Freescale GaN Overview and Roadmap Introduction

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A U G . 2 0 1 5

External Use

Agenda

- Freescale Overview
- Freescale GaN Product Introduction

RF's Global Footprint

Freescale Seoul
Marketing, Application

Freescale Tokyo
Marketing, Application

Freescale Chengdu
Design , Applications

Freescale Austin
Corporate Headquarters
Oak Hill Fab – 8"

Freescale Kuala Lumpur
Final Manufacturing

Freescale Shanghai
Marketing, Applications

RF Global Headquarters
Tempe, Arizona
Design, Marketing, Applications, Modeling, Systems

Freescale Toulouse
Design, Marketing, Modeling, Applications, Systems

Freescale Tianjin
Final Manufacturing

Radio Frequency

We pioneered RF technology and continue to be the leader with high-quality, high-performance products using the latest technologies

Why Customers Choose Us

- Best-in-class performance in linear efficiency, gain, bandwidth and power
- Fully optimized reference designs
- Long-term customer relationships

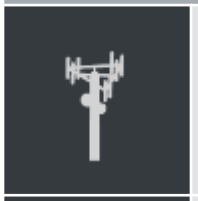
Customers

Airvana, Alcatel·Lucent, Cisco, Ericsson, Fujitsu, Huawei, Motorola, nsn, Samsung, ZTE中兴

Market Leadership

#1	**High Power RF Transistors for Wireless Infrastructure** (1)

Applications



Wireless Network Infrastructure

- Macro, Metro & small cellular basestations
- Digital front end

Broadcast, Industrial/Scientific/Medical

- UHF & VHF broadcast TV
- FM & shortwave radio
- CO_2 lasers, plasma generation, MRI

Enterprise Access Points, Professional Mobile Radio

- Converged cellular / wifi
- Public safety, dispatch, transportation, marine

Aerospace / Defense

- Radar
- Air traffic management
- Jammers

Products

Airfast RF Platform	RF Power ICs

Source: (1) ABI Research, February 2014

GaN solutions

from the #1 provider of High Power RF

Freescale's Differentiators

Leadership from 'Chip' to final Product

Die	• Optimized for Cellular • High power matching expertise • Optimization for low Rth
Design	• Doherty design expertise • Load pull test leaders leading to better designs • Modeling expertise
Packaging	• Die and wire bonding excellence • Package expertise. Use of standard cellular high volume packaging
Manufacturing	• **High volume manufacturing line in place (shared with LDMOS)** • **Secure supply strategy**
Market	• Knowledge of cellular market and requirements • Cooperation with cellular base station industry leaders

GaN Product Strategy for Cellular Markets

Optimum performance, size, cost for high band macrocells

- **Optimize performance for single band PA operation**
  - High efficiency /high gain combination makes GaN devices the best performing solution for single band operation
  - This is the primary focus of FSL in the first phase of product rollout
  - Target: GaN Products for 2.1GHz, 2.5-2.7GHz and 3.4-3.6GHz applications

- **Optimize performance for broadband PA operation**
  - High output real part impedance (Rp) and low Cds enables broadband design
  - Primary BW limitation in GaN comes from the input side
    - Freescale enabling broadband with input pre-match design techniques
  - Target: 1.8-2.2 GHz and 2.3-2.69 GHz designs

- **Expand GaN product offerings for low-power & small cells PAs**

GaN Portfolio Launch

- Technology qualified, first product fully qualified/launched
- 8 more cellular products in NPI pipeline.

- First product : A2G22S160-01S
  - Designed for 1.8-2.2GHz 40W avg applications

- 2.6GHz and 3.5GHz devices in Design
  - Sample availability : 2Q15

- Starting designs with GaN 4.0
  - A2G35S200-01S
  - A2G26H280-04S
  - A2G20H200-04N

- Moving to over-molded package
  - OM270 sampling now (A2G26S160-01N)
  - Qualifying OM780
  - No performance penalty up to 2.7GHz.

OM 270-2:

L1 420mils

W 240mils

SPH 41mils

GaN 3.0 Qualified in OM-270 Plastic Package

- Devices in OM-270 package passed qualification during March
  - HTOL ✓
  - HTRB ✓
  - HTSL ✓
  - THB ✓

- RF performance similar to ceramic
- R_{jc} improves 25%
- A2G26S160 samples available now

A2G26S160-01N

Cellular GaN in OMNI270 package

A2G26S160-01N

- First Freescale GaN high power cellular device in plastic over-molded package
- No performance degradation noted when moving to plastic over-molded @2.6GHz.
- Using a new member of our OMNI package family, namely the OM270-2
- We have innovated on the metallurgical bond of our GaN-on-SiC chips to copper flanges and over-molded them to enable unprecedented thermal performance.
- Copper based OM270-2 allows for significant thermal resistance improvement over ceramic counterparts (in the order of 25%)

GaN Packaging

- Implementing a broad portfolio packages for GaN devices.
- Adapted air-cavity metal ceramic packages for GaN
- GaN products implemented in NI360 and NI400 packages
- Implemented multi-die for matching
- AuSn die attach for GaN
- AuSi die attach for matching component
- Au wire-bond

- Differentiated packages with superior performance
- Qualified OMNI270-2 for GaN
- Cu flange, AuSn die attach for GaN
- 25% improved thermal performance over similar device in NI package.
- Improved pkg. tolerances vs NI pkgs.
- Implemented multi-die for matching

B7 2 way (3 devices) Doherty Performance Summary

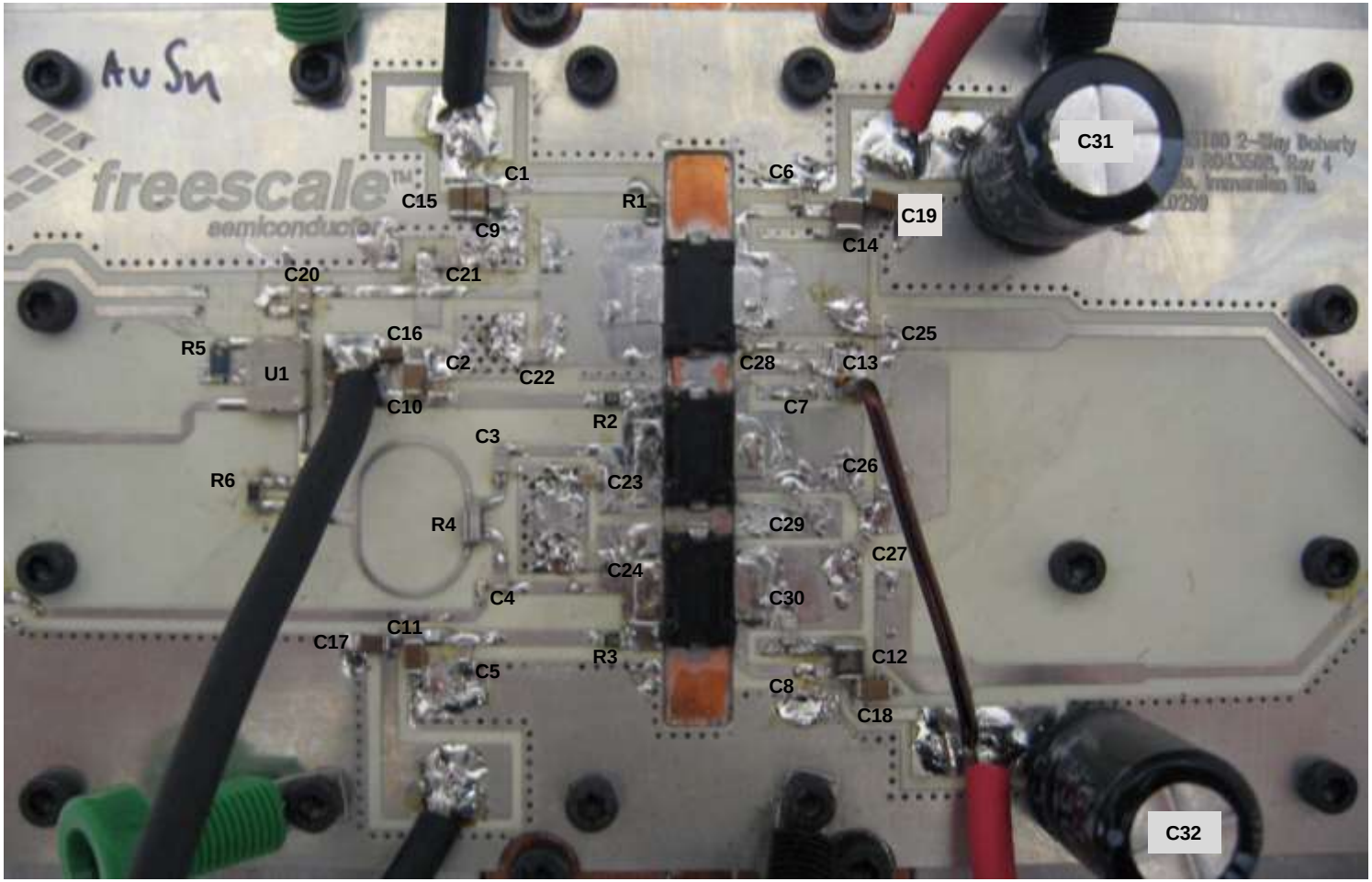
- Peak power = 56dBm

- Band 7 Performance:
  - Achieves up to **54% Eff**. @ 8dB OBO from 2.62 to 2.69 GHz
  - Gain is 14.5 dB
  - Gain flatness is 0.2dB in the B7 band

- DPD linearization corrects to -56 dBc @ 2.65 GHz when using 20 MHz LTE signal

B7 2-Way Asymmetrical Doherty PA

RFin



RFout

A2G26S160 detailed data

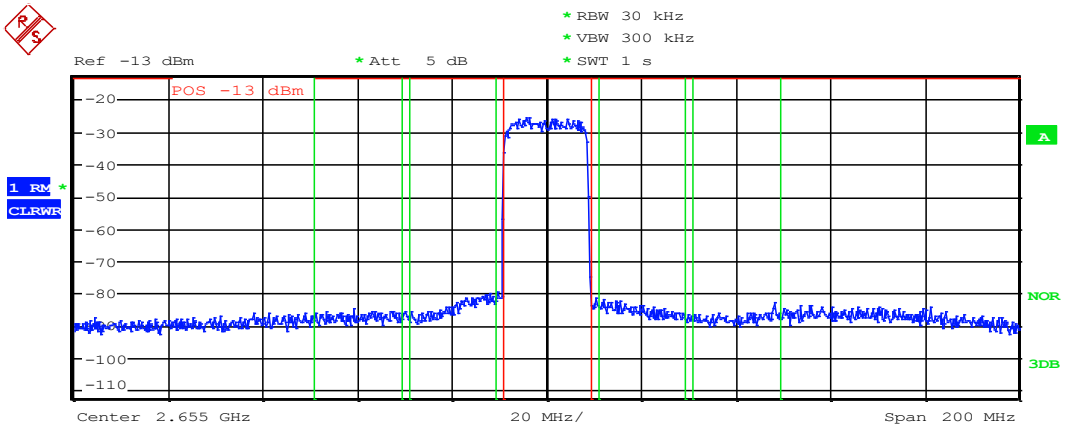
Bias Conditions: Vdd = 48V, Idqm = 350 mA, Vgp1 = Vgp2 = -4.3V
Test Signal: 1 Carrier WCDMA, 5 MHz Channel BW, 10 dB PAPR

Freq (MHz)	Pin (dBm)	Pout (dBm)	Gain (dB)	IRL (dB)	Adj-L (dBc)	Adj-U (dBc)	Alt1-L (dBc)	Alt1-U (dBc)	PAR (dB)	Eff (%)	ID1 (A)
8dB OBO											
2620	32.8	47.5	14.7	-10.5	-24.1	-24.3	-38.3	-37.9	7.8	51.7	2.3
2655	32.8	47.5	14.7	-11.4	-26.0	-26.1	-38.3	-37.9	7.8	52.6	2.2
2690	33.0	47.5	14.5	-12.4	-27.4	-27.4	-37.9	-37.9	7.7	51.9	2.2
7dB OBO											
2620	33.6	48.2	14.5	-10.9	-24.3	-24.5	-38.1	-37.8	7.2	52.3	2.6
2655	33.6	48.2	14.6	-11.9	-26.2	-26.3	-38.1	-37.9	7.1	53.9	2.6
2690	33.9	48.2	14.4	-12.9	-27.3	-27.3	-38.0	-38.0	7.1	54.5	2.5

A2G26S160 Circuit 1

Bias Conditions: Vdd = 48V, Idqm = 350 mA, Vgp1 = Vgp2 = -4.3V

Test Signal: 1 Carrier LTE, 20 MHz Channel BW, 7.1 dB PAPR



Tx Channel		**W-CDMA 4.096 FWD**	
Bandwidth	18.015 MHz	Power	-0.88 dBm
Adjacent Channel			
Bandwidth	18.015 MHz	Lower	-56.11 dB
Spacing	20 MHz	Upper	-57.28 dB
Alternate Channel			
Bandwidth	18.015 MHz	Lower	-59.38 dB
Spacing	40 MHz	Upper	-59.68 dB

F = 2655 MHz

Pout = 47.5

Drain Efficiency = 50.9%

A2G26H280-04S

Cellular GaN HIP

A2G26H280-04S

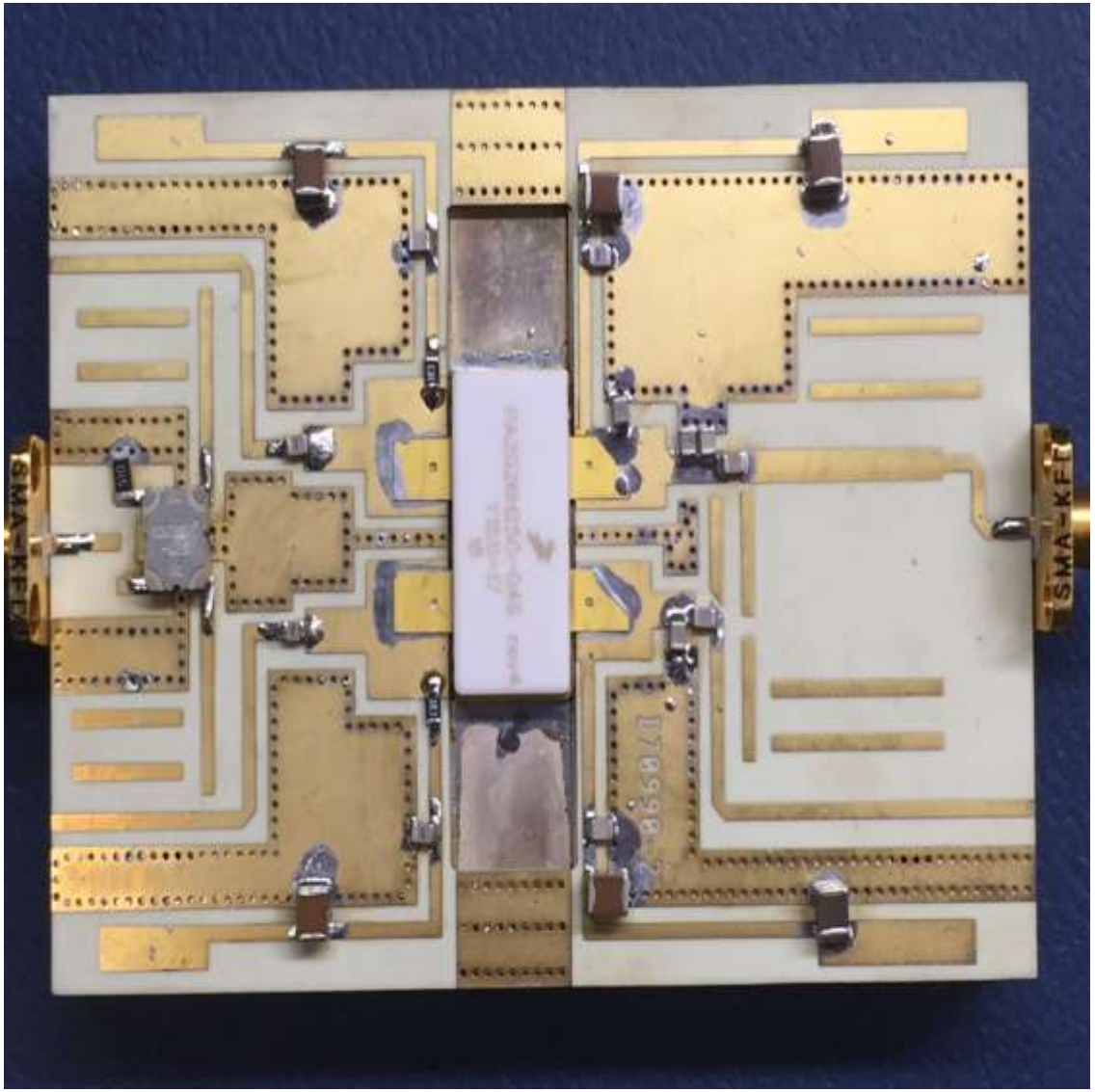
- First Freescale GaN high power cellular HIP device
- Asymmetrical Doherty reaching 54.1 dBm peak power in a single package.
- Targeting 2.5-2.7GHz 20/25W BTS applications
- Planning to move to OM780-4

CMCC asymmetrical Doherty Performance Summary

- Peak power = 54.1dBm

- CMCC 2575MHz-2635MHz performance
  - Achieves up to **55% Eff**. @ 8dB OBO from 2.575 to 2.635 GHz
  - Gain is greater than 14.7 dB
  - Gain flatness is better than 0.3dB in the full band

Demo Photo



GaN Portfolio Launch

- 10W and 25W GaN drivers A2G30S010-01N and A2G30S025-01N
- Good performance up to 3.8GHz
- OM270-2 package
- Sampling now

OM 270-2:

L1 420mils

W 240mils

SPH 41mils

Freq (MHz)	Pin (dBm)	Pout (dBm)	Gain (dB)	IRL (dB)	Adj-L (dBc)	Adj-U (dBc)	Alt1-L (dBc)	Alt1-U (dBc)	PAR (dB)	Eff (%)	Vg1 (V)	Vd (V)	I_6675 (A)
3800	19.9518	35.796	15.844	-8.502	-34.64	-34.62	-49.7	-49.91	6.731	32.447	2.72	48.041	0.244
3650	19.221	35.794	16.573	-13.131	-34.18	-34.01	-49.33	-49.68	6.955	32.434	2.72	48.041	0.244
3500	20.074	35.818	15.744	-6.554	-32.43	-32.9	-47.74	-47.79	6.923	33.399	2.72	48.041	0.238

A2G30S010-01N class AB performance at 3.8GHz

- 19W peak power
- 16dB of gain
- 32% at 7dB backoff

Freescale GaN Roadmap

Black: GaN 3.0
Red: Gan 4.0
Blue: Sample Date

Type	20W	30W	40W	60W
1.8-2.2GHz Finals 50V	**A2G20H200-04N** OM780-4 Q3 2015 	**A2G22S160-01S x2** NI400 Production 	**A2G22S160-01S x3** NI400 Production 	**A2G22S250-01N x3** OM270 Q4 2015 
2.5-2.7GHz Finals 50V	**A2G26H280-04S** NI780-4 Now 	**A2G26S160-01N x2** OM270 Now 	**A2G26S160-01N x3** OM270 Now 	**A2G26S250-01N x3** OM270 Q4 2015 
3.4-3.8GHz Finals 50V	**A2G35D200-04S** NI780-4 Q4 2015 	**A2G35S160-01S x2** NI400-4 Now 	**A2G35S160-01S x3** NI400 Now  **A2G35S200-01S x2** NI400 June 2015 	
Driver 50V				
	A2G30S025-01N OM270 Now 	**A2G30S025-01N** OM270 Now 	**A2G30S025-01N** OM270 Now 	**A2G30S025-01N** OM270 Now 
	A2G30S010-01N OM270 Now 	**A2G30S010-01N** OM270 Now 	**A2G30S010-01N** OM270 Now 	**A2G30S010-01N** OM270 Now 

GaN Portfolio Launch

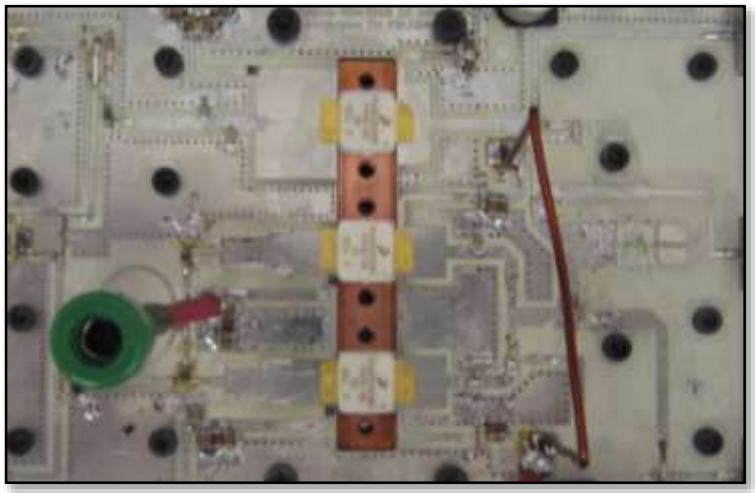
- Technology qualified, first products near qual, >10 more in NPI pipeline.
- First product (A2G22S160) launched Feb'15
  - Designed for 40W avg applications
  - 2.1GHz, 55% Doherty performance
- Products for 20W and 40W avg 2.6GHz & 3.5GHz follow shortly
- OM samples in development

A2G22S160 Asymmetric Doherty Circuit

P_{out} = 47.7 dBm, V_{dd} = 48V, *1C W-CDMA, PAR=10.3dB @ CCDF=0.01%*

Freq (MHz)	Gain (dB)	Adj-L (dBc)	Adj-U (dBc)	PAR (dB)	Eff (%)
2110	18.2	-27.1	-27.0	8.0	55.3
2140	17.9	-26.0	-26.0	7.9	56.5
2170	17.5	-24.8	-24.7	7.8	56.4

In Band Peak Power (WCDMA / CW): 55.6 dBm minimum



Circuit and Device Highlights:

- 2-way, 2:1 asymmetric Doherty circuit implementation
- High gain and efficiency; enabler for reduction in RRH volume and weight through
- Circuit level harmonic termination, resulting in significant efficiency boost over large dynamic range.

40W Average Power Applications

www.Freescale.com