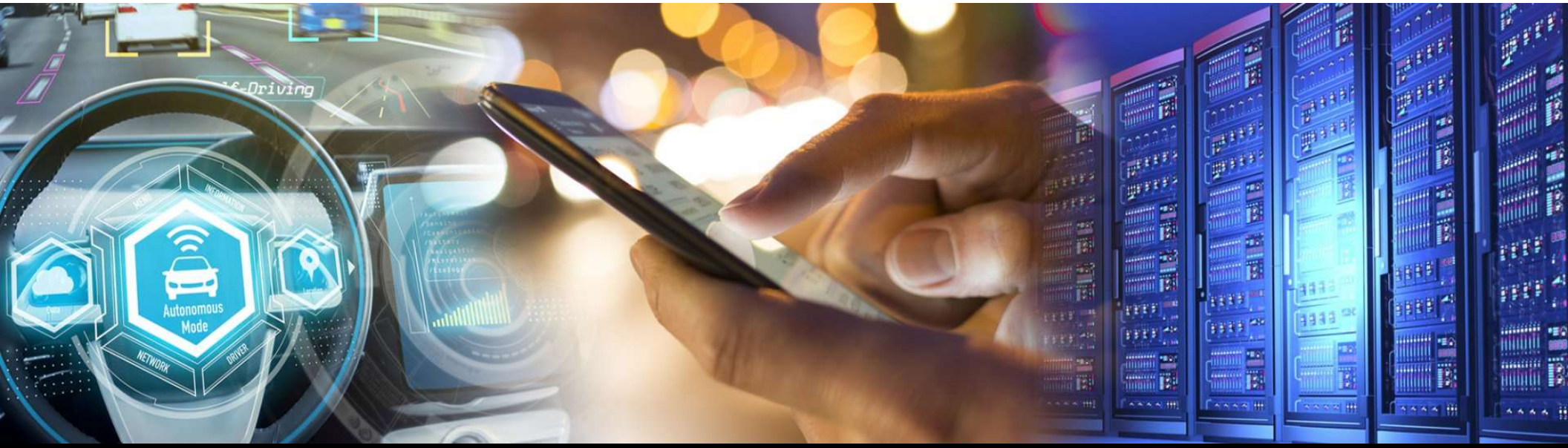

Power Electronics: Platforms and Applications

Dr. Ted Letavic | Vice President, Senior Fellow

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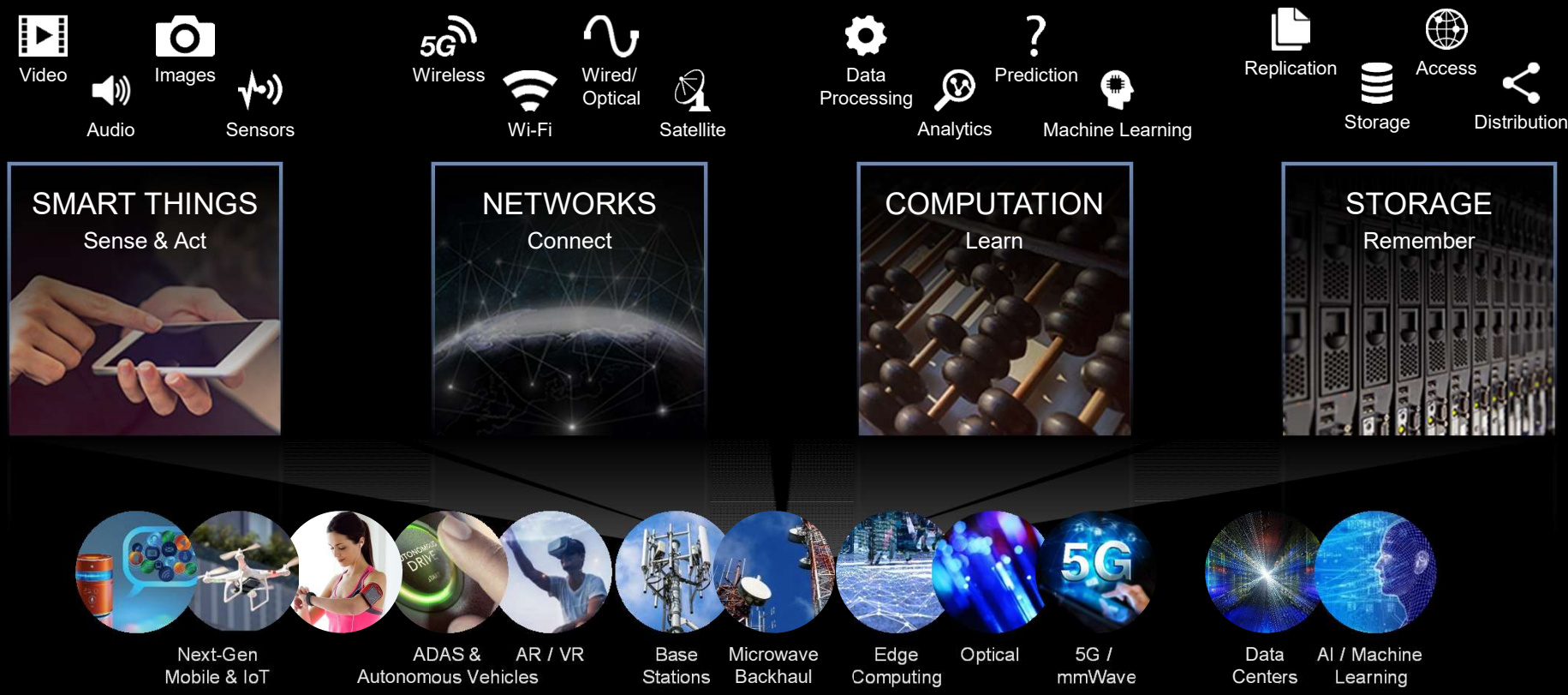
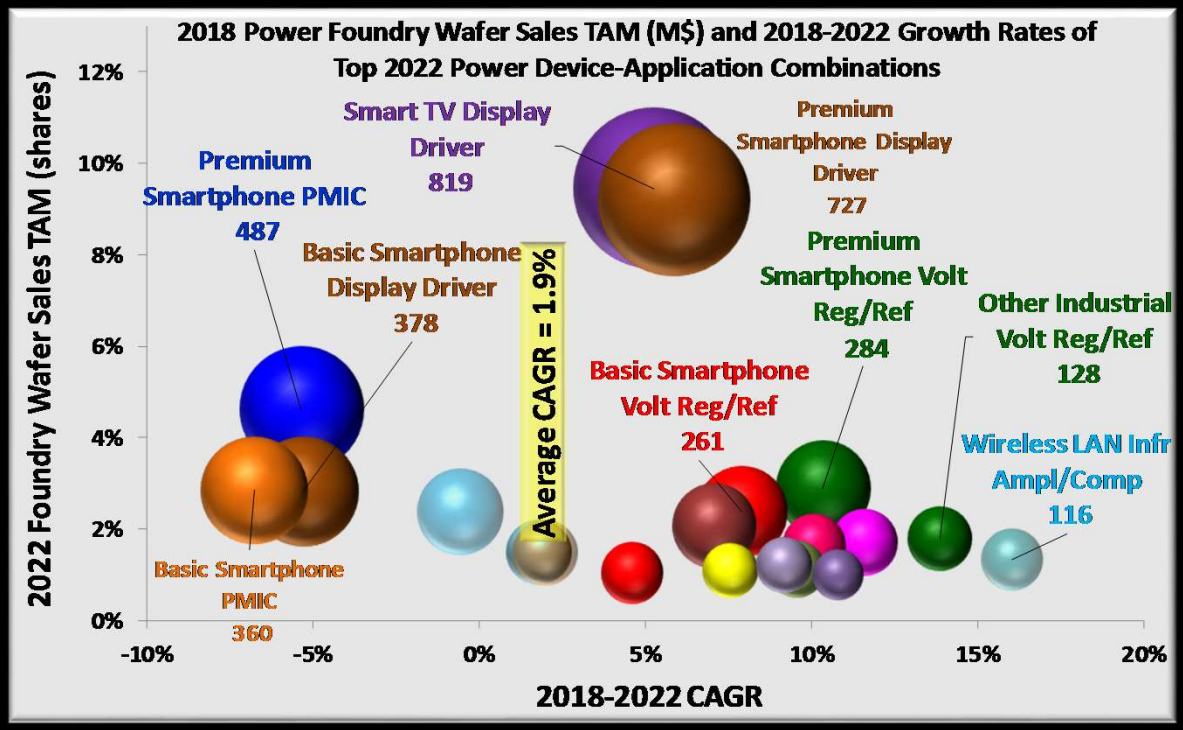
Agenda

1. Industry Overview
2. Power Electronics: Platforms and Applications
3. Discretes and Compound Semiconductors
4. Summary

Power semiconductors enable technological advancements…



2022: Power Foundry $TAM and CAGR Modeling



(GF Strategic Marketing & Marketing Analytics Foundry TAM by Application, 4Q 2018)

- Power foundry TAM by device/application modeling
  - Focus on high –growth low share applications with double digit growth, battery management systems, voltage regulation, LAN infrastructure

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Power Portfolio to address Multiple segments

	Logic	RF	Power	eFlash	HV / DDI
28nm	●	●		○	●
40nm	●	●	○	●	●
55nm	●	●	●	●	●
65nm	●	●	●		
130/110nm	●	●	●	●	
180nm	●	●	●		

● *Available* ○ *Development*

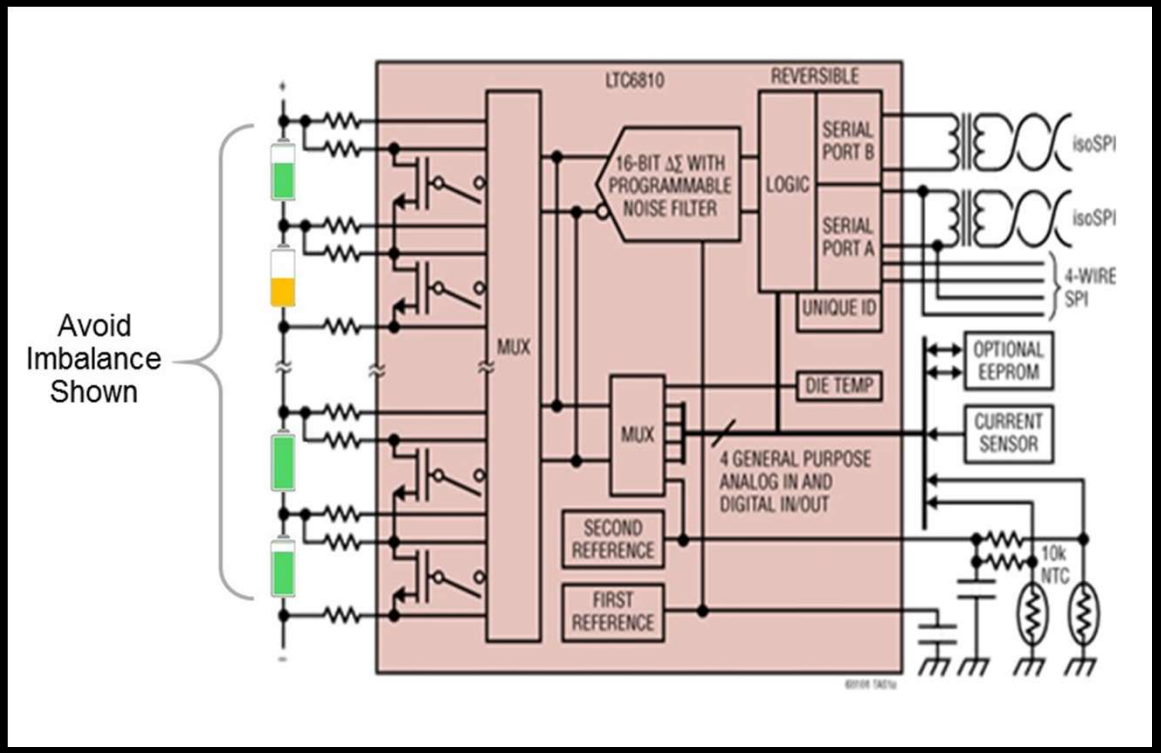
Next-Gen Mobile & IoT | ADAS & Autonomous Vehicles | AR / VR | Base Stations | Microwave Backhaul | Edge Computing | Optical | 5G / mmWave | Data Centers | AI / Machine Learning

Battery Management Applications (eHV, renewable energy)

- Mult-channel monitor cells to optimize battery array performance.

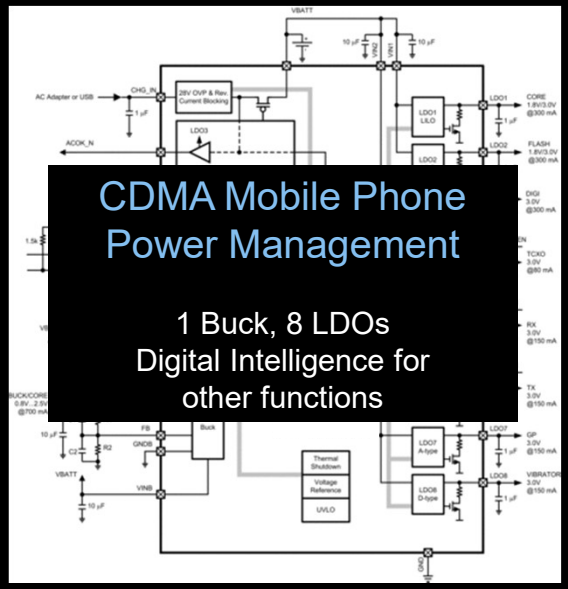
- HV: 25%
- Analog: 25%
- Digital + Memory: 25%

- Integration drives platform solution



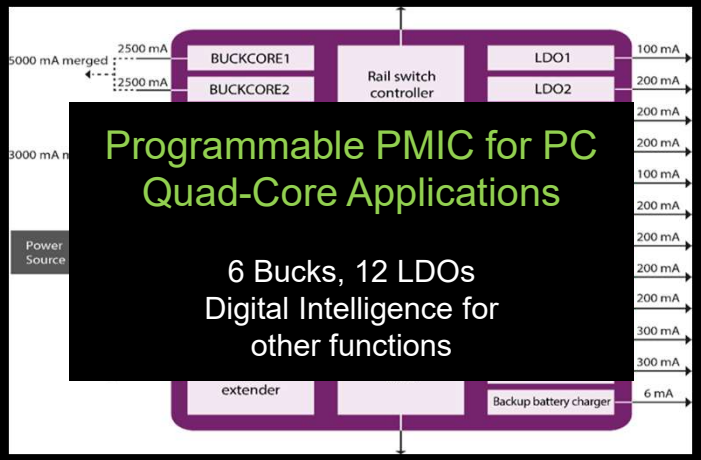
Block Diagram Image Reference
https://www.analog.com/en/products/ltc6810-2.html

PMICs serving many applications



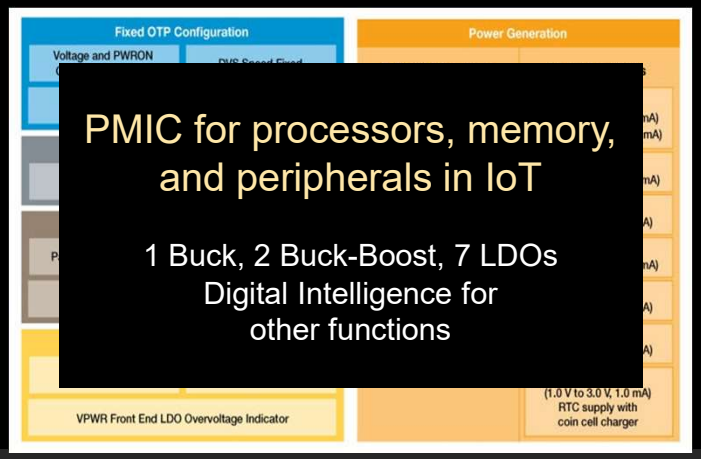
CDMA Mobile Phone Power Management

1 Buck, 8 LDOs
Digital Intelligence for other functions



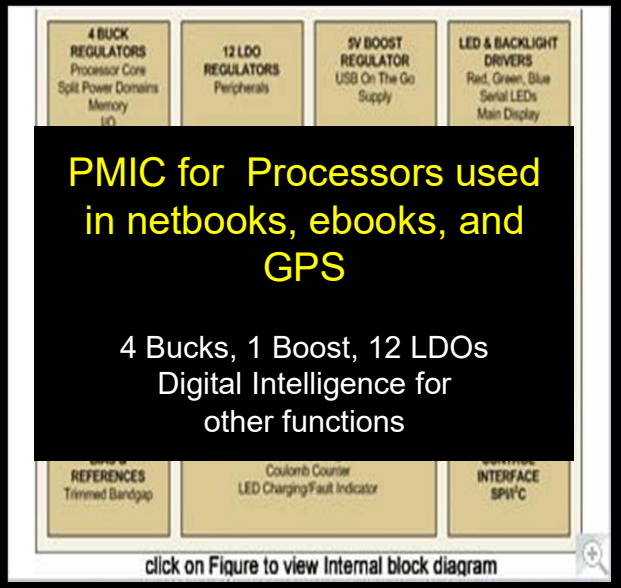
Programmable PMIC for PC Quad-Core Applications

6 Bucks, 12 LDOs
Digital Intelligence for other functions



PMIC for processors, memory, and peripherals in IoT

1 Buck, 2 Buck-Boost, 7 LDOs
Digital Intelligence for other functions



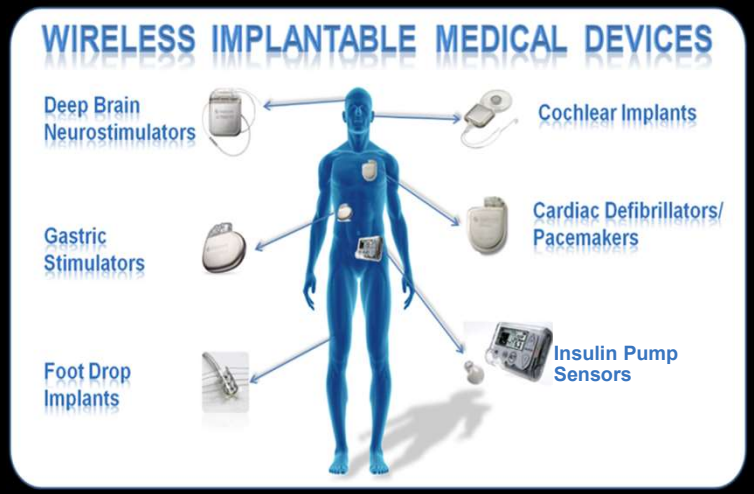
PMIC for Processors used in netbooks, ebooks, and GPS

4 Bucks, 1 Boost, 12 LDOs
Digital Intelligence for other functions

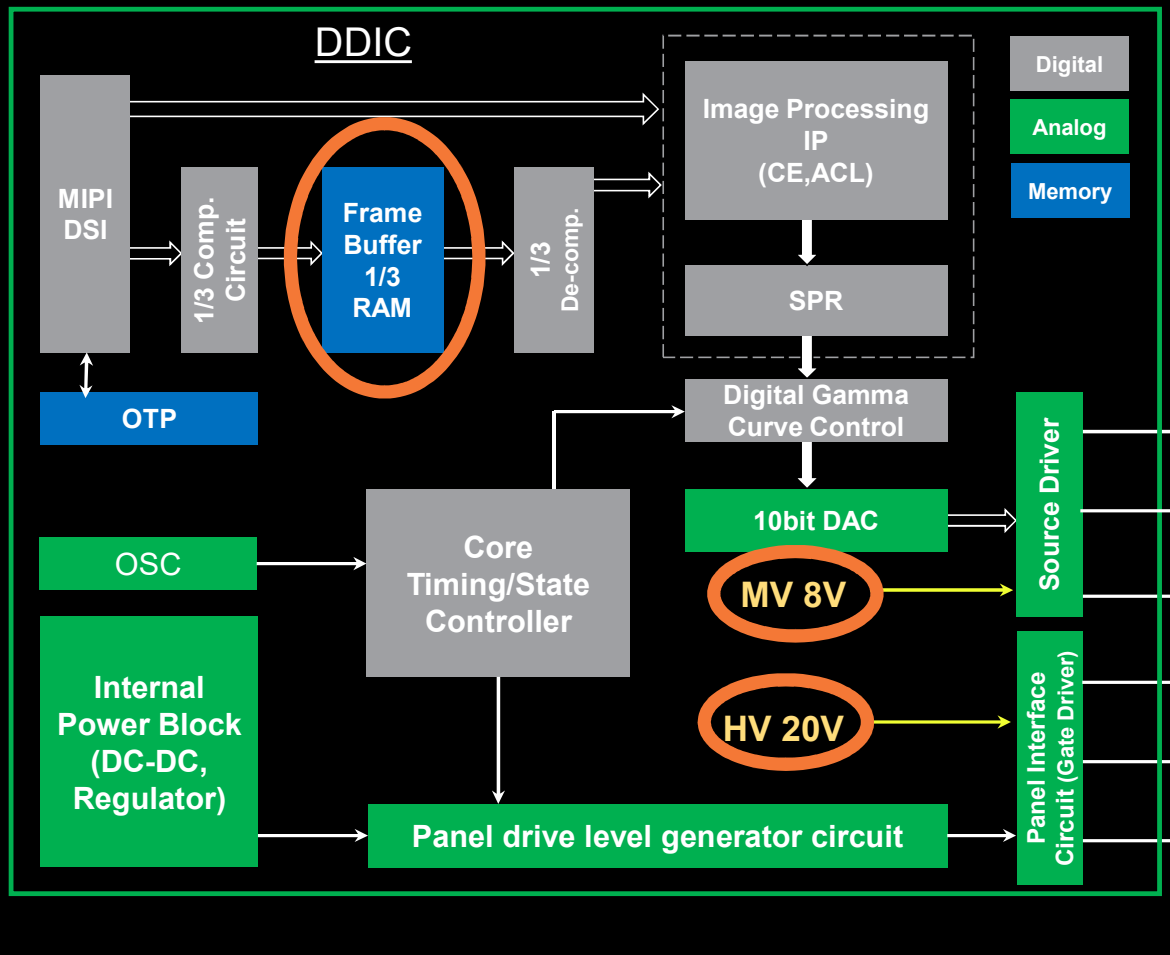
Wireless Charging

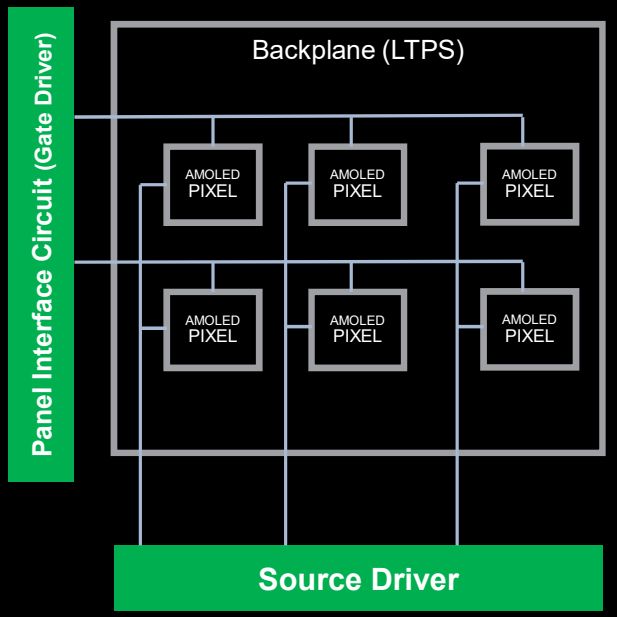
- Ubiquitous in coming years, possibly the most common charging method

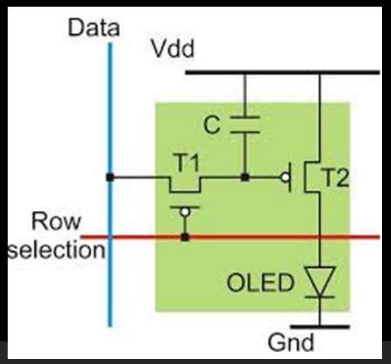
- Benefits being recognized and valued
  - Standardization eliminates need to find the right connector and proves useful for travelers
  - Implantable Medical Devices avoid infection at externally accessible ports and connector corrosion



AMOLED Display Driver IC (DDIC) Block Diagram –Triple Gate Oxide

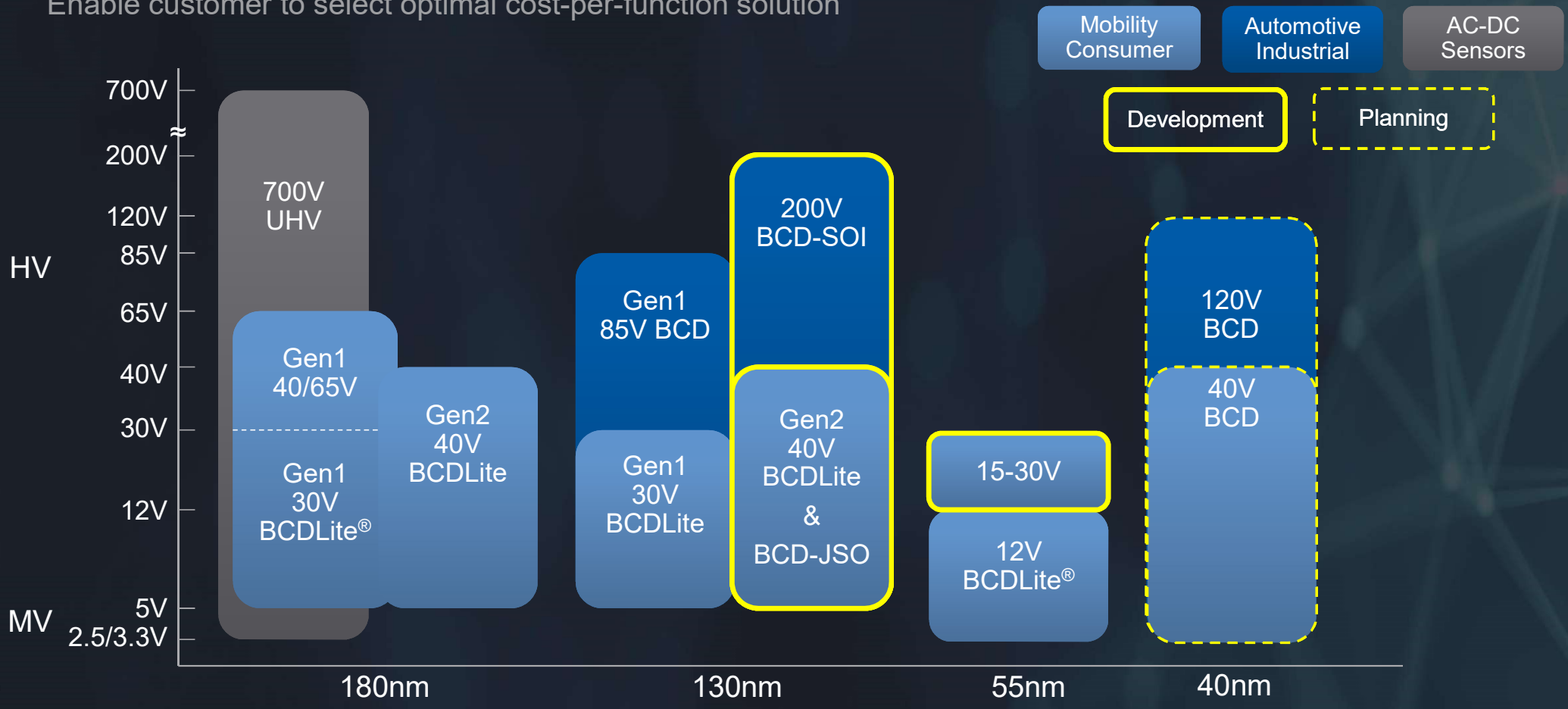






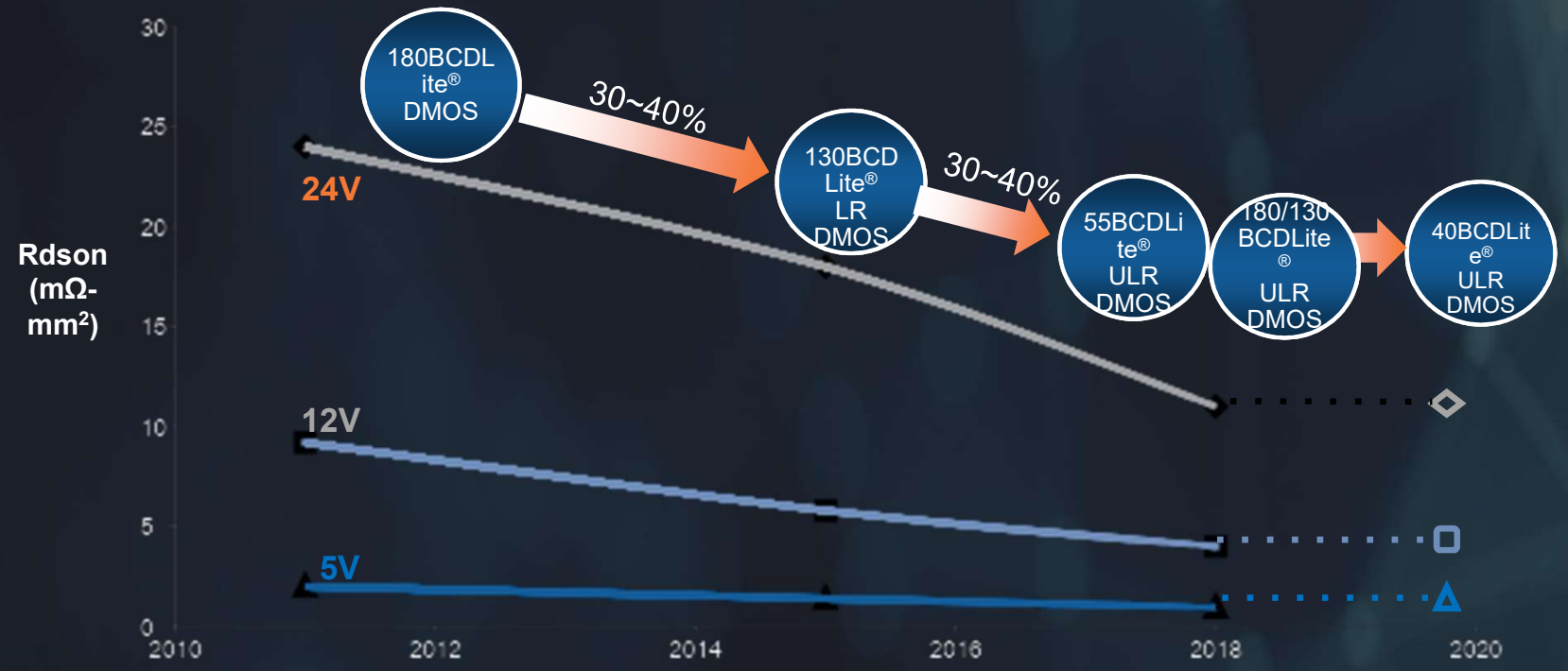
GF Power Platforms: Wide range of nodes and voltages

Enable customer to select optimal cost-per-function solution



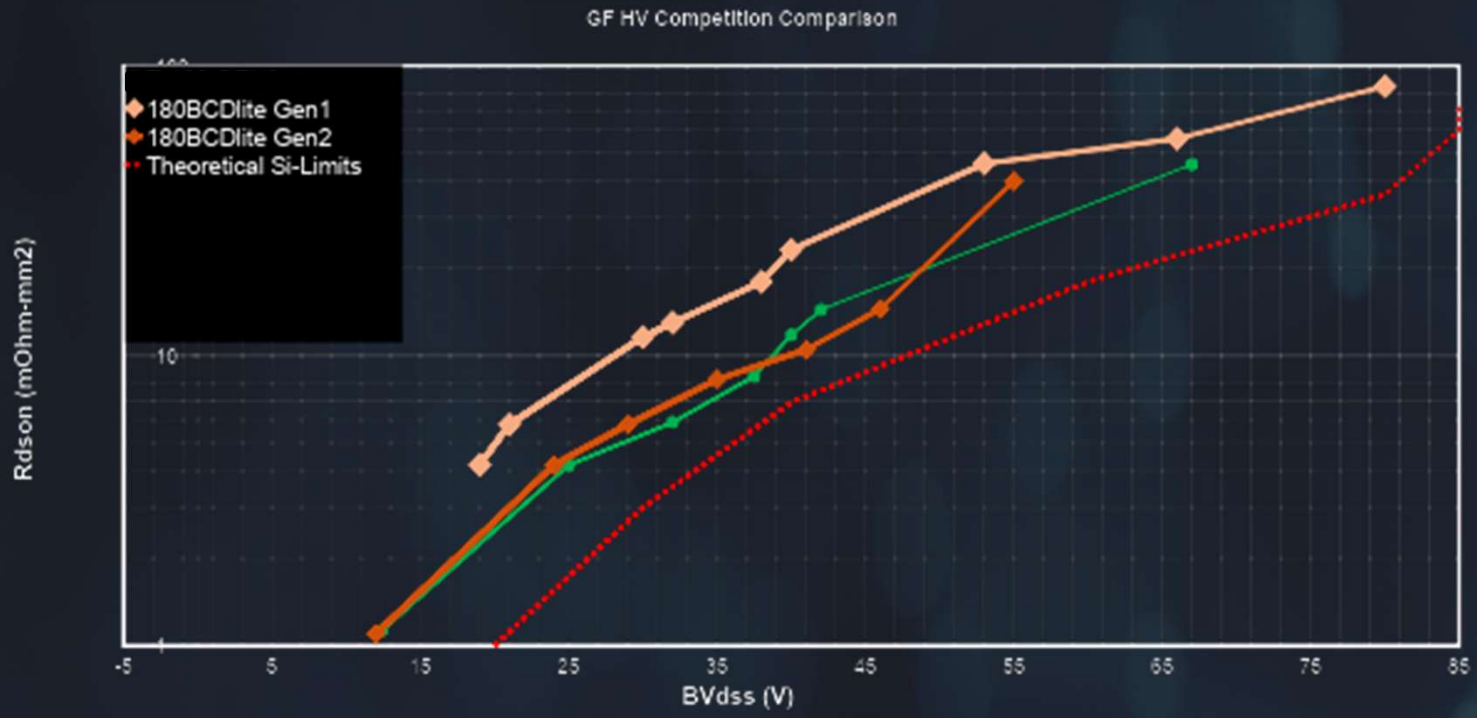
Continuous Improvement in Power Device Performance

Ultra-Low-Rdson (ULR) DMOS, 30~40% Power FET Area per generation



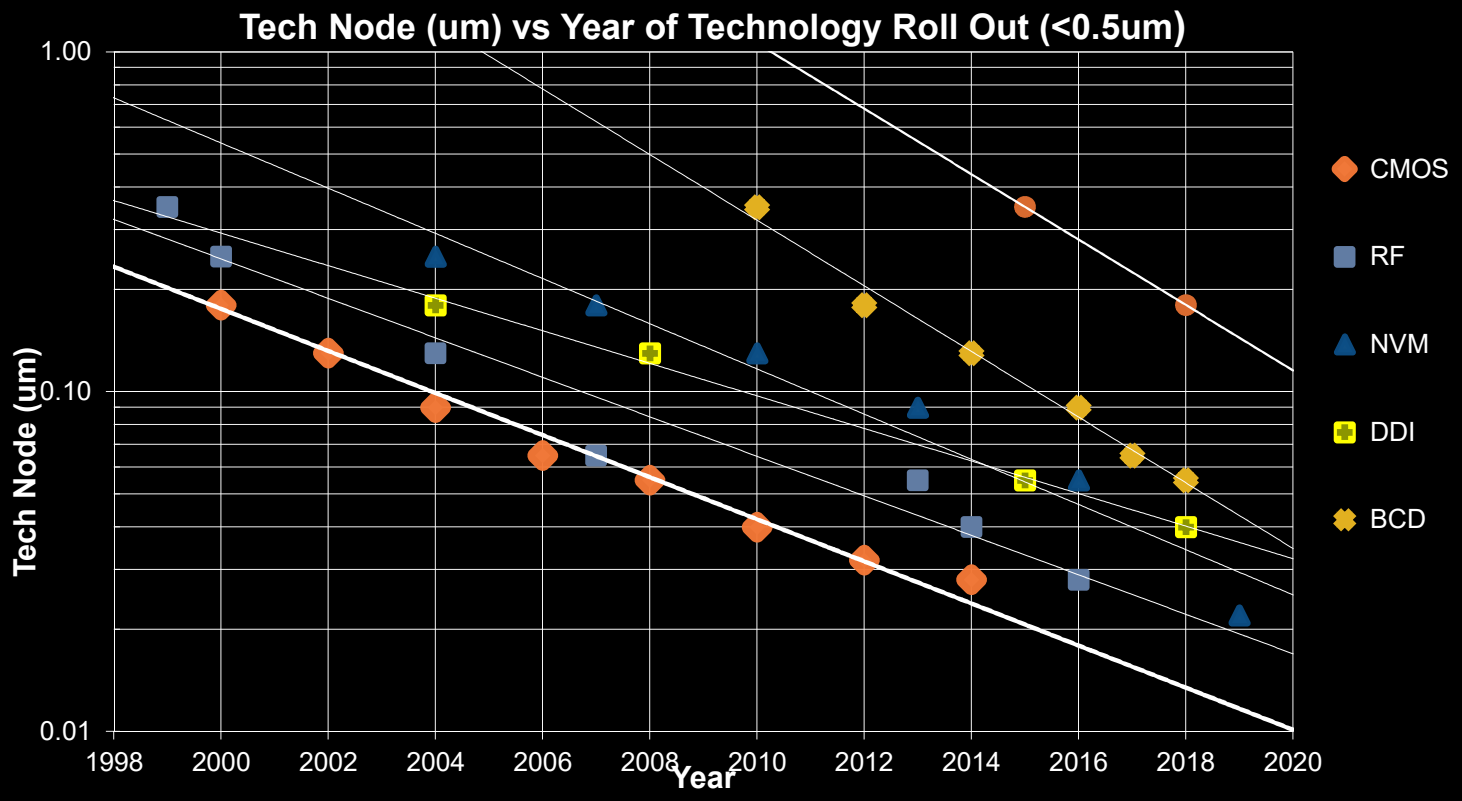
- Silicon Rdson vs BVds
  - Present rate of improvement 40%/generation, or 40% every 3 years
  - 180nm -> 40nm, power device improve at a 1.4X faster rate than the base digital CMOS

Silicon Power Device Performance Benchmarking – a limit ?



- Silicon Rdson vs BVds
  - In voltage range of 20-80V, within a factor of two of the theoretical 1D limit
  - Compound semiconductors (GaN) ideal candidate to maintain device and power scaling
- Other device metrics driving innovation (signal to noise ratio, high temperature characteristics, passives)

Power Semiconductors – More than Moore …



- 2021: Time difference from leading edge CMOS to integrated power falls from 10 years to 6 years !
  - Rate and pace of integration of power electronics is accelerating driven by applications

Power Platform Technologies enabling an efficient future

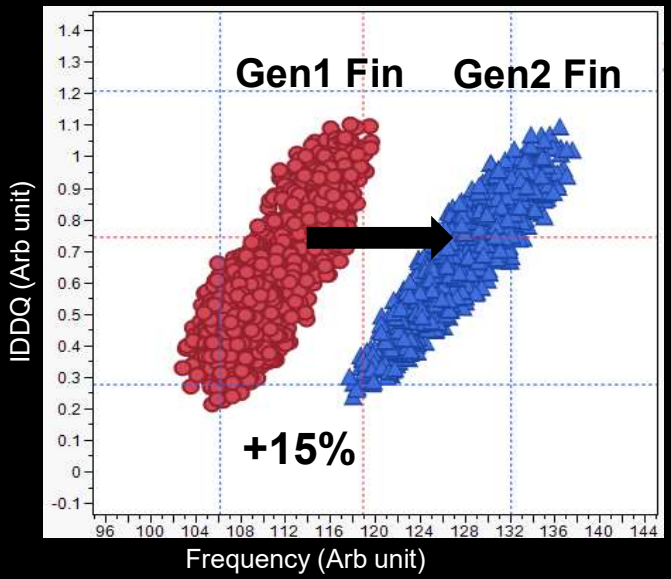
Power Electronics

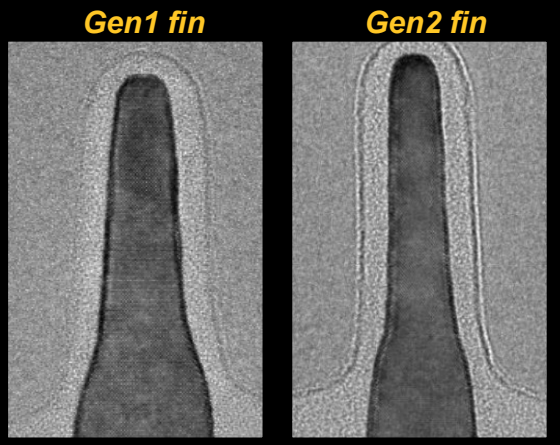
- BCD/BCDLite®
- BCD SOI
- Dense SRAM
- Rsp vs BVds evolution

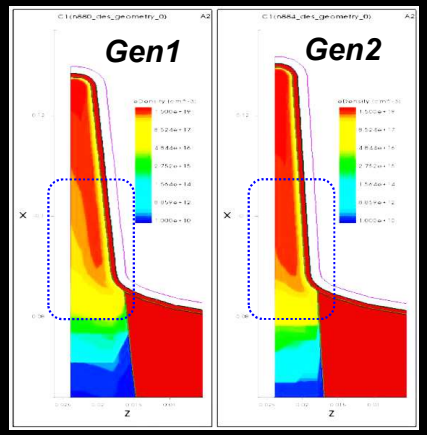
The Industry

- Applications drive platform solutions
  - BMS, AR/VR, DDi, PMICs, eHV drivers, ….
- Power device evolution
  - Rate and pace of power device innovation exceeds CMOS
- So what is next for Si ?

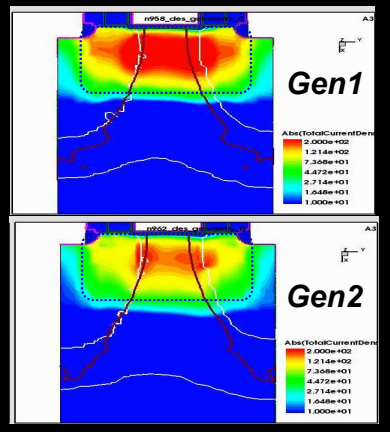
Power meets Leading Edge: FinFET Structure evolution







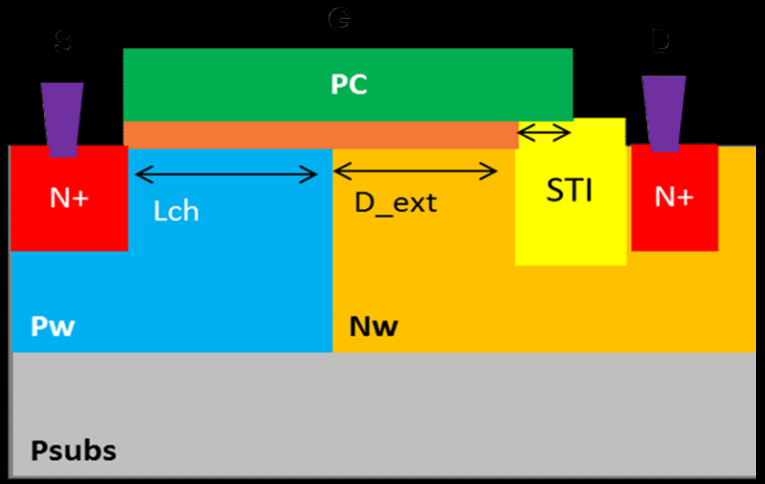
Higher Charge Inversion (Ion↑)

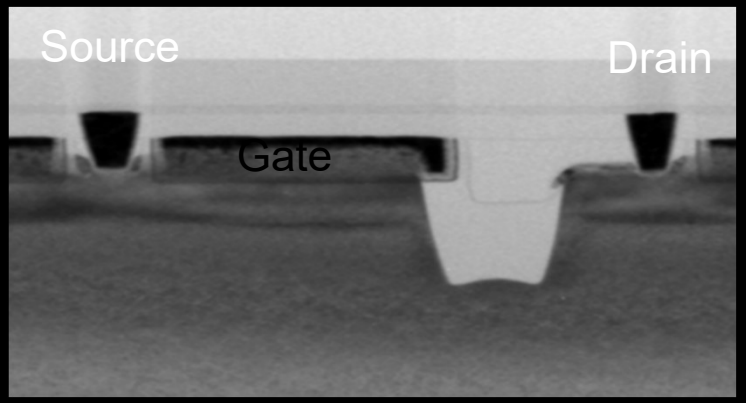


Stronger Gate Control (Ioff↓)

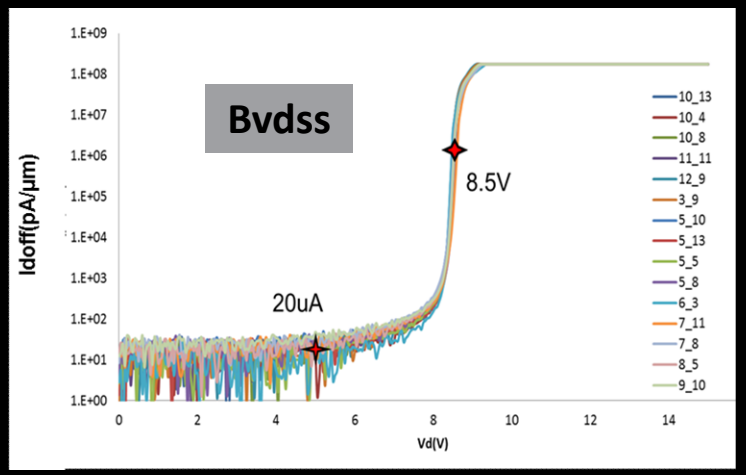
- Fin process evolution
  - Dual Work Function – reduced/removed Halos
  - Taller Fin with more vertical profile
  - Higher Charge Inversion (I_{on} boosting)
  - Stronger Gate Control (I_{off} reduction)
  - Lower GIDL, better matching, …

Power meets Leading Edge: FinFET Structure evolution





- 12nm FinFET integration
  - Planar asymmetric structures
  - Avalanche BVds ~8.5V
  - Fmax*BVds > 1500



Silicon on Insulator: 12V – 200V Applications

Current Growth Areas

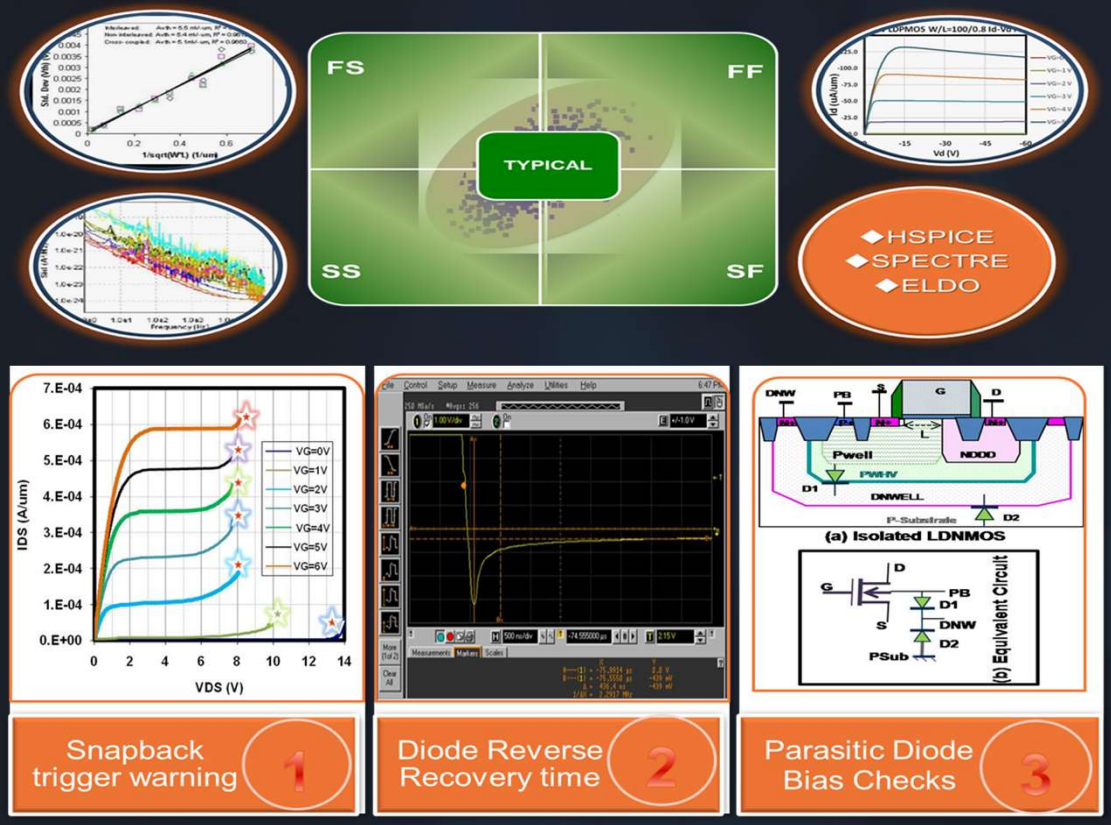
Application Segment		Mature	Ramping	Infancy / Early Ramp
	Automotive	• In vehicle networking • Car stereo amplifier *	• Engine control / monitor • Safety systems	• **EV systems** • **Battery management** • **Lidar**
	Communications	• Power over Ethernet	• Power line communications	• Smart grid
	Display	• Plasma driver (HDTV)**	• AMOLED driver – handhelds • LED signage – harsh environments	• AMOLED driver – large displays
	Lighting	• CFL ballast driver **	• LED ballast driver • Automotive LED driver	• OLED driver • LED ballast driver w/ wireless
	Medical & industrial	• **Pumps / motors** (harsh environment)	• **Medical imaging** • Security imaging	• Wireless bus
	Renewable energy	• Current sensor	• PV string inverter	• **PV micro-inverter** • **Battery management** • **High-temp gate drivers**
	Other high-end analog/PMIC	• Analog processing	• **DC/DC converter**	• Interface IC • Single chip isolation

Expect to <180nm lithography for digital content

- High temperature, signal to noise, analog matching replace standard R_{sp}-BV_{ds} value metric

Focus on Power and Analog Design Enablement – *Analog Rules*

Modeling for BCD/BCDLite



- Emerging Applications require improved enablement
- Advanced Analog Simulation Tools
  - Mismatch, Noise, Self-Heating, substrate injection, reliability …. are accurately modeled and verified with silicon
- Layout best practices
  - Enhance matching
  - Eliminate parasitic devices

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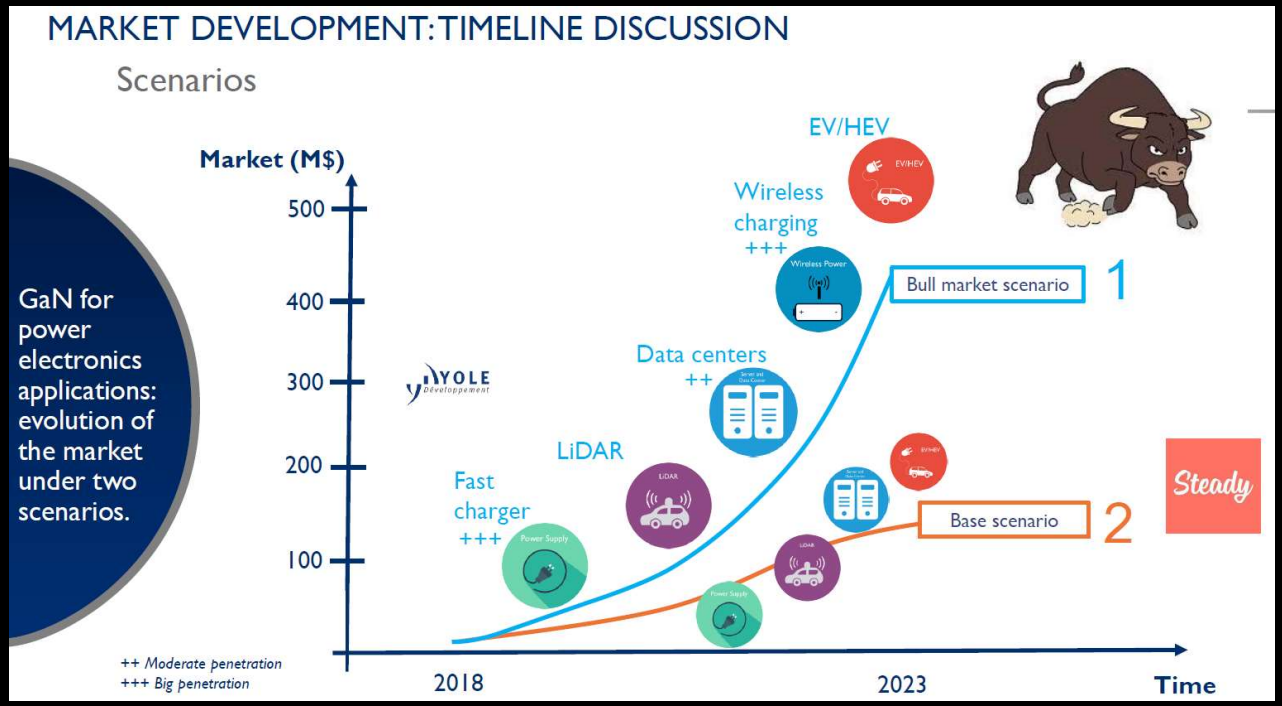
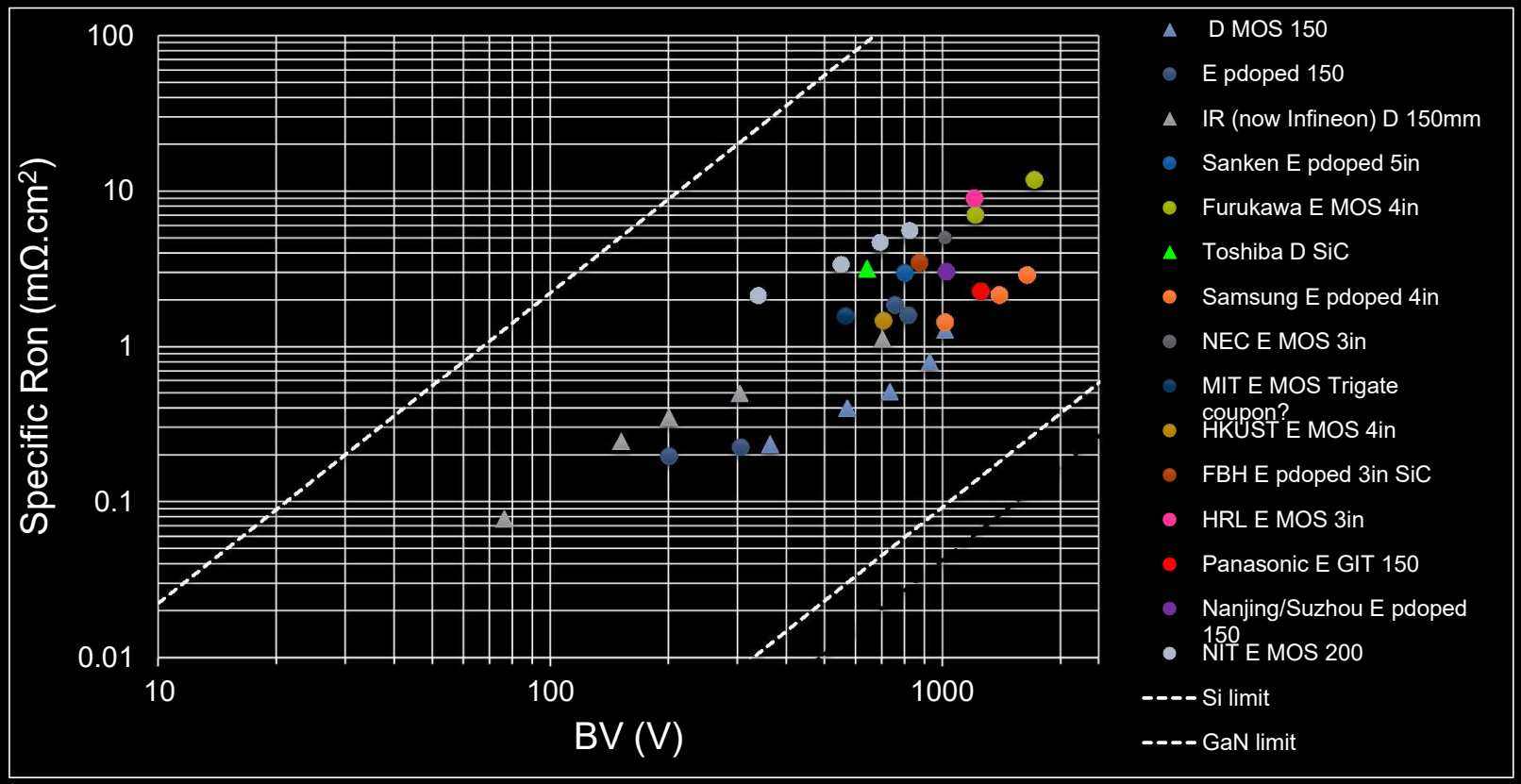
GaN: Market Development Timeline



(*)Yole, Power GaN: epitaxy, devices, applications and technology trends, December 2018

- **Which GaN scenario will occur ?**
  - **Few % of the total power discrete business in 2023**
  - **Most likely technology addressable by 200mm foundry, discrete and integrated solutions**

GaN Power Devices – Foundry Perspective …



- Experimental results from 70-1700V, wide distribution R_{sp} –BV_{ds}, but well below silicon limit
- E/D mode, reliability, TR/MR,….. readiness issues for mainstream Si foundry

GaN Power Devices – Foundry and CMOS …

- Selective heteroepitaxy of 200mm GaN on SOI
- <100> RFSOI CMOS with <111> substrate
- Suitable for both HV and RF applications

- Next step towards integrated RF switch FEM ?
- Will GaN on Si will be ready for mass production within 3 years ?

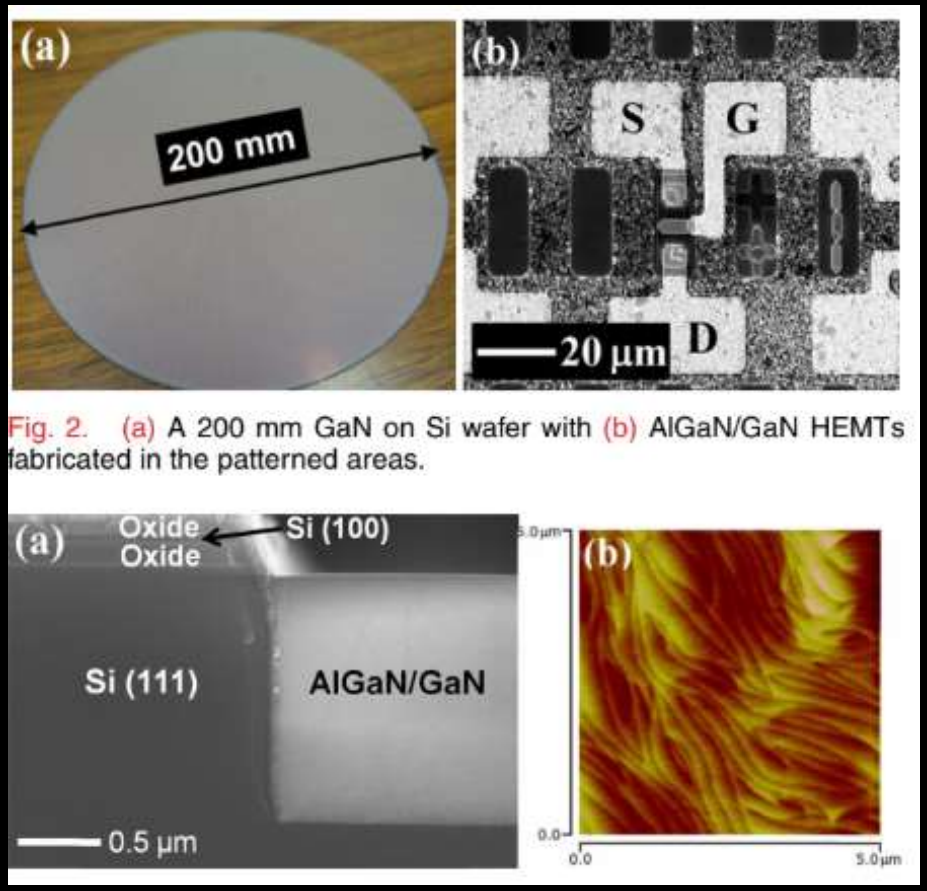
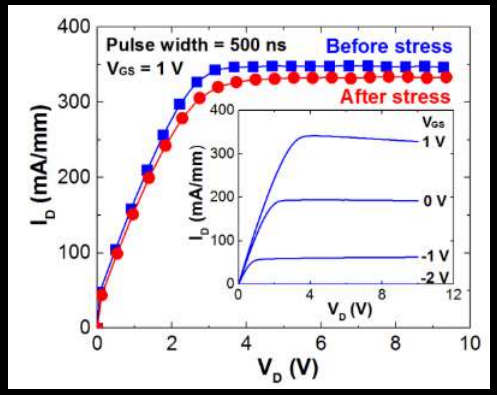


Fig. 2. (a) A 200 mm GaN on Si wafer with (b) AlGaN/GaN HEMTs fabricated in the patterned areas.



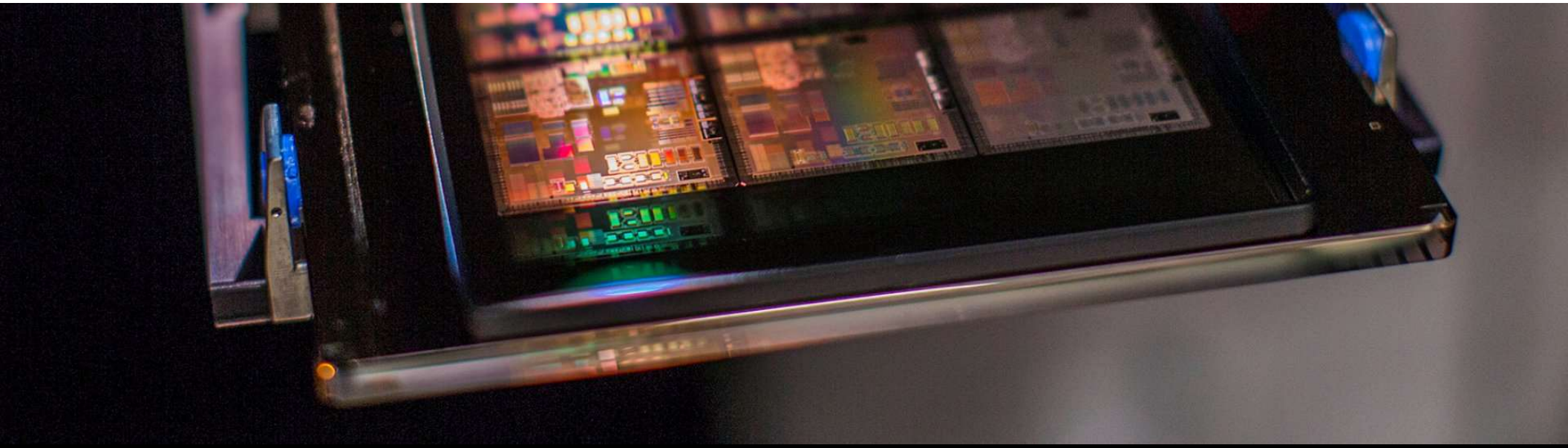
(*Lee et al., IEEE Electron Device Letters, vol 38, No 8 August 2017)

Summary

- Power Management Platforms and Technology
  - Existing and emerging applications drive a platform approach for economy of scale
  - Power foundry market driven by mobile PMICs, displays, battery management (eHV), wireless charging
  - Rate and pace of power developments exceeds that of baseline CMOS, *power all the way to 12nm*
  - Emerging technology solutions – BCD SOI, deeply scaled CMOS, emphasis on modeling

- Foundry link to GaN, compound semiconductors
  - Industry is starting to get *"interesting"*
  - Projections of a few percent penetration of the total power markets by 2022
  - Industry proof points exist, but with many device options and wide performance distributions

- Energy Efficient Future – driven by power electronics – ***and foundry***



Thank you

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