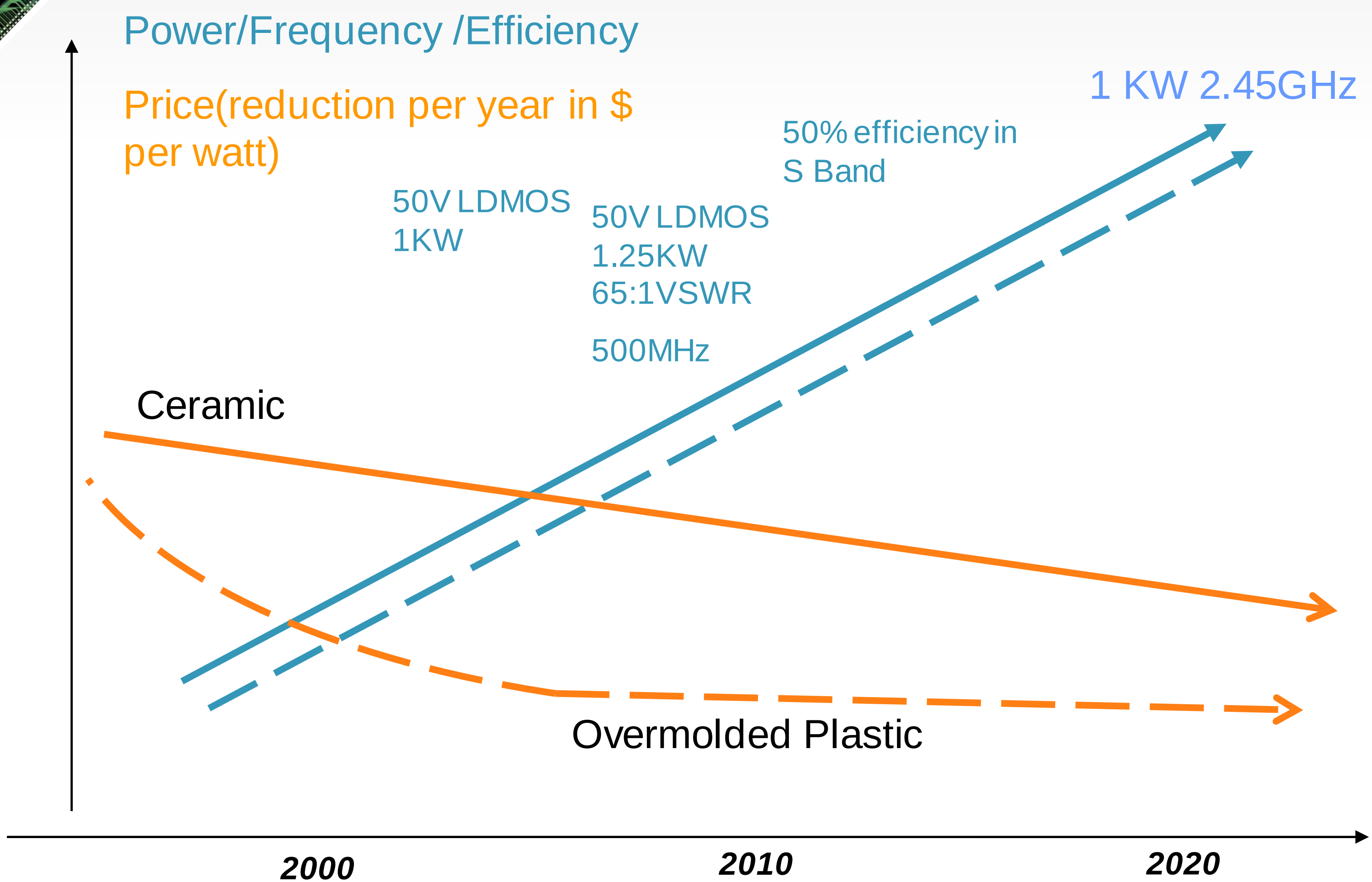
Wood dryer

Food processing

Medical

3

LDMOS Trends



Ruggedness

What is Ruggedness?

- For RF devices it is the ability to perform reliably when operated outside of “normal” conditions
- The more rugged a device is, the farther from normal conditions it operates without damage

Measures of ruggedness

- VSWR – A ratio that represents the impedance mismatch between device and load
- Energy Absorption (EA) – measure of ability to absorb energy applied to the output terminal.[(1)].
- Maximum operating temperature

Who needs it?

- Systems where normal operation is not into a matched load
  - Laser driver
  - Plasma generator
- Systems where availability is critical and unintended operation can cause a mismatch
  - Broadcast overdrive, causing Filter reflection, common because of DPD
  - Communications system antenna Icing
  - Broadcast system Damaged RF feed line
  - OOPS: tech forgot to shut down transmitter when operating changeover switch

Scenarios above describe impedance mismatch between the device and the load causing power to be reflected back to the device.

Mismatch also causes efficiencies to drop, resulting in sharply increased operating temperatures.

- *two mechanisms :*
  1. *Lower efficiency generating power*
  2. *Reflected power is dissipated in device)*

(1) http://www.freescale.com/files/rf_if/doc/white_paper/50VRFLDMOSWP.pdf (Page 6)

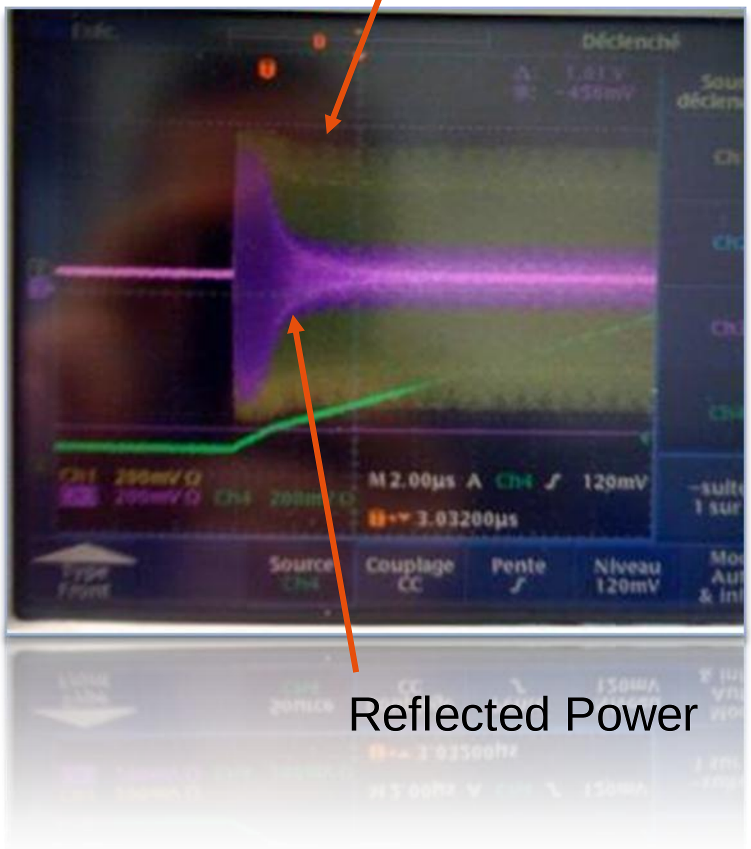
Stuff happens video

- http://contact.freescale.com/content/RuggedVideo?t=el

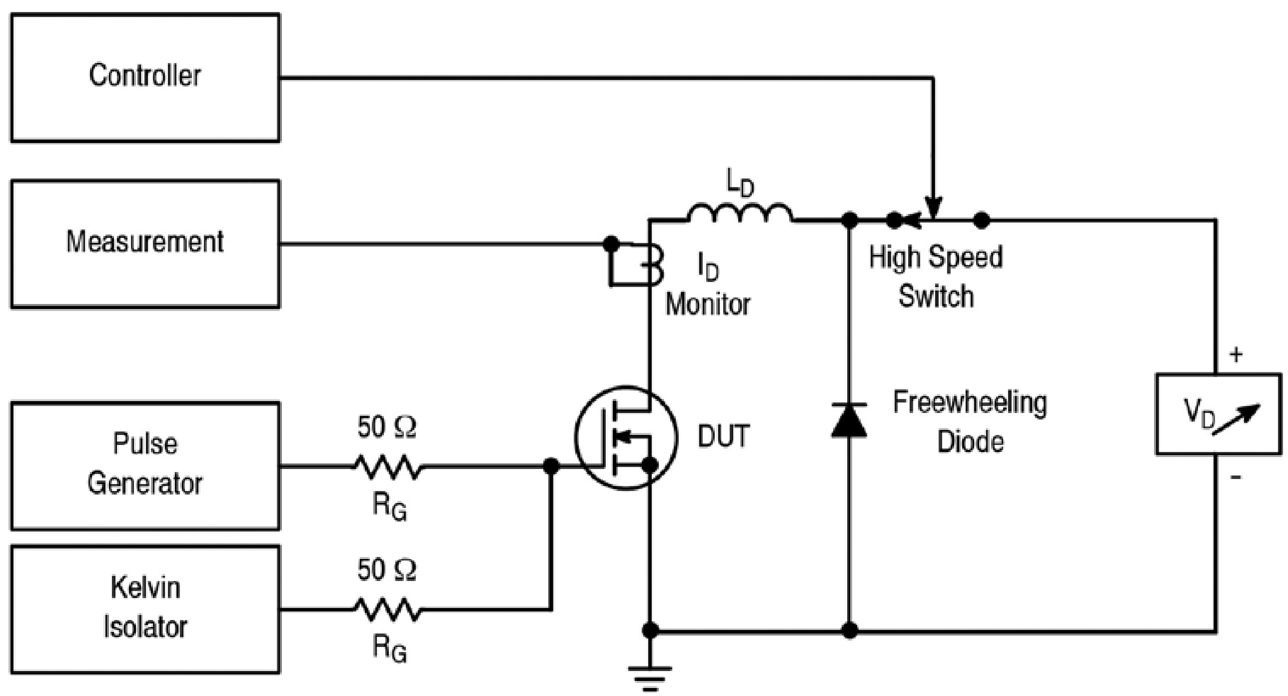
Freescale’s Latest Innovation 50V High Ruggedness Technology

- Developed primarily for high mismatch applications, such as Plasma generators, CO_2 lasers, and MRI power amplifiers

- **Key features:**
  - 50V operation
  - Capable of handling >65:1 VSWR at all phase angle, >50V and 3 dB overdrive
  - High efficiency
  - Low thermal resistance



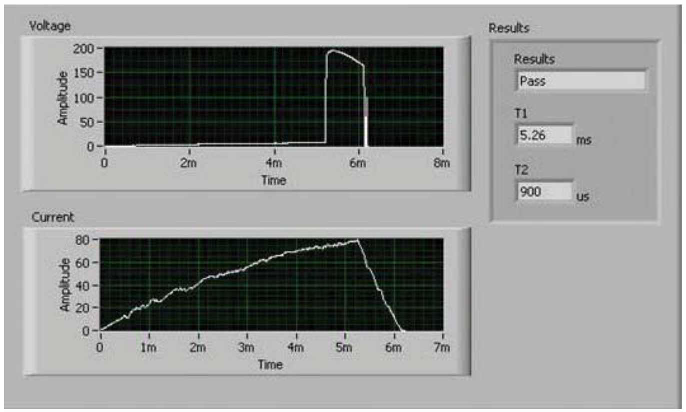
Unclamped inductive switch test

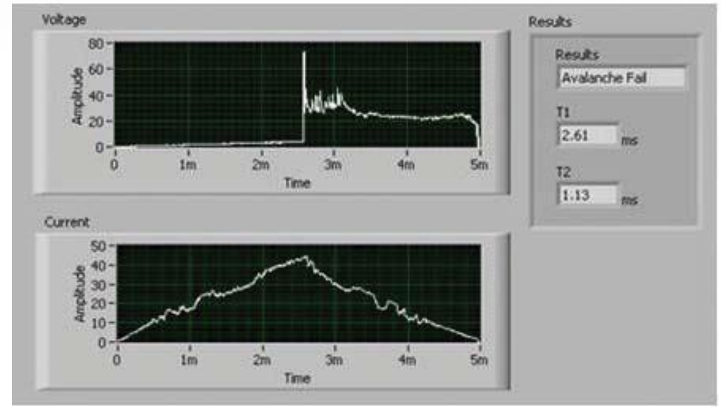


Test procedure:

1. Individual test sockets or automated handlers can be used with the ITC55100B Testers.
2. The test controller generates a clean gate pulse waveform at the gate of the transistor
3. The energy dissipation capability of the DUT is stressed by increasing the load current and load voltage by attaching a unclamped inductor to the device's drain and source connections.

Unclamped inductive switch test





Pass

Fail

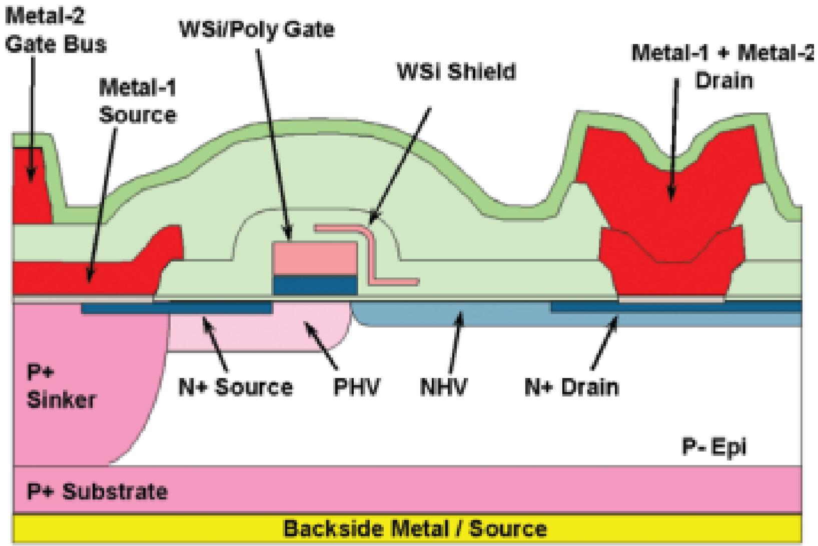
Parameter	1 kW Non-Rugged	1 kW Rugged	Improvement Factor
Max Voltage	164V	195V	+18%
ID_{peak}	40A	80A	+100%
Energy Absorbed	1.53J	5.30J	+240%

Freescale LDMOS Thermal performance

- Freescale maintained industry leadership in LDMOS thermal performance
  - Achieved through continual improvements in die layout and packaging performance
- Lower thermal resistances allows:
  - Lower die temperature
  - Longer device life by reducing impact of electro metal migration.

Thermal Resistance

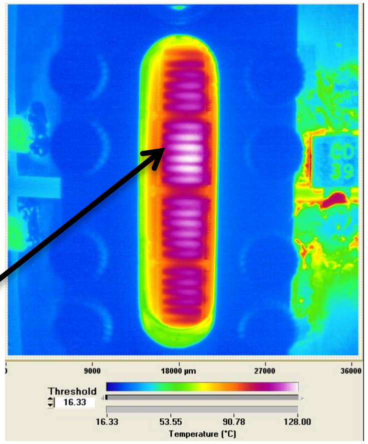
- LDMOS device thermal resistance benefits from having a backside source that is thermally and electrically bonded to the package flange, which in turn is directly mounted to the heat sink.
- The low thermal resistance of LDMOS allows significantly higher CW power levels in a given package than with competing technologies



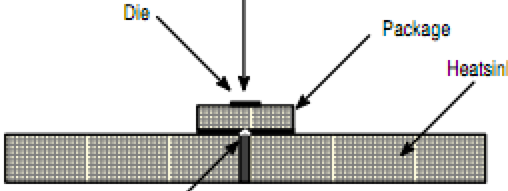
Thermal Resistance Measurement

Continuous Wave Test Signal

- Thermal resistance on Freescale LDMOS are calculated using:
  - $\mathbf{R_{th} = (T_{die} - T_{case})/(P_{Dissipated})}$
- Infrared microscopy is used to measure die surface temperature (T_{die}), during operation. During measurement, the die is exposed because this IR measurement method requires direct view of the die. The exposed die is coated to obtain a fixed emissivity value for IR thermal measurement. **The hottest portion of the die is used as T_{die}**



- The case temperature (T_{case}) is measured with a thermocouple that is mounted through the heatsink , so it comes in contact with the device flange underneath the hottest component within the package.
- Total power dissipated in the RF transistor is calculated by:
  - $P_{dissipated}$ = [RF input power + DC power(Idc*Vdc)] – [RF output power +RF reflected power]



Freescale LDMOS MTTF Calculator

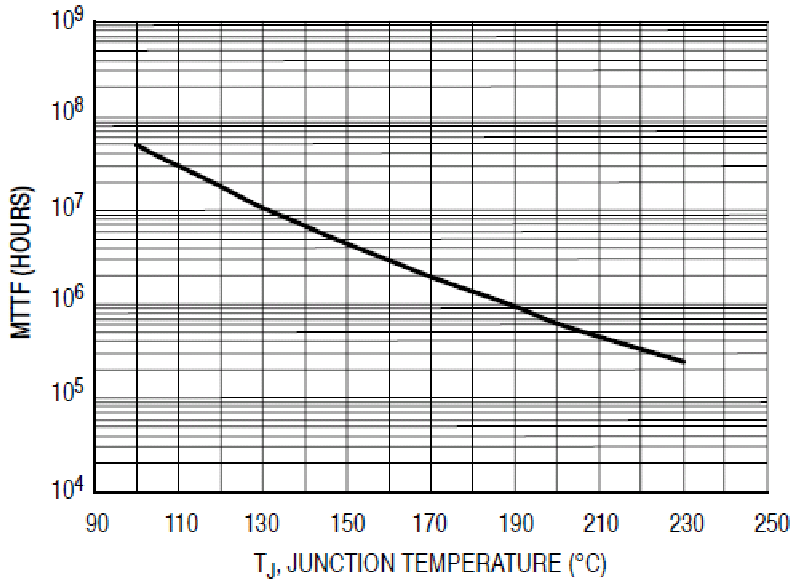
- MTTF (mean time to failure) is defined as a 10% reduction in current handling capability on 50% of the device within a given sample size. The primary factor in device failure is due to metal electro-migration on the die surface.

- By reducing device thermal resistance(R_{th}) we can increase the active life time of Freescale LDMOS devices

Freescale LDMOS MTTF

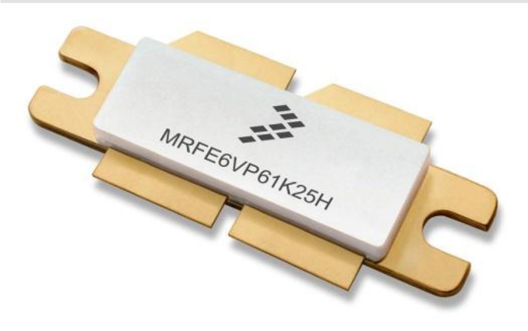
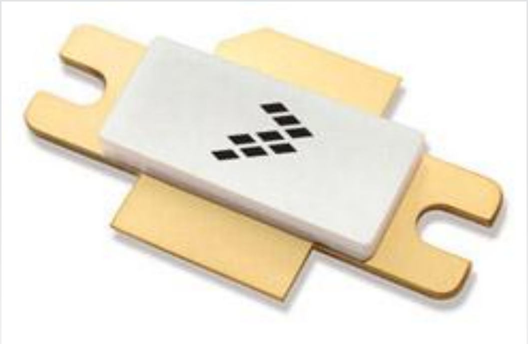
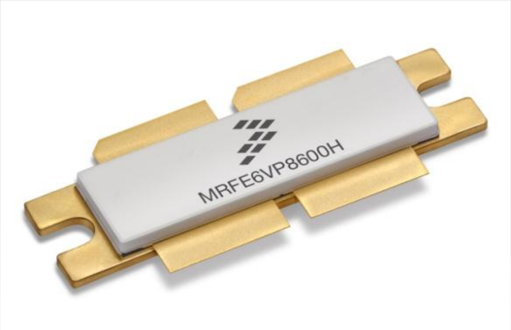
- Example: MRFE6VP6K1K25KH, operating at 1.25kW, with 74.6% efficiency at 230MHz.
- I_{Drain} = 1250W/(74.6% x 50V) = 33.5A
- MRFE6VP61K25H have R_{th} of 0.15W/°C, Case temperature = 80°C
- Dissipated power = $P_{DC} – P_{out} + P_{in}$
- Dissipated power = 50V*33.5A – 1250W +6W = 431W
- T_{rise} = 431W * 0.15W/°C = 64.7 °C
- $T_J = T_{rise} + T_{case}$ = 64.7 /°C + 80°C = 144.7°C

With R_{th} of 0.15W/°C, operating at 1.25kW 74.6% efficiency the MRFE6VP61K25H has a operating life time of ***450 years.***

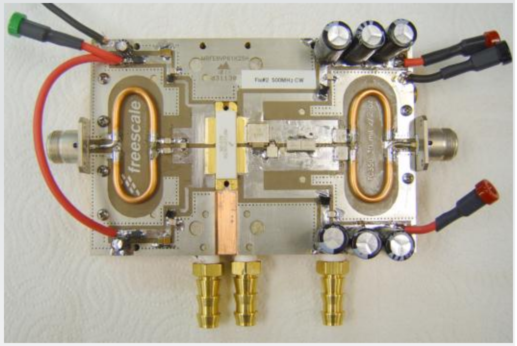
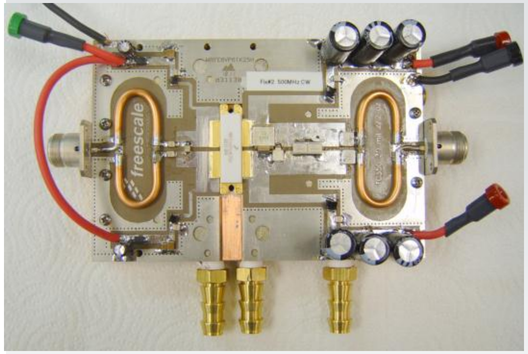
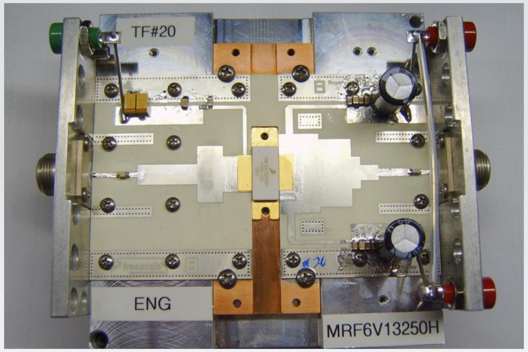


Available Devices

*All device are designed, fabricated and assembled in the US

MRFE6VP61K25H	MRF6V13250H	MRFE6VP8600H
		
Freq : 2MHz-500MHz Pout : 1.25kW @ 230MHz Vdd : 50V Air cavity package Longevity program	Freq : 1300MHz Pout : 250W Vdd : 50V Air cavity package	Freq : 460-870MHz Pout : 600W Vdd : 50V Air cavity package Longevity program

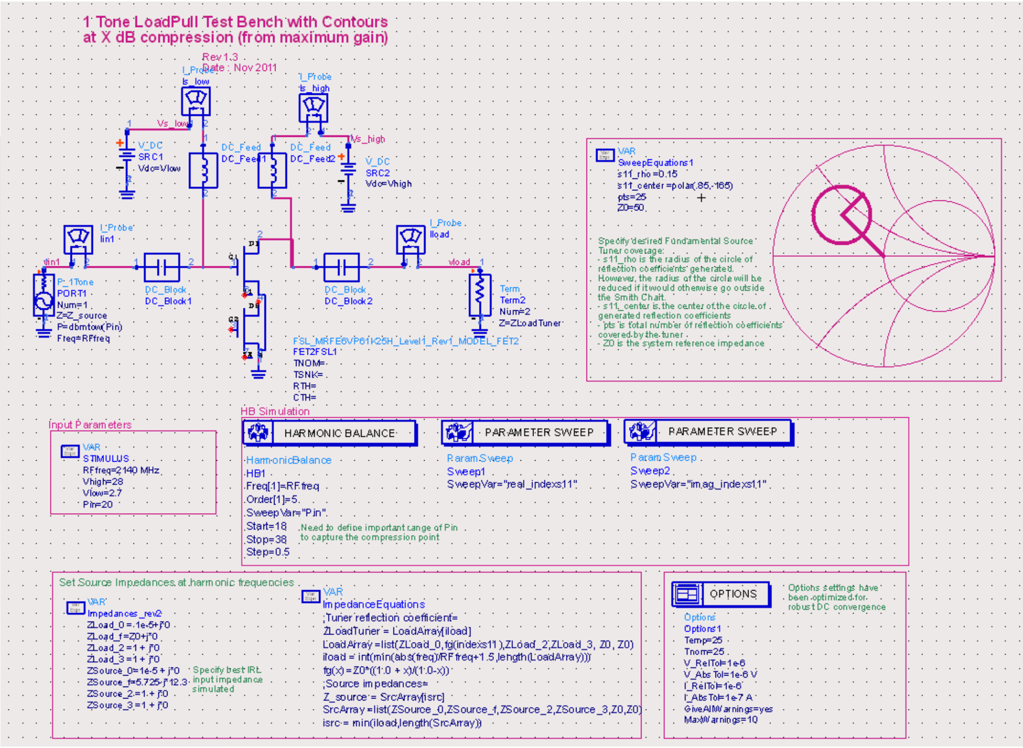
Available Reference Designs

MRFE6VP61K25H – 352MHz	MRFE6VP61K25H – 500MHz	MRF6V13250H – 1300MHz
		
Vdd=50V Pout > 1100W Gain > 20dB Eff > 62%	Vdd=50V Pout > 1000W Gain > 18dB Eff > 58%	Vdd=50V Pout > 230W Gain > 20dB Eff > 53%

Design support

Device model

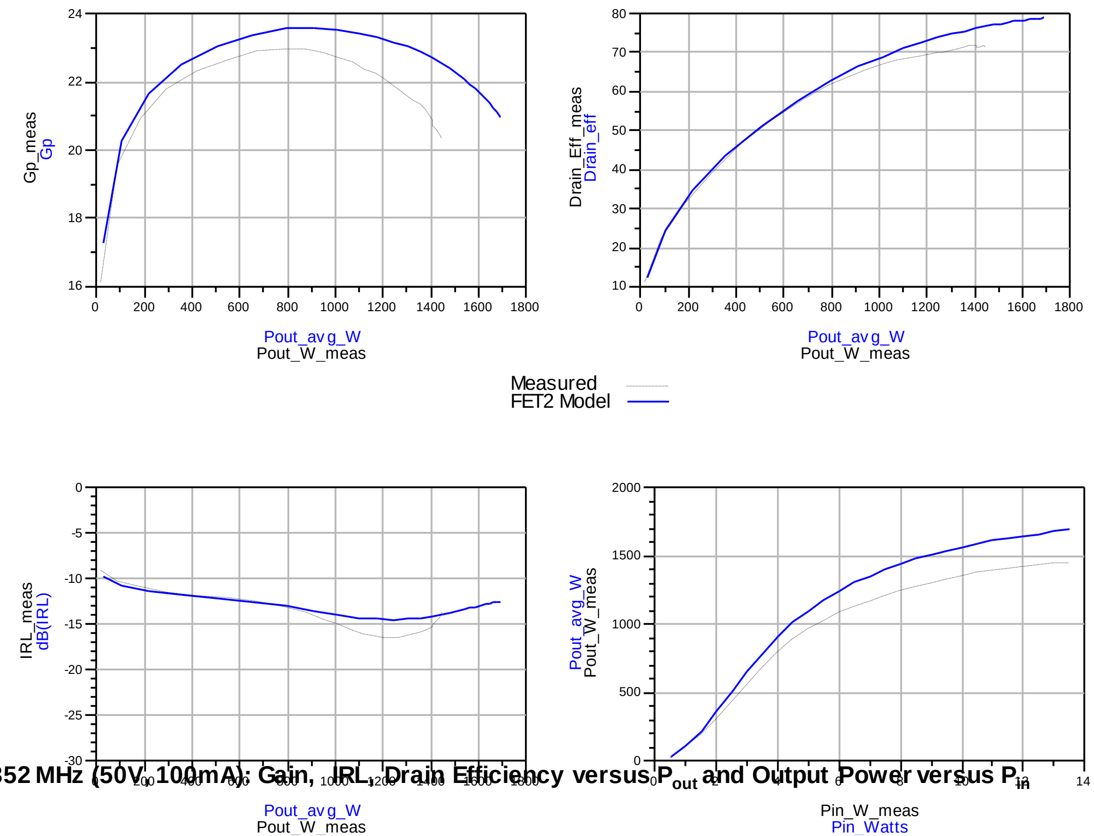
- Physical model available for both ADS and Microwave office.
- Use Loadpull simulation to evaluate matching impedance at target frequency, power and efficiency.
- Use Harmonic balance to simulate fixture performance



freescale™

MRF6VP2600H- Large signal simulation results

352 MHZ	MEASURED	MODEL FET2	DELTA
Source Impedance	0.79 + j 2.06	0.67 + j 1.37	30.8 %
Load Impedance	2.00 + j 1.98	2.39 + j 0.60	-12.4 %



•352 MHz (50V, 100mA): Gain, IRL, Drain Efficiency versus P_{out} and Output Power versus P_{in}