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US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

A Bipolar Current Actuated Gate Driver for JFET Based Bidirectional Scalable Solid-State Circuit Breakers

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Inventor: Mr. Damian Urciuoli

Technology Overview

The invention can improve high speed bi-directional fault protection in a broad range of power conversion and distribution systems such as hybrid vehicle drives and renewable energy systems.

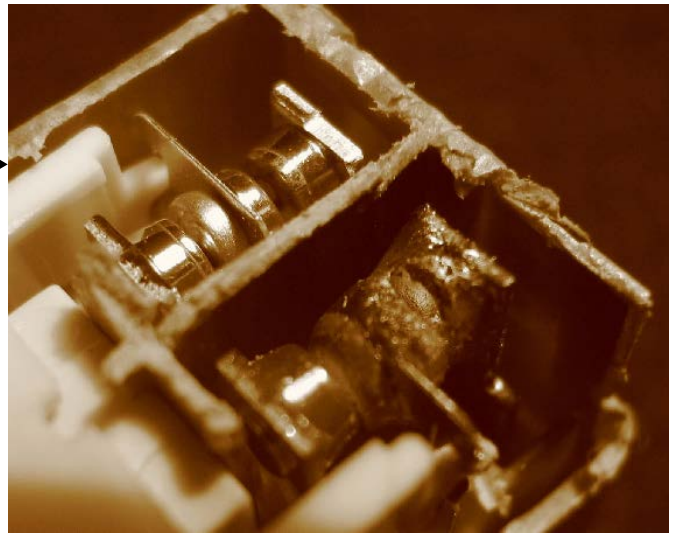
This gate driver enables bidirectional over-current protection to prevent system damage and destructive failure. Key features/benefits include:

- Controls normally–ON scalable bidirectional solid-state circuit breakers (BDSSCBs)
- Fast acting: actuates in approximately 2 µs
- Provides over-current protection, automatically compensating for temperature changes
- Responds to external sensor triggering, in addition to internal triggering
- Ultra low power consumption in the BDSSCB ON-state
- Has been demonstrated using very normally-ON 1.2-kV, 10-A silicon carbide (SiC)JFETs
- A robust addition to a battery pack providing protection during charge, discharge, and servicing.

Technology Differentiation

Mechanical Fault Protection

- Actuation times: 10 to 100 of milliseconds
- Low number of high energy fault events
- Suffer contact degradation



+ Low conduction and switching losses (heat)
+ Provides bi-directional isolation

vs.

Bi-directional solid-state fault protection

+ Actuation times <u>with</u> voltage suppression: 10 to 100 of microseconds, **10^3 faster**
+ Endures large number of high energy fault events
+ Ultra low degradation = high reliability and longevity
    - Conduction and switching losses (clearly manageable)
+ Controls bi-directional fault isolation

Pros:	+
Cons:	-

Technology Advantages

Key advantages of this fault protection

vs. generic solid-state

- Solid-state bidirectional protection for both DC and AC operation
- Normally-ON fault tolerant protection with no voltage to hold the ON-state
- SiC JFET is manufacturable and mature (inexpensive in production)
- Scalable design
- Very low driver cost
- Temperature compensated over-current protection

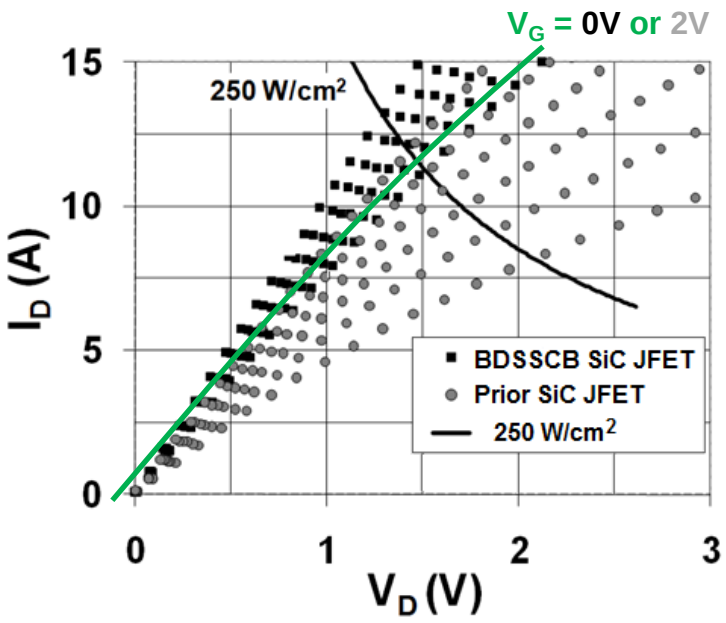
Technology Proof of Concept

Normally-ON is the desired default state:

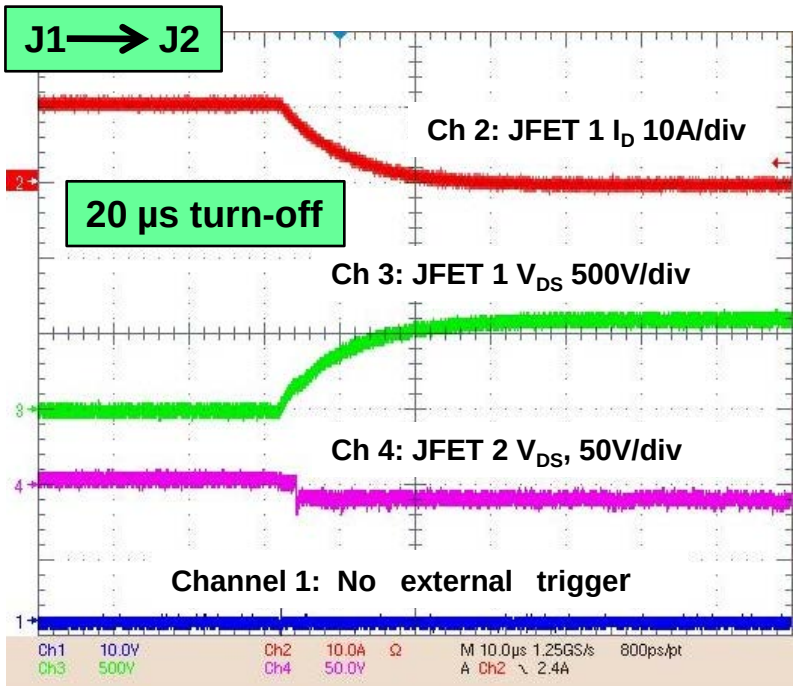
The (Junction Field Effect Transistor) JFET is a **normally-ON*, bi-directionally conducting**, **uni-directionally voltage blocking** semiconductor device. It provides more fault tolerant fault protection; high speed actuation (microsecond vs. millisecond); allows temperature compensated over-current protection; and improved reliability.

*** Not all JFETs are normally-ON**

Positive gate bias can improve conduction . . .or. . . **JFETs can be designed for zero-volt bias (very normally-ON)**



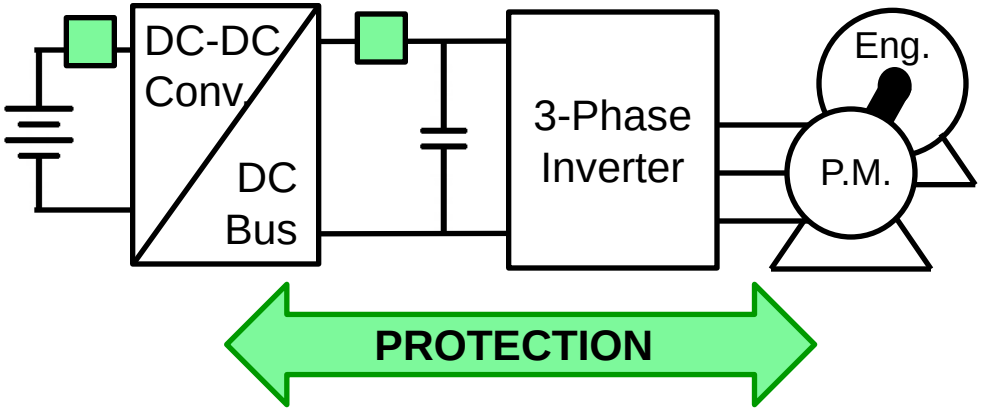
600 V, 10 A turn-off waveforms (10 µs per division)



Military Applications

BDSSCB is especially applicable to:

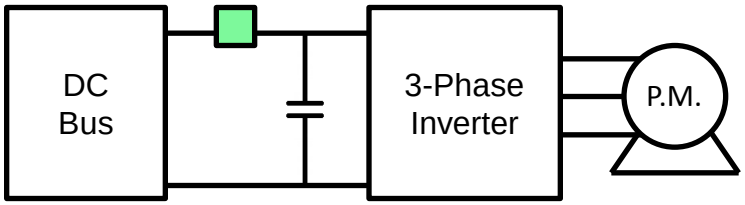
- Hybrid electric vehicle power systems
- Electrical energy storage systems having bidirectional power flow
- Military tactical and combat ground vehicles and aircraft where fault protection is critical for mobility and survivability.

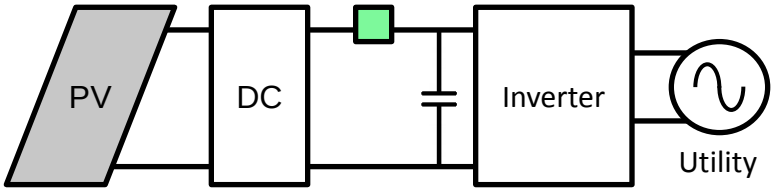


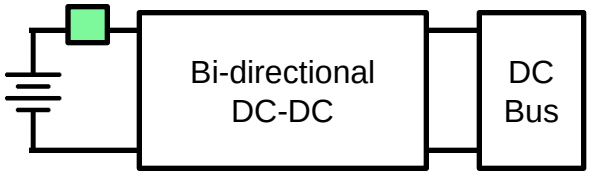
Commercial Applications

BDSSCB applications: DC or AC

- Hybrid electric vehicle systems
- Grid-tie renewable energy inverter systems
- Bidirectional DC-DC converters
- Charge and discharge of energy storage systems
- Regenerative power (brakes, elevators, etc.)







Technology Agreements

A patent license and CRADA is sought.

The current technology is TRL-5 and will benefit from a collaboration between the inventor team and the commercialization partner in order to speed the development to the market. This would most readily be done through a patent license agreement and CRADA.

A patent application has been filed.