Solid-State Circuit Protection: B-TRAN® Enabling Next-Gen AC/DC Distribution Systems

Bhuwenesh Gupta
Applications Engineering Manager
Ideal Power Inc.
Phone: +1 737-251-8907
bhuwenesh.gupta@idealpower.com

Ideal Power

Solid State DC Grid Protection is No Longer Optional

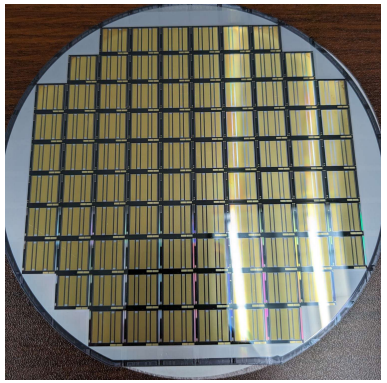
- Data centers moving toward 400V/800V DC distribution
- EV battery systems scaling to 800V with higher fault energy
- BESS scaling to 1500V with critical protection requirements
- DC microgrids and DC networks [for example in marine, railways, aerospace] require fast isolation
- **Mechanical interruption times (2–10 ms) are incompatible with 800V DC fault energy scaling**

Next-Generation Breakers Must Deliver These 4 Things

- **Fast fault interruption** enabling branch level selective isolation to minimize disruption and improve resilience specially in DC microgrid systems
- **Controlled switching** to mitigate transients in converter-driven grids
- **Deterministic switching timing** to support protection coordination, prevent bus sag and transients' propagation, to ensure power quality
- **Durable operation** enabled by eliminating mechanical contact wear mechanisms by reducing arcing risk

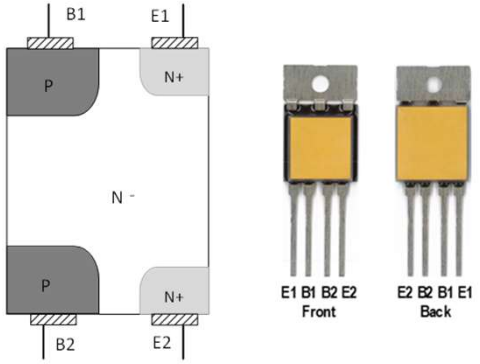
B-TRAN® – A New Class of Power Switch

- B-TRAN® is a proprietary bidirectional semiconductor power switch
  - Novel, disruptive design
  - Fabrication on both sides of wafers
  - Leverage same B-TRAN® die across many applications



B-TRAN© prototype silicon die

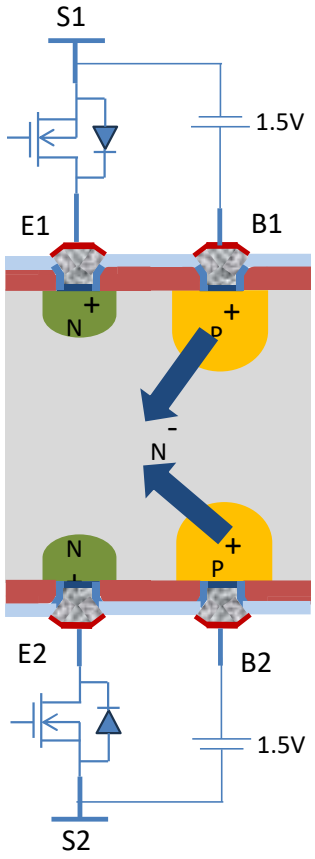
- B-TRAN® architecture has 3 compelling advantages
  - Bidirectional switching supports new intelligent power distribution and control systems
  - Lower conduction losses result in improved power efficiency that translates to lower end-user costs
  - Enables smaller, lower cost system solutions



B-TRAN® architecture in silicon with symmetrical structure

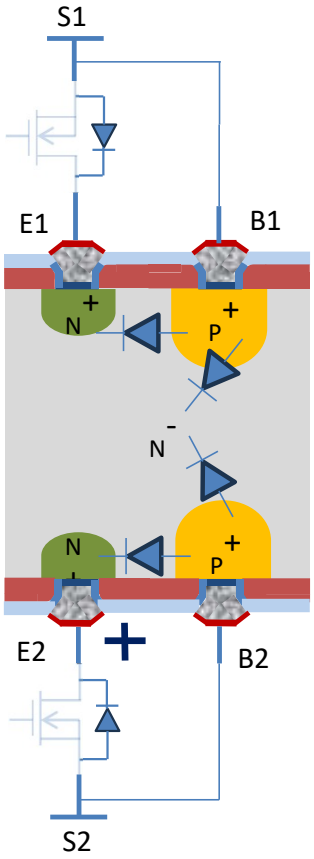
B-TRAN® unlocks true bidirectional switching across multiple large, high-growth emerging applications.

B-TRAN® Bidirectional Switching Operation

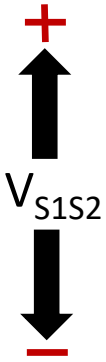


Turn ON
Turn ON cascode FETs and drive current in B1/B2. For bidirectional operation, drive both.

Turn-ON Mode



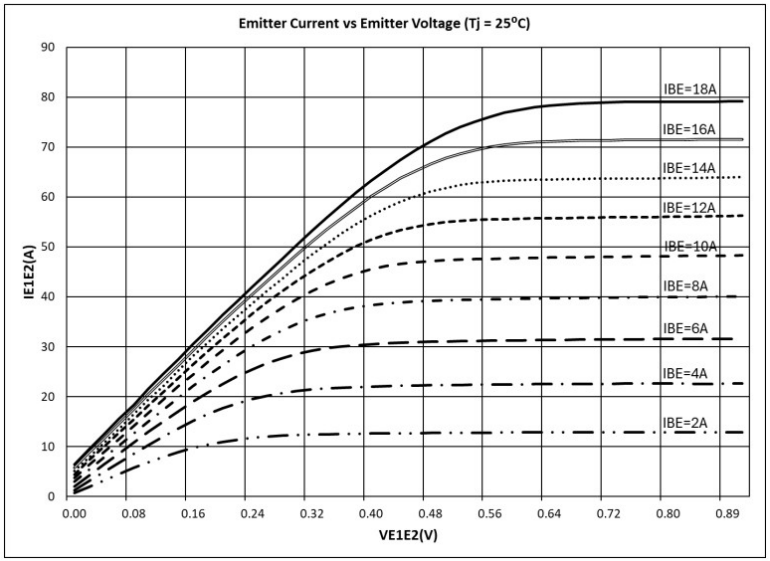
Turn OFF
Short B1 and B2 to S1 and S2. Open cascode FETs



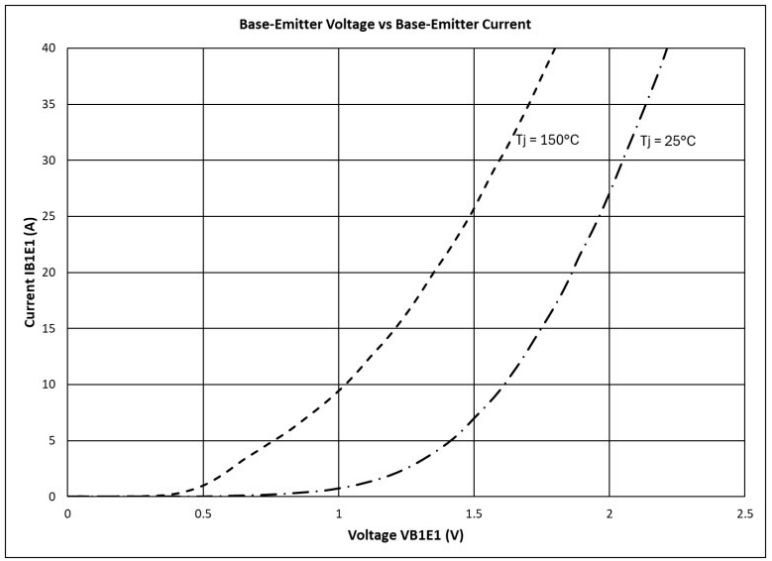
Turn-OFF Mode

B-TRAN® Performance Characterization

- **Ultra-Low VE1E2ON = 0.4V @50A**
- Easy to implement overcurrent protection due to saturation current.
- Positive temperature coefficient to enable paralleling of multiple devices



Output Characteristics

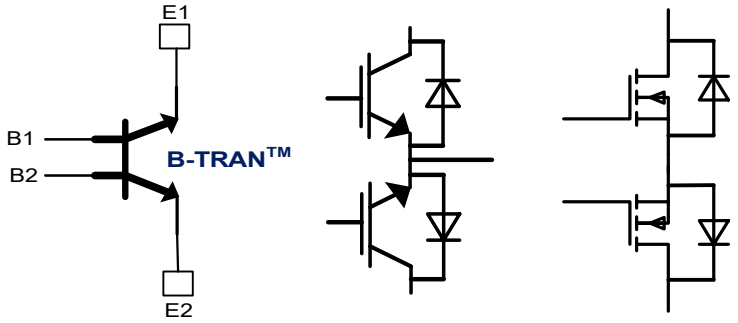


Driving Characteristics

The Bidirectional Switch Penalty in Today's SSCBs

- Most solid state devices are inherently unidirectional and lossy
- Bidirectional interruption requires back-to-back stacks

- This means **DOUBLE**:
  - conduction loss
  - thermal load
  - driver complexity
  - cost and volume

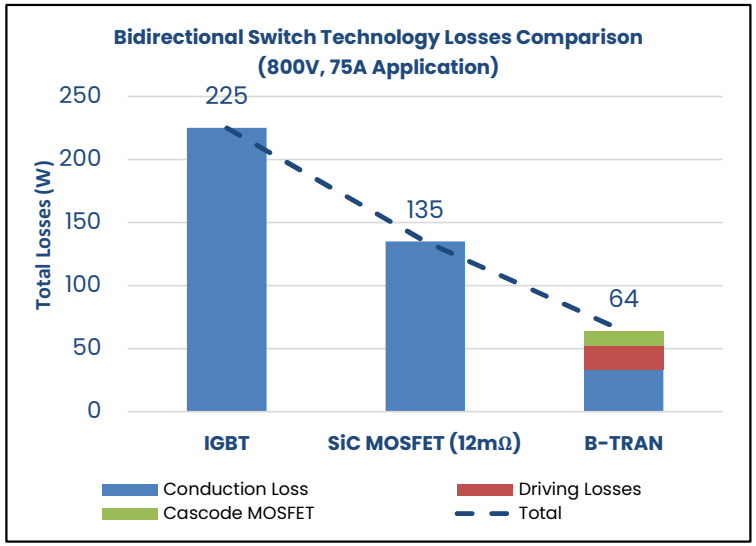


B-TRAN® IGBT SiC Mosfet

- B-TRAN® overcomes existing adoption barriers for SSCB applications

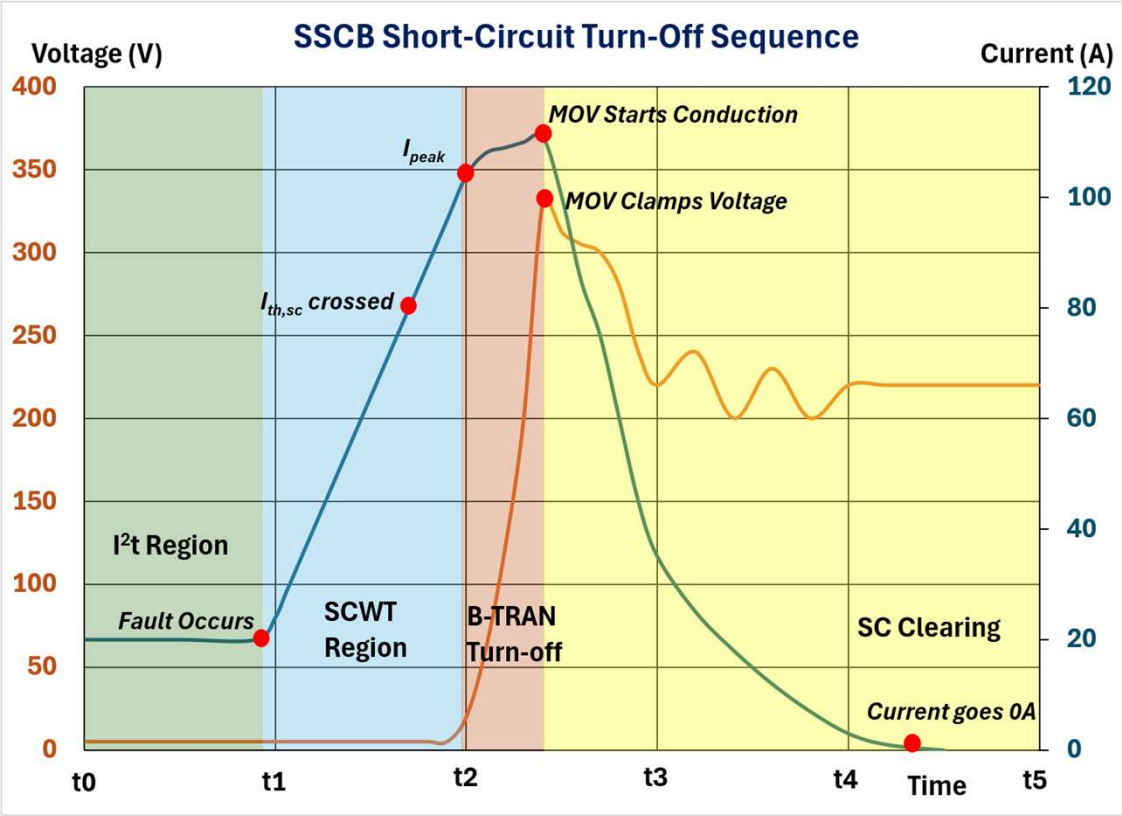
B-TRAN® Competitive Advantage in Bidirectional Power

- B-TRAN® replaces 4 conventional power devices in a bidirectional switch
- B-TRAN® can reduce total losses by more than 2x compared to a SiC MOSFET solution while reducing the system cost by up to 4x



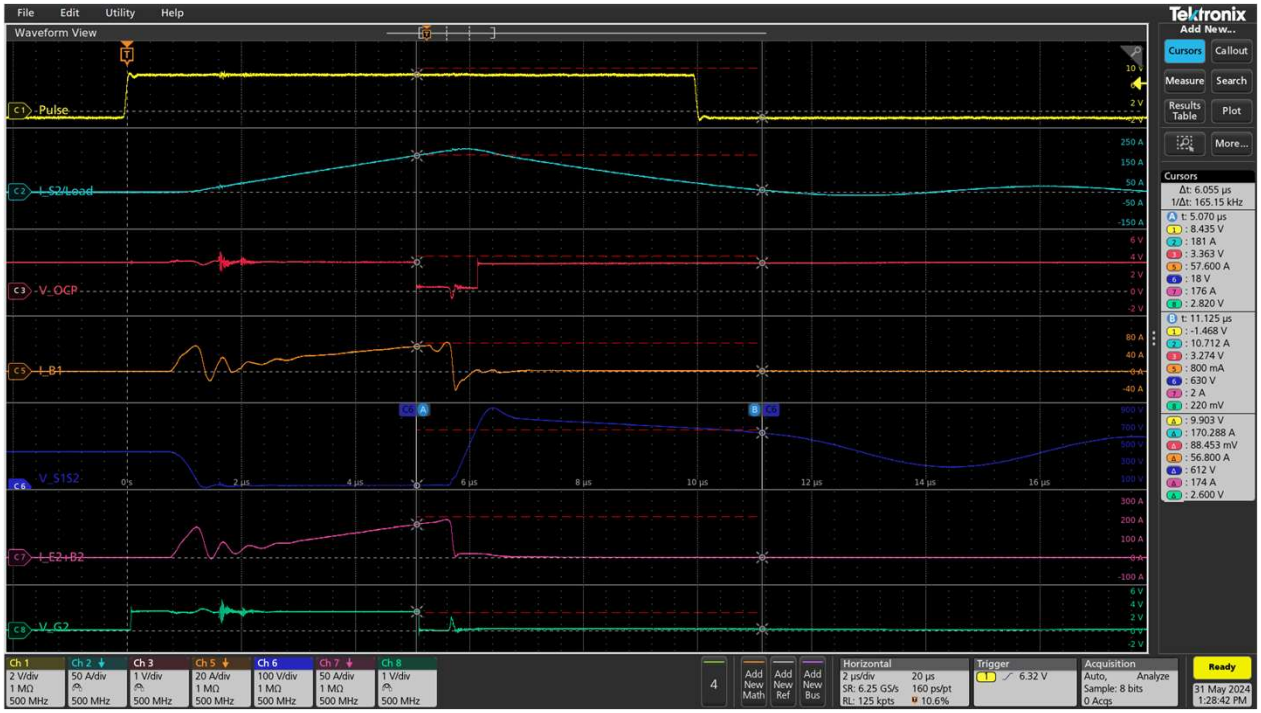
Evaluation Metric	B-TRAN®	SiC MOSFET	SiC JFET	IGBT
Steady-state conduction loss	Excellent	Good	Very good	Fair
Intrinsic bidirectional blocking and conduction	Yes	No	No	No
Switching device count for bidirectional operation	1	4	4	≥4
Gate-drive and control complexity	Moderate	Moderate	Moderate	Low
Short circuit protection	Excellent	Good	Good	Good
Packaging and thermal simplicity	Good	Moderate	Moderate	Moderate
System-level semiconductor cost	Low	Moderate	High	Low

Short-Circuit Protection : Envelope-Based Approach, Not a Single Number



- Fault current rise depends on system inductance (di/dt)
- Interruption is defined by:
  - detection time
  - commanded turn-off
  - energy managed by clamp/snubber network

SSCB Application: Fast Fault Interruption



- Short circuit detection to cascode shutoff: **45 ns**
- Current begins to fall: **<1 µs**
- Fault cleared: **~6 µs**
- Demonstrated on **400V / 181A** platform, **di/dt = 50A/µs**
- Confirms interruptibility with fast detection + controlled turn-off

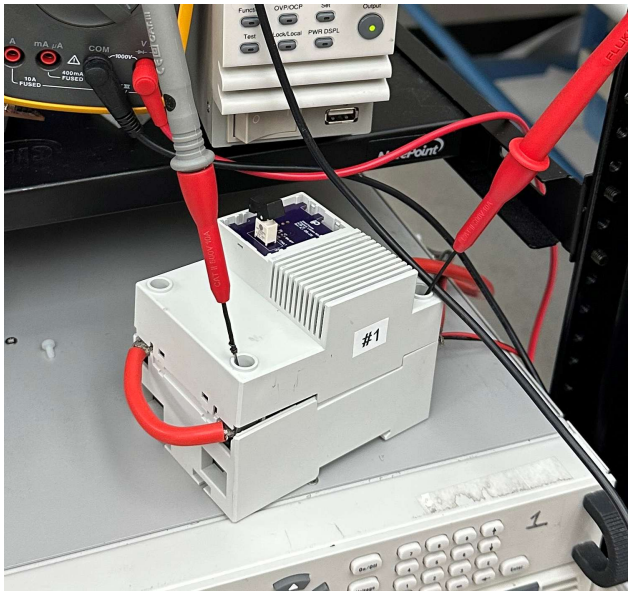
Industry Case Study – SSCB

Same Footprint. Delivered 2x Voltage, 4x Current AND Made it Bidirectional

- A market leader in the circuit breaker industry provided a SSCB implemented with SiC MOSFET technology. It was rated at 400V, 20A and operated only unidirectionally

- **Ideal Power modified the design using the same physical form factor with B-TRAN®. The result was a SSCB rated at 800V / 80A which operates bidirectionally**

IPWR SSCB Reference Design



Customer SSCB

Evaluation Hardware Available Now – and Scaling

- SSCB reference design kits rated for **400V, 40A ships today**
- Work in process for:
  - Higher DC current **400V-120A/800V-120A** SSCB reference design kit
  - 3 Phase AC rated **480V-120A** SSCB reference design kit
  - High Voltage DC **1500V, 40A** SSCB reference design kit

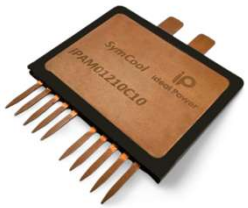
Production-Ready Devices and a Growing Patent Estate

B-TRAN® Discrete

- TO-264 packaged device rated at 1200V/75A
- Single die with double-sided cooling package
- Tested up to 150A

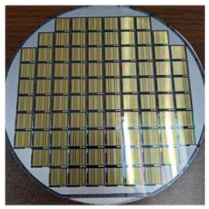
SymCool®

- Multi-die module rated at 1200V/200A
- Simplifies system design where multiple B-TRANs are used
- Tested up to 430A



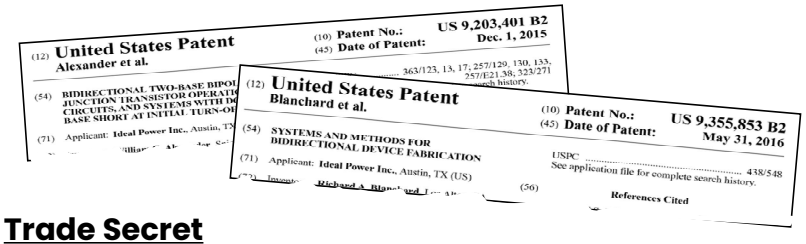
B-TRAN® Die

- Known Good Die (KGD)
- Designed for power module makers and OEM custom packaging
- Rated at 1200V/75A, tested up to 150A



Patent Coverage

- B-TRAN® device architecture and packaging
- Control methodologies and techniques
- Double-sided device manufacturing techniques
- Applications specific uses of B-TRAN®



Trade Secret

- Proprietary process flow for B-TRAN® fabrication

Region	Issued Patents	Pending Patents
United States	52	17
Foreign	48	61
TOTAL	**100**	**78**

Bhuwenesh Gupta
Applications Engineering Manager
Ideal Power Inc.
Phone: +1 737-251-8907
bhuwenesh.gupta@idealpower.com

Presentation Number IS27.2 from APEC Program