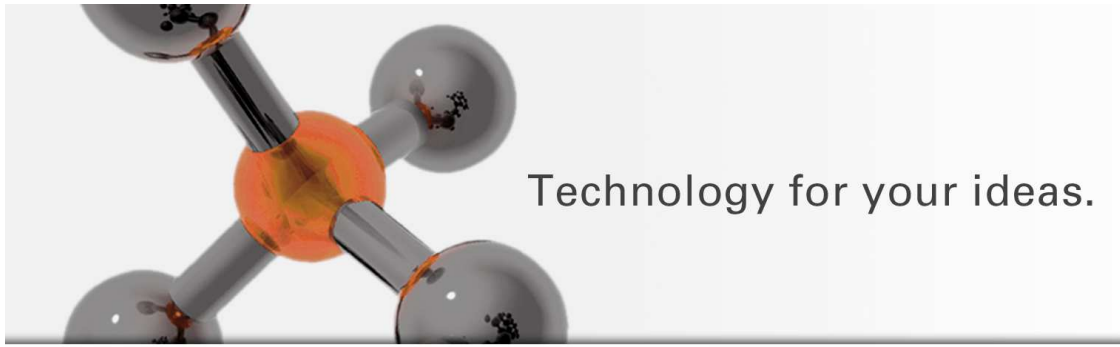

LFoundry

High performance LDMOS RF & HV technology for a 0,15µm foundry design kit

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Outline

- **Motivation**
- 0,15µm technology & RF performance for leading analogue applications
- LDMOS set up and results
- LDMOS applications
- Conclusion

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Motivation:
LDMOS & 0,15µm Design Kit for Digitally Assisted Analogue

- One of the most advanced analogue technology as basis for digitally-bridging analogue applications
  - 0,15µm process with design rules allowing small chip sizes for analogue + digital SoC (System on Chip) designs
  - Devices with excellent RF performance for advanced analogue applications in the digital market arena (wireless, mobile, …)

- Device expansion with a LDMOS transistor with high RF performance, enabling digital realization of analogue functionality where high voltage is a must

- Digitally assisted analogue as a method to improve the performance of analog ICs
  - taking into account the lack of precision of analog devices by compensating in the digital base band

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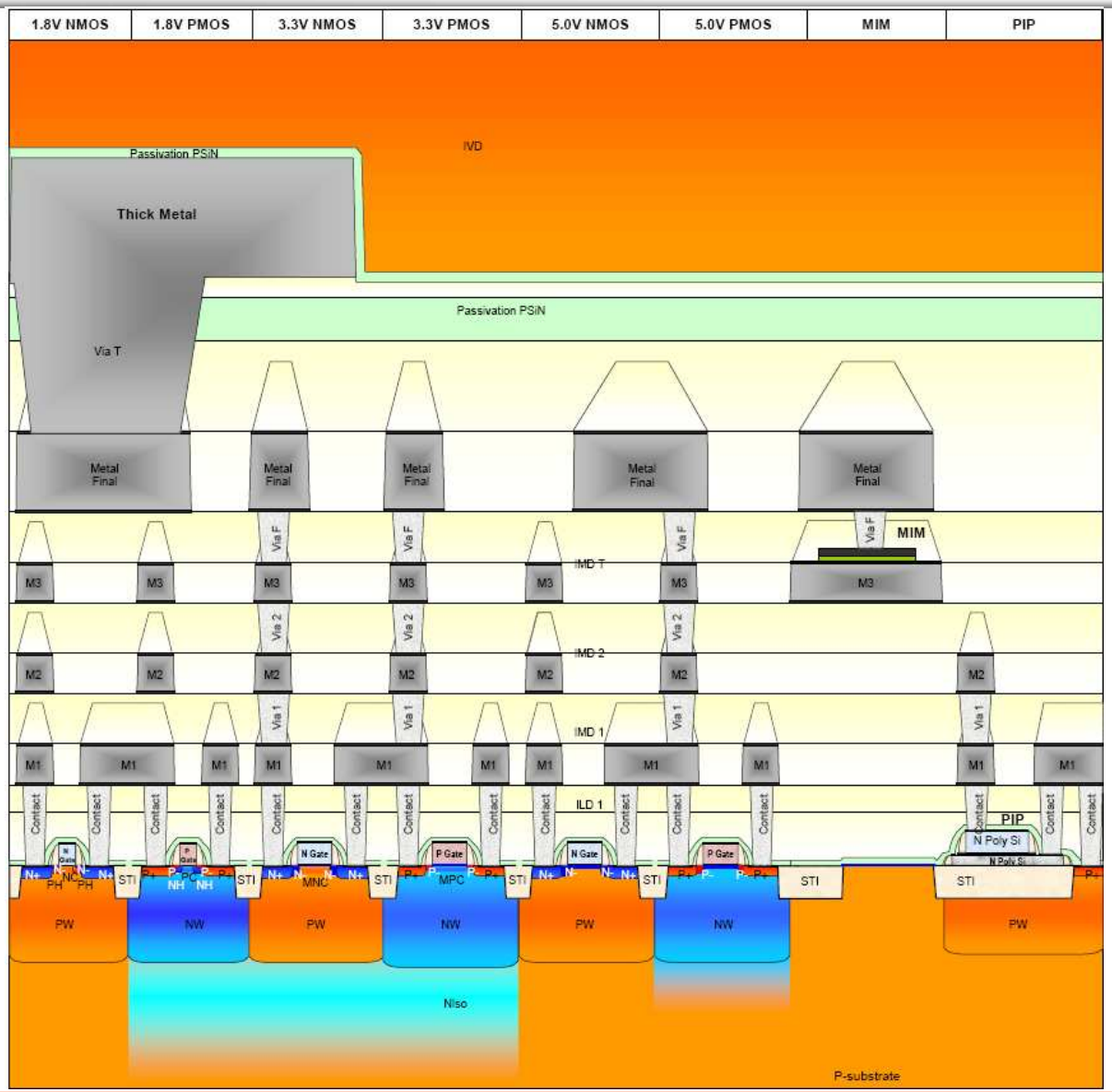
LFoundry 0.15µm Technology: X-Section



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LFoundry 0.15µm Technology: Key Data

- 150nm modular CMOS process:
  - 19 masks for standard process
  - Shallow trench isolation
  - deep N-well
  - 1-2 poly layers
  - Gate oxide thickn.[nm]: **2.8**/6.8/16.0
  - Cobalt salicidation
  - up to 6 level of Al (330nm, 800nm)
  - extra thick top metal (2-6µm)
  - Intermetal dielectric: HDP
- **Core Voltage: 1.8 V**
- Design rules:
  - Physical gate length: 150 nm
  - Contact/Via size: 180/240 nm
  - Metal pitch: 0.48 µm
- MOS Transistors:
  - **1.8 V low leakage NMOS/PMOS**
  - **1.8 V high speed NMOS/PMOS**
  - 3.3 V NMOS/PMOS
  - 5 V NMOS/PMOS
- Poly-, Metal- and Diffusion Resistors
- MIM Capacitors
- Diodes
- NPN-Bipolartransistor (within the standard CMOS-Process)
- **RF-Devices like Transistors, Resistors, Capacitors, Inductors and Varactors**
- GPIO library 1.8V, 3.3 V, 5V
- Full Analog PDK for Cadence Virtuoso 6.1.3 **including >370 digital standard cells** (available for low leak and high speed)
- Full analogue PDK for Tanner **including >20 digital standard cells**
- Constantly increasing IP portfolio:
  EEPROM, Flash, OTP, SRAM, µController, ADC, LDO, POR, SPI bus, Bandgap & Bias generator, Op Amp, Charge pump, 25MHz oszillator

Red: digitally-bridging analogue functionality

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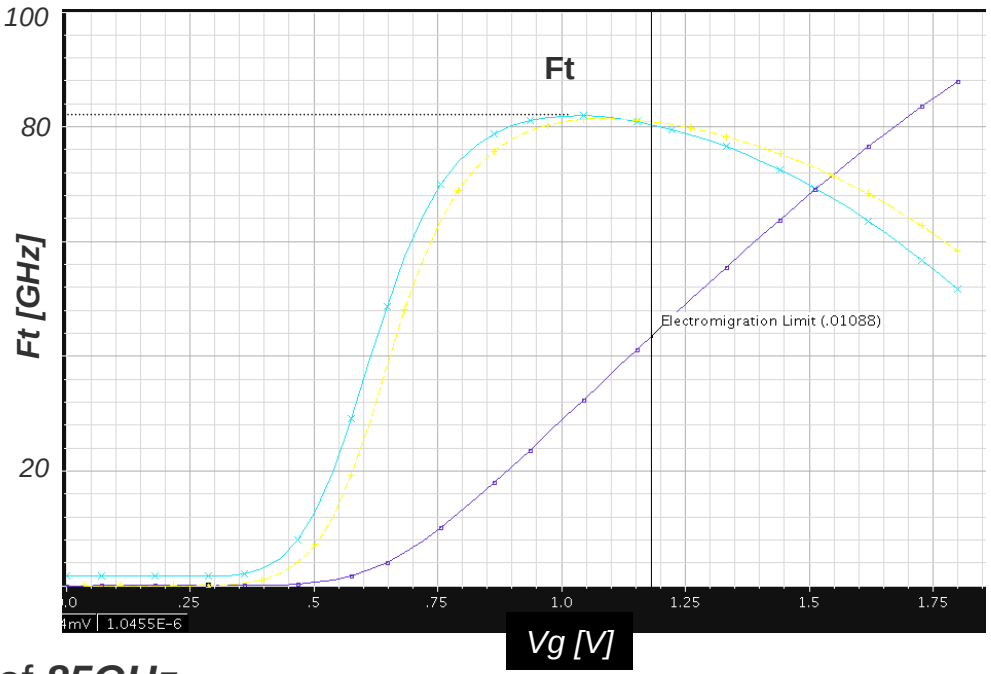
LFoundry 0.15µm Technology: RF Performance

- MOS Transistors (embedded) :
  - 1,8V HS N-Channel f_t ~ 85 GHz
  - 1,8V LL N-Channel f_t ~ 70 GHz
  - 1,8V HS-P-Channel f_t > 30 GHz

HS = high speed
LL = low leackage



- LF150 RF Performance
  - High speed MOS Devices with a ft of ***85GHz***
    - 30-40% faster than 180nm
    - Data reported from some 130nm technologies are 80GHz and 90GHz
      → Comparable RF performance to a 130nm process operating of a 1.2V supply voltage
  - Due to LF150 1.8V core voltage there is more freedom to implement analogue functions compared to 130nm 1.2V processes
  - LF150 with digitally-bridging RF characteristics and high variety of possible analogue functionality

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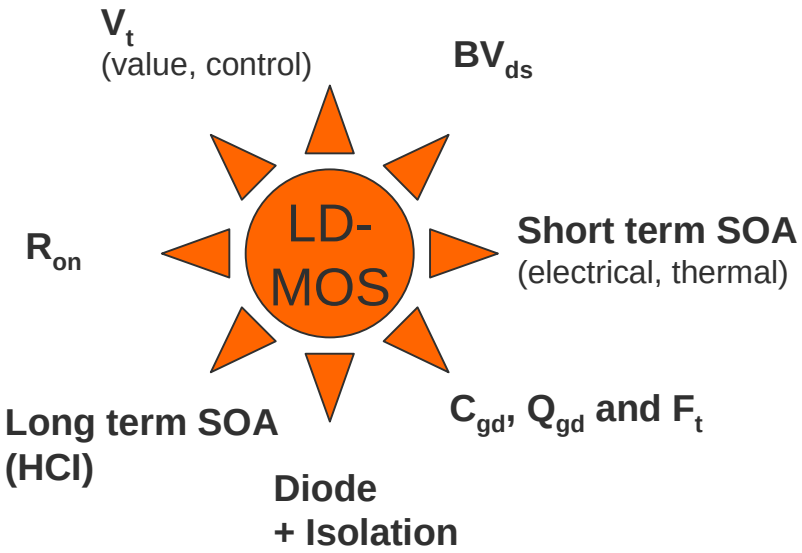
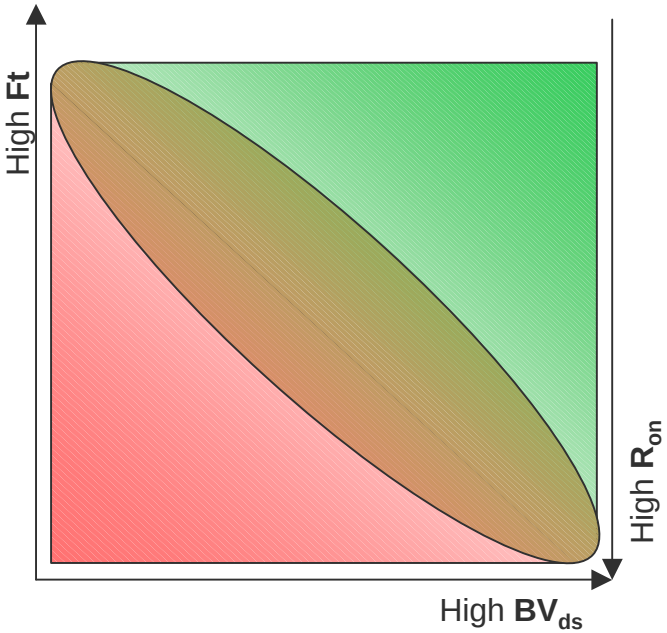
Our LDMOS Approach

- Flexibility for customer demands for tailored devices regarding
  - BV_{ds}/R_{on}, V_{dd}/BV_{ds}, V_t, Idsat, f_t, f_{max}

Trade off parameters for LDMOS optimization





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0,15µm LDMOS Device: Specification Requirements

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- Low cost through modular integration of high performance NLDMOS and PLDMOS into an advanced 0.15µm CMOS technology
- Relaxed process windows with respect to misalignment and CD variation
- DC performance
  - Well saturated output characteristics
  - Low I_{ds} leakage at minimum V_t
  - Low $I_{n\text{-}well}$ leakage current to p-substrate
  - Maximum BV_{DS}/R_{on}
  - Degradation of Id_{sat} and Id_{lin} < 10% in 10 years @ $V_{dd}/BV_{DS} > 0.5$
- RF performance
  - Small signal:
    - Maximum ft and fmax, large BV_{DS}* f_t product
  - Large signal: (power amplifier, power switches)
    - Maximum power added efficiency, power gain, output power

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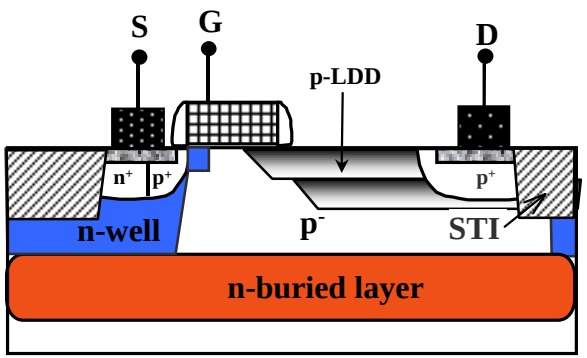
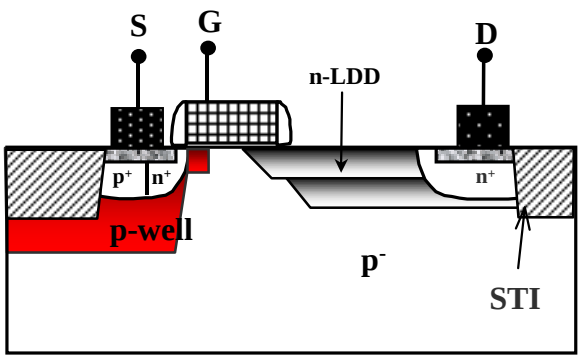
0,15µm LDMOS Device: Construction

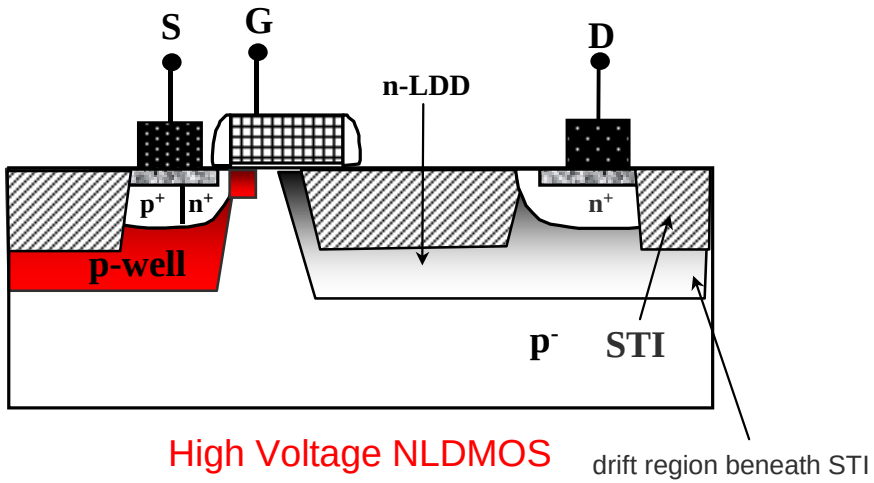


RF PLDMOS



RF NLDMOS

- Self aligned channel doping
- Large depth of drift region for low Ron
- Gate overlapped drift region for RESURF
- 2 extra masks



High Voltage NLDMOS

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0,15µm LDMOS Device: Performance Results

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- Currently 4 LDMOS devices with the following key parameter

NLDMOS								
application	**Vdd**	**BVds**	**Vt**	**Ron**		**Idsat**	**Ft**	**Fmax**
RF	5 V	20 V	0.5..0.8 V	< 4 Ohm mm	< 20 mOhm/mm²	> 450 µA/µm	> 22	> 42
	8 V	24 V	0.5..0.8 V	< 5 Ohm mm	< 24 mOhm/mm²	> 420 µA/µm	> 20	> 40
HV	40 V	70 V	0.5..0.8 V	< 14 Ohm mm	< 91 mOhm/mm²	> 300 µA/µm	> 10	> 20
	60 V	100 V	0.5..0.8 V	< 30 Ohm mm	< 220 mOhm/mm²	> 200 µA/µm	> 4.5	tbd
PLDMOS								
application	**Vdd**	**BVds**	**Vt**	**Ron**		**Idsat**	**Ft**	**Fmax**
RF	-5 V	-25 V	-0.5..-0.8 V	< 12 Ohm mm	< 57 mOhm/mm²	> 300 µA/µm	> 11	> 21
HV	-42 V	-55 V	-0.5..-0.8 V	< x Ohm mm	< x mOhm/mm²	> x µA/µm	tbd	tbd

for delta Id < 10% in 10 years

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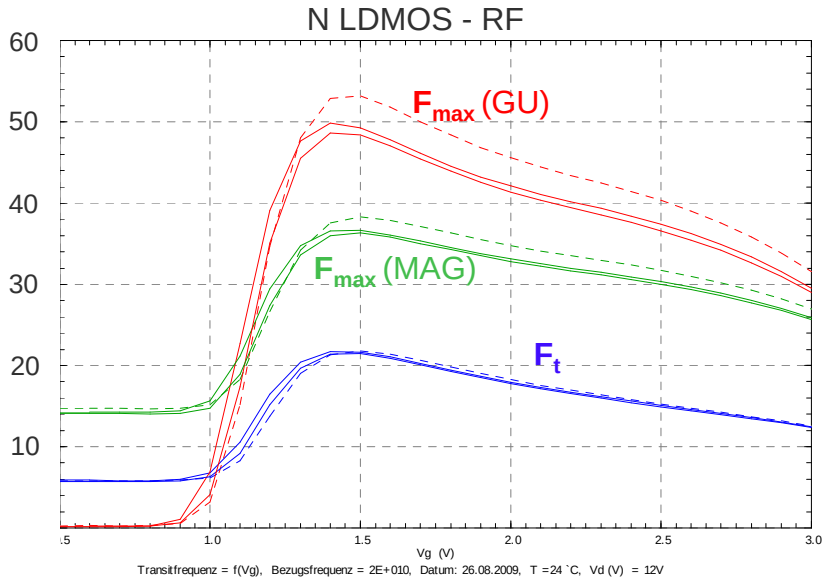
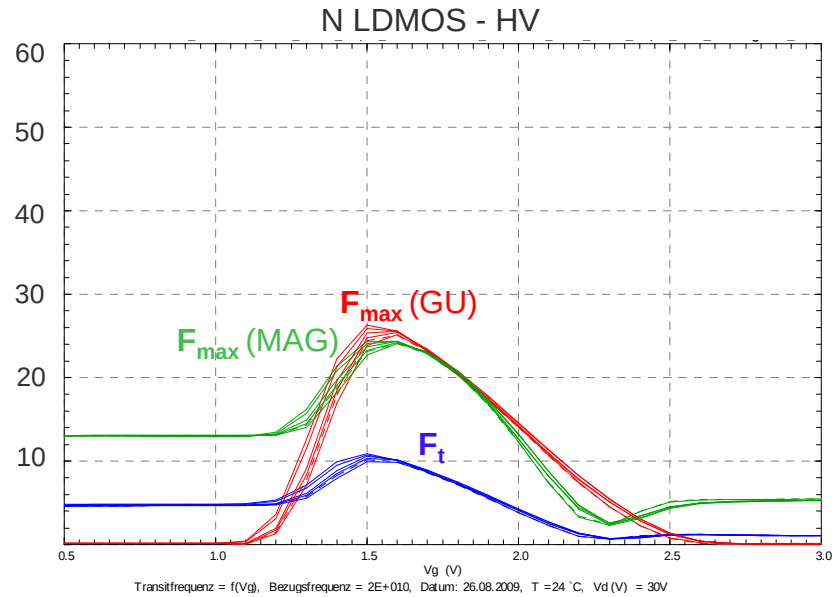
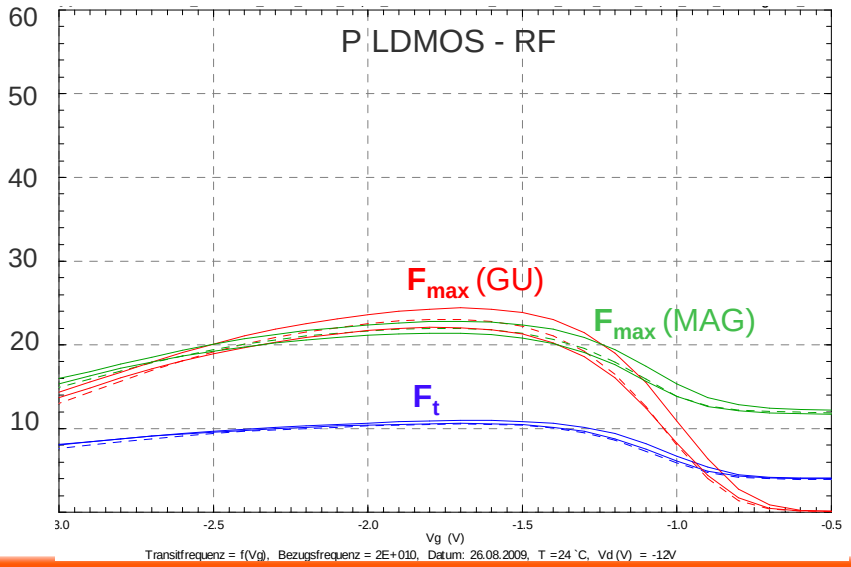
0,15µm LDMOS Device: Performance Results





- F_t & F_{max} data
  - **N LDMOS** for RF application: F_t >20
  - **N LDMOS** for HV application: F_t >10
  - **P LDMOS** for RF application: F_t >10



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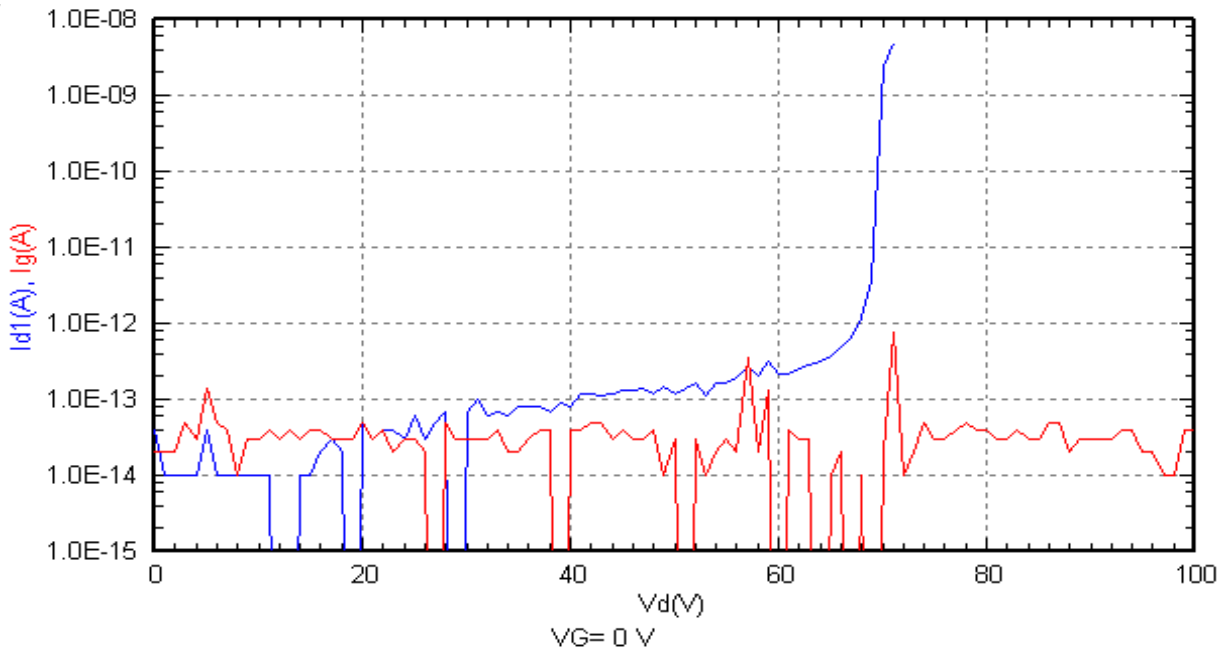
0,15µm LDMOS Device: Performance Results

- V_{DS} data



- Good leak current performance
- Good breakdown characteristics (steep profile)

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LDMOS Applications

LFoundry

- Power management
  - DC/DC up and down converters: 42V/16V/12V to 12V/5V/3.3V/2.4V/1.8V
  - Complementary LDMOS in the power amplifier output stage with high RF performance for switching frequencies up to several 10 MHz
  - Significantly reduced values for the input and output capacitances and the output inductance at high conversion efficiency > 90%

- RF power amplifier
- High voltage circuits for controlling of embedded FLASH, EEPROM, MEMS
- Actuators (12V and 42V) for intelligent automotive circuits
- Display drivers

- Audio class D amplifier for mobile applications
  - Realizing efficiency Class D 90% - 95% (Class AB-Designs < 50%, Class A 20% -25%)
  - Frequency of pulse width modulation (PWM) signal for the switching amplifier is in MHz range
  - High efficiency class & 0,15µm technology results in small space required for power supply, heat sink, package → valuable cost saving

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Conclusion

- LFoundry's 0.15µm CMOS technology with excellent RF performance as basis for digitally assisted analogue functionality

- Modular integration of RF and high voltage LDMOS in LFoundry's 0.15µm CMOS flow realized
  - 2 additional mask steps for LDMOS integration
  - Dense layouts for LDMOS arrays using 0.15 µm design rules
  - Predicted LDMOS performance proven for i.e. high F_t , low R_{on} values and possible V_{dd}

- LFoundry 0,15µm LDMOS for advanced analogue applications in the digital market arena (wireless, mobile, multi media, …) and areas like power management, MEMS, ...

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