

Enable better reliability in HEVs and EVs with best-in-class isolation technology

Solid-state relays (SSRs)

Alex Triano

Where are isolated switches used in EVs?

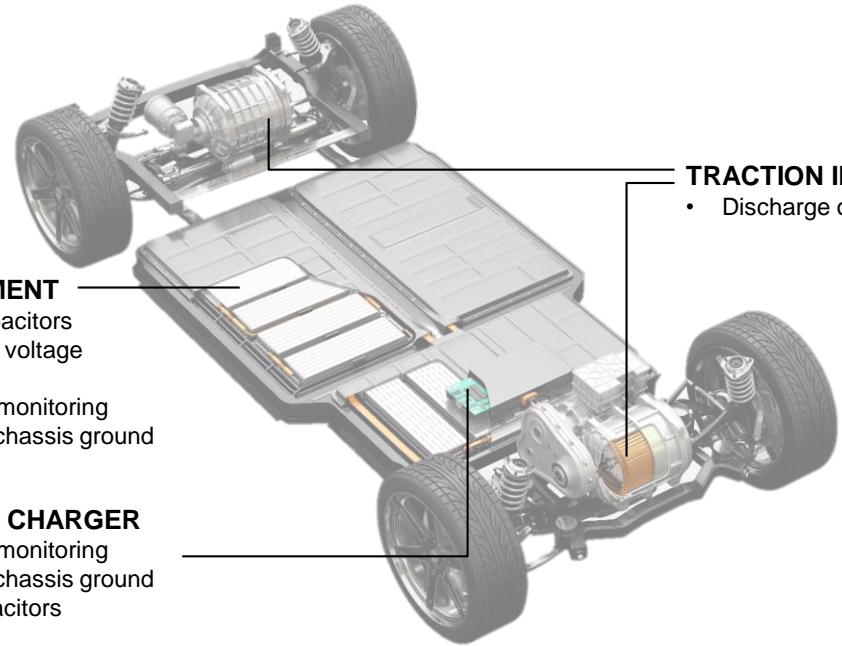
Trend towards 800-V and higher battery packs are increasing the need for isolated switches throughout the vehicle.

BATTERY MANAGEMENT

- Pre-charge of HV capacitors
- Battery pack and port voltage monitoring
- Insulation resistance monitoring between HV rail and chassis ground

DC/DC & ON-BOARD CHARGER

- Insulation resistance monitoring between HV rail and chassis ground
- Discharge of HV capacitors



TRACTION INVERTER

- Discharge of HV capacitors

What isolation technologies are available?

	Electromechanical relay	Photo / Optical	Inductive transformer	Capacitive isolation
Insulation material	Air, gas, or Epoxy	Epoxy or Polyimide	Laminate or Polyimide	Silicon dioxide (SiO ₂)
Dielectric strength (1sec)	~1 V _{RMS} / μm ~20 V _{RMS} / μm	~20 V _{RMS} / μm ~300 V _{RMS} / μm	~300 V _{RMS} / μm	~500 V _{RMS} / μm
Advantages	Low resistance High power transfer	Low-EMI emissions	High speed (μs) High power transfer	High speed (μs) Low power consumed
Disadvantages	Slow speed (ms) Mechanical wear, vibration/magnetic immunity	Photodegradation and partial discharge (PD) Limited power transfer	IC design to limit EMI	IC design to limit EMI Limited power transfer
Operating ambient temp.	-40C to 85C	-40C to 85C	-40 C to 125 C	-40 C to 125 C
Cost	\$\$\$	\$	\$	\$

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<p>TI's inductive and capacitive isolation technologies provide the highest dielectric strength at the fastest speed, highest operating temp, and lowest cost.</p>			-40 C to 125 C	-40 C to 125 C
			\$	\$

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<p>TI's isolated switches and drivers form a complete isolated solid-state relay solution. They offer increased reliability, with no wear over time.</p>			-40 C to 125 C	-40 C to 125 C
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Pre-charging high voltage capacitors

Problem

Failure to manage inrush current into high voltage capacitors can cause welding or pitting within a mechanical HV contactor.

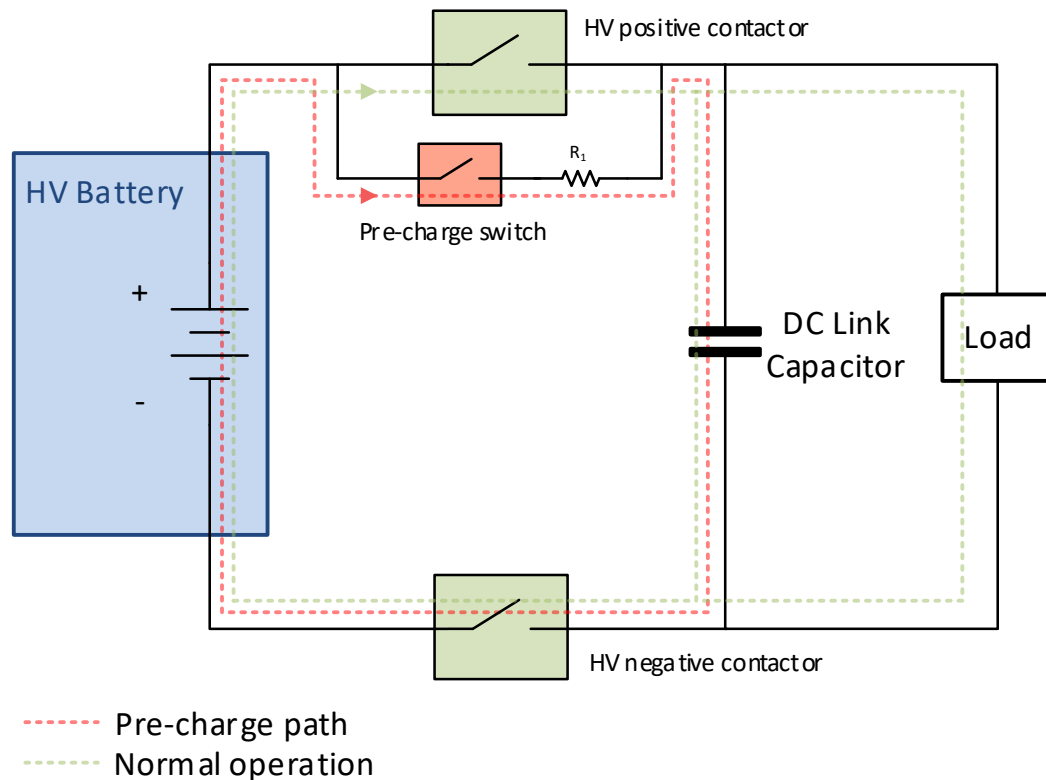
Solution

Pre-charge circuits are used along with a power resistor (R_1) in order to limit inrush current during startup.

TI's solid-state relays

[TPSI3050-Q1](#) & [TPSI3052-Q1](#): Isolated switch drivers

- 5kV_{RMS} reinforced isolation rating
- AEC-Q100 Grade 1 qualified up to +125C
- Integrated isolated bias supply
- Can drive SCRs, MOSFETs, IGBT, or SiC FETs to form a **solid-state relay** solution
- 10-V or 15-V gate voltage options
- Up to 80% smaller than a mechanical contactor



Active discharge

Problem

When the vehicle turns off or in the case of an emergency crash, need to discharge high voltage capacitors to a safe level within seconds.

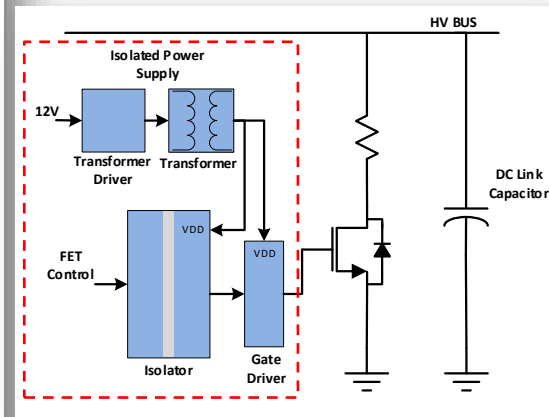
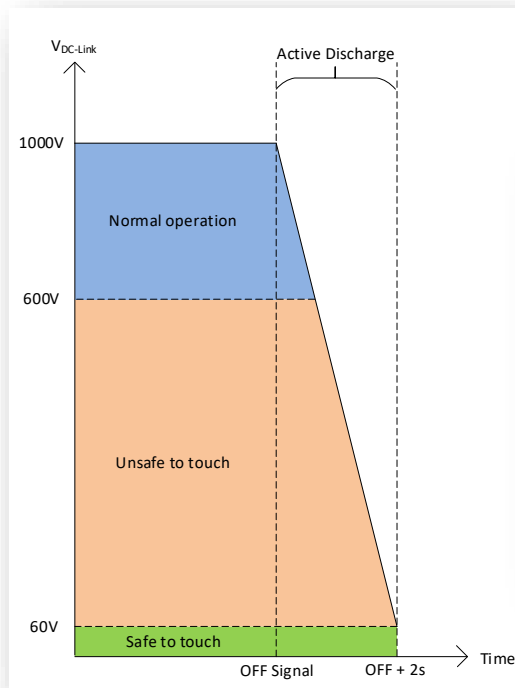
Solution

Solid-state relays can be used to connect and disconnect a high power pull-down resistor.

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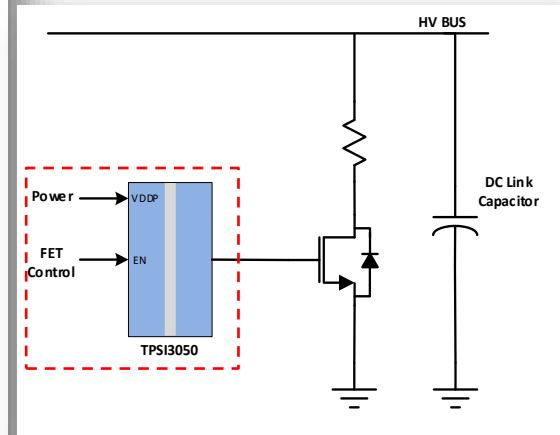
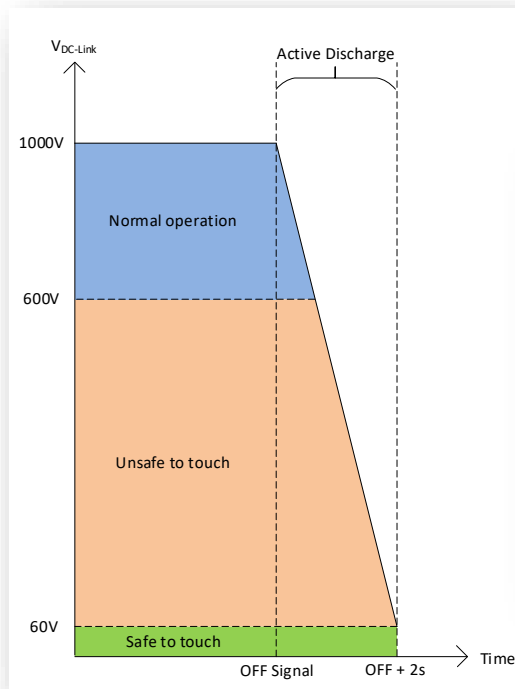
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Insulation resistance monitoring

Problem

HV battery terminals must be insulated from chassis to protect drivers and passengers.

Electric Vehicle Safety Standards (ISO 6469-3)

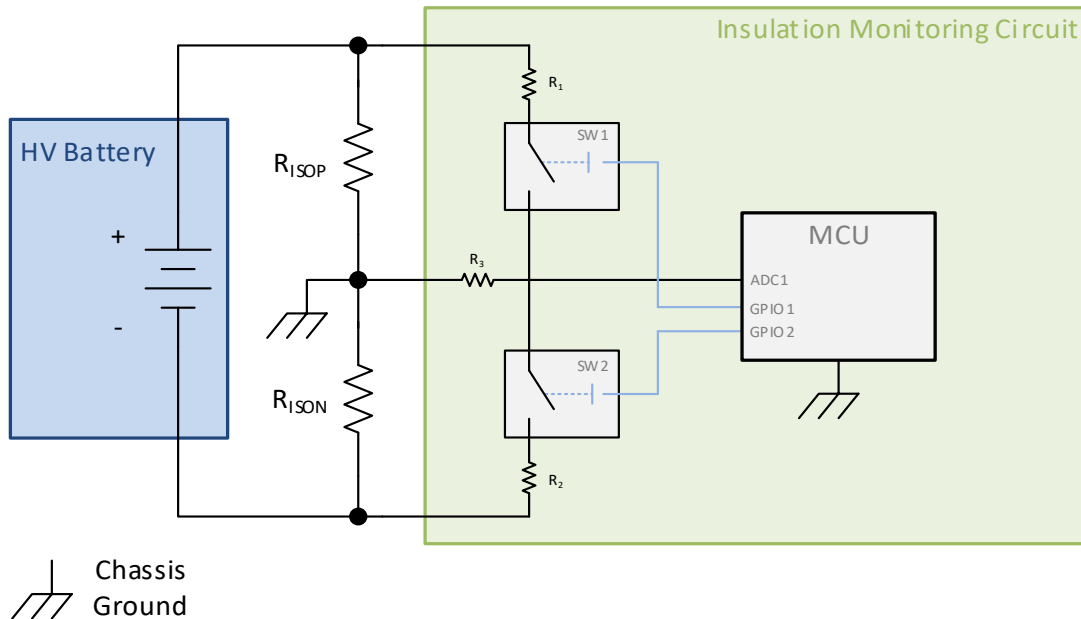
Solution

HV isolated switches (SW1-SW2) are used to connect known resistors (R_1 - R_3) and monitor the unknown insulation resistance (R_{ISOP} and R_{ISON})

TI's solid-state relays

TPSI2140-Q1: 1400-V, 50-mA isolated switch

- **Solid-state relay**, >26-year projected lifetime
- 3.75kV_{RMS} isolation rating
- AEC-Q100 Grade 1 qualified up to +125 C
- Suitable for 400-V or 800-V battery systems
- 2-mA avalanche capability survives hi-pot and surge tests without reed relay disconnect
- Enables use of <1Mohm HV resistors, leading to improved accuracy measurements



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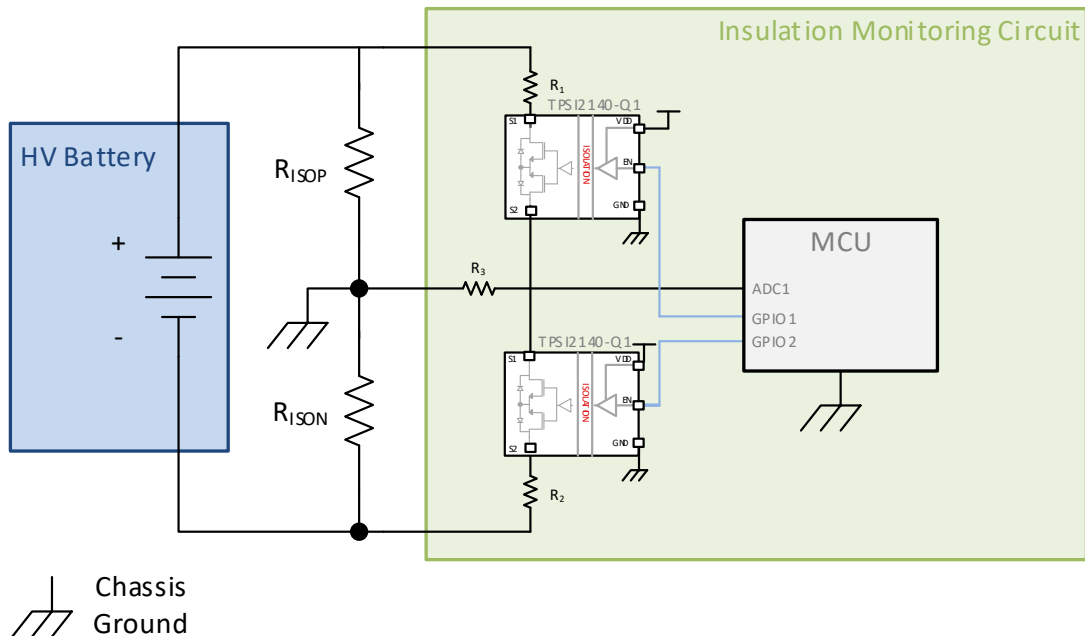
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Summary

- ✓ Isolated switches are used throughout EVs to solve problems including:
 - Pre-charging high voltage capacitors
 - Active discharge
 - Insulation resistance monitoring

- ✓ TI's new portfolio of solid-state relays use inductive and capacitive isolation
 - Highest dielectric-strength materials helps reduce solution size and cost.
 - Qualified up to AEC-Q100 grade 1, +125 C.
 - Robust isolation barrier with >26 year projected lifetime.
 - Size, reliability, and cost advantages over mechanical relay and photo/optical technologies.

Learn more at ti.com/SSR