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The growing challenge of testing automotive analog and sensor systems

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SVP and CTO

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Public Information

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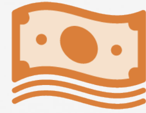
1. **New strategy, aiming for market leadership**
2. **Aligning with high-growth megatrends in Automotive and Industrial**
3. **Differentiated technologies driving disruptive innovation**
4. **Optimized manufacturing capabilities**

Corporate Overview

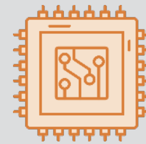
$5.3 billion
revenue in 2020



34,500
employee global workforce

12,101
metric tons of CO2 emissions Reduced through 49 projects in six countries

$755 million
in sustainability product revenue



44% female
global workforce

1.71 billion gallons
recycled water – enough to fill 2,500 Olympic-sized pools

99.6%
Responsible Minerals Assurance Process (RMAP) conformant smelters

27.9%
minority workforce (U.S. only)

76%
of hazardous and non-hazardous waste recycled

Since 2009
membership in the Responsible Business Alliance (RBA)

7
affinity network groups

$1.8 million
community investments

18% female
board of directors

$10.8 million
sustainability project savings

$312,000
in COVID-19 relief efforts

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onsemi – a Market Leader

$5.3B
2020 Revenue

#1
Automotive Front Lighting

#1
Automotive Image Sensors

#2
Power Semi Devices

Highly Diversified Customer Base

Vast Global Sales and Application Engineering Network

Advanced Packaging Technology

Strong Momentum in Electric Vehicles

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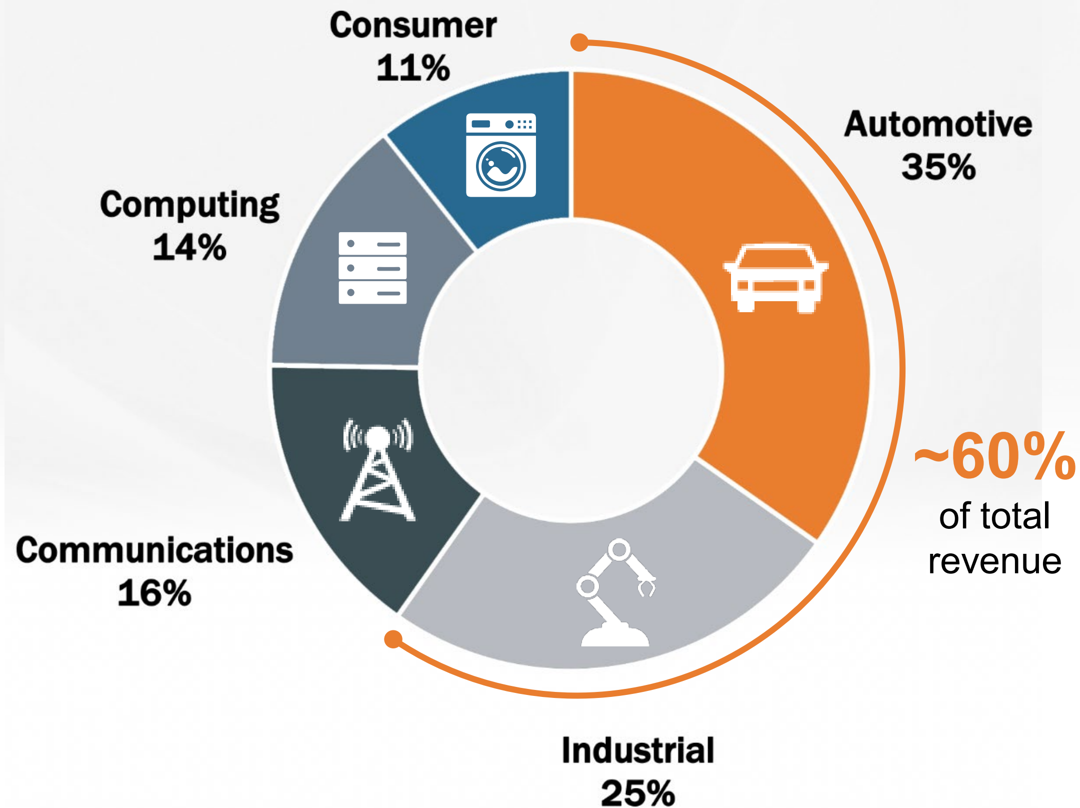
1. New team & market leadership
2. **Aligning with high-growth megatrends in Automotive and Industrial**
3. Differentiated technologies driving disruptive innovation
4. Optimized manufacturing capabilities

Aligning with High-Growth Megatrends in Automotive and Industrial

Q1’21 Revenue by Market



Source: Gartner Report and 2019-2020 Automotive Camera Marketing Analysis; Company internal estimates
Note: Amounts may not total due to rounding of individual amounts.

AUTOMOTIVE

- #1 in image sensors
- #1 in ultrasonic sensor interfaces for automated driving and park-assist
- Emerging leader in LiDAR for ADAS
- Silicon Carbide and IGBT power modules for EV/HEV
- Power management for automotive CPUs, LED lighting and body electronics

INDUSTRIAL

- MV and HV MOSFETs, Silicon Carbide and IGBT power modules for improving energy efficiency of industrial systems
- Image sensors for machine vision, robotics, and automation applications
- Silicon Carbide and IGBT power modules for charging infrastructure and alternative energy applications

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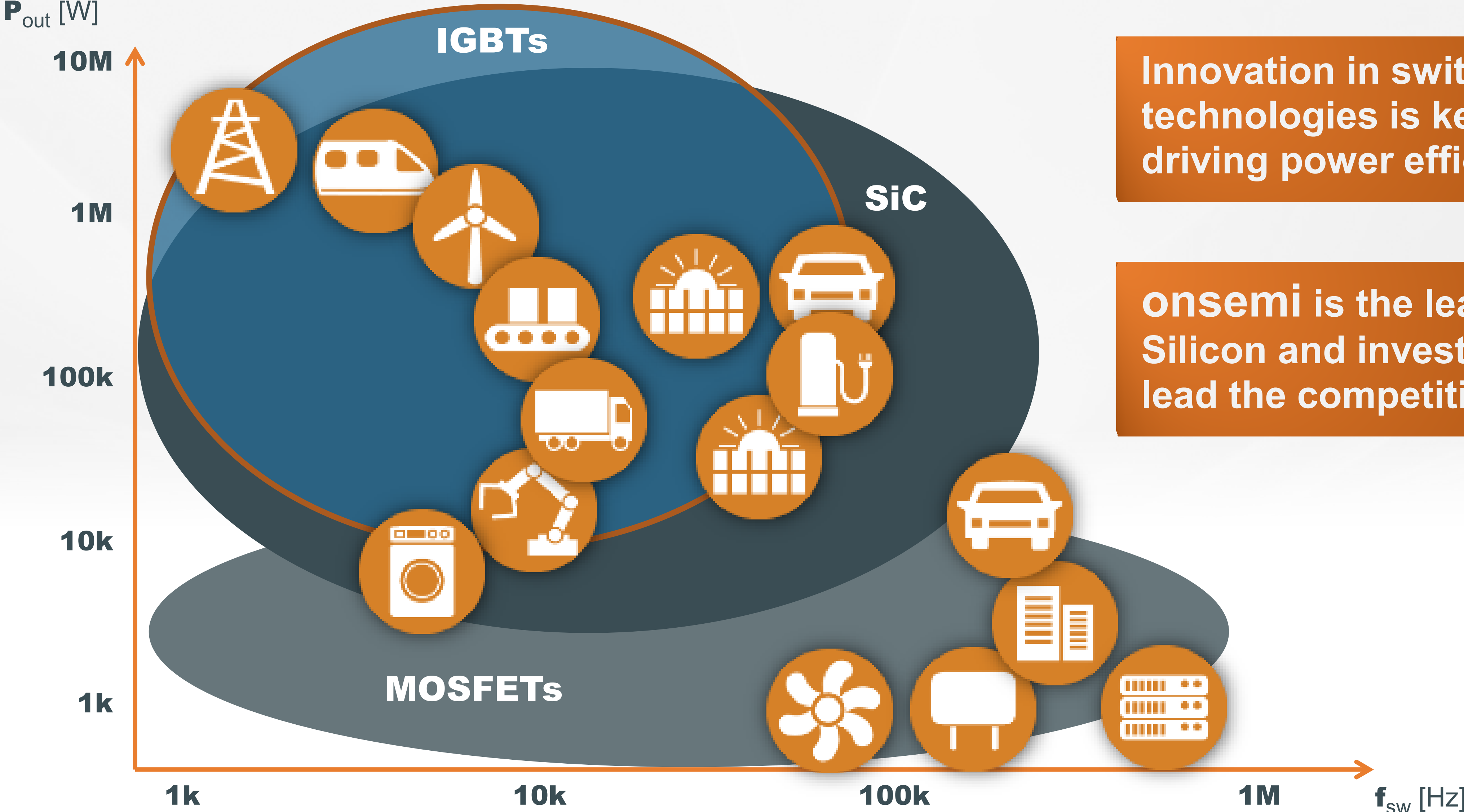
Breadth of Technology is the Foundation to Win



Innovation in switching technologies is key to driving power efficiency

onsemi is the leader in Silicon and investing to lead the competition in SiC

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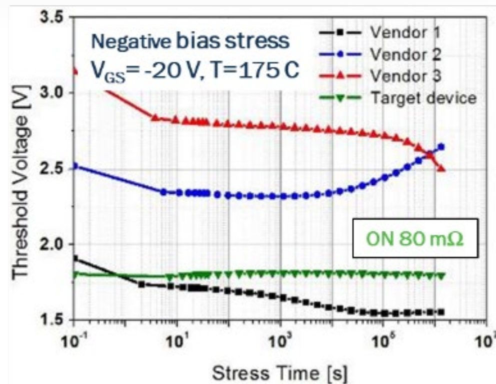
The Silicon Carbide (SiC) Advantage

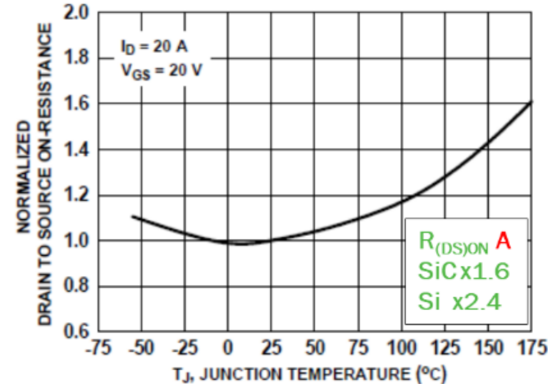
Features	ON Advantage	Benefits
• No reverse Qrr recovery , No forward recovery • Low Vf (lower conduction losses) • Leakage current stability at varying temperature • Higher surge and avalanche capacity • Positive temperature coefficient • Higher operating temperature (Tj=175Deg C)	• First and only 6 inch wafer • Better termination structure • ~15% Lower Vf • ~20% higher avalanche energy • Higher UIS capability • Robust and reliable • Paralleling friendly	• Higher power density and lower systems costs • Higher system efficiency & lower losses • Improved system reliability and low failures • Reduced losses and cooling requirement • Reduced EMI due to high frequency operation

Outstanding SiC Figures-of-Merit

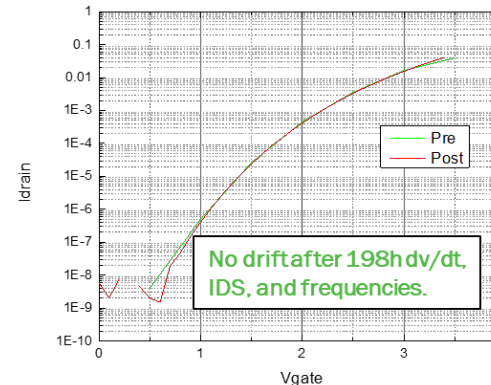
Stable and reliable Vth and $R_{(DS)ON}$ vs Gate bias



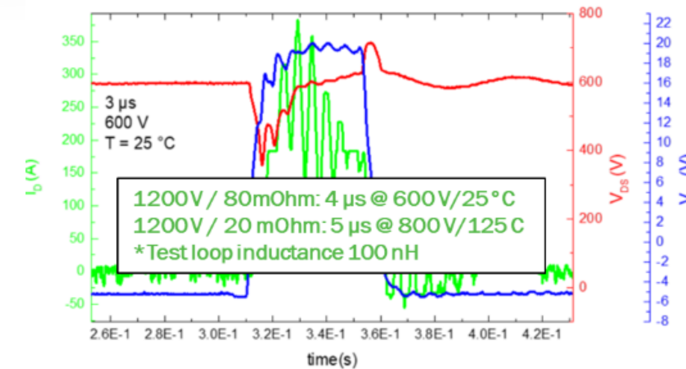
Excellent $R_{(DS)ON}$ stability with T_J



Superior body diode ruggdness



Shortcircuit withstand times



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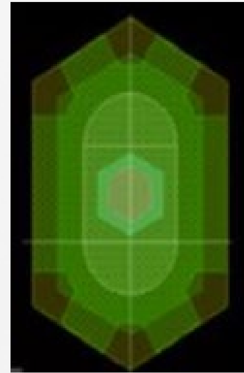
SiC – onsemi's Differentiation



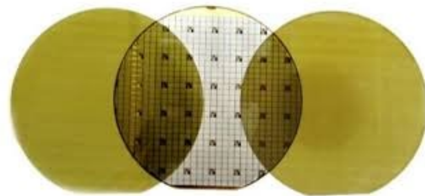
Switching (Generate Less heat)

Best-in-class performance

- **Cell density (photo-lithography)**
- **High energy implanters (lower Rsp)**
- **Gate oxide integrity / Transconductance**
- **Application Specific Optimization (FIT)**

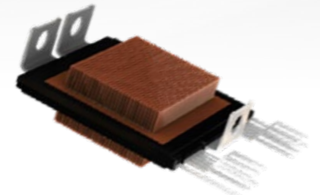
Cost Leadership through Quality

- Substrate (~20% of cost)
- SiC Yield Loss (~20% of Cost)
- Burn-In (5%)



Lowest Cost

Packaging (Eff & Heat dissipation)



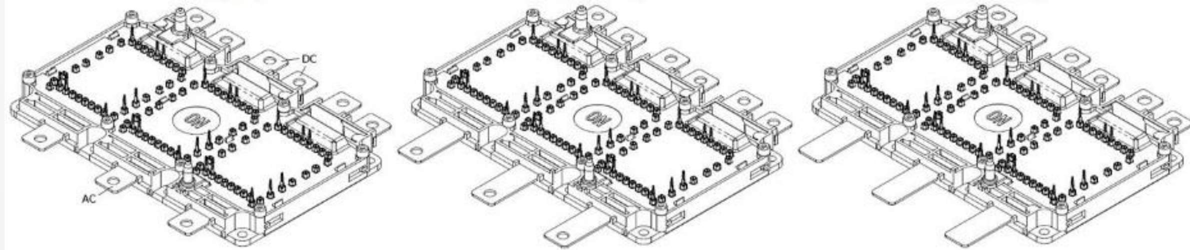
Differentiation Strategy

- **Transfer mold packaging vs. Gel Filled (5x PC & 2x TC)**
  Very low inductance (5μH)
- Dual-side Direct Cooling
- System-packaging/Cooling (embedded)

VE-TracTM Direct Value Proposition

Pin & functional compatibility

Drop-in replacement with minimal design adaption

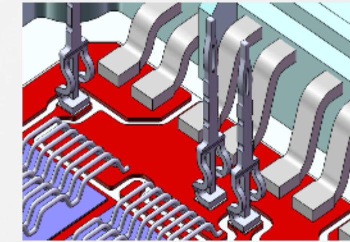


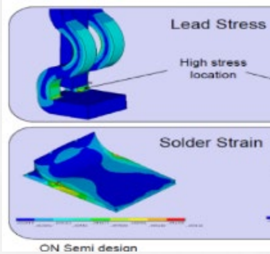
Robust Press-fit design

Innovative press fit design for accurate pin-positioning & robust contact lifetime

Competitor design

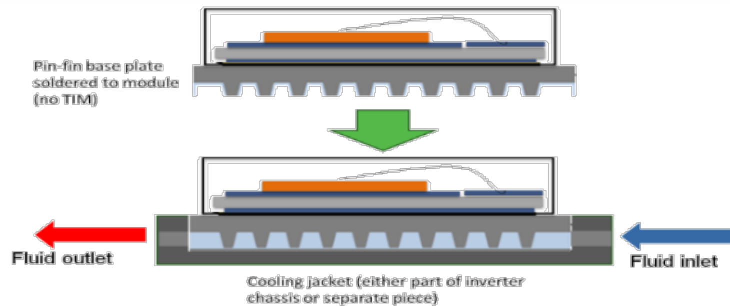
ON's design





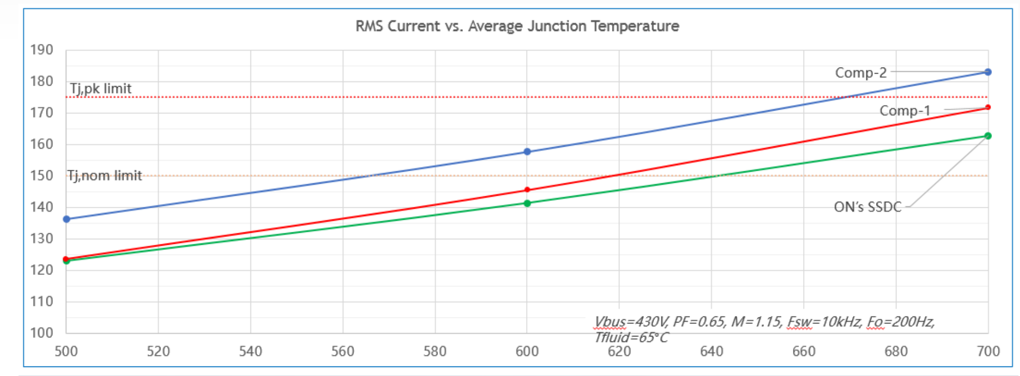
Advanced direct cooling

New Pin-Fin Structure improves Rth.j-f



Excellent Performance

Beats the best performing competitor module



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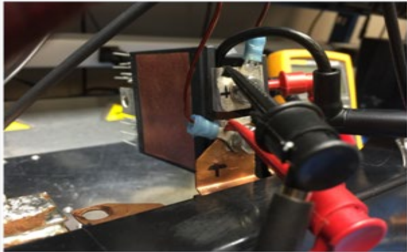
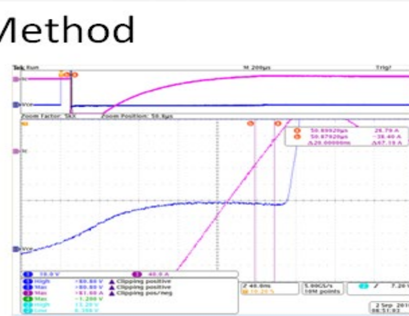
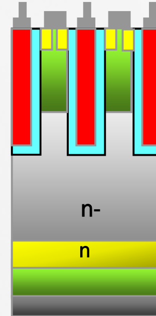
VE-TracTM Dual Value Proposition

Excellent thermal & electrical

Best in class silicon in ultra low inductance package <7nH

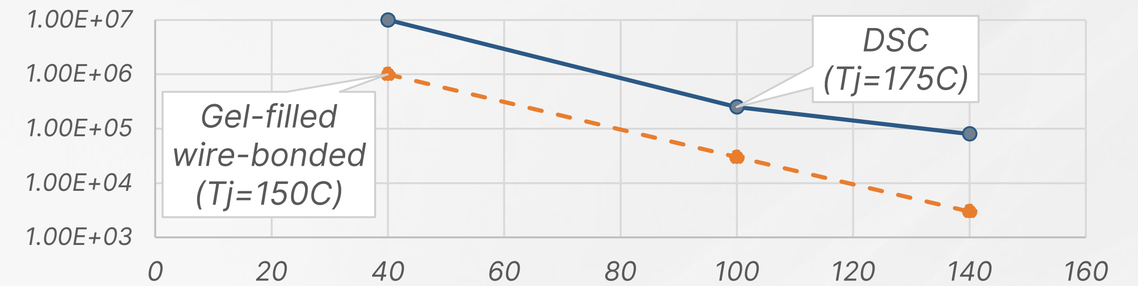






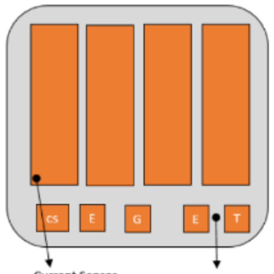
High Lifetime – wire bond free

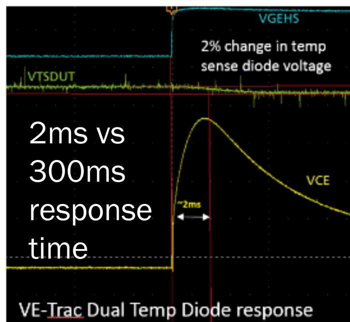
3x power cycling lifetime @ 175°C continuous operations

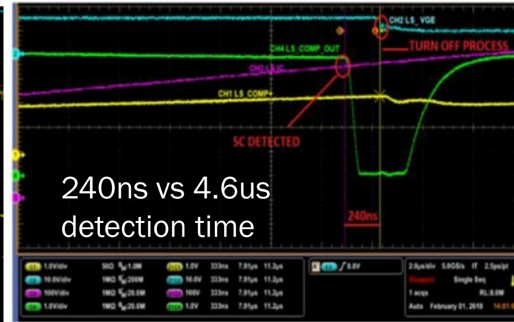


Smart IGBT /w on-Chip Sensors

Integrated sensors on-Chip for fast & accurate diagnostics

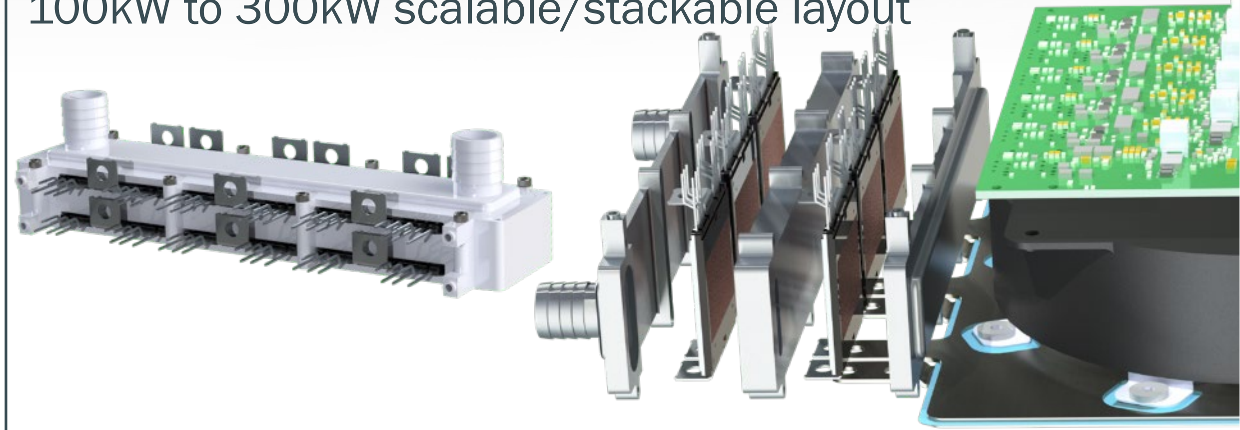






Scalability

100kW to 300kW scalable/stackable layout



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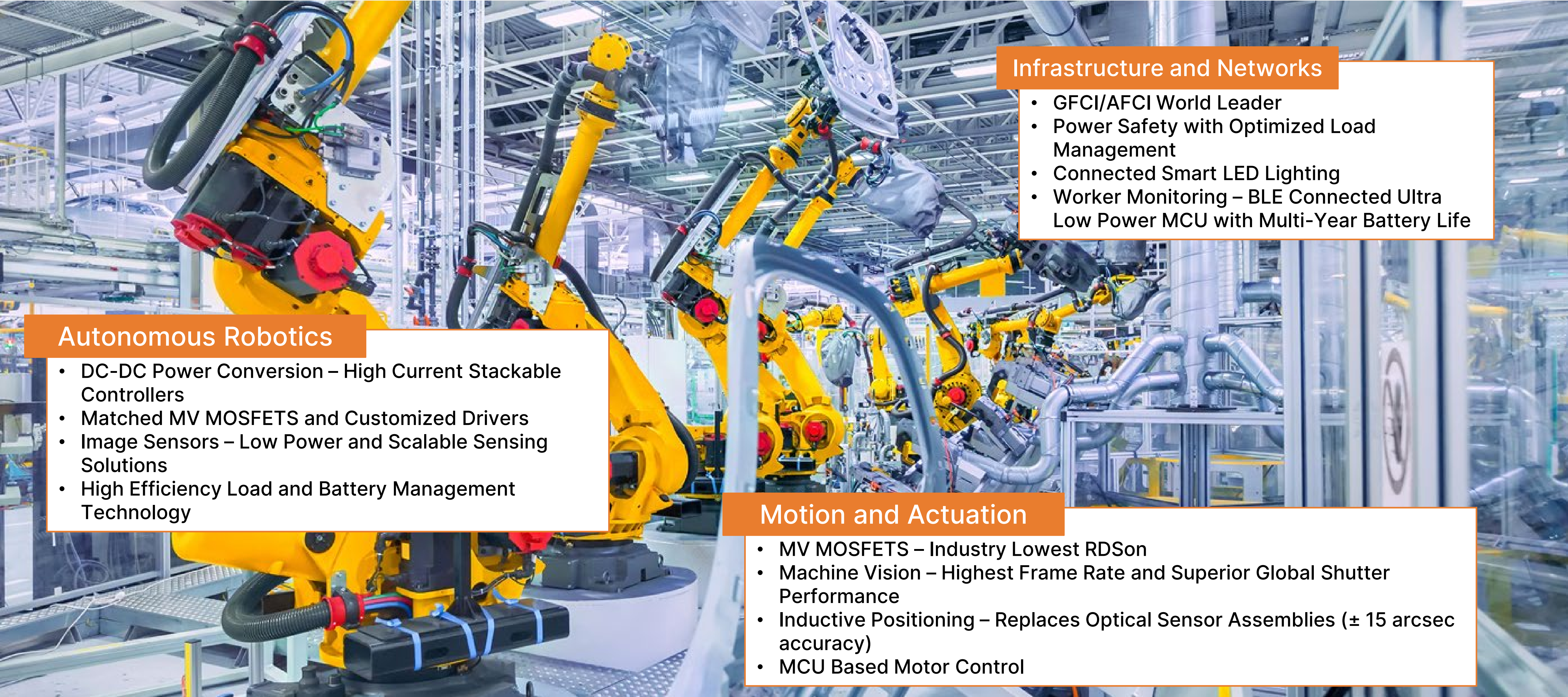
Providing Complete Solutions for Industry 4.0



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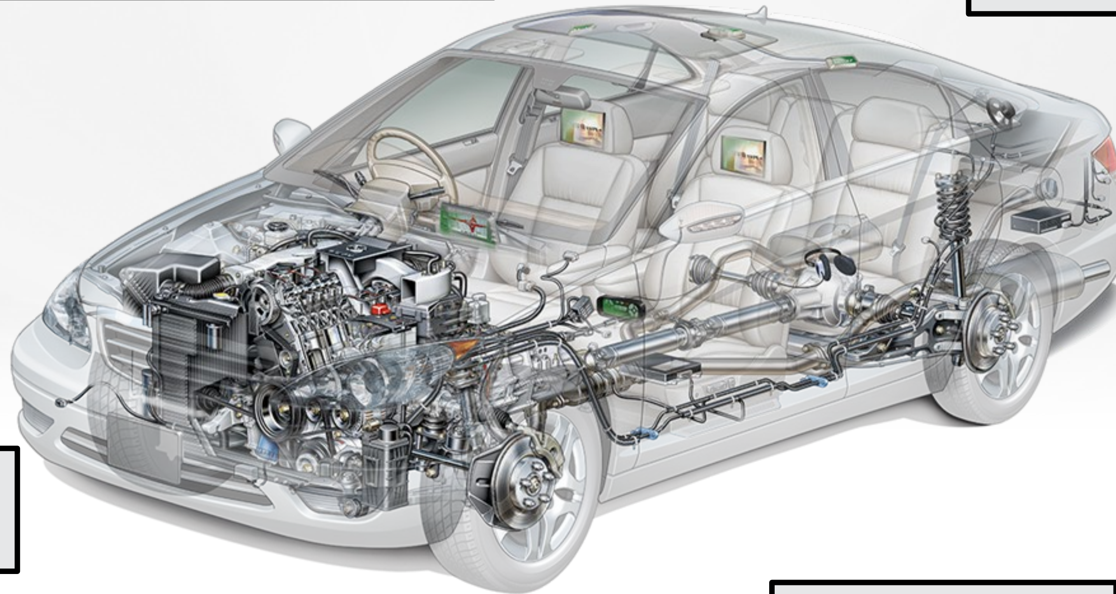
ADAS DCDC Sensor Power Solutions - Focus Applications

NCV890430 – High-voltage Buck Converter
NCV6323F – Low-voltage Buck Converter
NCV896530 – Dual Low-voltage Buck Converter
NCV92310 – ASIL-B/C PMIC
NCV91235 – ASIL-B/C PMIC 3x2A Buck Converter, 2x0.3A LN LDO
NCV91621 – ASIL-B/C Dual Phase 12A Buck Converter
NCV92330 – Polaris PMIC
NCV899630 – ASIL-B High-voltage Buck/Boost Converter

Sensing/View Camera/ICMS

NCV88/891930 – High-voltage Buck Converter
NCV91235 – ASIL-B/C PMIC 3x2A Buck Converter, 2x0.3A LN LDO
NCV91621 – ASIL-B/C Dual Phase 12A Buck Converter
NCV899630 – ASIL-B High-voltage Buck/Boost Converter

Fusion/SoC



NCV97200/400/401 - Power Management Units
NCV881930/891930 – High-voltage Buck Controllers
NCV6356/7 – 3-5A Buck Converters
NCV91300 – 3A Buck Converter
NCV974xx – ASIL-C Radar PMIC

Long Range Radar

Short/Mid Range Radar

NCV97200/400/401 - Power Management Units
NCV88/891930 – High-voltage Buck Controllers
NCV6356/7 – 3-5A Buck Converters
NCV91300 – 3A Buck Converter
NCV974xx – ASIL-C Radar PMIC

Production
Development - Samples Available
Development
Roadmap

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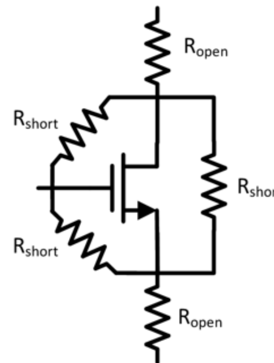
Analog Fault Coverage is Unknown

Analog faults can have an infinite amount of different values

- ✓ *R&D opportunity to make* **theoretical analog models** *for real physical defects based on equivalent resistances, capacitances, inductances*

- concept: **model** defects by faults and **simulate** their effects on the circuit
- 5-fault model MOSFET :

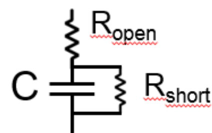


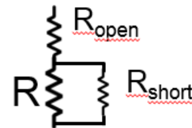
with R_{open} = 1 GΩ

R_{short} = 100 Ω

[Mil89, Kru11]

- model cap/res :





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Analog fault coverage can be made good

This work

100,0%
90,0%
80,0%
70,0%
60,0%
50,0%
40,0%
30,0%
20,0%

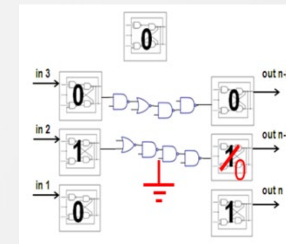
Fault Coverage

0,005
0,05
0,5
5

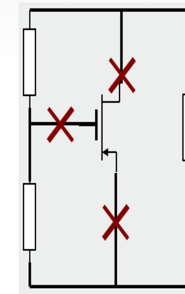
Silicon Area (mm²)

▲ Analog
◇ Digital
■ Dobbelaere, ITC 2015
◆ Esen, patent pending 2016
● Coyette, VTS2015
▲ Coyette, ETS 2014

Digital



Analog



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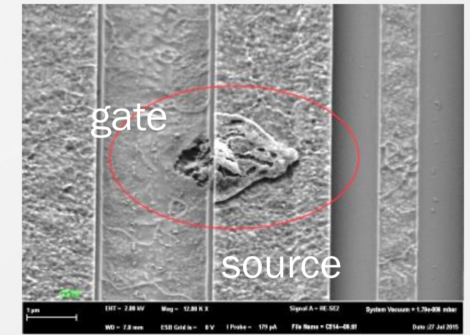
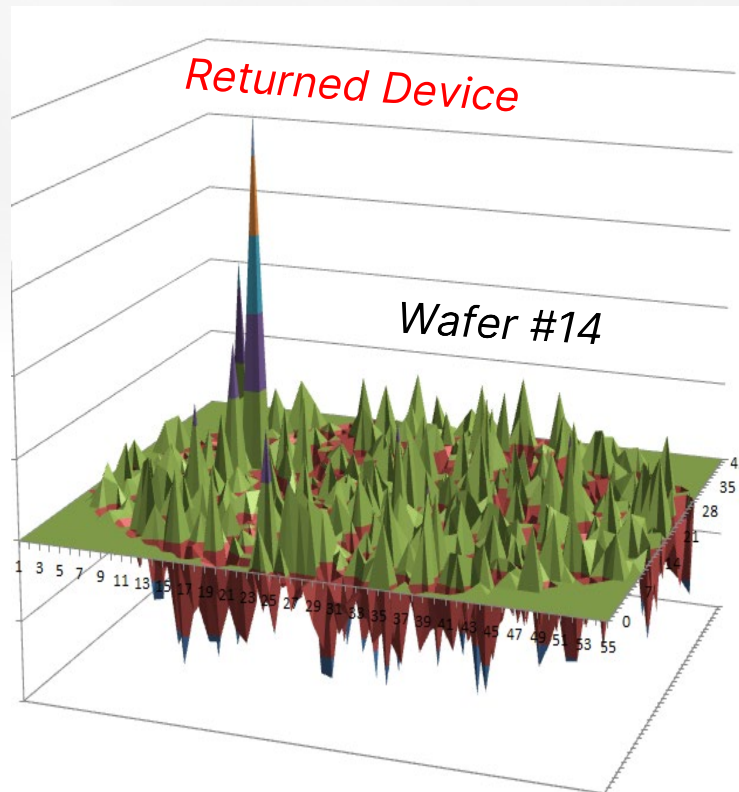
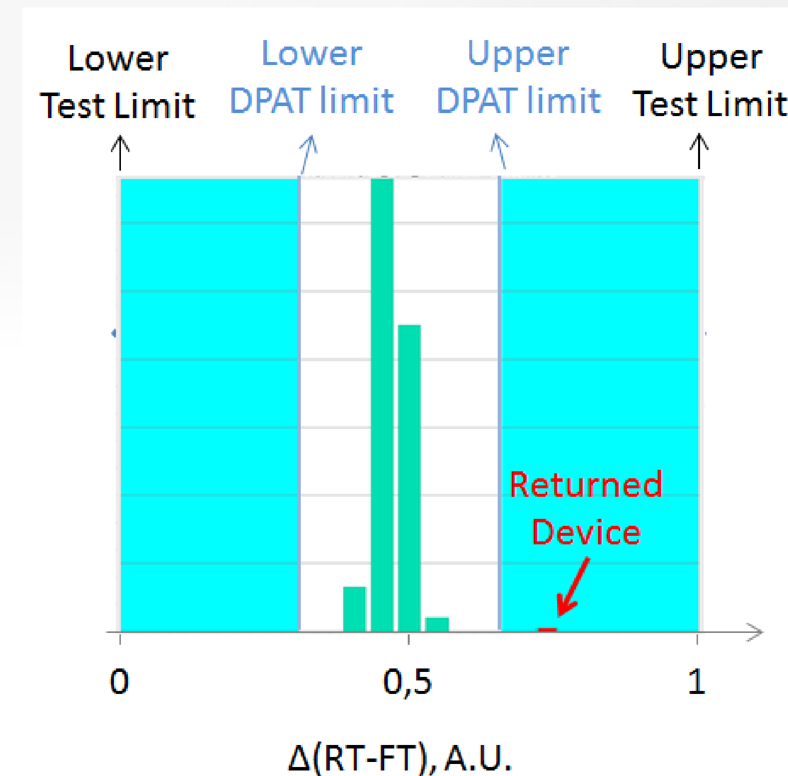
Dynamic Part Average Testing (DPAT) exposes hidden defects

- For every individual wafer and for every individual test parameter 6 sigma limits are calculated
- Limits are applied after testing to remove outliers
- **Outliers** are typically caused by defects
- DPAT is always possible at probe
- DPAT recently is also done at Final Test by programming the x-y location, wafer-number and lot-number in the chip at wafer level (also known as “Die Level Traceability”)







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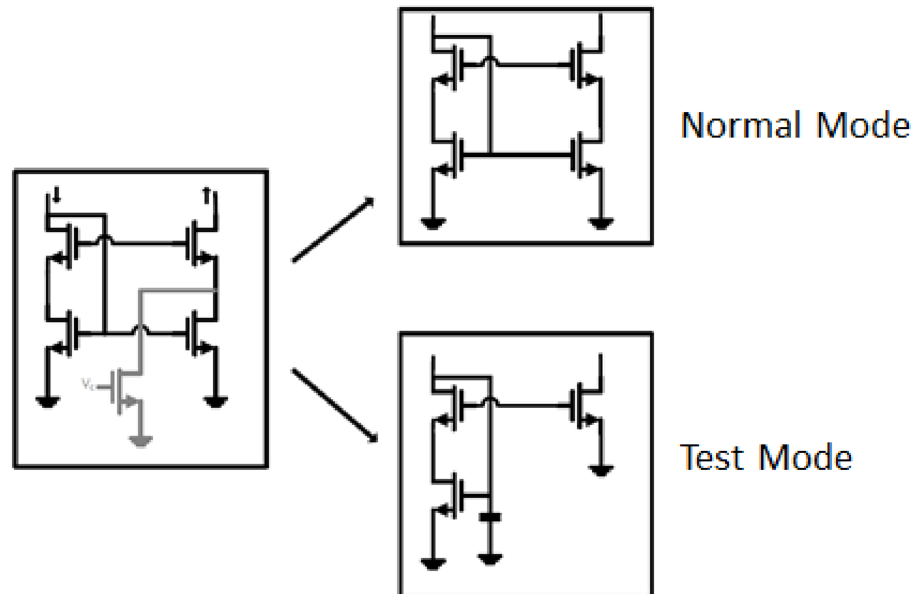
Design for Test

- *There are no standard methods to implement "design for test" features in analog circuits.*
    - ✓ *R&D opportunity to* **develop new "design for test" features** *that would allow to test analog circuits in a structured approach*



Biggest remaining issue for Analog ?

Structural approach towards Design for Test is missing

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Potential Solution ?

IEEE 1687.2 standard for describing
Analog Test Access and Control

>20 Semiconductor and EDA and ATE companies
Release expected in 2022

The Instrument Connectively Language (ICL) describes all connections and test features (=HARDWARE)
The Procedural Description Language (PDL) describes all TESTS (=SOFTWARE)

The IEEE1687.2 standard advances the "state-of-the-art" by enabling IP reuse in an unprecedented way:
Tests are written at IP level, then mapped through the "access network" to the SOC
This will be done automatically by new EDA software
Development lead times should go down by a factor of 2+

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Providing “Best Performance” in ADAS

ASIL Multi-Phase Power

- *ASIL controllers for all major Processor platforms*
- *ASIL multi-rail PMIC’s that are scalable*

ADAS Solutions

- *World Leader in Low light and HDR Image Sensing*
- *World leader in Ultrasonic Sensor Interfaces*
- *ASILx Camera, Radar, and Lidar PMICs*

In Vehicle Networking

- *Broad portfolio*
- *Highest EMC/EMI/ESD immunity*
- *ISO 26262 Compliant*

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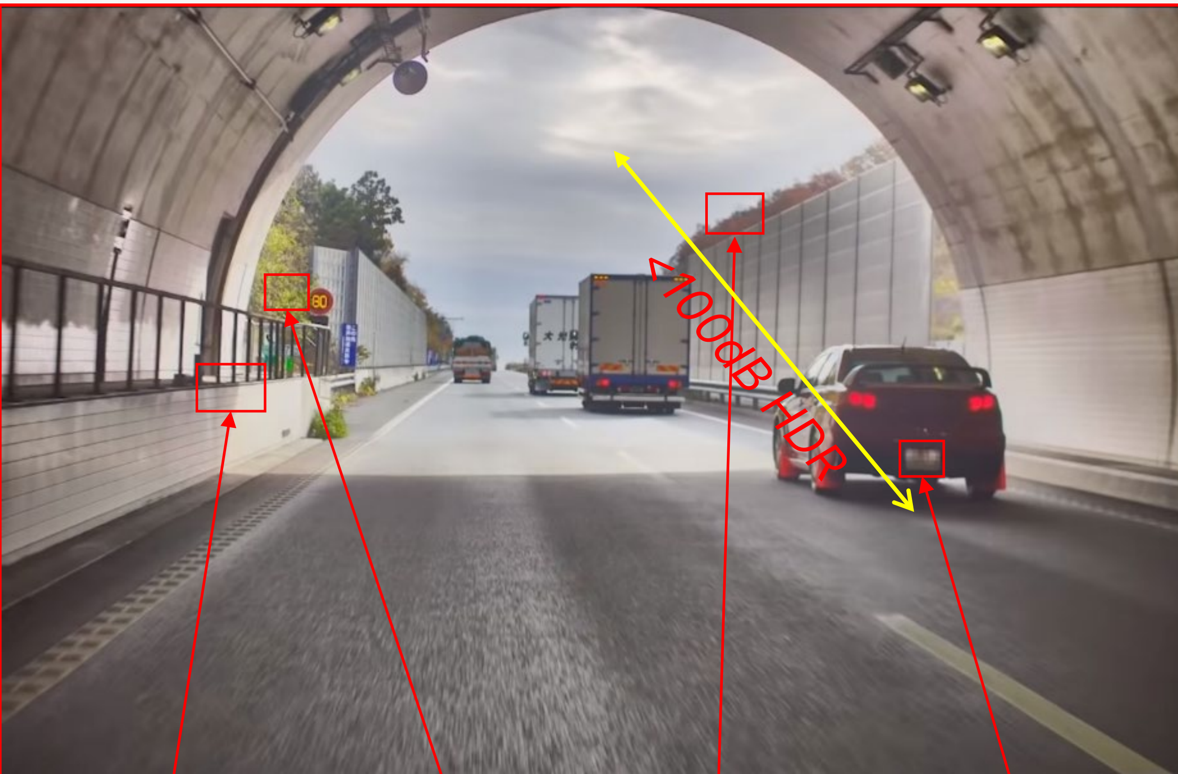
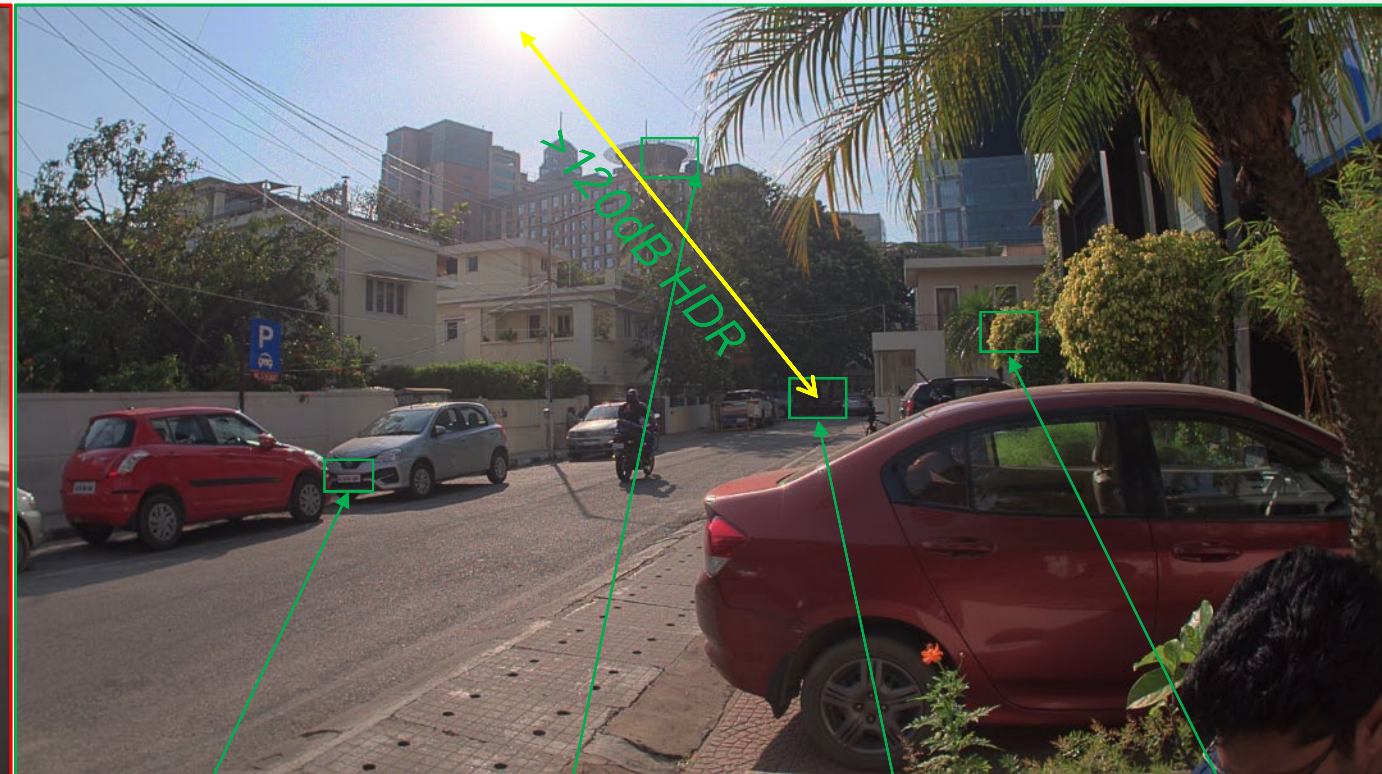
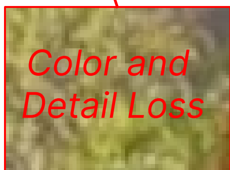
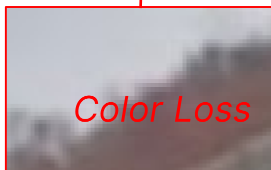
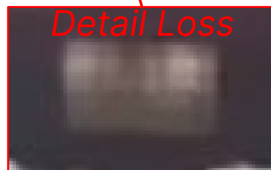
onsemi HDR Technology vs. the Competition

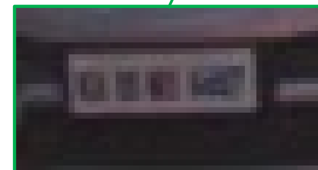


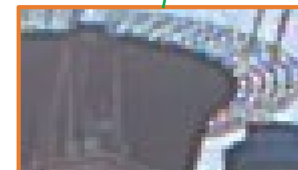


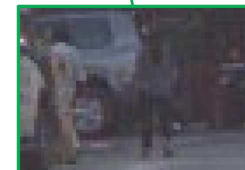


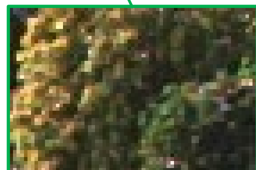












Onsemi pixel design showed significantly better dynamic range, image sharpness, and color fidelity

IMX490 may be not suitable for both ADAS and visual applications due to strong "animation"-like image effects

Long Distance Multiple Object Detection

onsemi's 8MP Automotive Sensor at 185 Meters

100x Human Eye Under All Conditions

Global Shutter Enhances Machine Vision

Leading shutter efficiency in the smallest package

120fps for Machine Vision applications

High Quantum Efficiency (QE) at Near Infra-Red (NIR) light
- → Reduces active illumination power
- → Increases range for depth applications

Only Global Shutter can Detect Eyes Blinking in Automotive Safety Systems

QE: Quantum efficiency. A measure of ability to convert photons to electrons
NIR: Near Infra-Red. Scanning, Driver monitoring, Wavelength below what the human eye can detect

Image Sensor Test Challenges – Increasing Requirements

- Image sensor applications drive significant differences in
  - Resolution
  - Frame Rate
  - Application
  - Light Quality
  - Thermal requirements
- One size (or options) does not "fit all"
- Testing capability requirements must grow to cover the breadth of requirements
  - Resolution drives image complexity and capture size
  - Frame rate drives interface speed higher
  - Application drives unique complexity in product test data management
  - Small differences in light quality can result in differe test results
  - Thermal requirements drive complexity in manufact

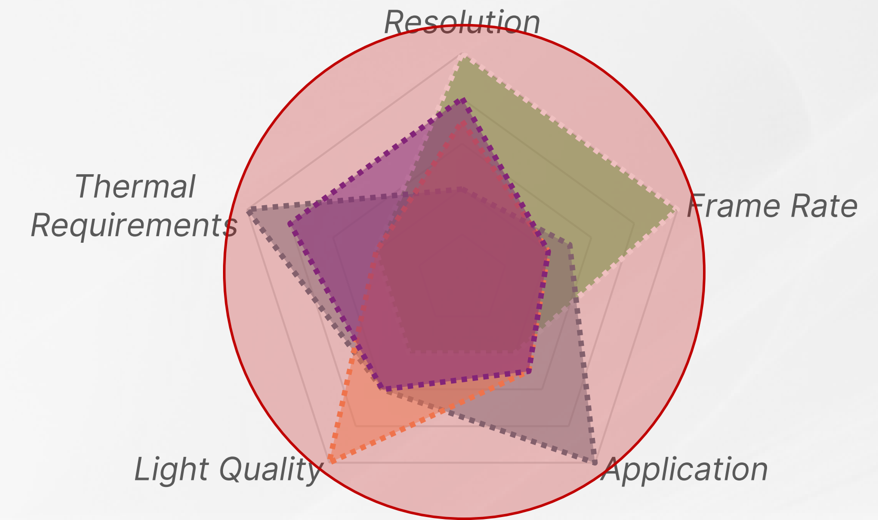


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Image Sensor Test Challenges – Resolution/Frame Rate

- Resolution
  - Increasing pixel counts drive complexity in captured images, as well as size of data that must be captured and managed
- Frame Rate
  - Signal Integrity
    - Interface speeds growing (D-PHY, C-PHY, A-PHY), as more and faster data is moved off of die
  - Power integrity
    - With higher speeds and more complex mixed signal processing, keeping power delivery 'clean' is critical
  - Both become more challenging as 'windows' for light are added for Imager test interfaces

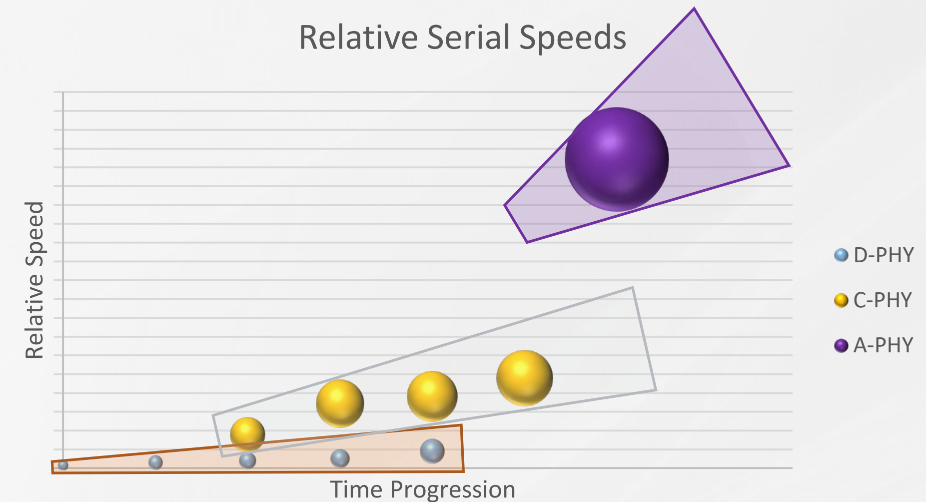
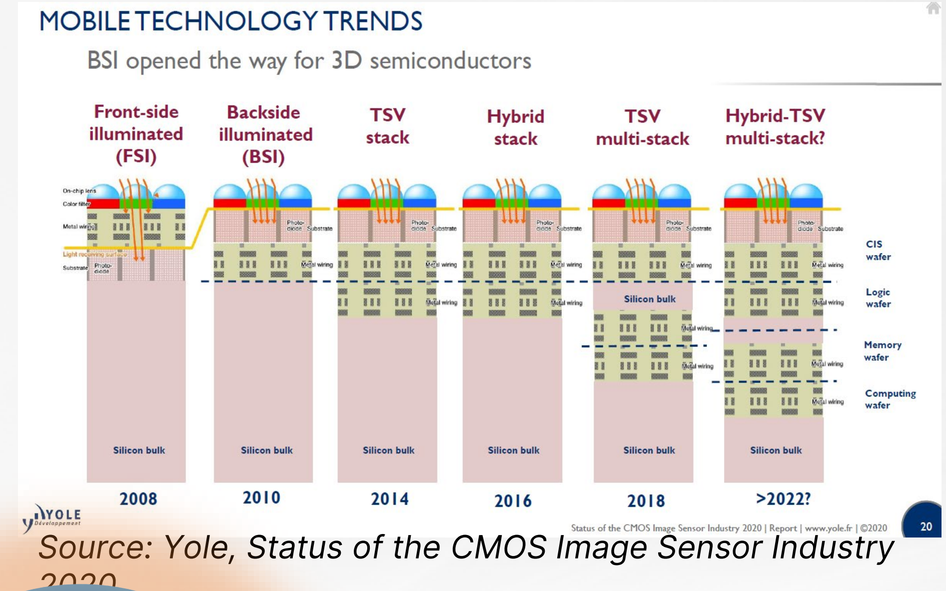


Image Sensor Test Challenges – Application/Light Quality

- Application Complexity
  - Added complexity in product features drives complexity in product test and data management
  - Stacked functions, ADAS, Cybersecurity….
- Light Quality
  - Wavelength, intensity, and uniformity are key across the entire area that tested devices are present



Source: Yole, Status of the CMOS Image Sensor Industry 2020

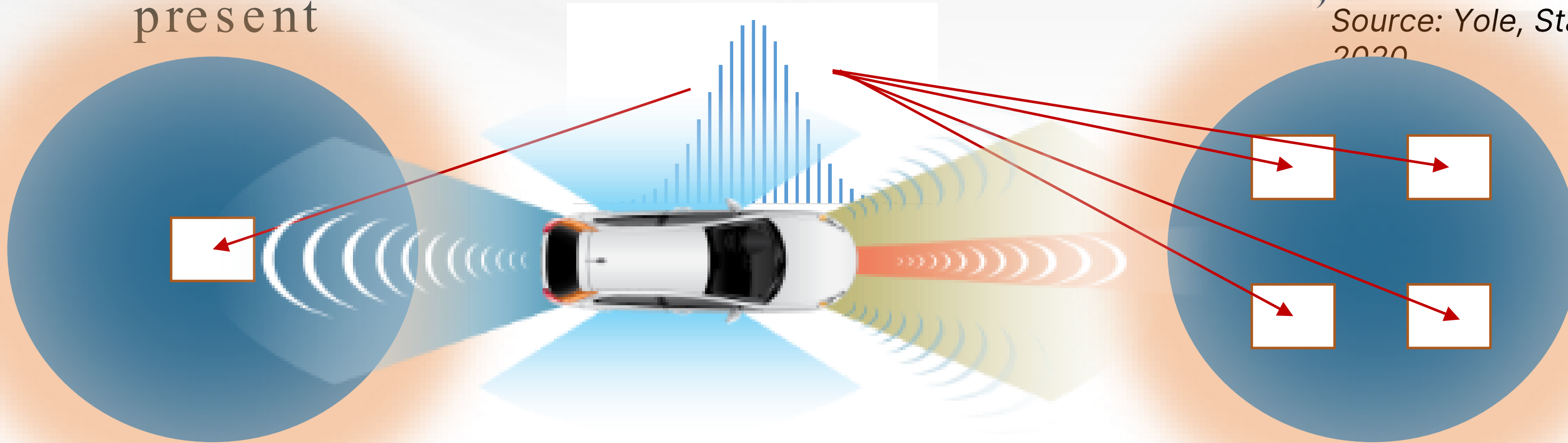


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Image Sensor Test Challenges – Thermal Requirements

- Testing through thermal ranges
  - Sensors must operate through a high range of temperatures
    - Backup cameras
    - Lane Departure
    - Collision avoidance
  - Extremes in temperature require test interfaces to be capable
    - CTE mismatches, multiple interface contacts

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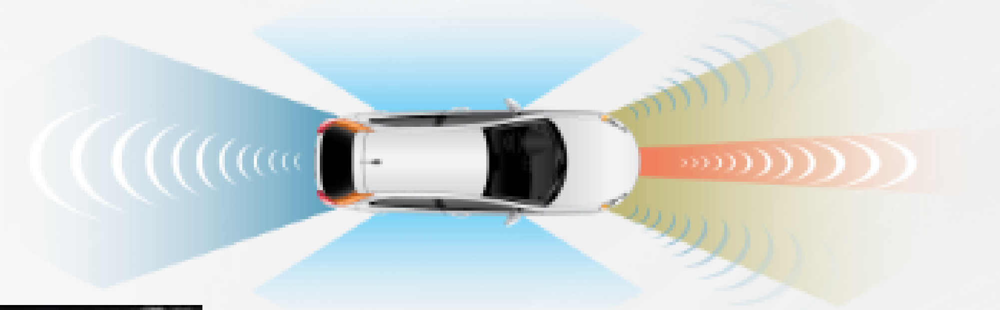
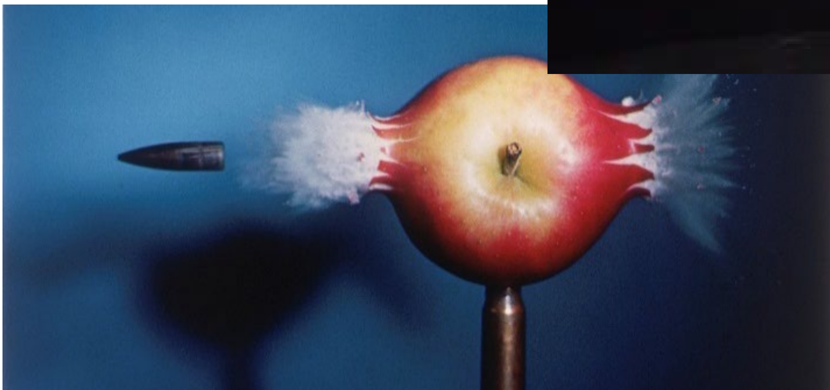
Summary of Image Sensor Test Challenges

- As Image sensor complexity and diversity continue to grow, our testing approaches must grow faster to meet our customers needs
  - Electrical test is 'easy'
  - Electrical + Optical is harder





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1. New team & market leadership
2. Aligning with high-growth megatrends in Automotive and Industrial
3. Differentiated technologies driving disruptive innovation
4. Optimized manufacturing capabilities

Manufacturing Capabilities

Scale provides industry leading cost structure – 64.3 billion units shipped in 2020

- Ability to add capacity and source from multiple sites, including production ramp of 300mm fab
- Front-end internal capacity to manufacture 150mm and 200mm silicon substrates
- One of world's largest and most efficient back-end operations

Quality and delivery

- Better control as key differentiators in automotive and industrial markets

Technology and product development

- Accelerates time to market for new technologies and fine tune processes to maximize performance

Front-end & Substrate Facilities

Aizu, Japan

Gresham, OR, USA

Czech Republic Fab

Czech Republic Substrates

Bucheon, Korea

Portland, ME, USA

Oudernaarde, Belgium[1]

Seremban, Malaysia

Pocatello, ID, USA

Mountain Top, PA, USA

Niigata, Japan[2]

East Fishkill, NY[3]

Back-end Facilities

Leshan, China

Suzhou, China

Shenzhen, China

Carmona, Philippines

Tarlac, Philippines

Cebu, Philippines

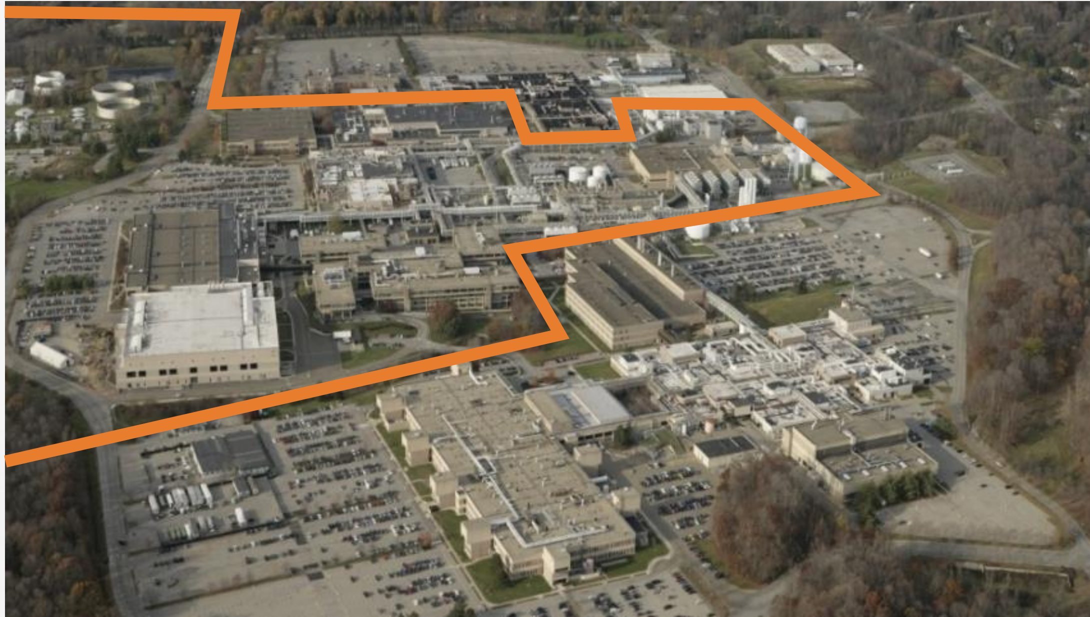
Seremban, Malaysia

Vietnam OSBD

Vietnam OPP/IPM

[1] In February 2020, onsemi announced it is exploring the sale of the six-inch fab in Belgium
[2] In August 2020, onsemi announced the plan to explore the sale of the six-inch fab in Niigata, Japan
[3] In April 2019, onsemi entered into an Asset Purchase Agreement to acquire East Fishkill from GlobalFoundries on Dec 31, 2022 for $400mm (onsemi paid $70mm in 2019 as deposit and remaining payment is $330mm).

300mm Fab Addition will Add Significant Capacity



Summary of Key Facts

- Location: East Fishkill, NY
- Acquired from GLOBALFOUNDRIES
- Agreement allows for optimal ramp of capacity by **onsemi** while GLOBALFOUNDRIES ramps down

BUILDING SPACE	212k sqft of fab clean room and 70k sqft of backend clean room space
REVENUE POTENTIAL	$2B per year
START OF ONSEMI'S PRODUCTION	2020
FULL FAB OWNERSHIP	End of 2022
LICENSES	License to 45 nm & 65 nm CMOS processes
PRODUCTS/TECHNOLOGIES	Mid & High Voltage Power MOSFETs, Trench IGBTs, Analog, BCD

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WORLD FINANCE SUSTAINABILITY AWARDS 2020

Most Sustainable Company in the semiconductor industry in 2020 World Finance awards

2021 WORLD'S MOST ETHICAL COMPANIES WWW.ETHISPHERE.COM

One of 3 semiconductor companies included in the **electronics and semiconductor industry** in 2021 for **6 consecutive years**

Top 1% of 768 companies in the "Manufacture of electronic components and boards industry"

100+ individual projects focused on conservation, reduction and recycling in 2020

onsemi *is committed to* ESG *and* Sustainability

Member of Dow Jones Sustainability Indices

Three consecutive years in Dow Jones Sustainability Index

Second consecutive year, **#38 out of 399** U.S.-based companies across 14 industries

Corporate ESG Performance Prime RATED BY ISS ESG

Recognized as **"Prime"** in 2021 (top 20% of semiconductor companies)

Ranked #10 among Barron's 100 **Most Sustainable Companies** in the U.S. for 2021

Acknowledgement

Thanks to SWTEST for allowing me the opportunity to discuss these challenges with you here today

Thanks to many colleagues for providing me the collateral to discuss these challenges with you here today