High-frequency LDMOS in 0.18um BCD Technology for Power Supply-On-Chip

IL-Yong Park, Dongbu HiTek
Ashraf Lotfi, Enpirion

Introduction

- DC/DC converter market requires high efficiency and high current driving capability
- Power SOC (Supply-On-Chip) requires
  - high efficiency and fast switching DC/DC converter
  - integrated passives (inductor)
- Fast switching DC/DC converter allows to reduce inductor size and increase the power density per unit volume

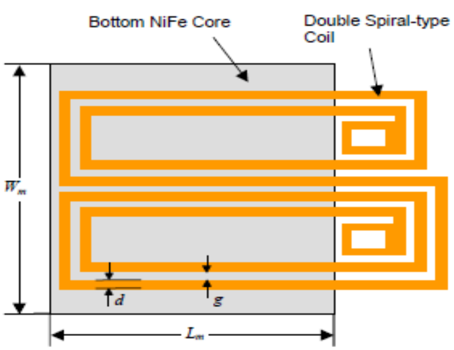
Introduction

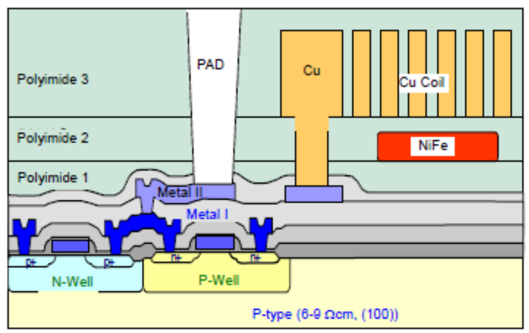
- High frequency LDMOS achieves
  - low parasitic capacitance
  - fast switching speed realizing low switching power dissipation
  - DC power dissipation might higher than conventional low Rsp LDMOS

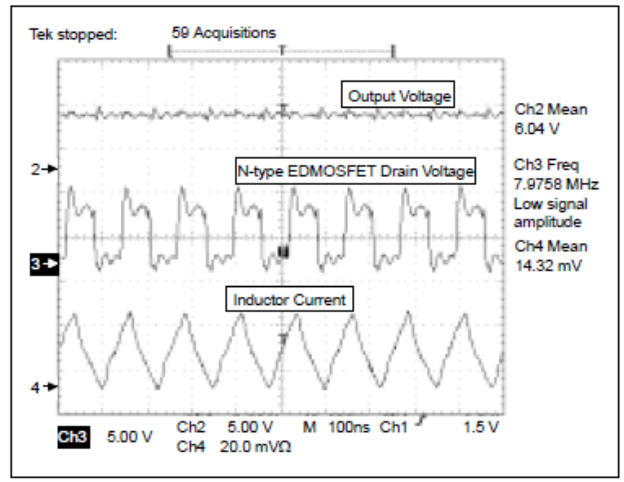
- Dongbu HiTek developed high frequency LDMOS with thin gate oxide, short gate length, high breakdown voltage in 0.18um Analog CMOS/BCD technology

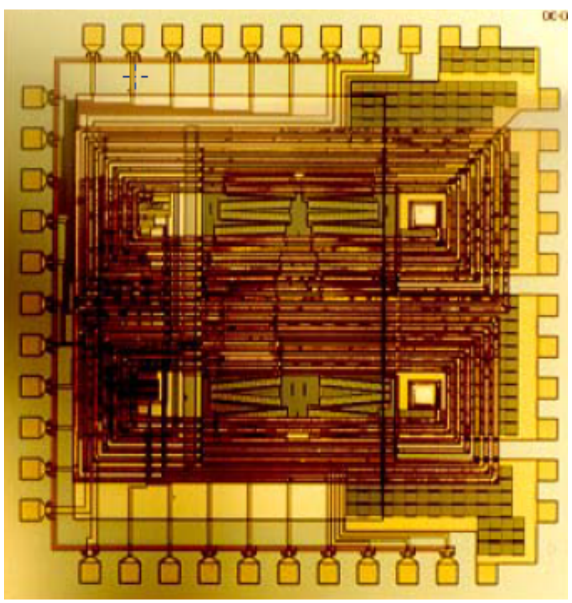
Introduction

Monolithic DC/DC Converter (2002, ETRI)









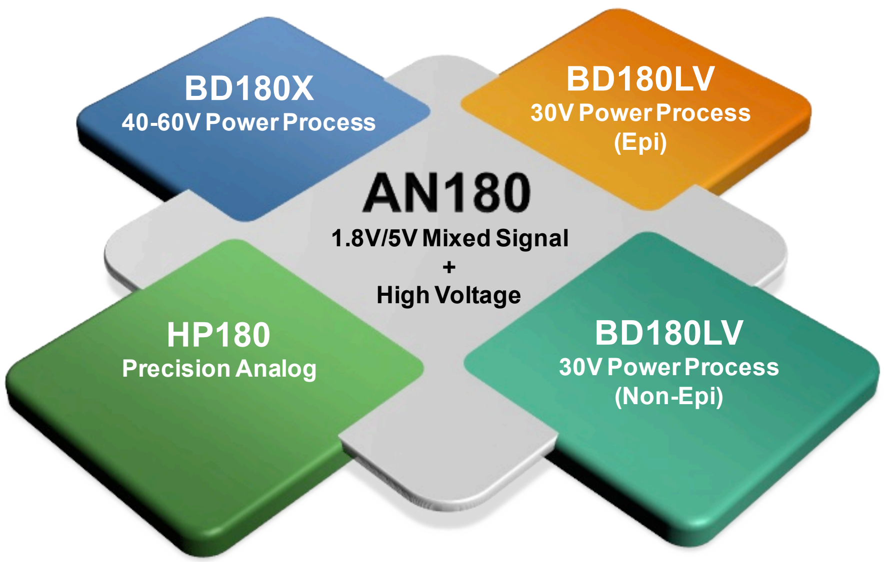
0.8um CMOS + DE(Drain-Extended)CMOS Process

Waveforms of FET switching voltage and thin-film inductor current when Vi=3.5 V, Vo=6.0 V, and the operating frequency was 8 MHz.

Micro inductor: 0.5 ~ 0.6 uH
Magnetic Material; NiFe (2.5um)

Power Efficiency: 72%

AN180 Process

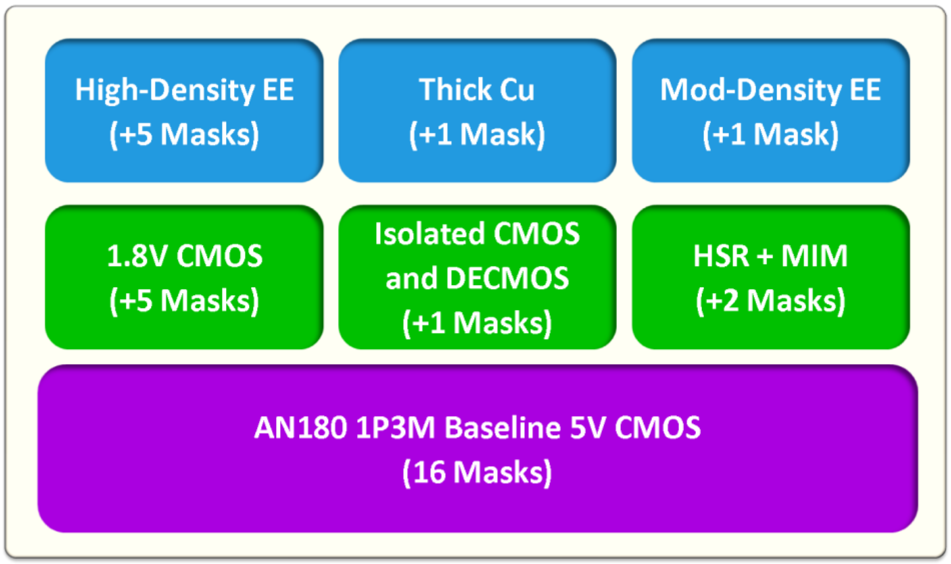


<0.18um modular technology platform for power management application>

- Process Modularity
  – To save development time for the process and optimize the mask layer
  – Use 1 process platform and provide several process options
  – Process modularity is the Key feature

* Currently BD180LV (non-epi) version merged into AN180

AN180 Process



Process modularity of 0.18um 30V AN180 process

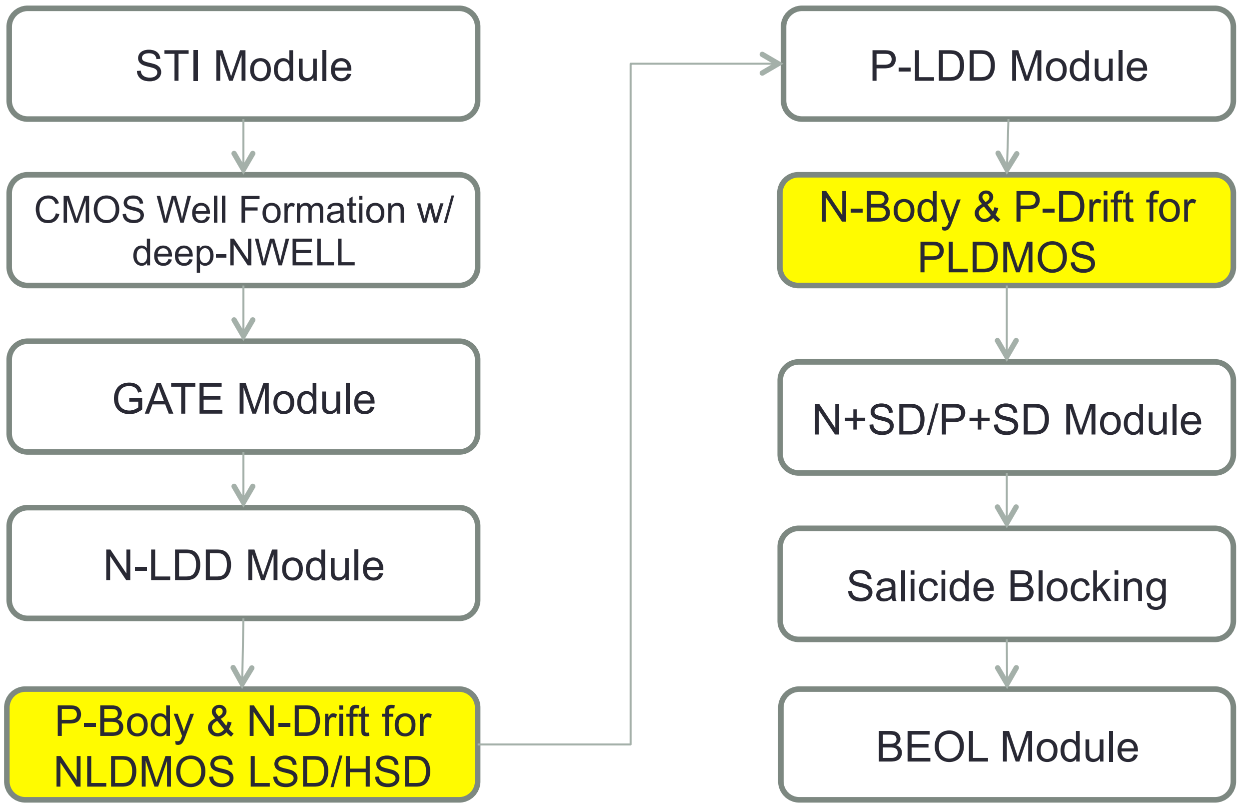
- Process Modularity
  - 5V CMOS baseline
  - HVCMOS and iso CMOS
  - 1.8V CMOS option
  - HSR, MIM option
  - Thick Cu option
  - Mod-density EEPROM
  - High-density EEPROM
  - **High Frequency LDMOS (additional implants)**

Dongbu HiTek
Semiconductor Business
ENPIRION

Process Features

- 4 additional implant masks for HF-LDMOS;
  - 2 mask for NLDMOS
  - 2 mask for PLDMOS
  - No additional thermal budget → fully compatible with existing AN180 process
- For fast switching
  - 30Å thin gate oxide for Vgs power scaling
  - 0.26μm channel length
  - Drift implant after gate formation for small gate-to-drain overlap capacitance
- High driving current capability
  - Short channel length even at high drain voltage without punch-through
  - Optimized halo implant at source side

Process Flow

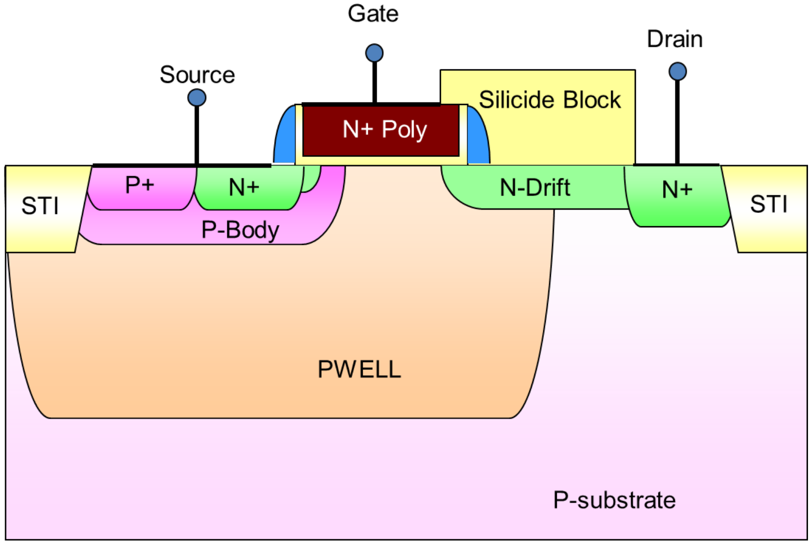


Additional implants for HF-LDMOS module

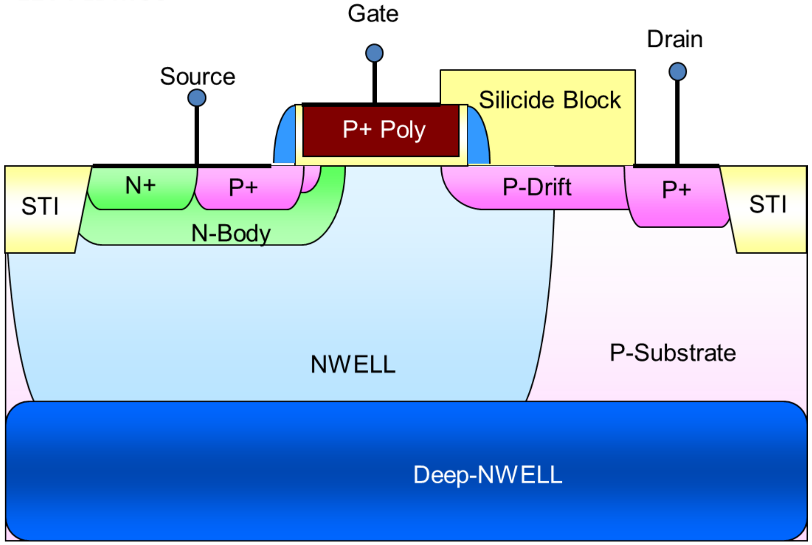
Dongbu HiTek Semiconductor Business ENPIRION

Device Structure

12V NLDMOS LSD



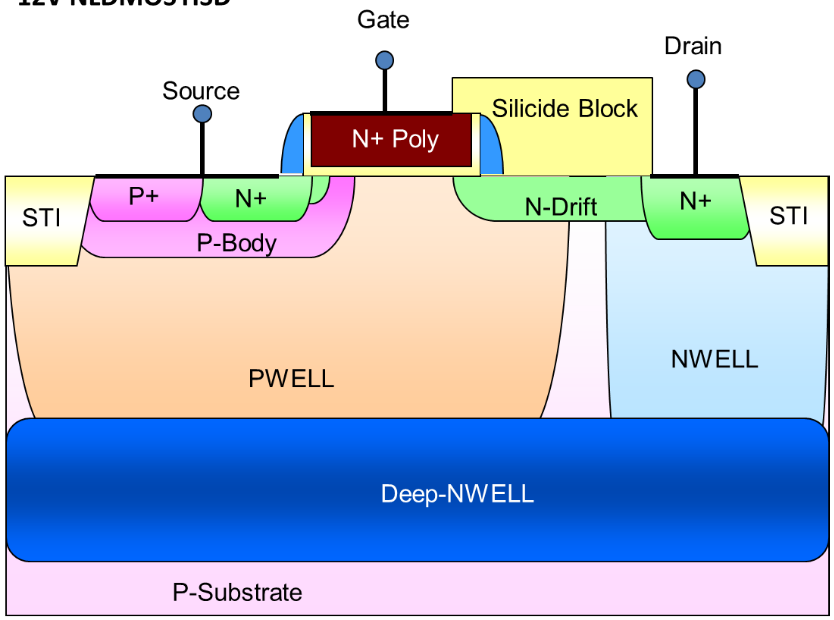
12V PLDMOS



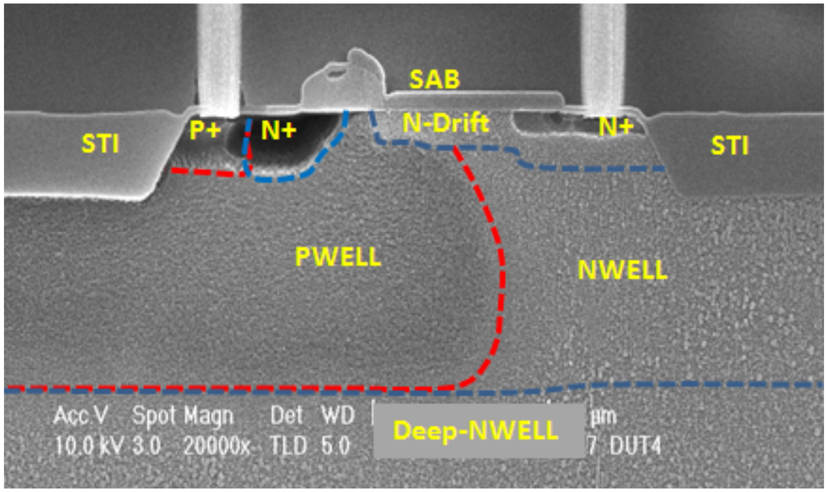
- Dedicated Implant Layers are used
  - 2 layers for P-Body and N-Drift of NLDMOS
  - 2 layers for N-Body and P-Drift of PLDMOS
- PWELL/NWELL extension
  - For the RESURF action, WELL is extended to the middle of drift region

Device Structure

12V NLDMOS HSD



<VSEM photograph of 12V NLDMOS>



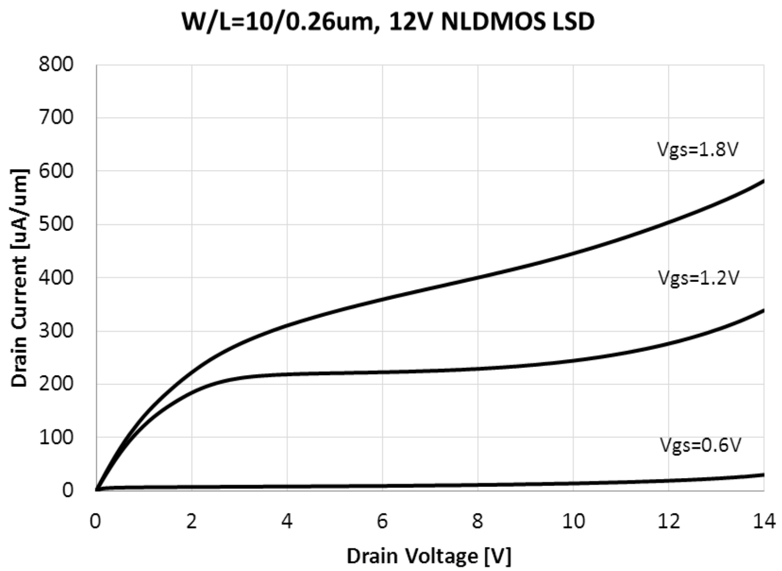
- Single-sided high tilt implant
  - To prevent punch-through breakdown even at high voltage of 20V
  - Source region width is limited by shadowing effect
- Optimized 2-step drift implant
  - At surface region of N-Drift for better HCI immunity

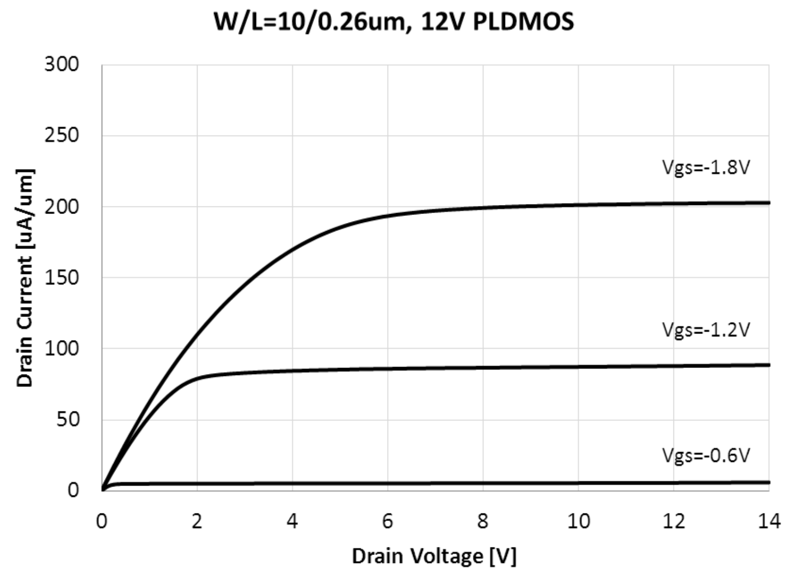
Summary of Electrical Performance

Parameters		Values		
		12V nLD LSD	12V nLD HSD	12V pLD
L_{CH}	㎛	0.26	0.26	0.26
V_T	V	0.45	0.45	0.40
$I_{D,SAT}$	㎂/㎛	500	500	200
BV_{DSS}	V	20	20	20
R_{SP}	mΩ·㎟	14	15	38
I_{OFF}	㎀/㎛	3	3	3
C_{ISS}	fF/㎛	1.98	-	2.07
C_{OSS}	fF/㎛	0.46	-	0.45
$F_{T,MAX}$	㎓	37.2	36.5	12.9
F_{MAX}	㎓	66.9	50	38.4

Dongbu HiTek Semiconductor Business ENPIRION

12V HF-LDMOS I-V Characteristics



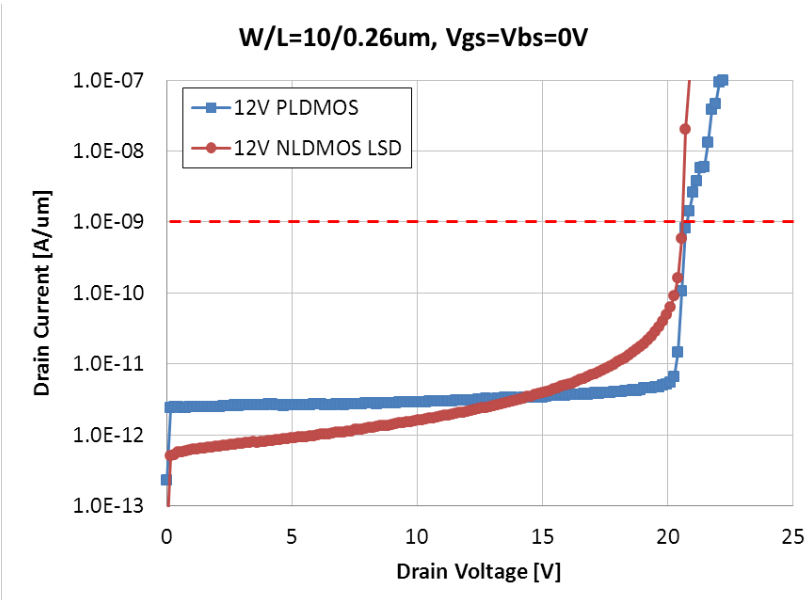


<DC output characteristics at Vgs=0.6V, 1.2V and 1.8V>

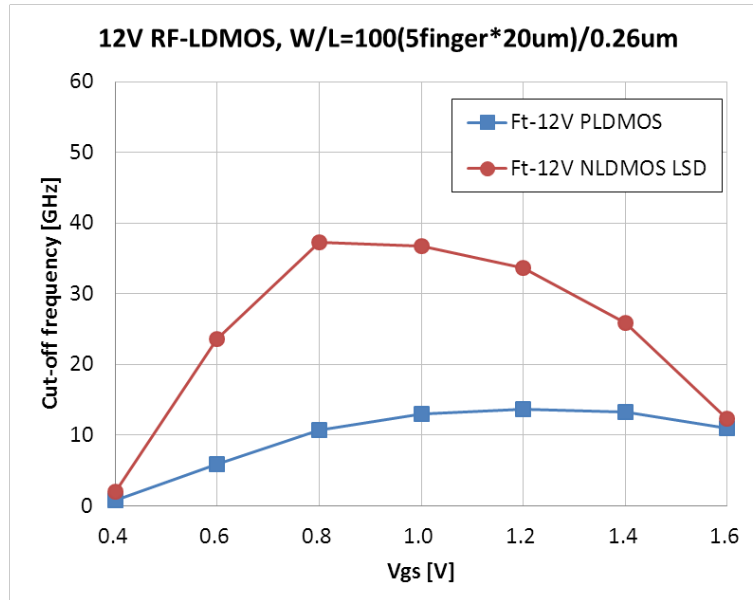
- Stable I-V characteristics up to 14V of Vds at 1.8V of Vgs
    - On-state BV: 18.5V, Off-state BV: 20V
- Current capability
    - NLDMOS Id,sat = 500[uA/um] at Vgs=1.8V and Vds=12V
    - PLDMOS Id,sat = 200[uA/um] at Vgs=-1.8V and Vds=-12V

Dongbu HiTek Semiconductor Business ENPIRION

12V HF-LDMOS – BVdss & Ft



<Off-state breakdown characteristics>

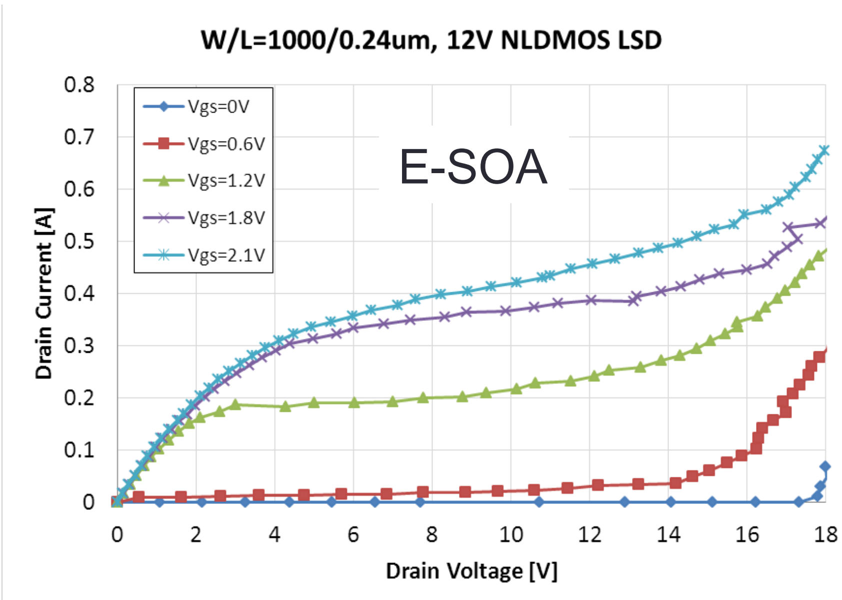


<Measured Ft vs Vgs at Vds=6V>

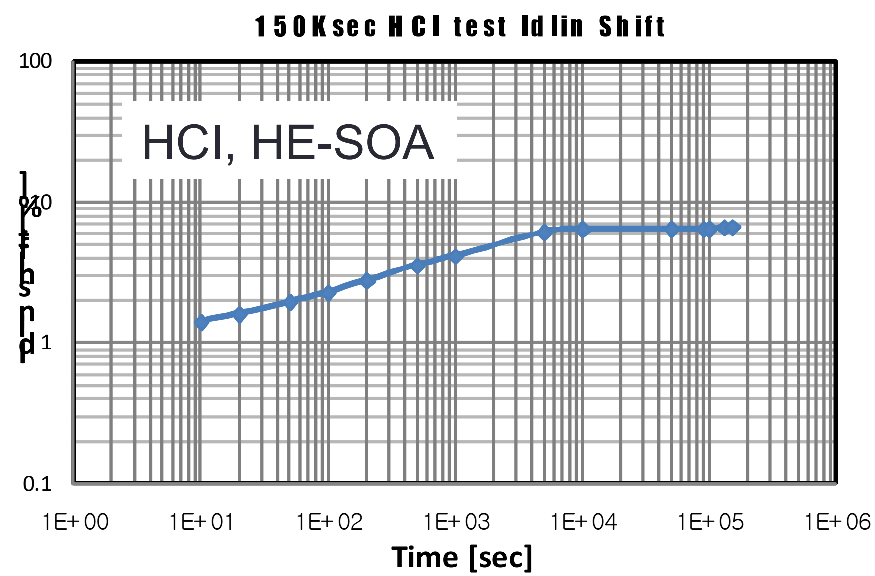
- Over 20V off-state breakdown voltage with low leakage
  - 4A, 6A, 9A, 15A in production, 20A and 40V product in develop.
- Ft and Fmax characteristics according to Vgs at Vds=6V
  - Ft,max/Fmax = 37.2GHz/66.9GHz for 12V RF NLDMOS LSD
  - Ft,max/Fmax = 12.9GHz/38.4GHz for 12V RF PLDMOS

Dongbu HiTek Semiconductor Business ENPIRION

12V HF-LDMOS – Reliability (HCI)



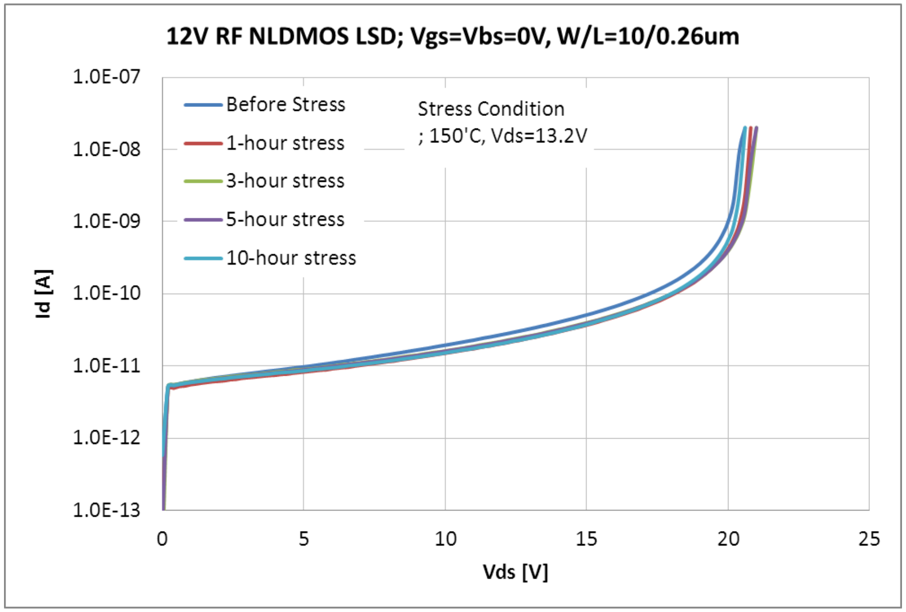
<TLP I-V characteristics; pulse width=100ns>

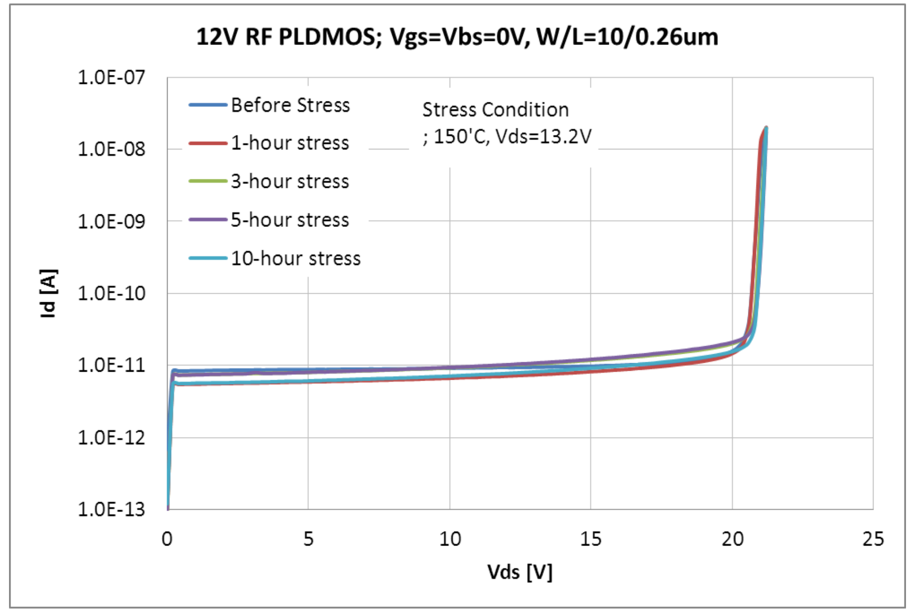


<Long-term HCI test at Vds=12V, Vgs=1.8V>

- Wide electrical SOA enough for operation up to 15V of Vds
- Long-term HCI results;
  - Idlin drift 6.7% after 150Ksec stress at Vds=12V and Vgs=1.8V

12V HF-LDMOS – Reliability (HTRB)



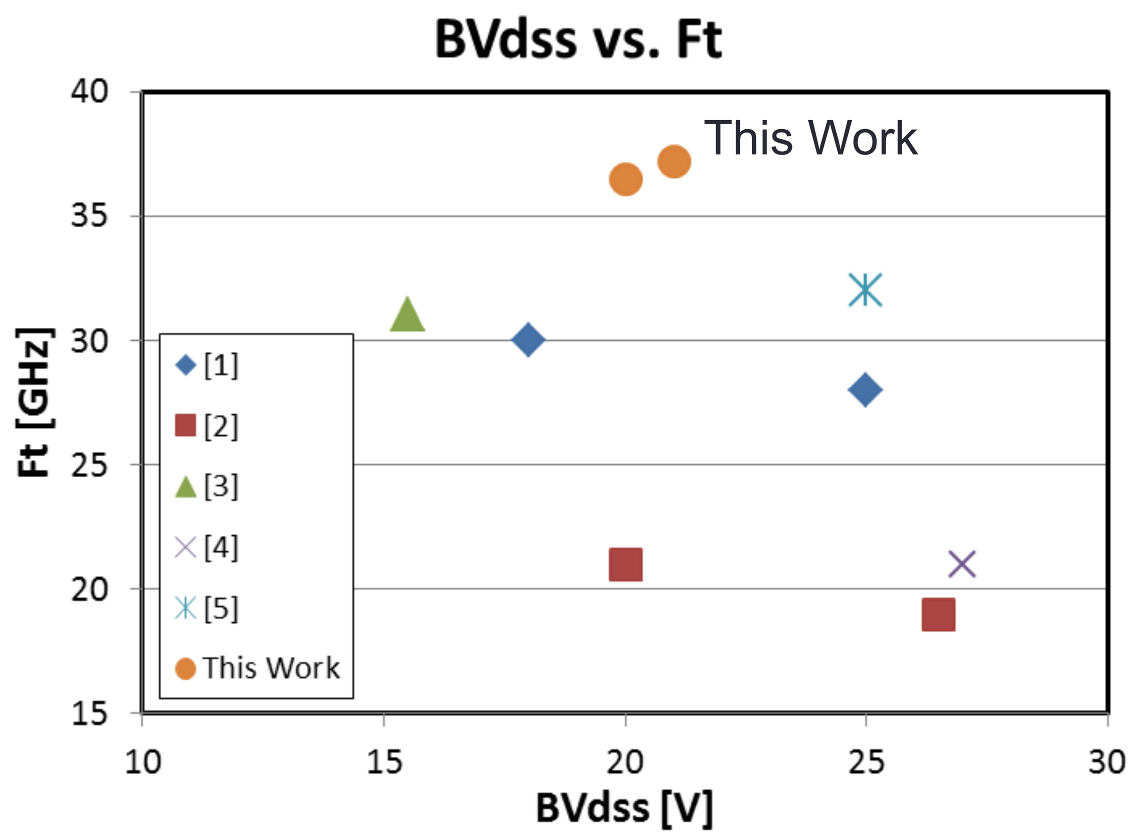


<BVdss curve with stress time; stress condition 150'C, Vds=13.2V>

- Negligible BV & Off-leakage shift with stress time during Hot Temperature Reverse Biasing stress test
- Customer: product level HTOL (up to 1500 hrs) qualified

Dongbu HiTek Semiconductor Business
ENPIRION

BV vs. Ft comparison

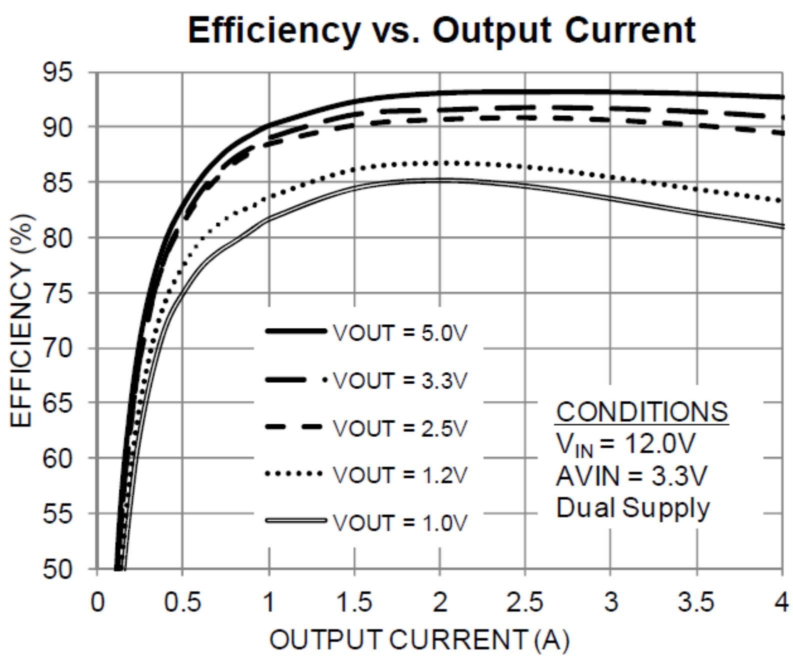


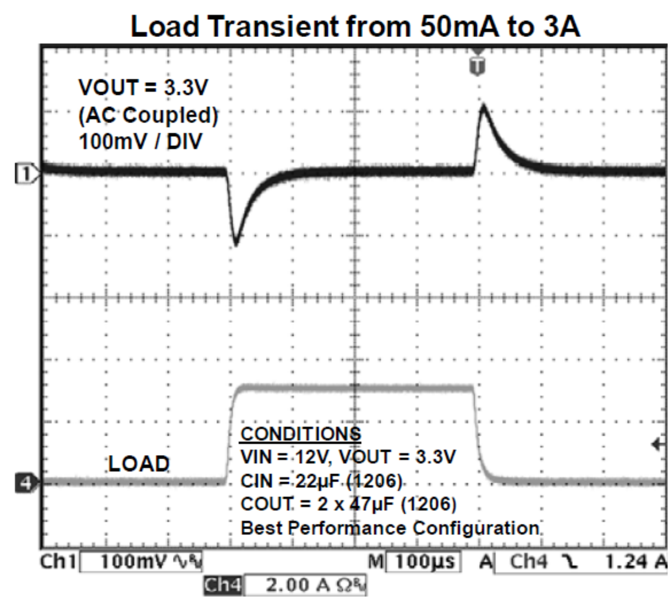
[1] Z. Lee et al., IEEE BCTM, pp.1-4, 2006
[2] K. E. Ehwal et al., IEDM Tech. Dig., pp. 895-898, 2001
[3] D. Muller et al., IEEE T-ED, Vol. 54, No. 4, pp. 861-867, 2007
[4] N. R. Mohapatra et al., IEEE ISPSD, pp.1-4, 2006
[5] Andreas Mai and Holger Rucker, Solid-St. Electron., pp. 45-50, 2011

Dongbu HiTek Semiconductor Business ENPIRION

Application – ENPIRION DC/DC Converter

- Enpirion unveils the EN2340QI 4 Amp, EN2360QI 6 Amp, EN2390QI 9 Amp, and EN23F0QI 15 Amp devices further broaden Enpirion's extensive PowerSoC (power-system-on-chip) portfolio by using **AN180 12V High Frequency LDMOS** and **integrated inductor**
- EN2340QI Measurement data (refer to datasheet)





Dongbu HiTek Semiconductor Business
ENPIRION

Summary

- 12V HF-N/PLDMOS transistors with 1.8V Vgs have been developed and integrated on **Dongbu HiTek 0.18µm Analog CMOS (AN180)**/BCD(BD180LV) process
- Each of 2 additional implants are used to make NLDMOS and PLDMOS without adding thermal budget
- Short channel length(0.26um) and small gate-to-drain overlap capacitance are used to achieve high Ft, which can reduce the inductor size of the DC/DC converter system
- BVdss*Ft figure-of-merit
  - 744GHz*V for 12V RF NLDMOS
  - 258GHz*V for 12V RF PLDMOS

Summary (Cont.)

- Enpirion developed DC-DC converter using 12V HF-LDMOS process and integrated controller, power MOSFET, and integrated inductor into one chip realizing Power System-On-Chip (PowerSoC)
- The Enpirion shows high efficiency, highest density and reliability without compromising the performance

Dongbu HiTek Semiconductor Business ENPIRION

Thank You!

IL-Yong Park, Dongbu HiTek, ipark@dsemiusa.com
Ashraf Lotfi, Enpirion, lotfi@enpirion.com