Performance of 2nd Generation EPC2014 GaN Power FETs after Exposure to Radiation, Long-Term Thermal Cycling, and High Temperature Reverse Bias testing

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Scope of Work

- A NEPP (NASA Electronic Parts & Packaging) collaborative effort among NASA Centers to address reliability of new COTS wide bandgap power devices

Test Approach

- Evaluate performance of EPC gallium nitride (GaN) power field effect transistors (FET) before, during, and after subjecting to the test sequence:
  - Heavy Ion Irradiation (Xenon: 25MeV/u)
  - Long Term Thermal Cycling
  - High Temperature Reverse Bias (HTRB)

Second Generation GaN FETs

- EPC GaN enhancement mode transistors
- Grown on Si wafer, passivated-die form with solder bumps

  http://epc-co.com/epc/

Sample die mounted on test structure

Part #	EPC2014
Drain-Source Voltage, VDS (V)	40
Gate Threshold Voltage, VTH (V)	1.4 @ VDS = VGS, ID = 2 mA
Drain Current, ID (A)	10
Drain-Source On Resistance, RDS(ON) (mΩ)	12 @ VGS = 5V, ID = 5 A
Operating Temperature, TC (ºC)	-40 to +150
Package Type	Passivated-Die with Solder Bumps

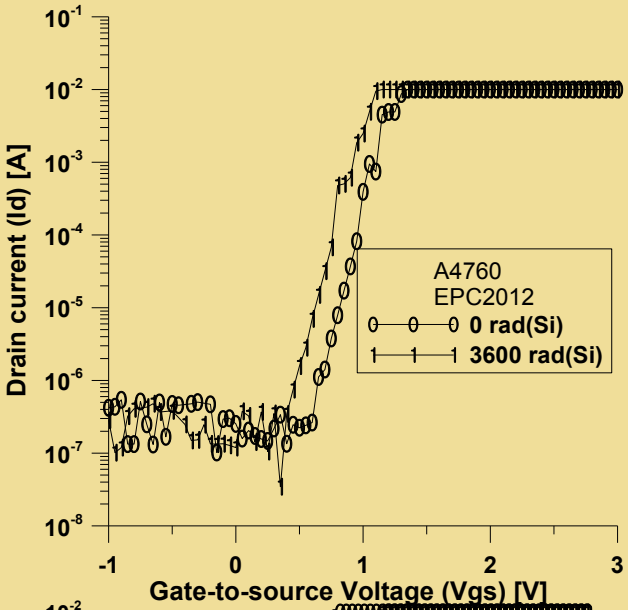
Radiation Exposure

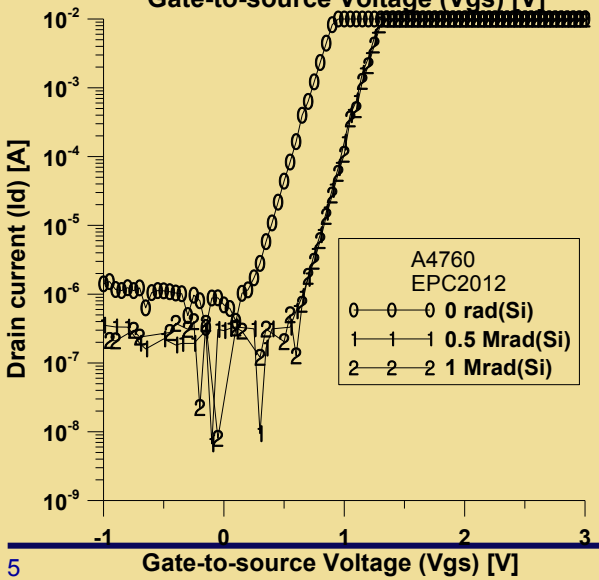
- Heavy Ion Irradiation by JPL
- Texas A&M University Radiation Facility

# of Parts	Device Label	Condition	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Range (µm)	Dose (rads(Si))
1	K7325	Irradiated	Xe	1583	51	125	822
1	K7328	Irradiated	Xe	1583	51	125	822
1	K7347	Irradiated	Xe	1583	51	125	822
1	K6985	Control (un-irradiated)					
1	K6986	Control (un-irradiated)					
1	K7072	Control (un-irradiated)					
1	K7336	Control (un-irradiated)					
1	K7346	Control (un-irradiated)					

Radiation test results

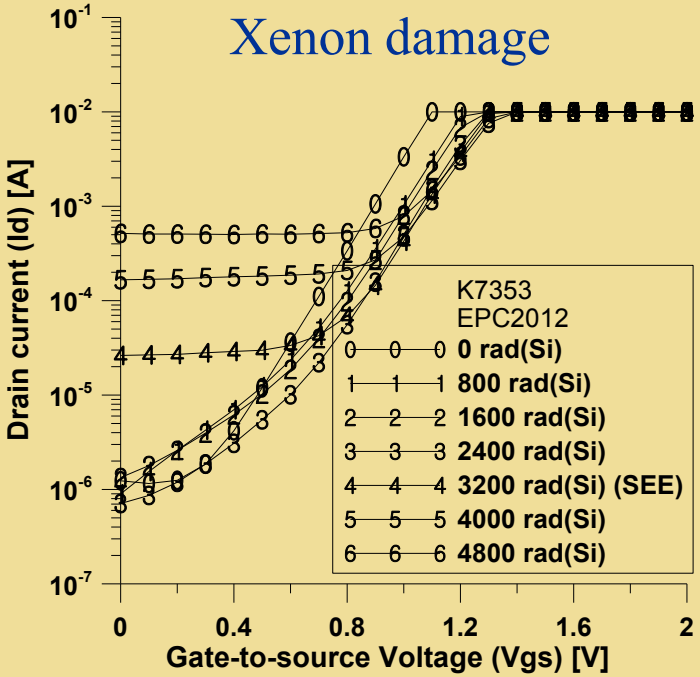
Proton damage

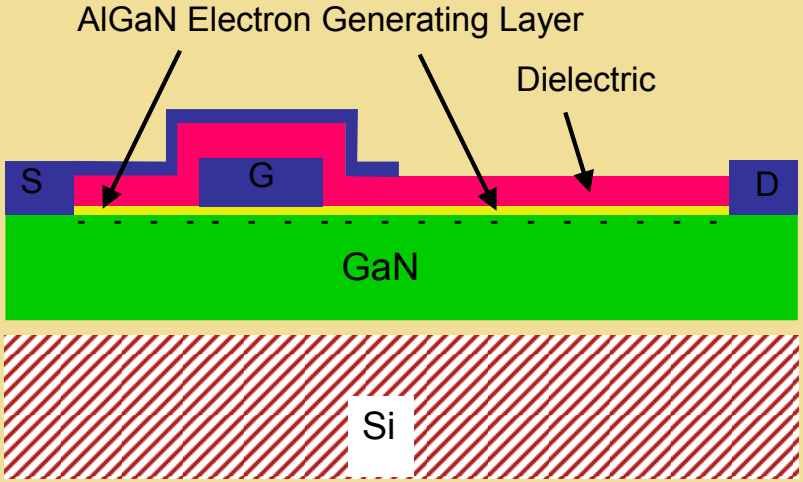




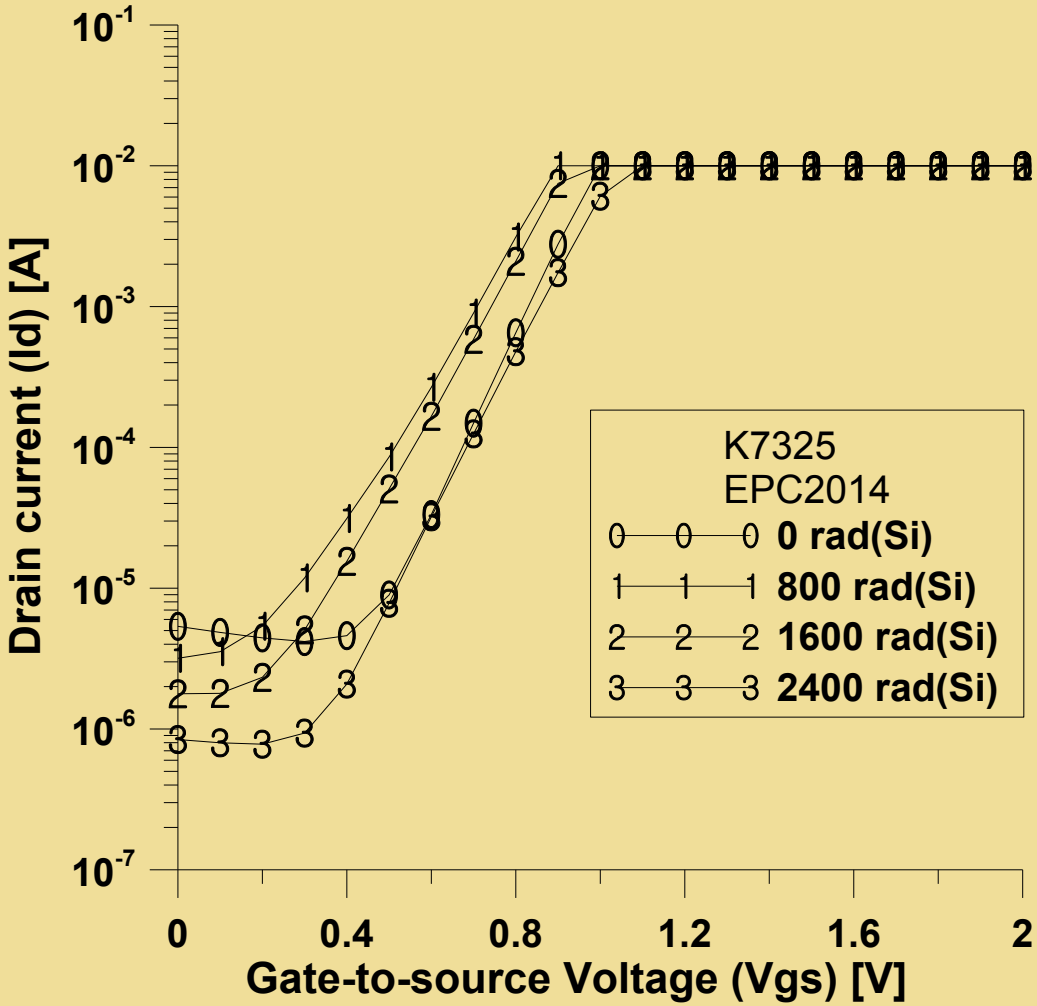
No SEE from protons.

Xenon damage





Radiation test results

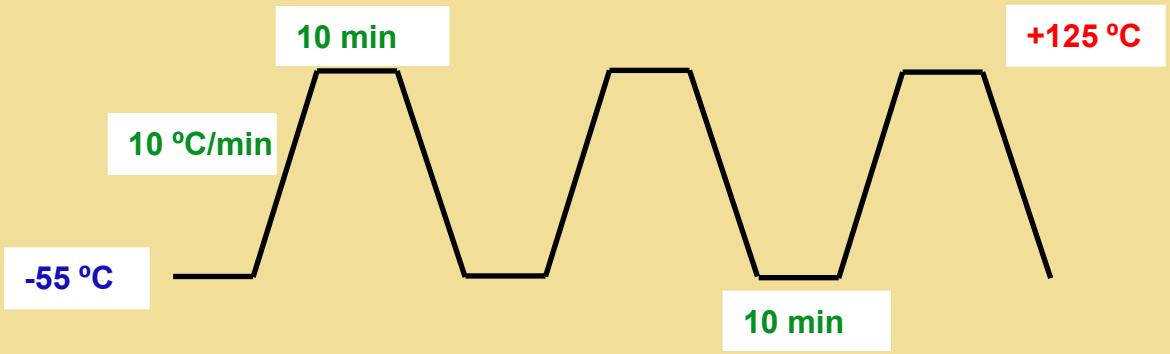


Radiation test results

- Proton damage
  - DDD and proton SEE apparently not an issue for GaN
    - ✓ Minor shift in threshold voltage for proton effect
    - ✓ No SEE seen at 60 MeV protons – higher energy proton may cause more damage
  - Observed effects may be architecturally dependent
    - ✓ GaN HEMTs are fairly uniform, but isolation structure will vary
- Failure mechanism identification
  - Isolation oxide is the drain-to-source path
  - SEE mechanism under study
    - ✓ Gate identified as sensitive volume

Thermal Cycling

- Cycling Profile:
  - Total # of Cycles 1000
  - Temperature rate of change: 10 ºC/min
  - Temperature range: -55 ºC to +125 ºC
  - Soak time at extreme temperatures: 10 min
- Repeat measurements on devices during cycling
- Perform measurements after conclusion of cycling activity



Test Setup

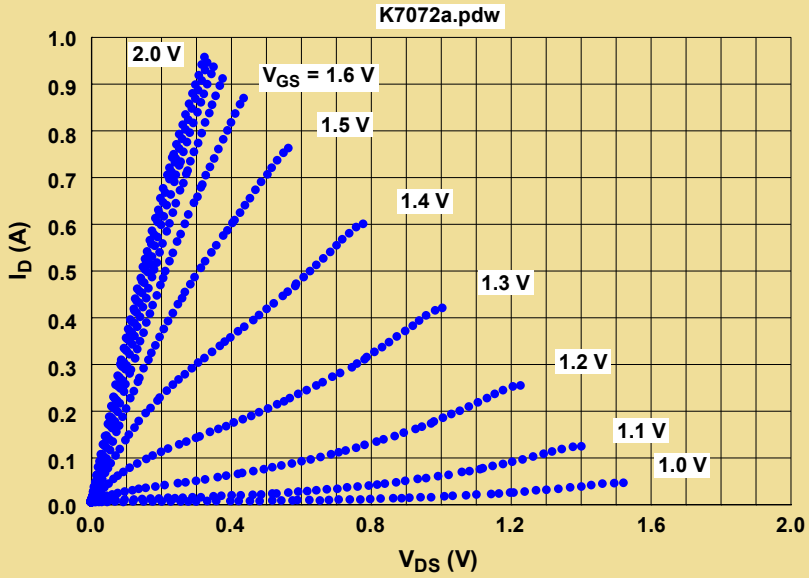
Parameters Investigated:

- I-V Output Characteristics
- Gate Threshold Voltage, V_{TH}
- Drain-Source On-Resistance, $R_{DS(on)}$
- Pre, during, & post-cycling, measurements at selected temperatures

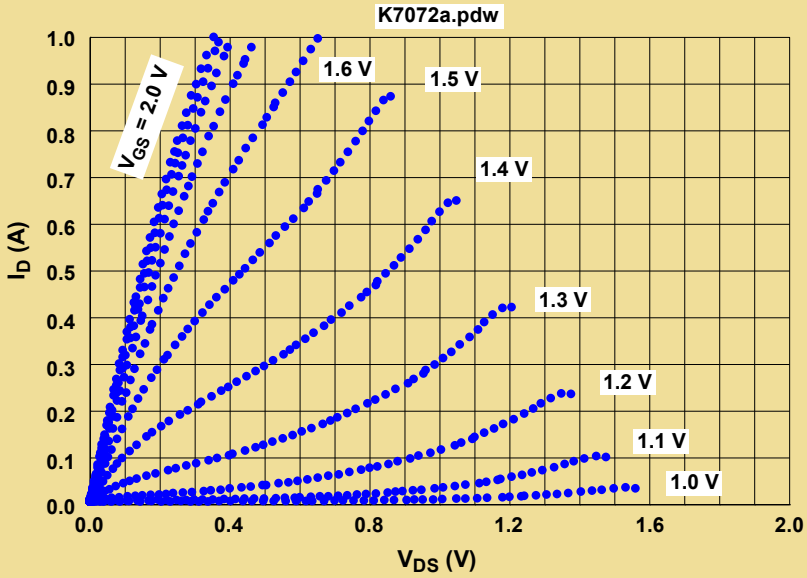
Equipment Used:

- SONY/Tektronix 370A Curve Tracer
- Keithley 238, 237, 2400 Source-Measure-Units
- LN-cooled Sun Systems Chamber

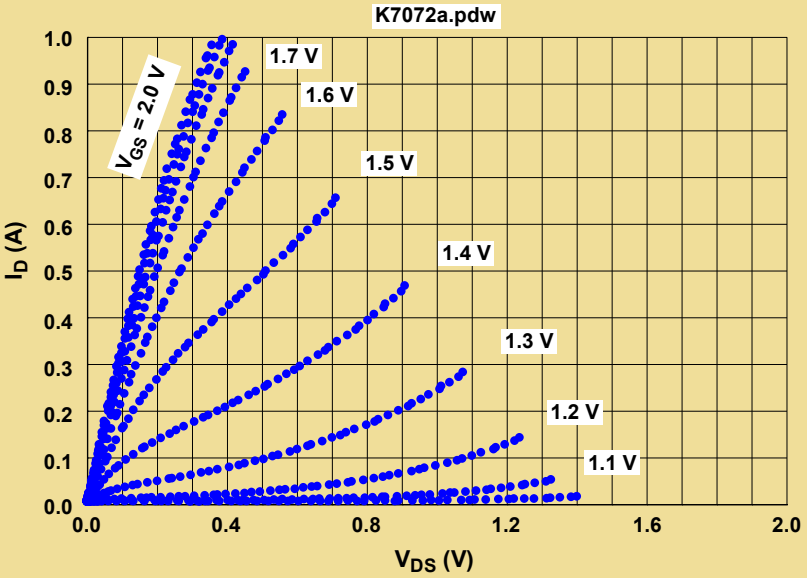
I-V Curves for K7072 (control)



Pre-Cycling

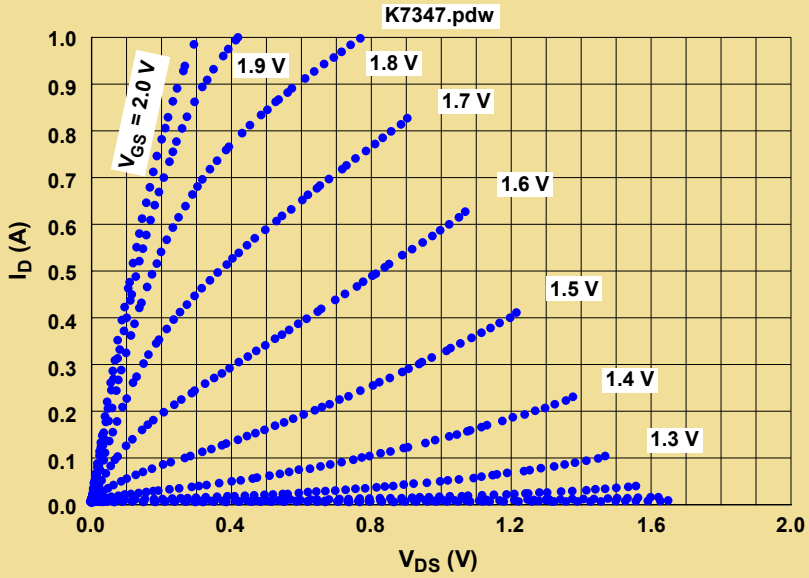


After 500 Cycles

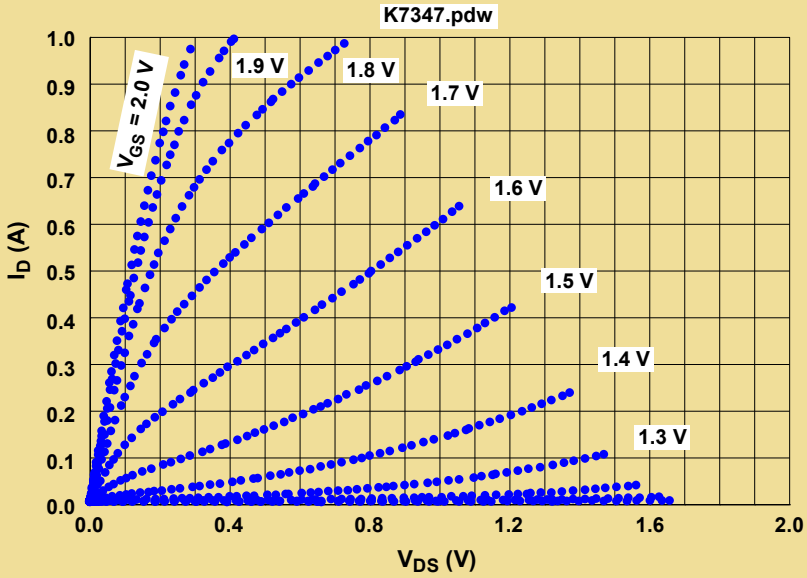


After 1000 Cycles

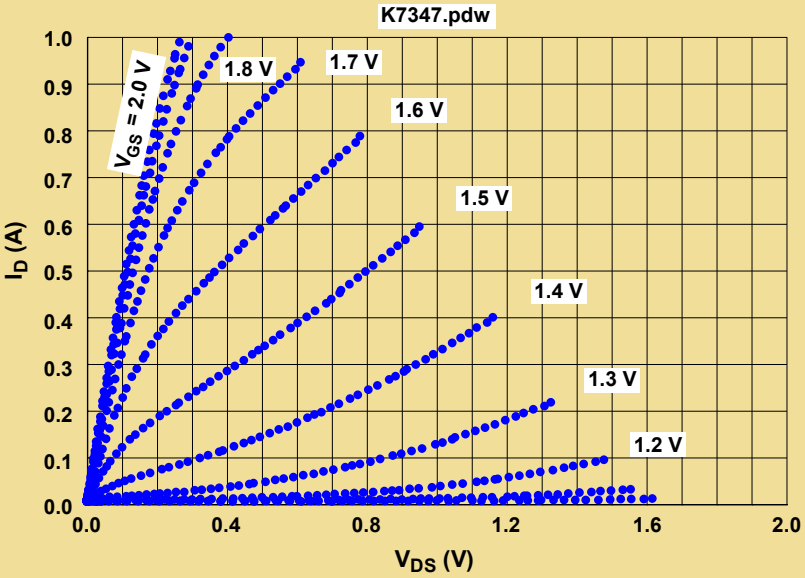
I-V Curves for K7347 (irradiated)



Pre-Cycling

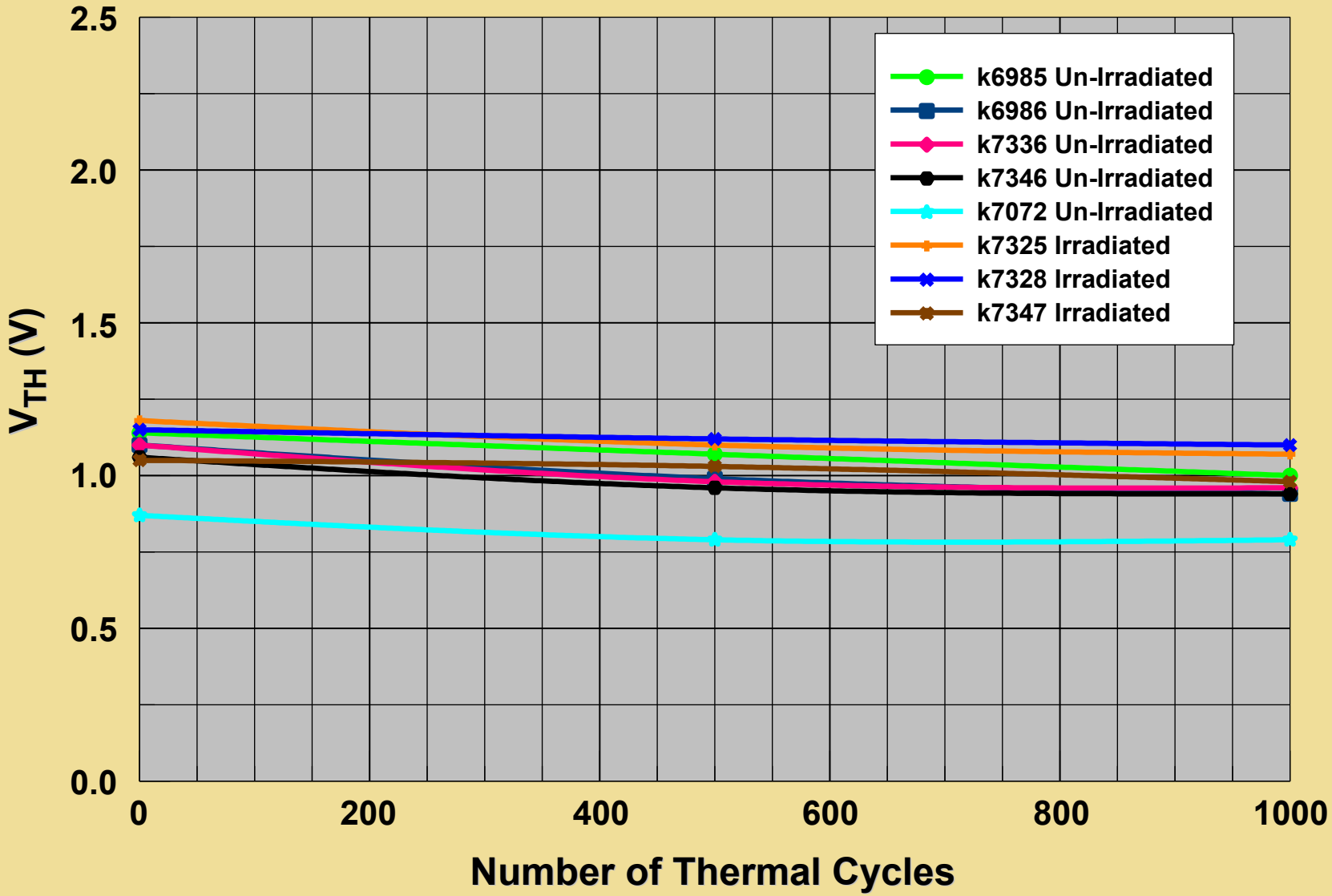


After 500 Cycles

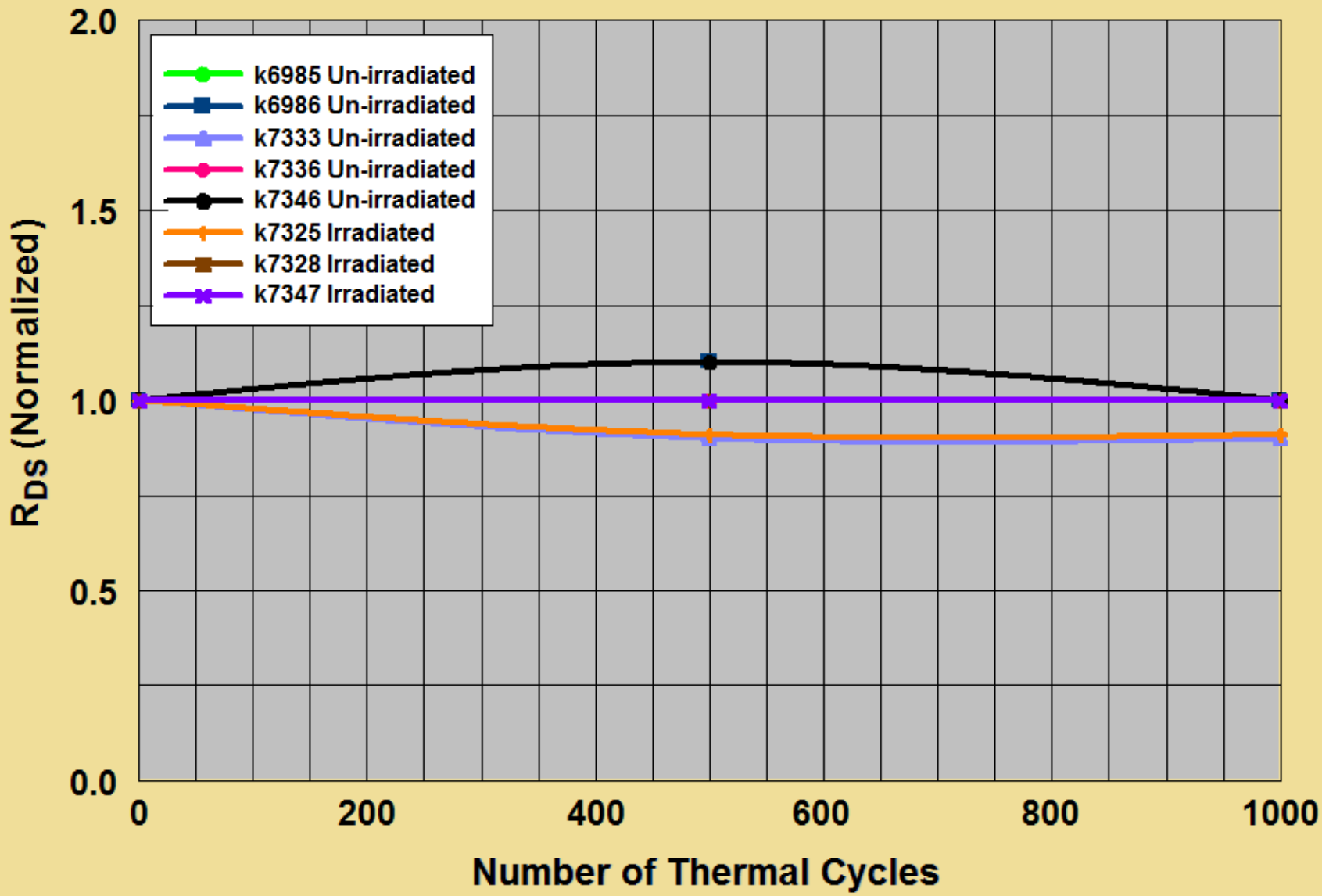


After 1000 Cycles

GATE THRESHOLD VOLTAGE, V_{TH}



Drain-Source On Resistance, $R_{DS(ON)}$



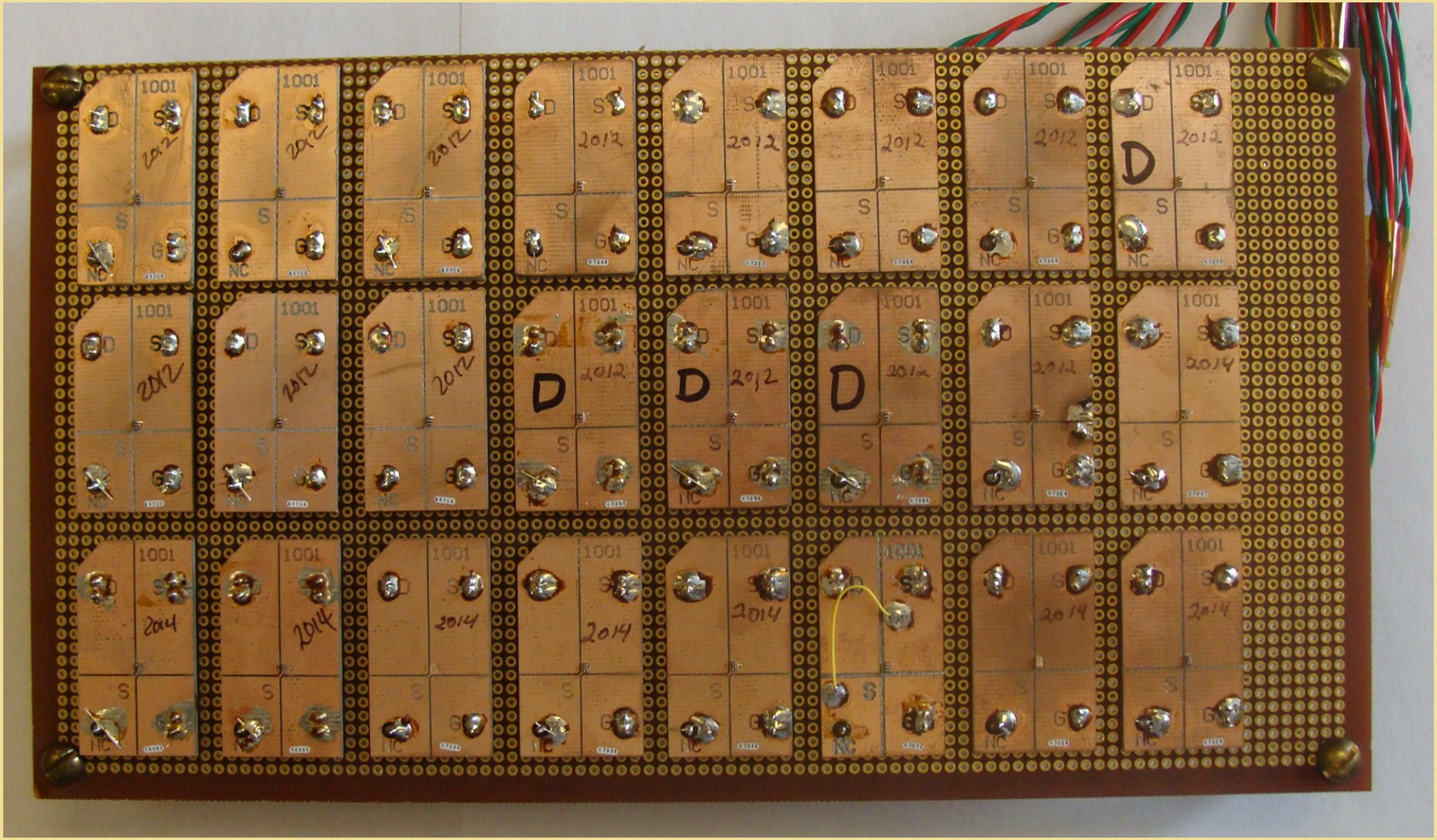
OBSERVATIONS

- All eight EPC2014 GaN transistors, control & irradiated, remained functional after exposure to radiation followed by 1000 thermal cycles between -55 & +125 ^{0}C
- Slight changes in I-V curves of irradiated parts
- Thermal cycling seemed to slightly improve the I-V characteristics of both control and irradiated samples
- Part-to-part variation in output characteristics
- No alteration in device packaging or terminations

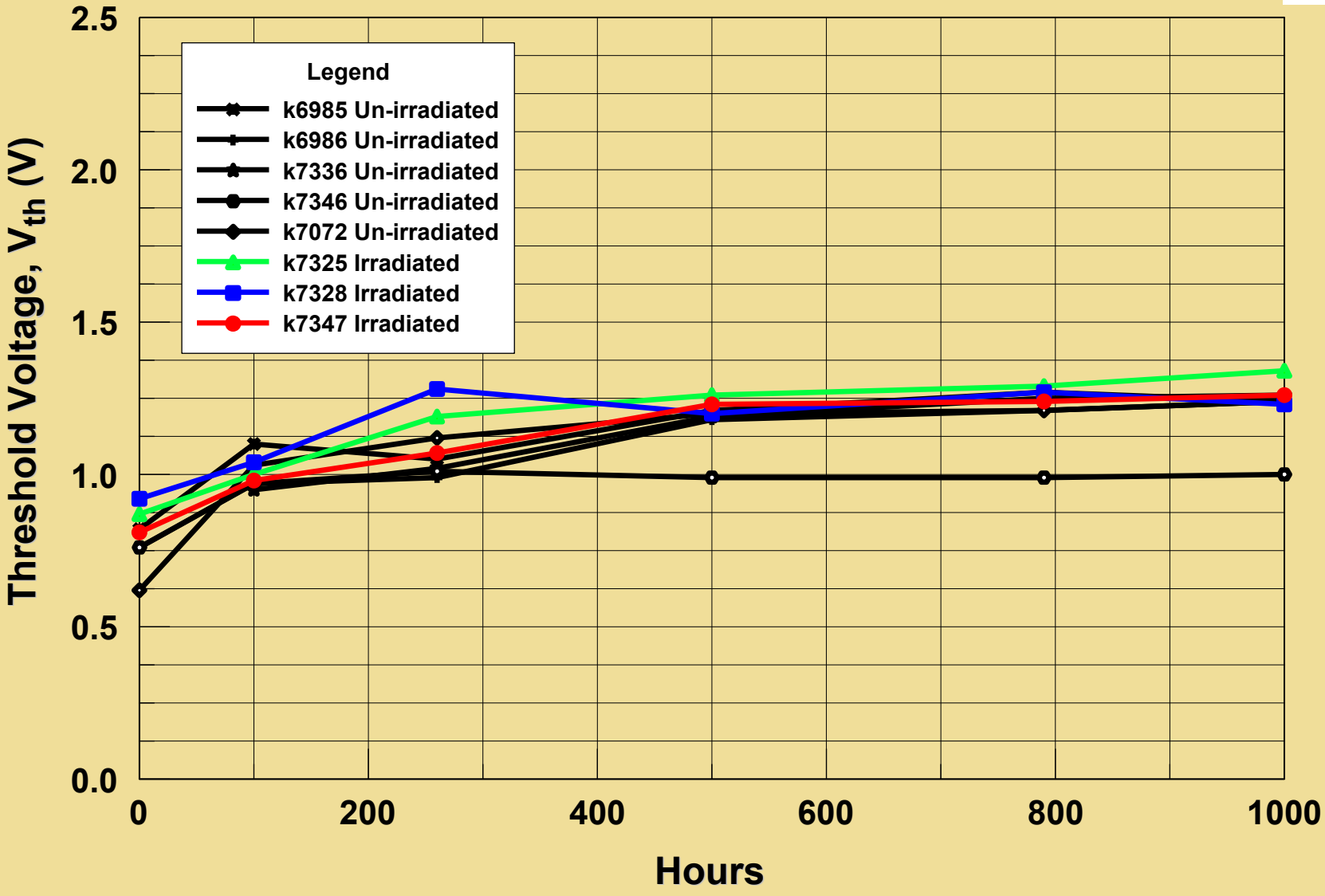
HTRB Test

- Duration: 1000 hours
- Temperature: 125 °C
- Bias: 80 % rated BV_{DSS}, V_{GS} = 0 V
- Parameters:
  - Gate threshold voltage
  - Drain leakage current
  - Gate forward leakage current
  - Gate reverse leakage current
  - I-V characteristic curves
- Measurements performed at high temperature at intervals

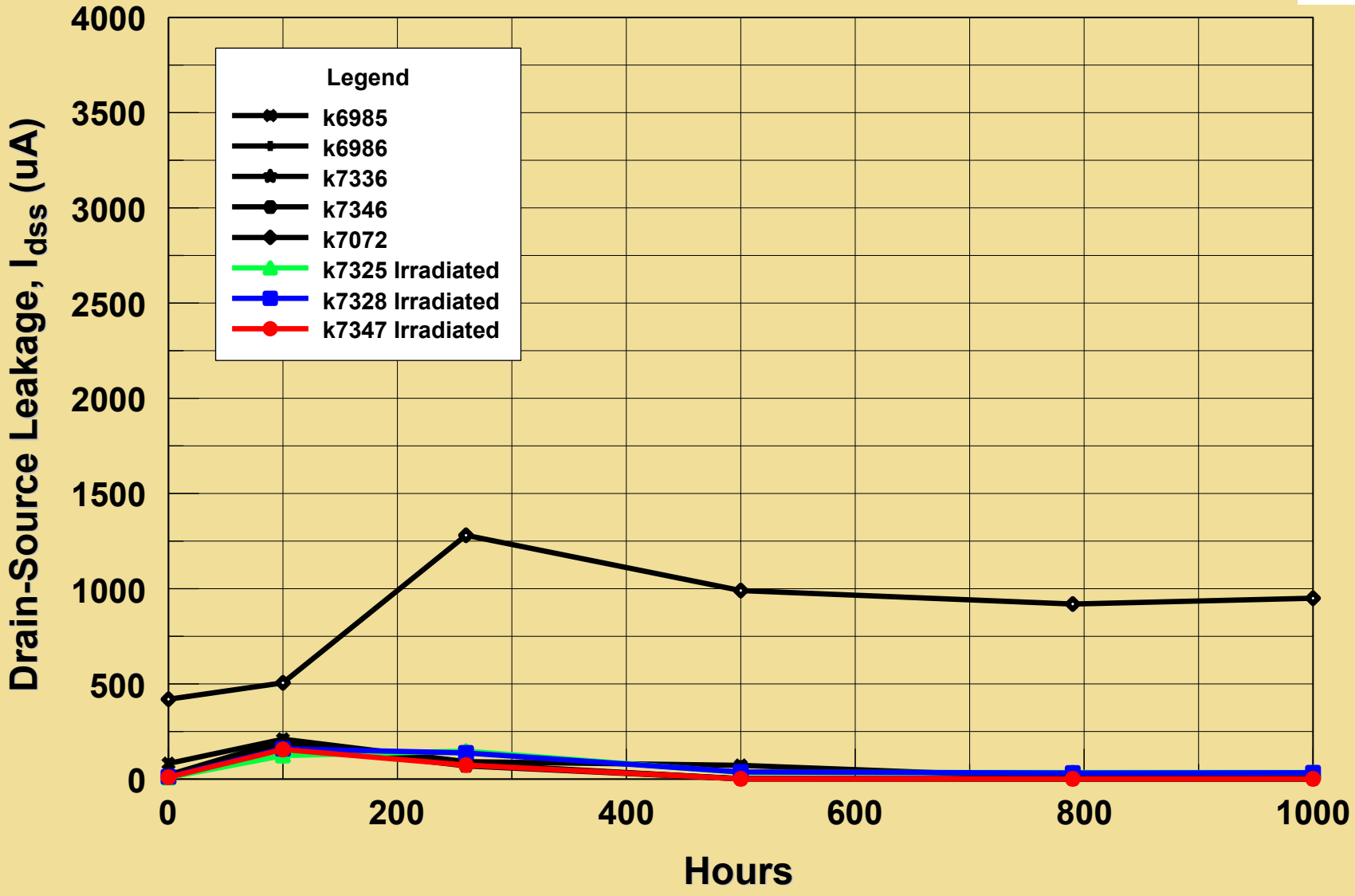
Test Board



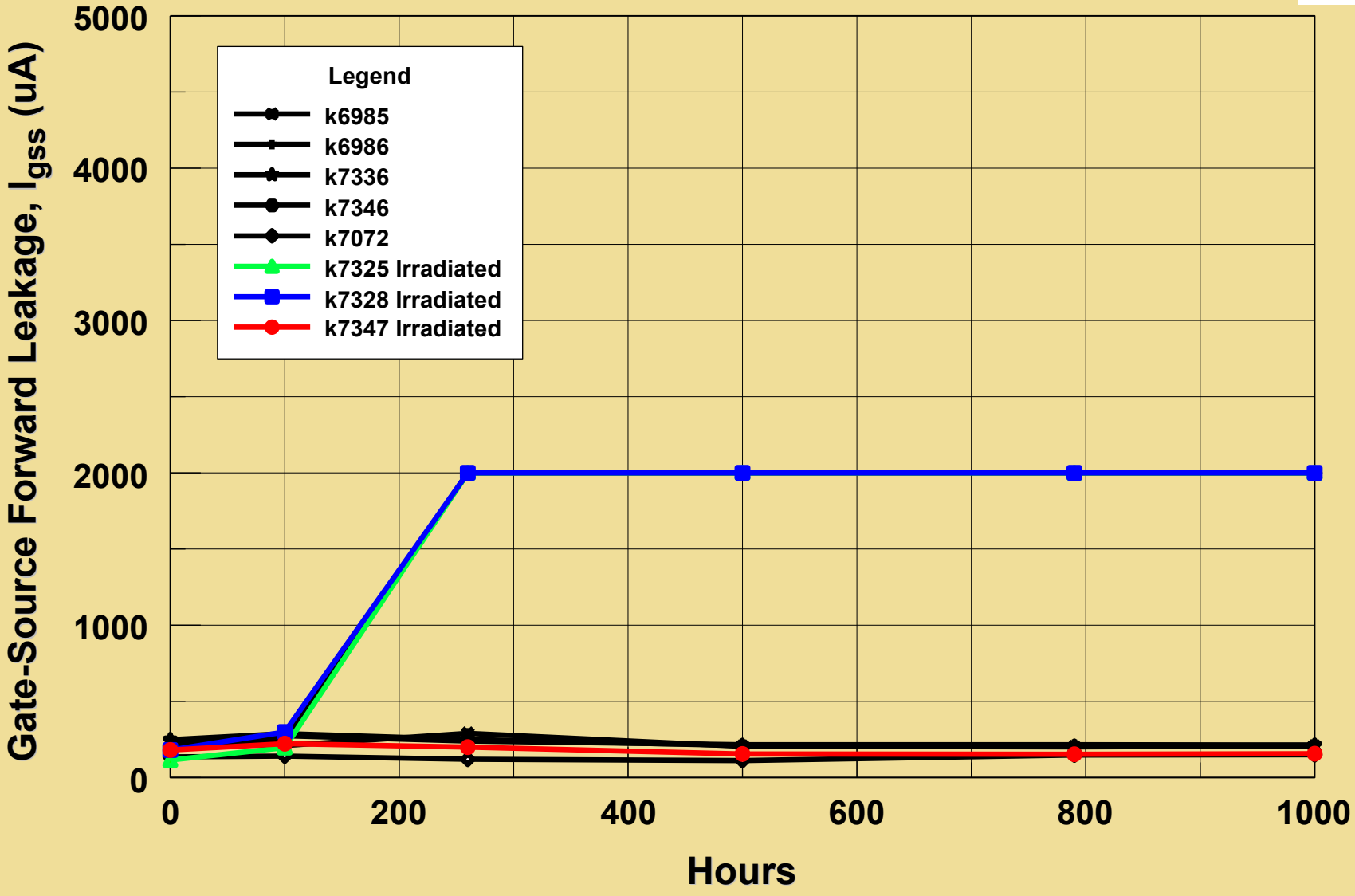
GATE THRESHOLD VOLTAGE



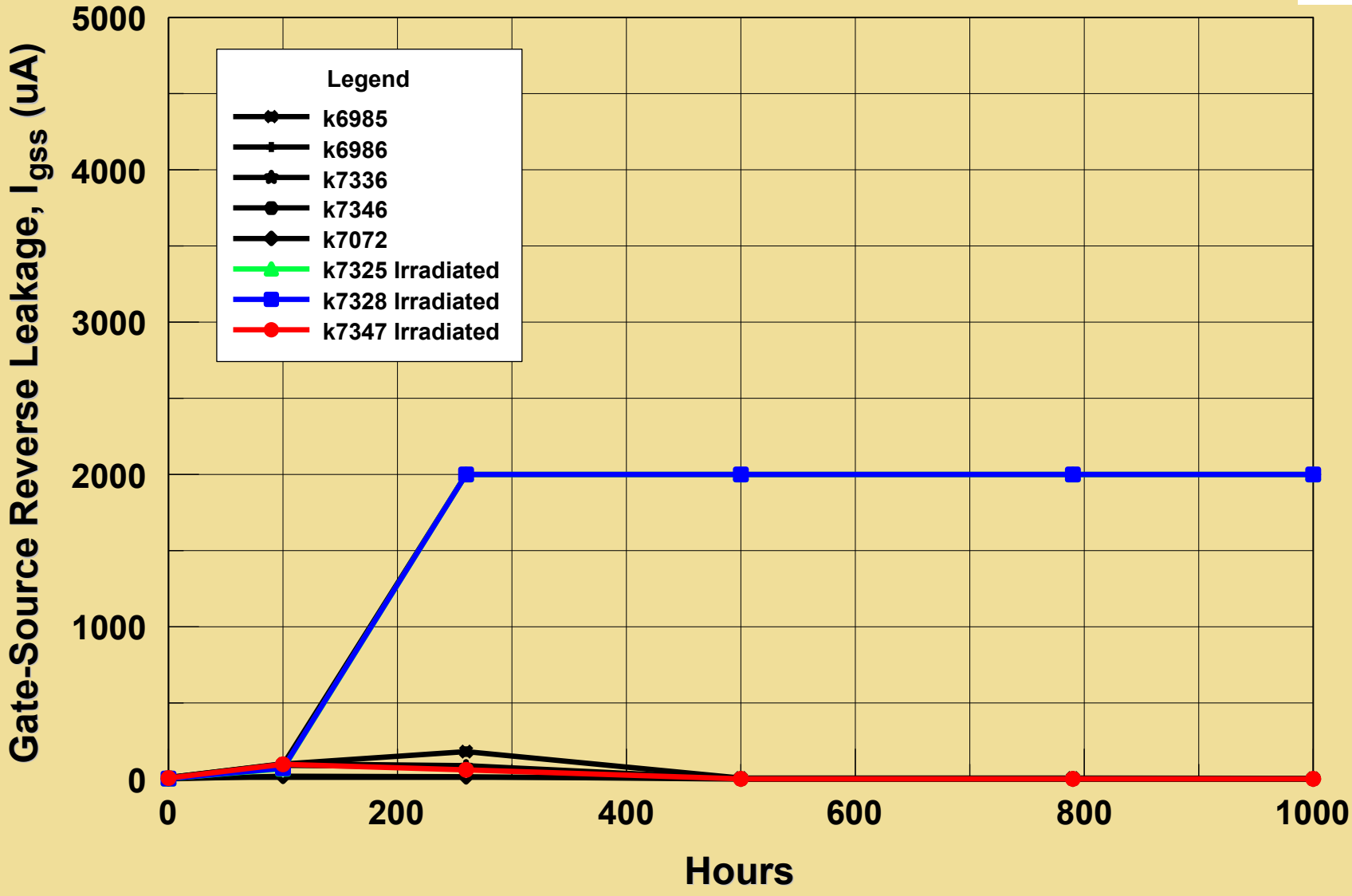
DRAIN-SOURCE LEAKAGE



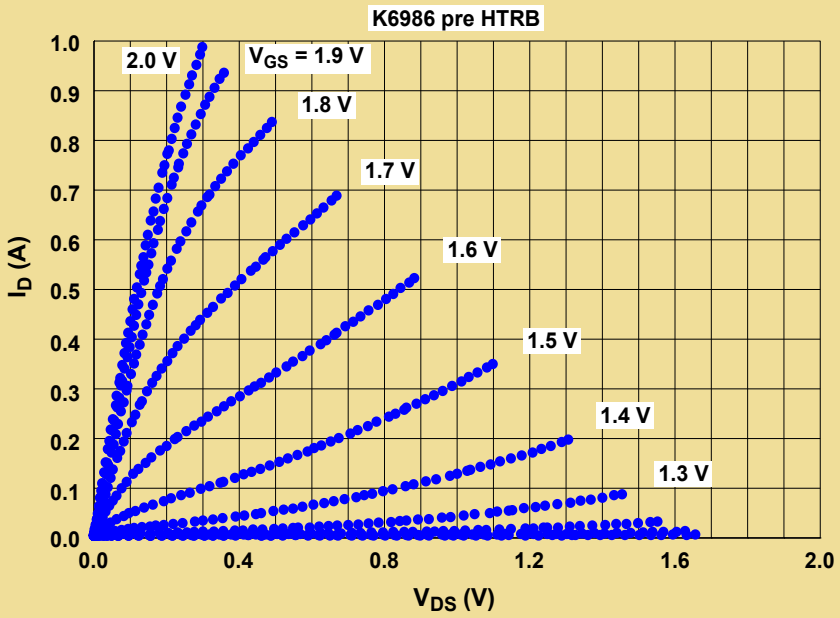
GATE-SOURCE FORWARD LEAKAGE

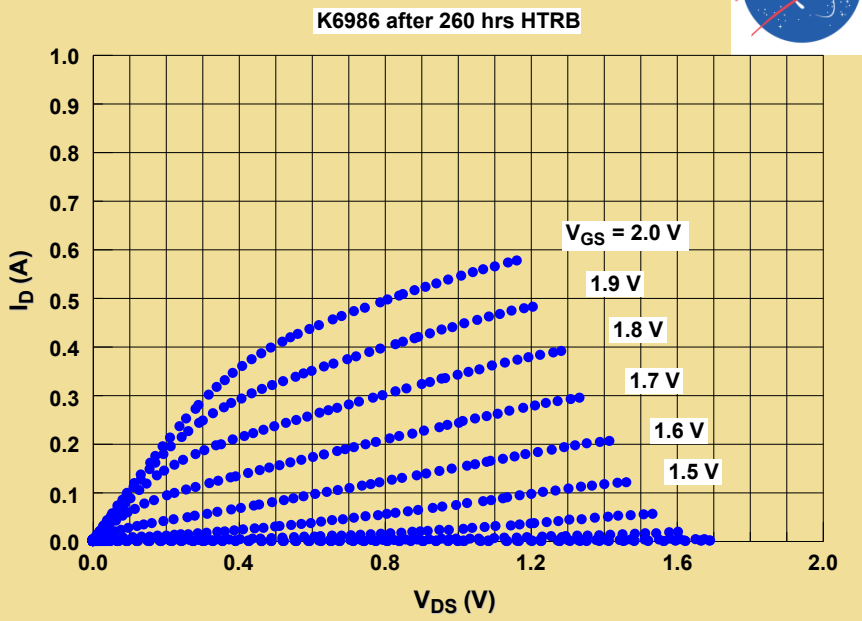


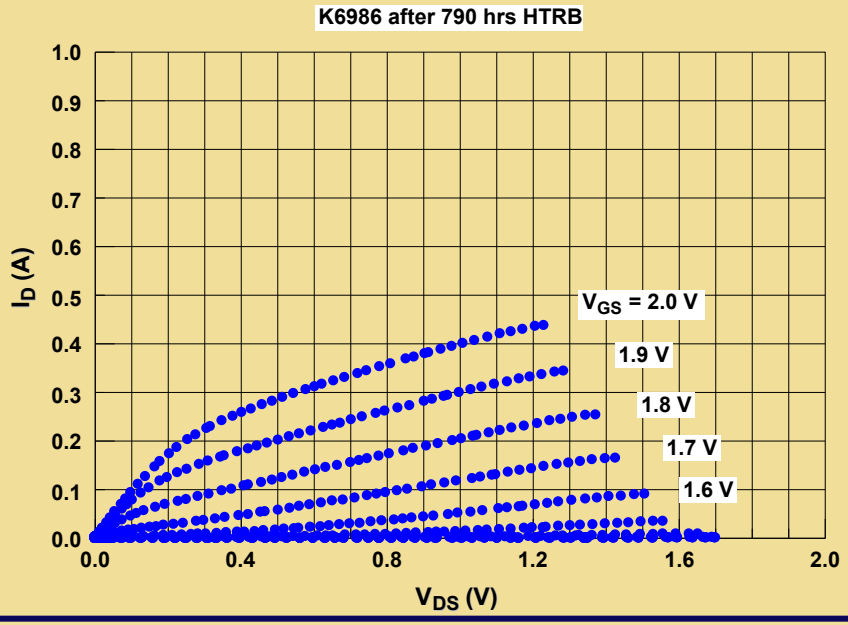
GATE-SOURCE REVERSE LEAKAGE

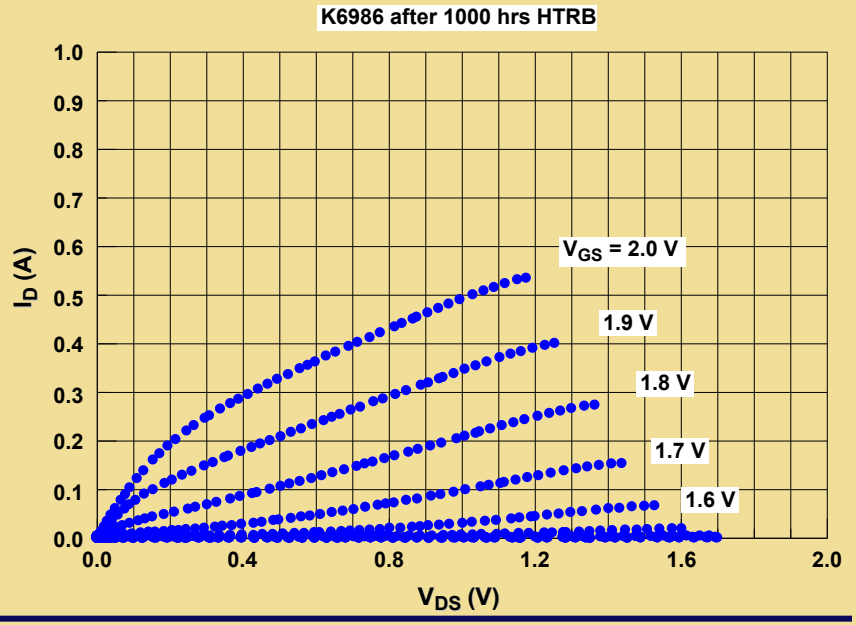


I-V Curves for K6986 (Control)

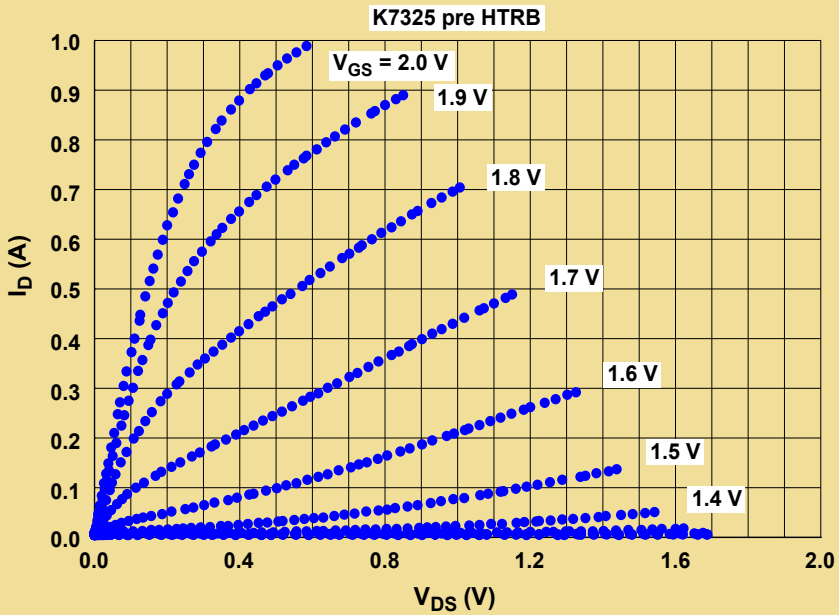


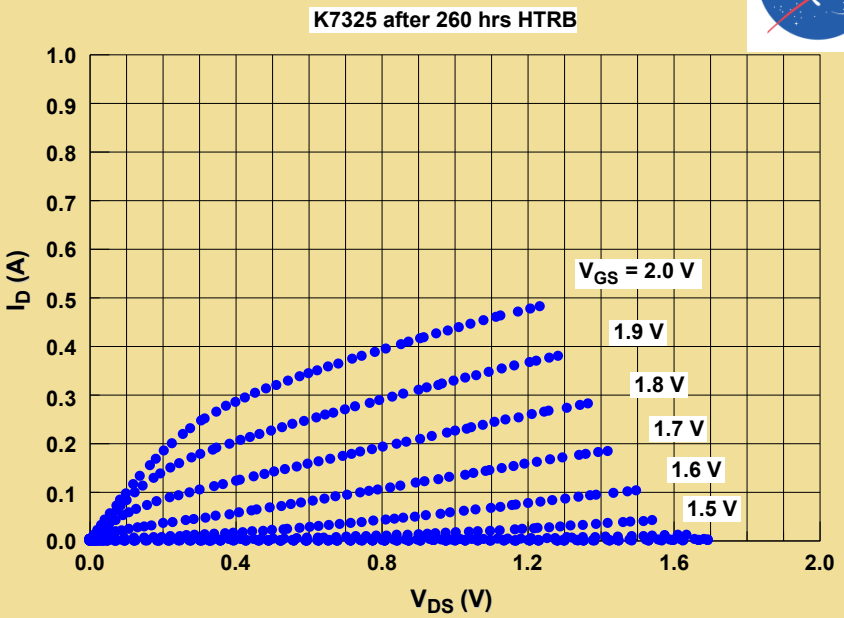


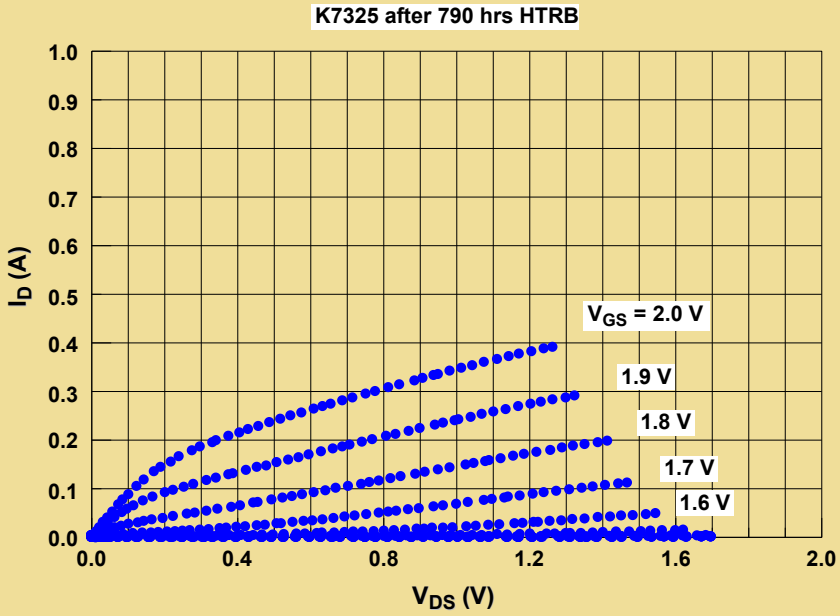


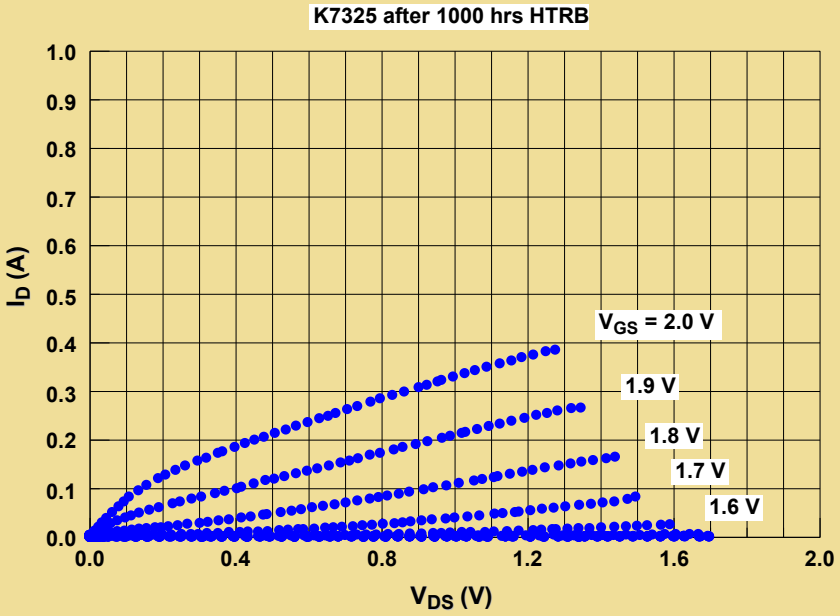


I-V Curves for K7325 (Irradiated)









OBSERVATIONS

- HTRB testing did not cause any catastrophic failure or major degradation in performance of any of the control or irradiated EPC2014 GaN transistors
- The only noticeable effect was reflected by an initial slight increase in the threshold voltage; followed by stability with further stressing
  - Trend was similar for both, control and irradiated, parts
  - This effect was evident by the downward shift in the I-V curves of the devices
- HTRB had no significant effect on either the drain or the gate leakage currents
- No alteration was observed in device packaging or terminations

Planned Work

- Perform multi-stress tests on control & irradiated GaN devices
- High Temperature Gate Bias (HTGB) Test
  - Bias: 80 % rated V_{GS}, V_{DS} = 0 V
- Power Cycling
  - Static (Gate DC voltage)
  - Dynamic (Gate AC voltage)

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