GaN In-Circuit Reliability:
Dynamic Life Testing of 650V GaN FETs

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Bodo‘s Wide Bandgap Event 2025

Making WBG Designs Happen

GaN

Types of Reliability Stress Tests

Test to Failure

Objective:

Characterize failure behavior, e.g. determine

- Acceleration Factors
- Activation Energies
- Correlate stress to failure mode

- Tests can exceed datasheet limits

- Traditional, electrically static tests
  - Voltage Off State
  - High Current On State
  - Temperature Cycle
  - Power Cycle

- Dynamic electrical switching tests
  - high current / high voltage

- Simple test vehicle (test circuit)

Test to Pass

Objective:

Validate performance in stringent, but realistic use,

a) discover new failure modes or
b) confirm that there are no undiscovered failure modes

- Testing within datasheet limits

- Dynamic switching tests should cover all different application switching use cases

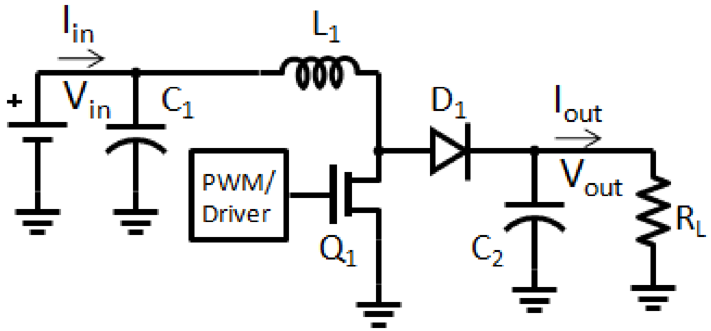
- Failure is determined by key device parameter measurement
  - in-situ during stress or
  - Pre- and post stress

- More complex test vehicle (system/application circuit)

No single test tells the whole story

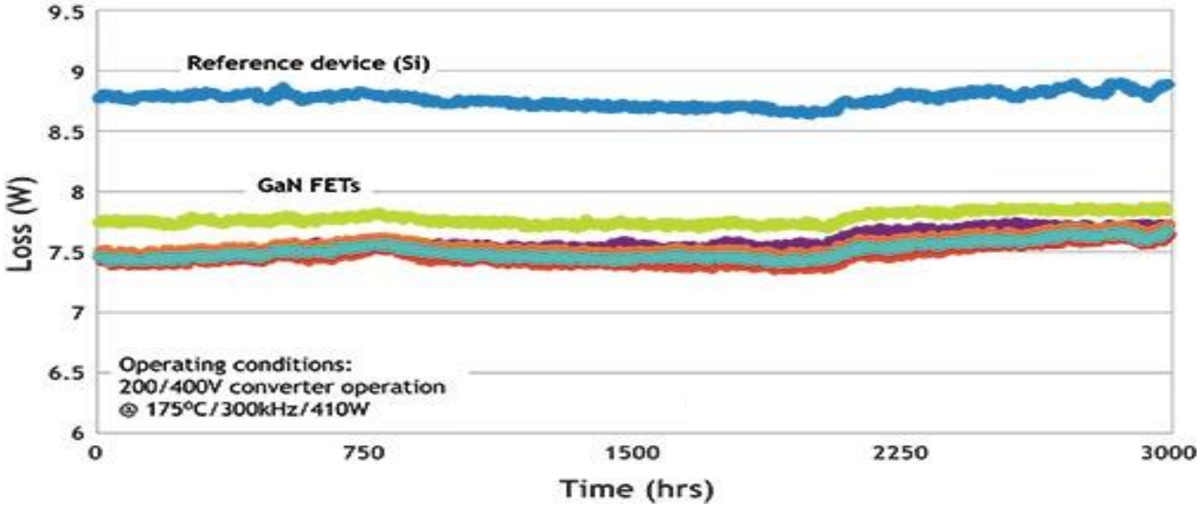
High Temperature Operating Life Data Shows Excellent Stability

Previous HTOL test:

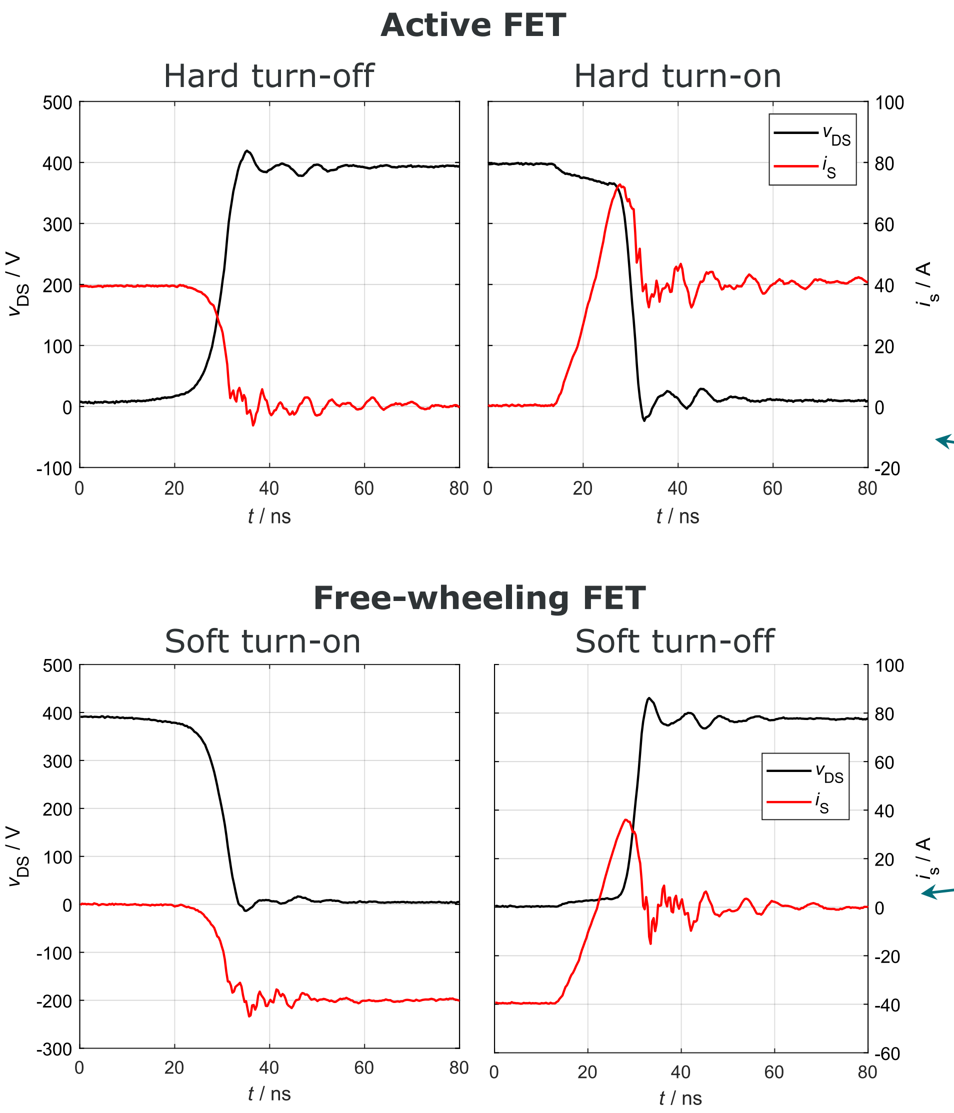


- Boost converter: 200V → 400V
- Operating frequency: 300kHz
- Output power: 410W

T_j = 175°C
Test Time = 3000 hours



Hard and Soft Switching: Both are relevant for GaN



Basic Half-Bridge in continuous-conduction mode.

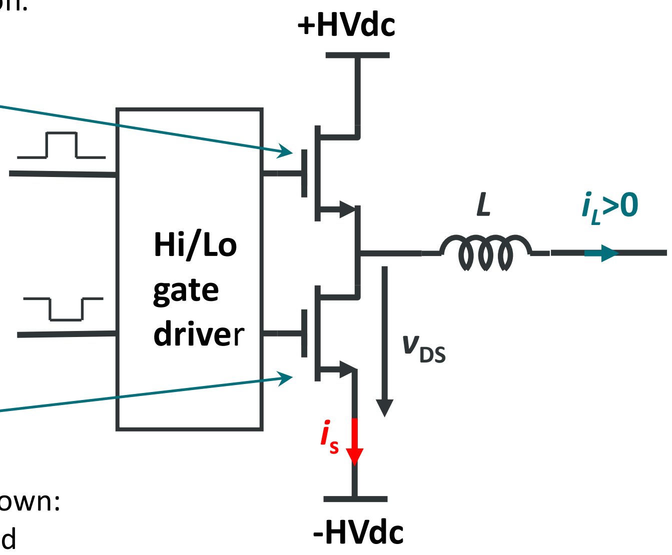
Could be part of a

- Totem-Pole PFC or
- an inverter, or
- a bidirectional DC/AC, or

For these topologies the current changes direction during every AC cycle.

- a simple buck or boost

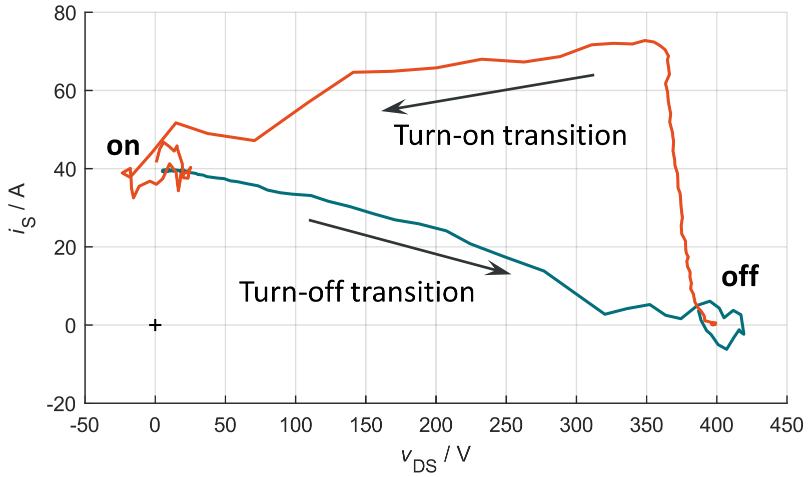
For load current in direction shown:
HS FET with hard turn-on and turn-off.



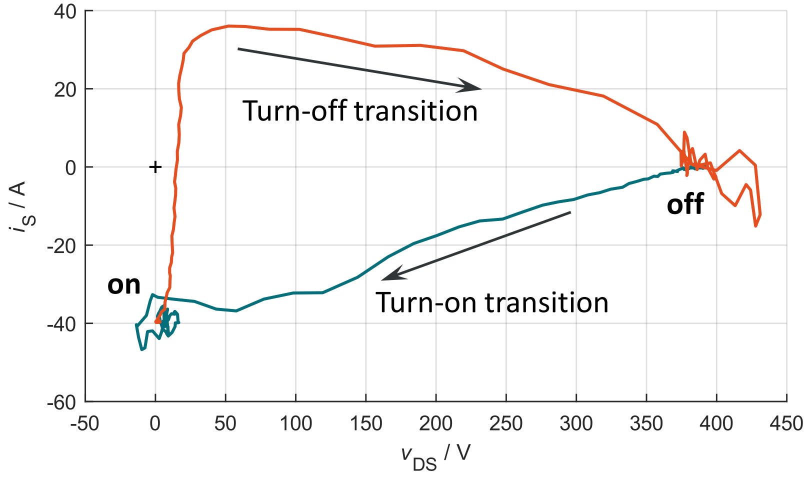
For load current in direction shown:
LS FET with soft ZVS turn-on and turn-off.

Hard and Soft Switching: Both are relevant for GaN

Active FET, i_D vs v_{DS} locus



Free-wheeling FET , i_D vs v_{DS} locus



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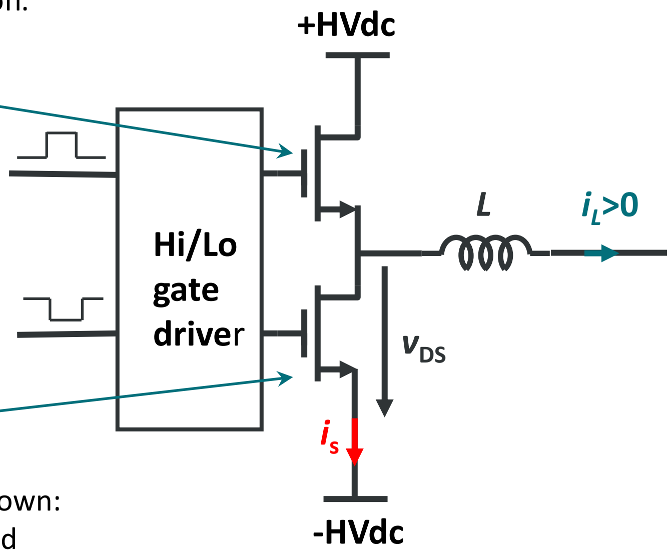
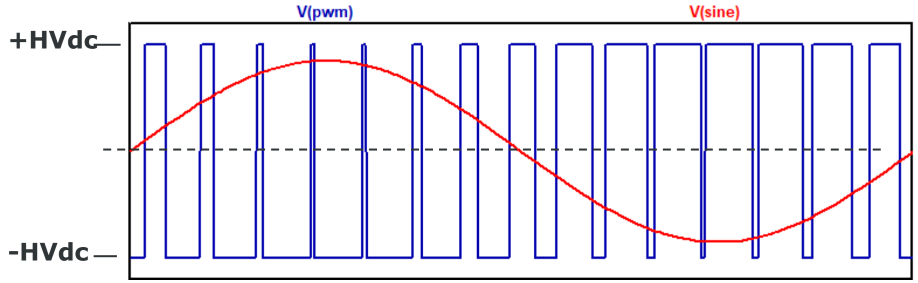


For load current in direction shown:
LS FET with soft ZVS turn-on and turn-off.

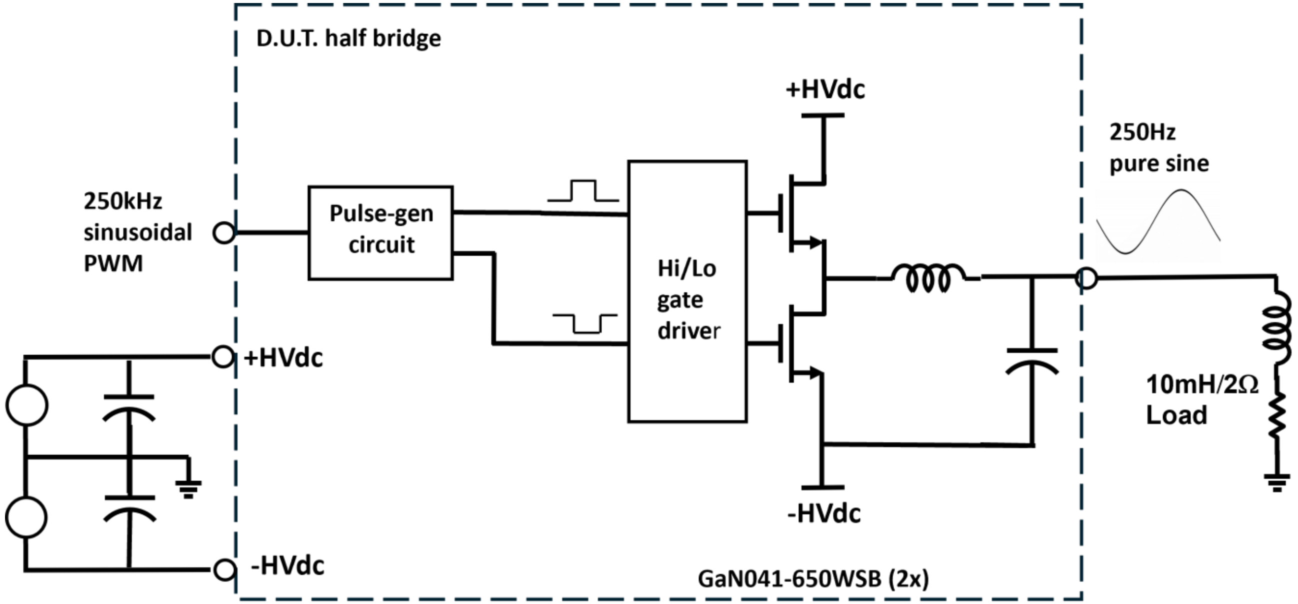
Test Vehicle for Operating-Life Test

DC/AC Converter

- Sweep the GaN FETs through a continually varying range of operating points at high supply voltage.



- PWM Switching frequency = 250kHz
- Each FET experiences all the switching modes:
  - Hard and soft turn-on and turn-off,
  - 125k events per second of each
- Sinewave frequency = 250Hz:
  - Note grounded reactive load – minimizes real power
  - Higher fundamental frequency (>50Hz) permits smaller load



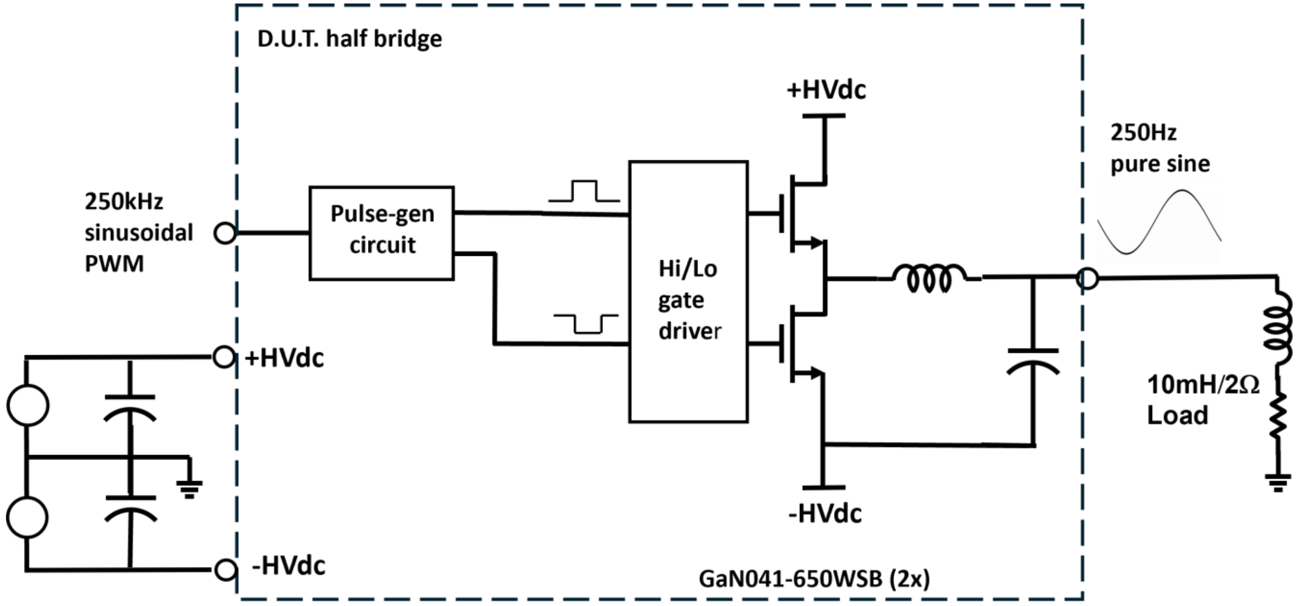
Test Vehicle for Operating-Life Test

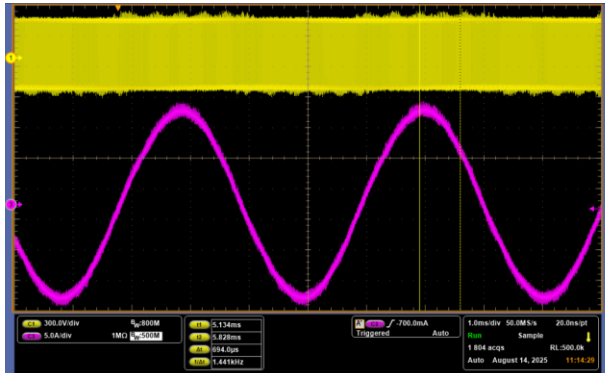
DC/AC Converter

Additional details:

- An array of DC/AC converters* operating continuously
- DC bus at 80% or 100% rated voltage (520V or 650V)
- Grounded inductive load for minimized real power consumption
  → DC power source only supplies the losses.
- Temperature, Input/Output Voltage and current are monitored for each half bridge for detection of R_{ds} drift or other failures.

- Open-loop operation: simple and robust
- Load current can be changed by either changing the fundamental frequency of the output or the modulation index of the sinusoidal PWM command.



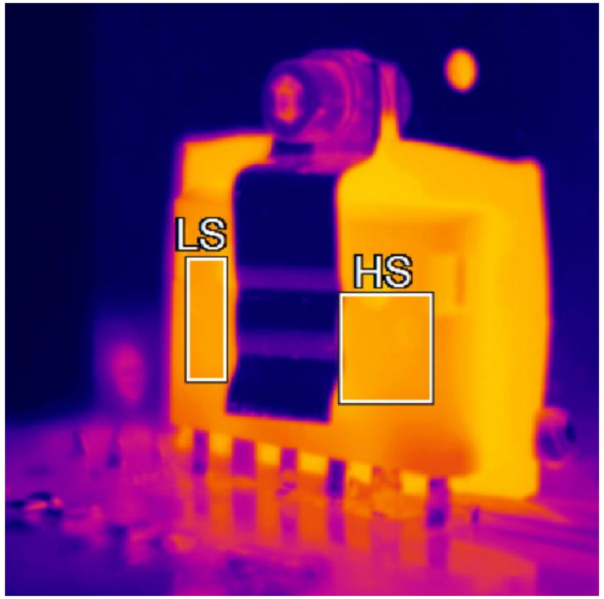


* For example, 18 half-bridges, with devices from 3 lots.

What About Temperature?

Doesn’t *HT* in *DHTOL* mean High Temperature?

- High Temperature is normally assumed to be a worst-case stress in electronics.
- Until activation energies are determined and correlated to failure modes, neither temperature extreme should be assumed to be the worst stress.
- Operation at realistic temperatures achieved by self heating is a reasonable starting point. In this test, $T_c \approx 90°C$
- Temperature sensors monitor heatsink temperatures to assure the operating condition is stable.
- Regulated heaters can be used in place of heatsinks on the half-bridge boards to achieve controlled high-temperature, if desired.



Test results, 650V 35mΩ cascode GaN FETs

Summary of DC-AC Operating Life Test, 520V Trial							
Trial ID	**Status**	**V_{DC}**	**Output load current**	**Frequency**	**Sample size**	**Test time completed**	**Results after 1000h:**
A	Completed	520V	7A RMS	250 kHz PWM	6	1000 h	• No fails, all DUTs operational • No significant shifts in V_{th}, $R_{ds(on)}$ and I_{dss}
B					12		
C					12		

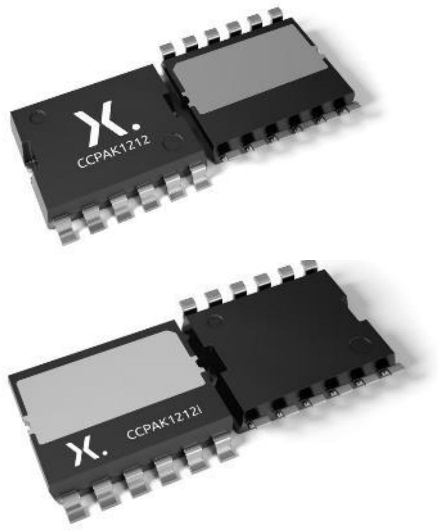
Post trial measurements:

→ v_{th} shift of <0.5%

→ I_{dss} increase <5%

→ $R_{DS(on)}$ within datasheet limits, <10% shift for 28/30 samples

Cascode GaN FETs used in this study



Product type	Package	V_{DS} max (V)	$R_{DS(on)}$ max @ V_{GS} = 10 V (mΩ)	T_j max (°C)	I_D max (A)	Q_{OSS} (nC)
GAN039-650NBB	CCPAK1212	650	39	150	58.5	173
GAN039-650NTB	CCPAK1212i	650	39	150	58.5	173

Product type	Package	V_{DS} max (V)	$R_{DS(on)}$ max @ V_{GS} = 10 V (mΩ)	T_j max (°C)	I_D max (A)	Q_{OSS} (nC)
GAN063-650WSA	TO-247	650	60	175	34.5	125
GAN041-650WSB	TO-247	650	41	175	47.2	150
GAN111-650WSB	TO-247	650	114	175	21	65

Thank you for your attention!

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