Syntetic Data for Predictive Maintenance in power electronics

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Department	Electrification
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Customer	ICPT
Project	Predictive maintenance Lecture
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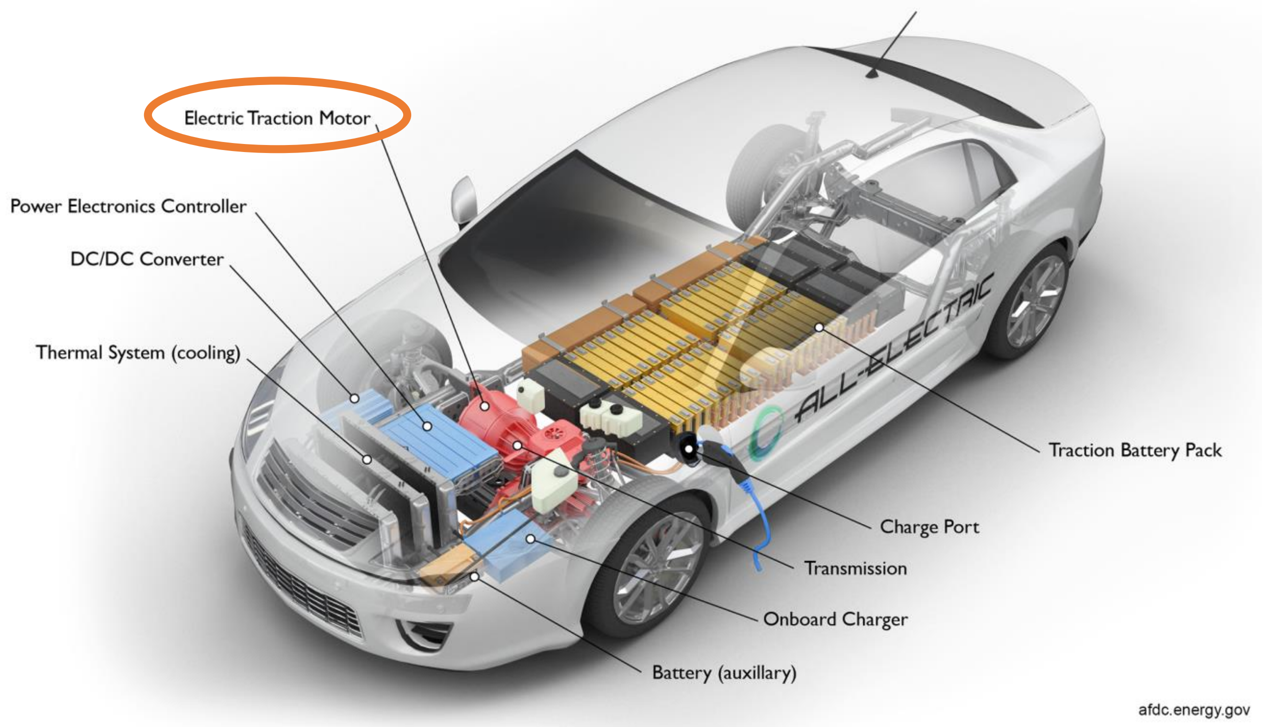
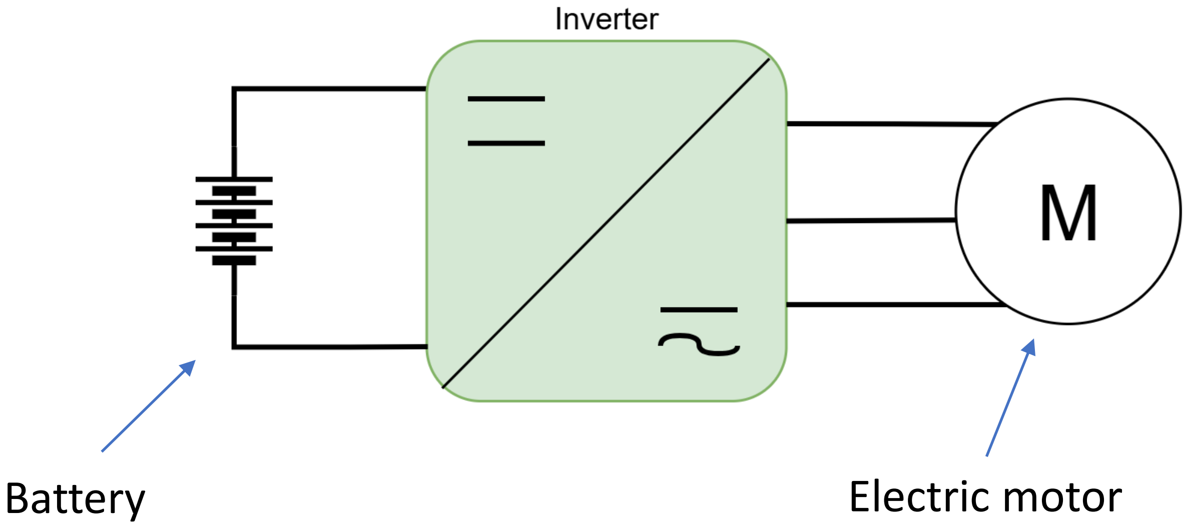
Power electronics in automotive

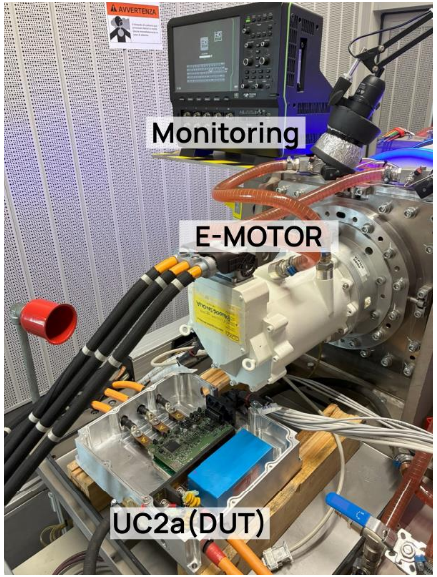
All-Electric Vehicle



afdc.energy.gov

Traction inverter

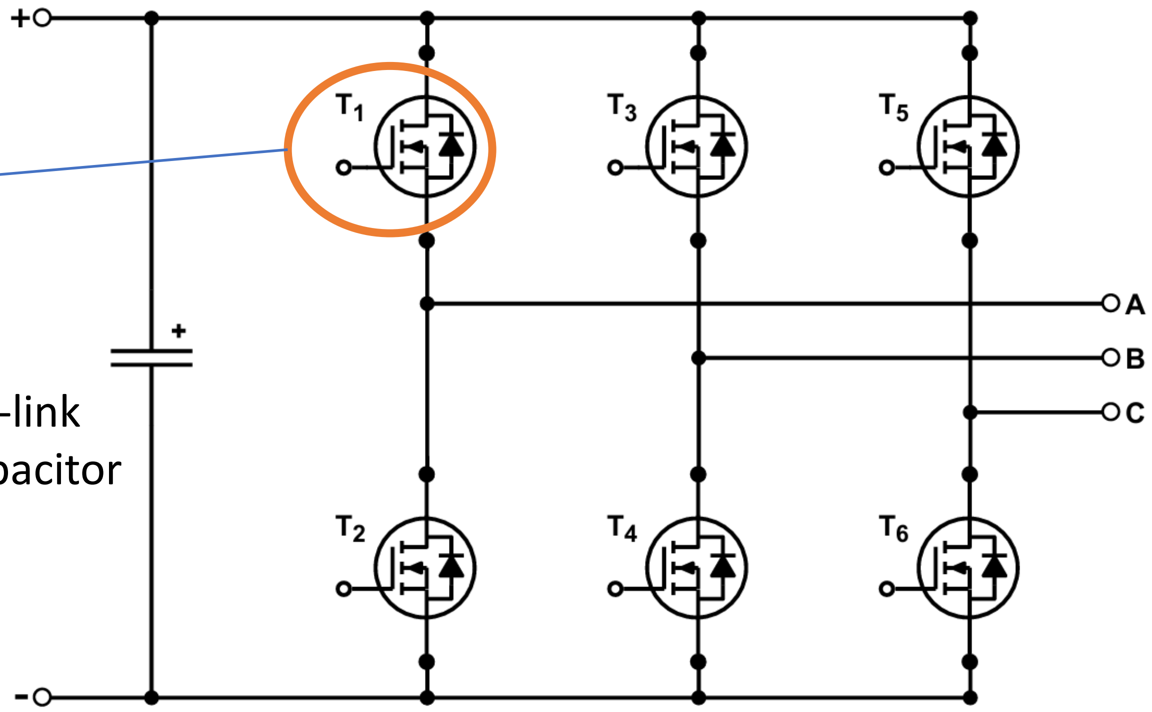




Inverter, how is it made?

ELECTRIFICATION SIMULATION AND AI

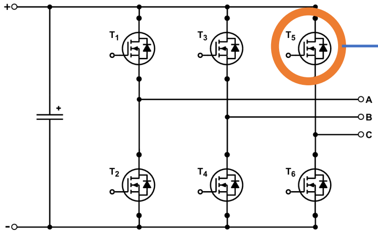
Switch



DC-link capacitor

Switch, how is it made?

ELECTRIFICATION SIMULATION AND AI

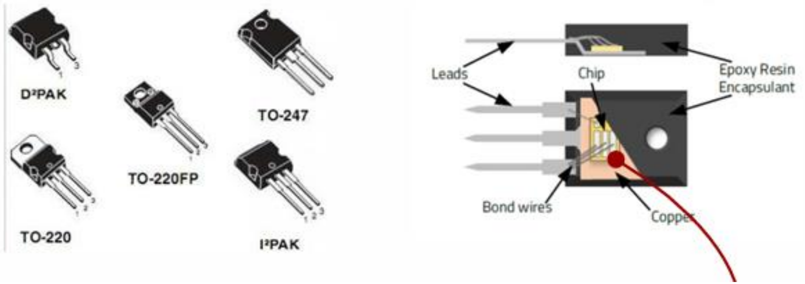


MOSFET
IGBT
HMET

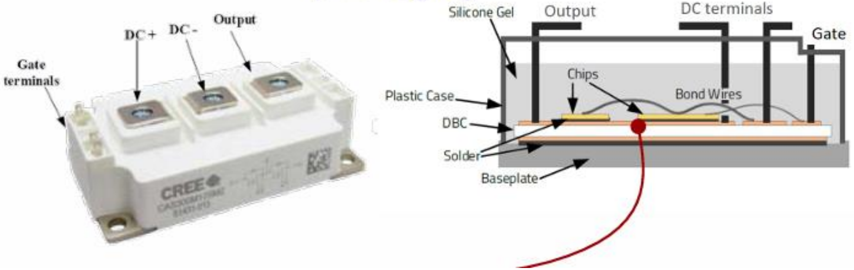
Si
SiC
GaN

Wide Bandgap

Discrete packaging



Module packaging



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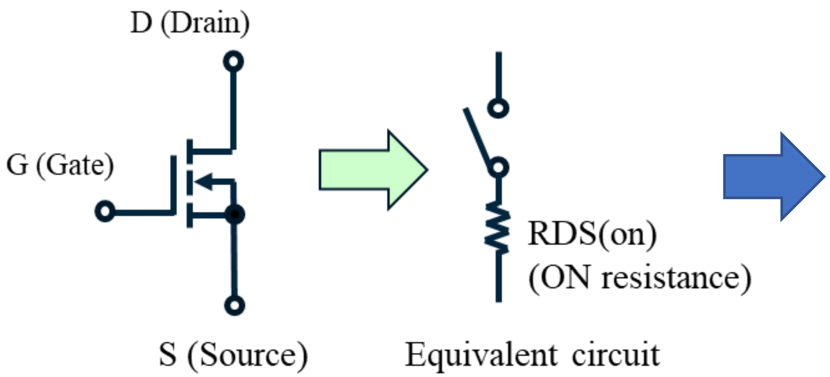
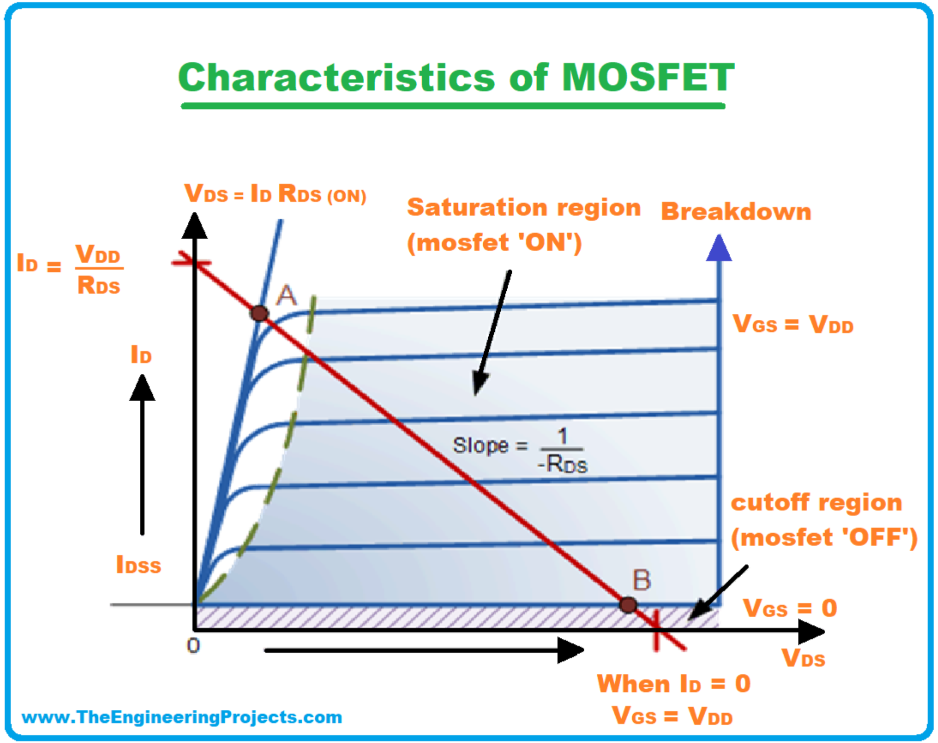
Mosfet Characteristics





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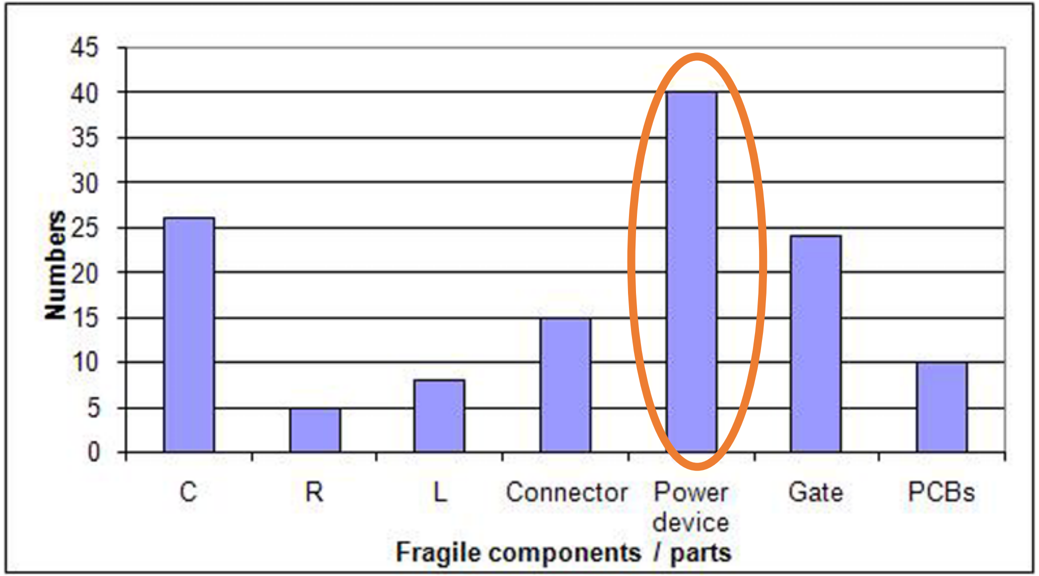
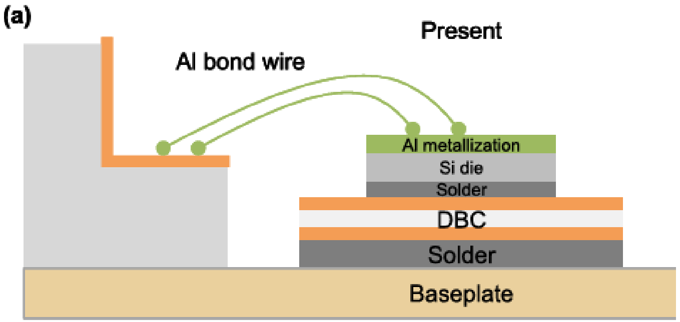
Why so important?

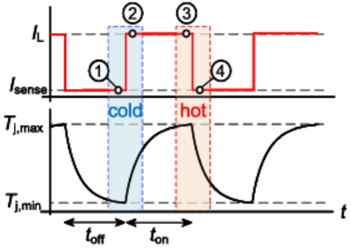
An Industry-Based Survey of Reliability in Power Electronic Converters

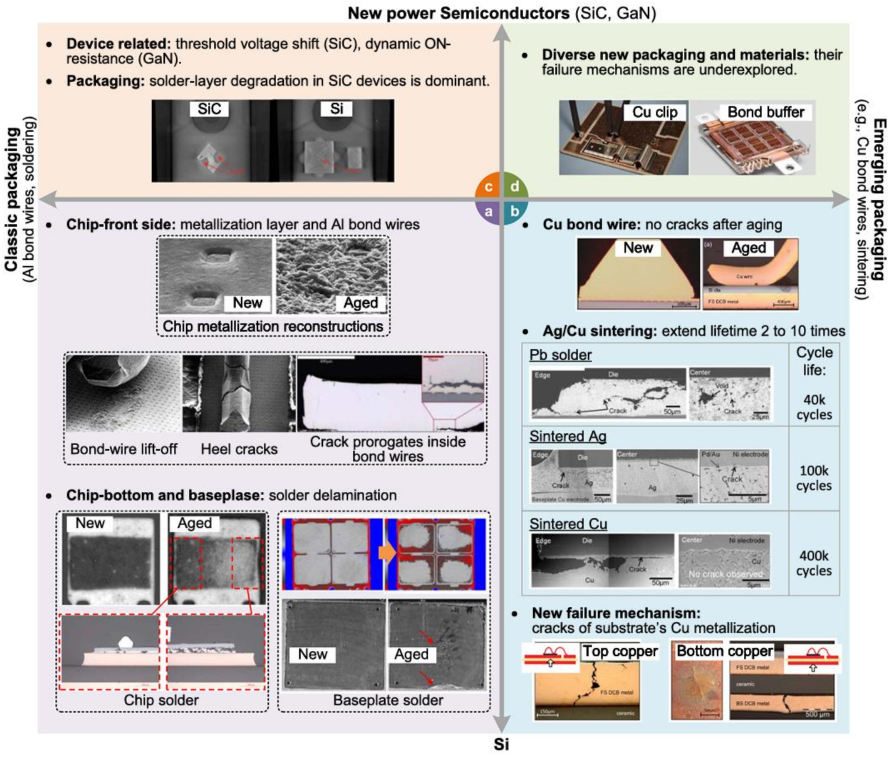


How switches breaks?

Power Cycling Testing for Power Semiconductor Switches: Methods, Standards, Limitations, and Outlooks







How we can understand it?

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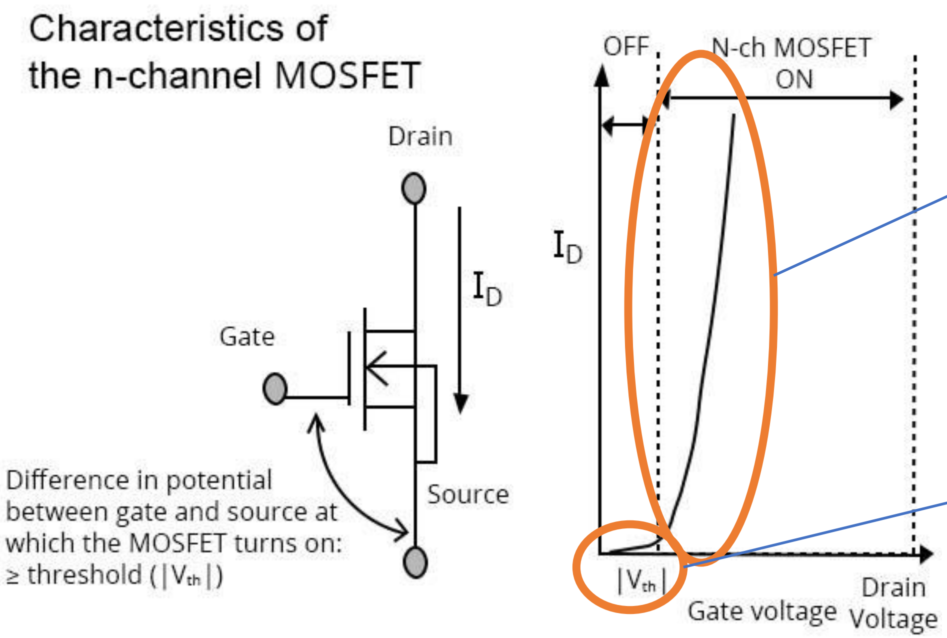
- Aging indicators!



Rdson

+20%->device broken

Vth

Rule of thumb

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How can we estimate remaining useful life?

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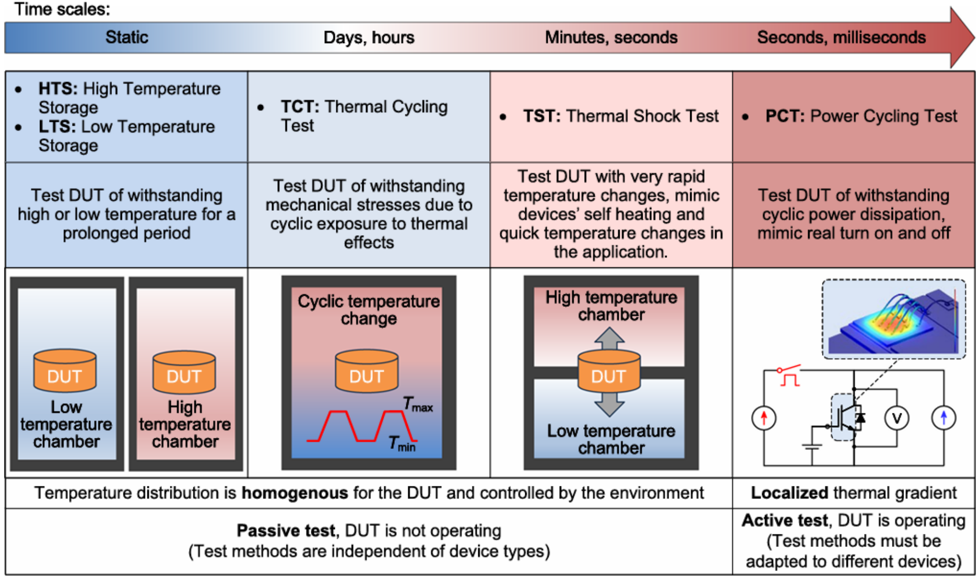
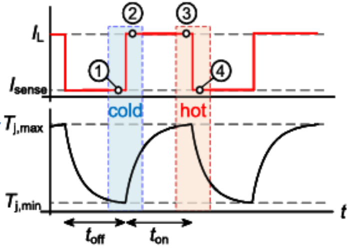
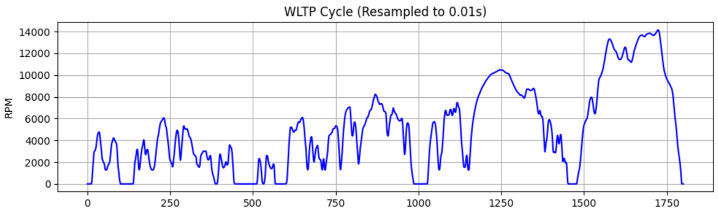
- Accelerated lifetime testing!



Accelerated cycle





Normal cycle (WLTP)

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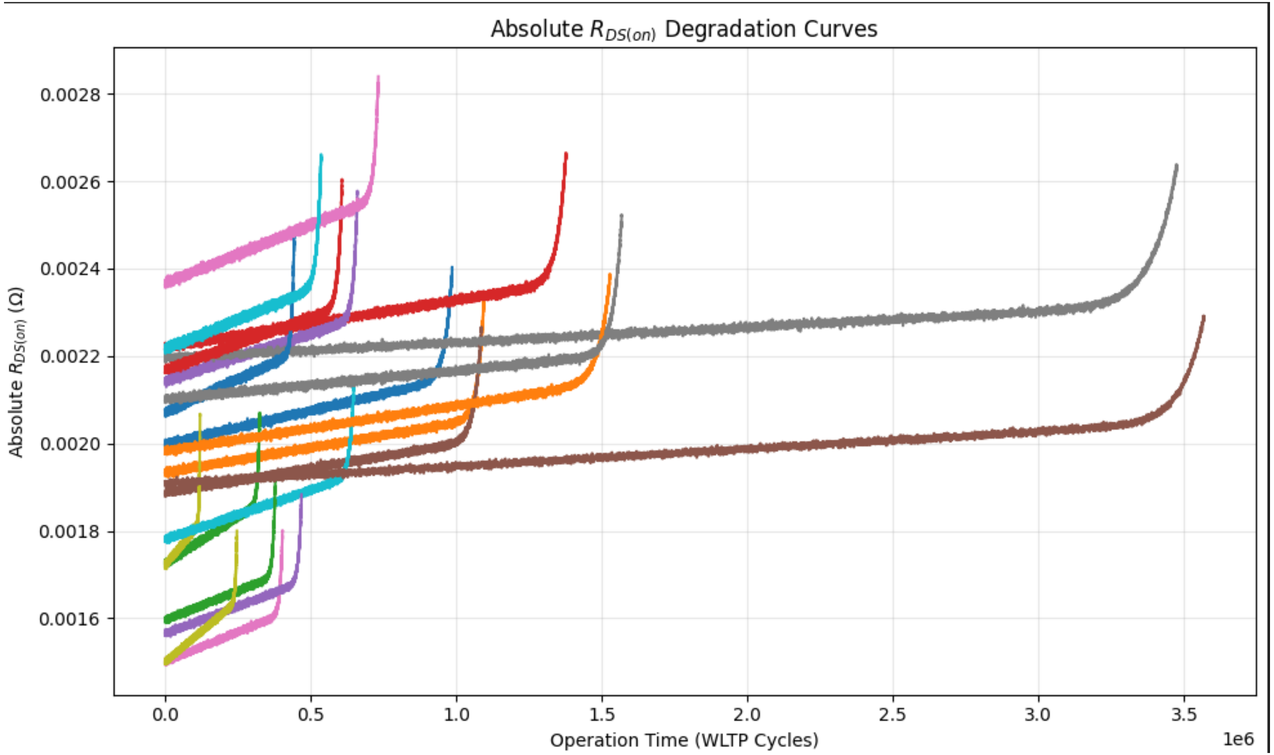
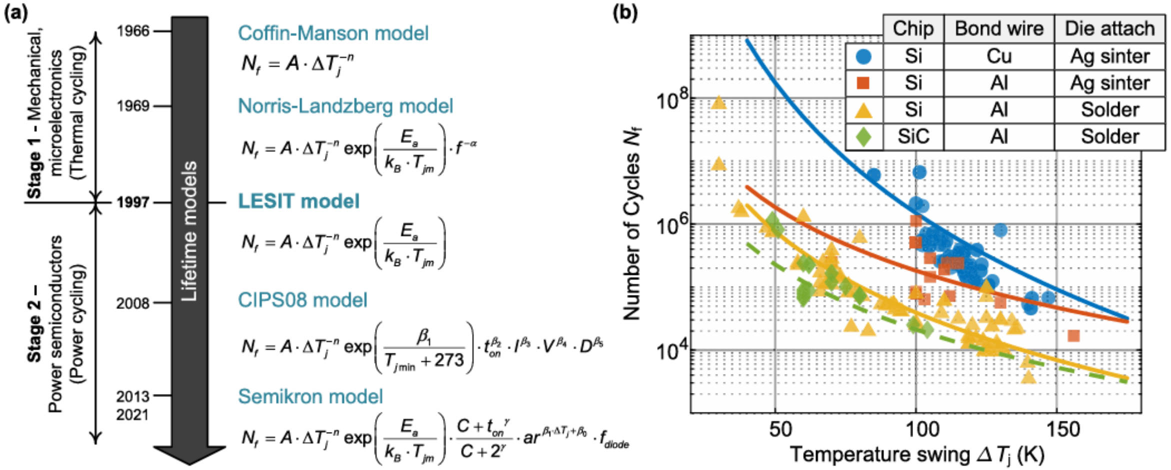
Example of accelerated testing results



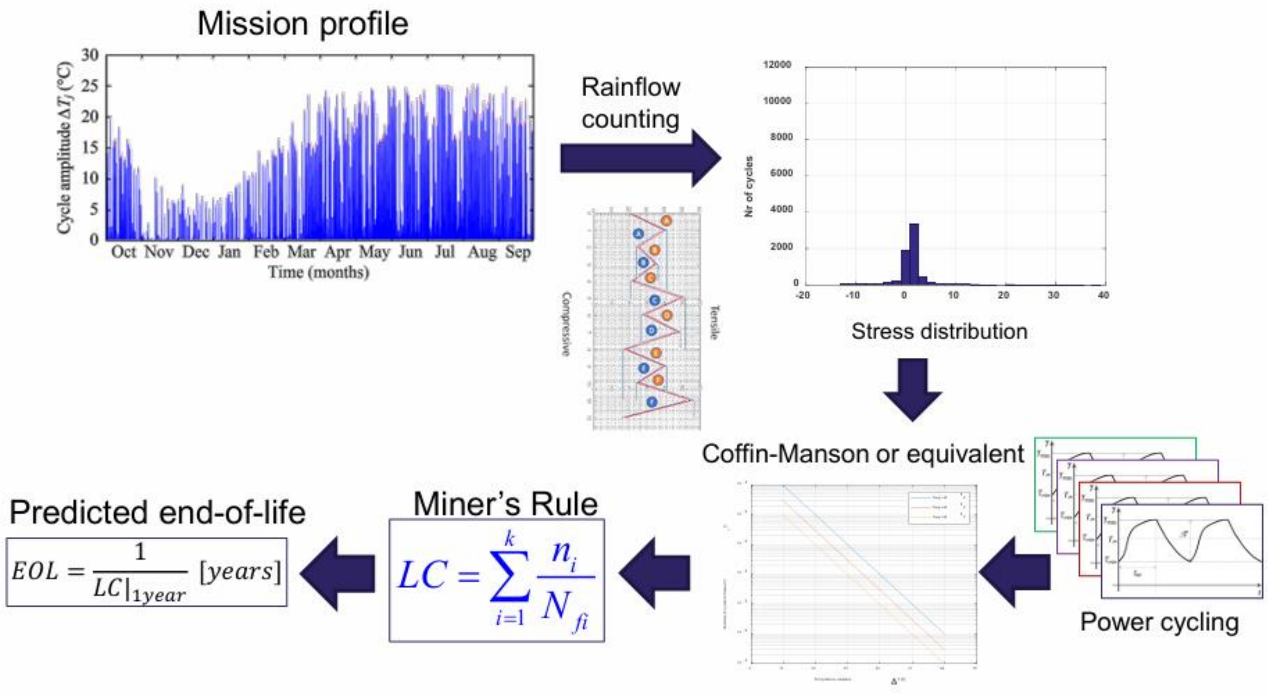
Lifetime estimation from ALTs



(c)

Generic lifetime model	A	n	β_1	β_2	Packaging materials
$N_f = A \cdot \Delta T_j^{-n} \exp\left(\frac{\beta_1}{T_{j\max} + 273}\right) \cdot t_{on}^{\beta_2}$	1.88×10^{15}	6.88	4641	-0.32	Cu bond wire + Ag sintered die attach
	1.14×10^{9}	3.12	2402	-0.39	Al bond wire + Ag sintered die attach
	9.01×10^{11}	4.31	1191	-0.16	Al bond wire + soft soldering
	1.86×10^{8}	3.42	2993	-0.54	SiC MOSFET: Al bond wire + soft soldering

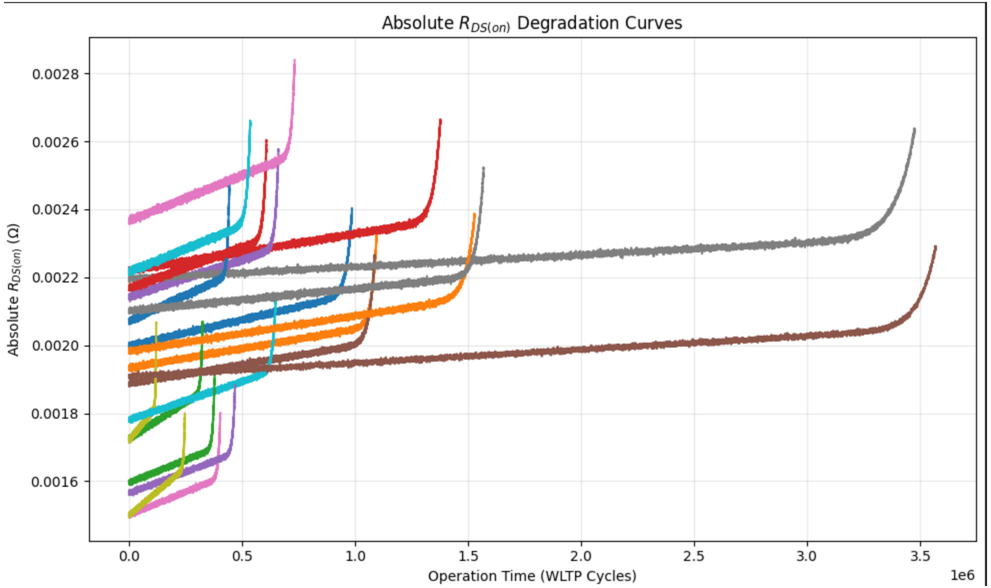
Lifetime estimation from mission profile



Not enough data!

- Time consuming
- Cost
- Hw is difficult to predict

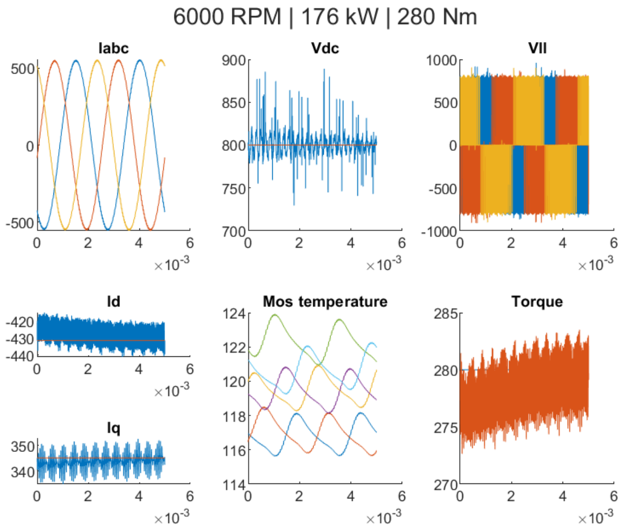
Solution: Synthetic data!

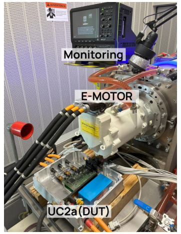


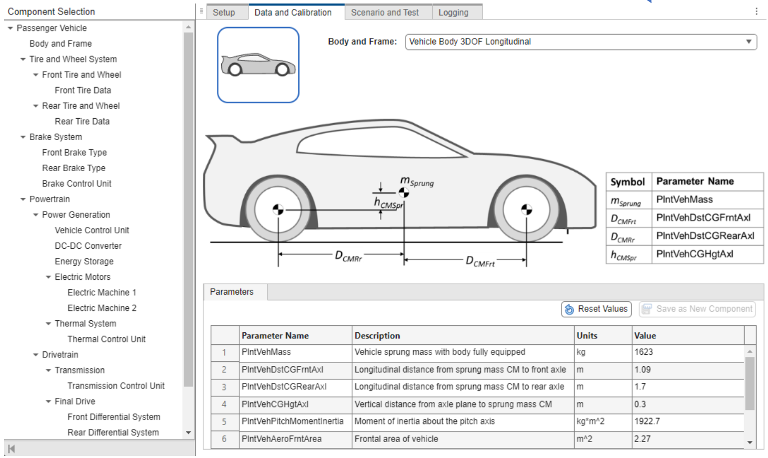
Let's produce syntetic data

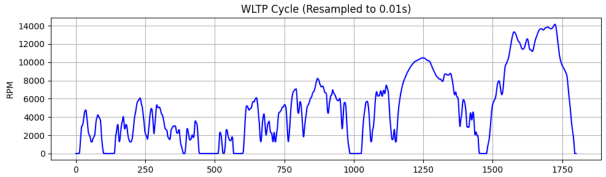
Environments :

1. Inverter Simulation (INV+CTRL+MOT)
2. Vehicle Simulation (driver+MOT)
3. Generative Simulation (Device)







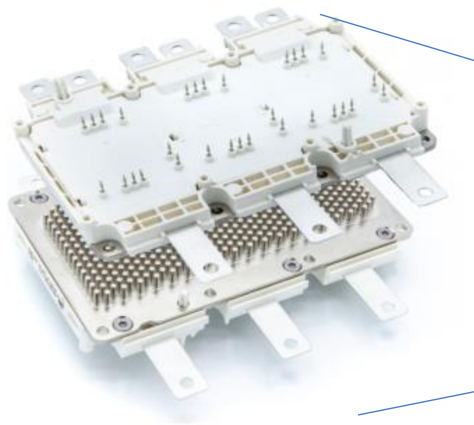


1. Inverter Simulation

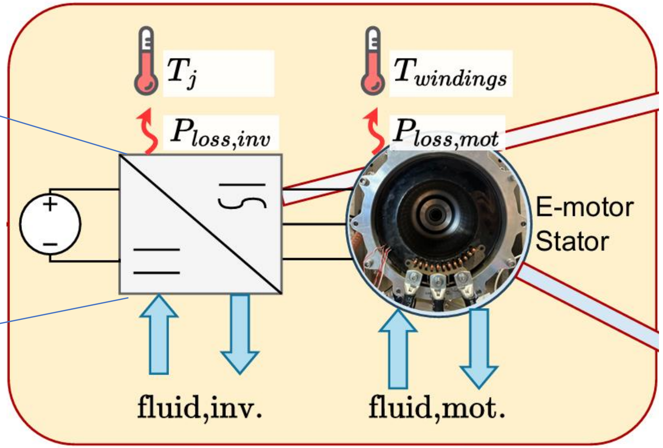
Automotive-grade ACEPACK DRIVE power module, sixpack topology
1200 V, 1.9 mΩ typ. SiC MOSFET gen.3 based

\+

HPE PMSM motor



ACEPACK DRIVE



inverter-motor system

2. Vehicle Simulation (driver+MOT)

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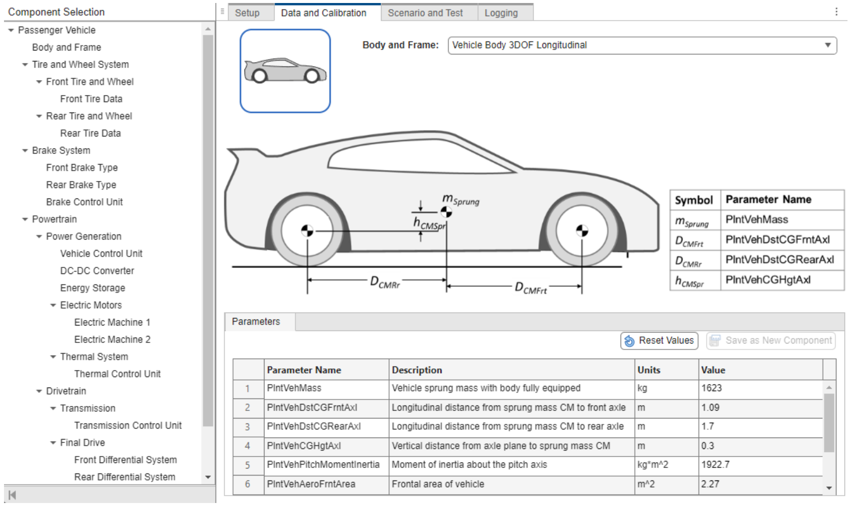
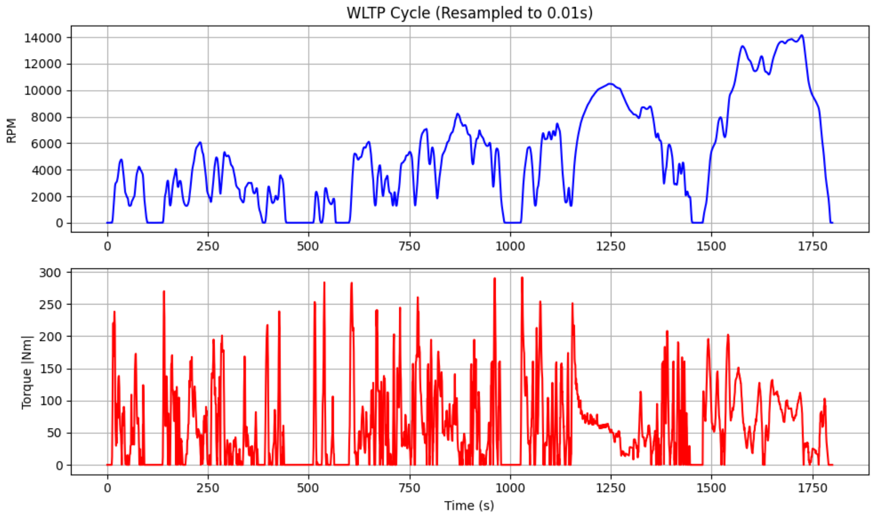
Simulink Vehicle composer

- EV + WLTP drivecycle -> straight forward!





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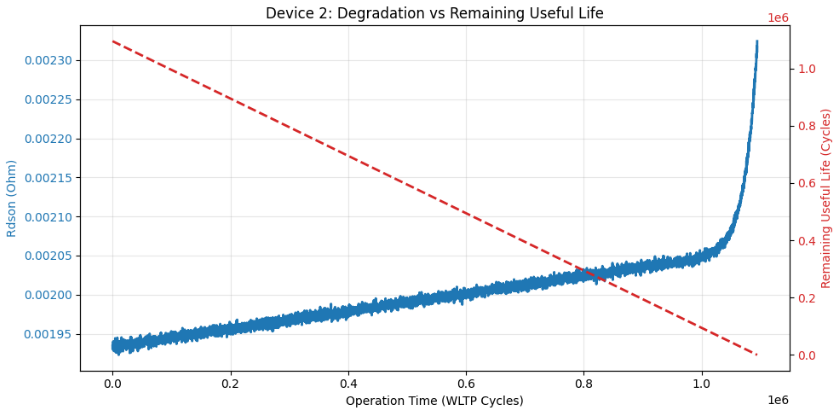
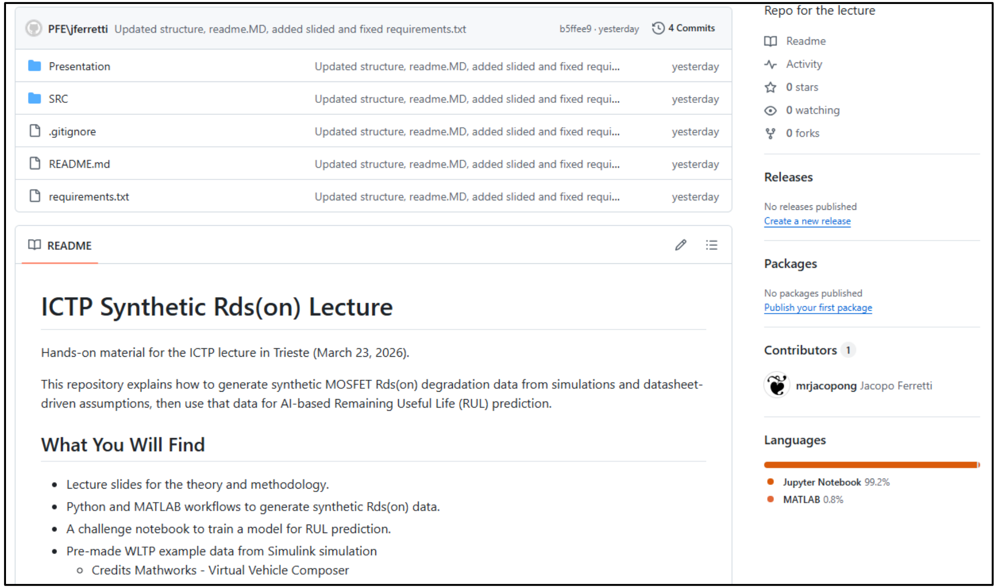
3. Generate Rdson

1. Load Dt(RPM,Trq) map -> each RPM and torque point has a mosfet temperature
2. Load RPM-Trq from vehicle simulation
3. Calculate Dt(t) for the whole drive cycle
4. Calculate Lifetime of the device using stress calculation
5. Extend lifetime results using Monte Carlo
6. Resample and output data for next step, AI prediction



Your turn!

- Clone the repository from: https://github.com/mrjacopong/ICTP_SyntheticRdson_lect
- Read README.MD for instructions
- Have fun generating Rdson and creating your RUL predictor!



Any questions ?

Reach out to:

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