Application Brief

Why Pre-Charge Circuits are Necessary in High-Voltage Systems

Claire Chang and Tilden Chen

Failure to manage inrush current can lead to damaged cables, connectors, or fuses (11 Ways to Protect Your Power Path). High-voltage systems (100V+) often use precharged circuits to limit inrush current. This process protects the system from damage, extends lifespan, and increases reliability. TPSI3050-Q1 is an isolated switch driver that drives external FETs to create a Solid State Relay (SSR) solution. This solution can replace the mechanical pre-charge contactor while improving power density.

Applications and Benefits

Pre-charge circuits are often used in electric vehicles (EVs) such as battery management systems, on-board chargers, and in industrial applications such as power supplies and power distribution units. In EVs, controllers with high capacitive loads regulate motors. High voltage (HV) positive and negative contactors are used in this system to act as an emergency disconnect when the motor regulator fails. Without a pre-charge circuit, welding can occur within the contactor as it closes and there could be a brief arc resulting in pitting.

Pre-charge

In a high voltage system, a typical block diagram may consist of two high current contactors with a separate pre-charge contactor, and a DC link capacitor in parallel with a load (for example, traction inverter). Figure 1 through Figure 3 show the steps taken to pre-charge a DC link capacitor. In Figure 1, the two high-current capable contactors, HV positive and negative, are open. The HV battery is disconnected from the load at both terminals and the DC link capacitor remains discharged. Pre-charging introduces a new state in the system, which we will call the pre-charge state. In the pre-charge state, the pre-charge contactor and the HV negative contactor are closed as shown in Figure 2. The DC link capacitor charges to nearly the same voltage as the voltage source. After the pre-charge state, the pre-charge contactor opens and the HV positive contactor closes to drive the system or charge the battery. Since the DC link capacitor charged before the HV positive and negative contactors were closed, there is no high inrush current and the system operates normally as shown in Figure 3.
TPSI3050-Q1 Features for Pre-charge

The three main features the TPSI3050-Q1 provides is that it can perform as an isolated switch driver, disable switches quickly, and generate its own secondary bias supply. Each of these features provides benefits of increased flexibility, reliability, and smaller solution size.

- **Isolated Switch Driver**
  TPSI3050-Q1 has the flexibility to drive external FETs or IGBTs to form a Solid State Relay solution, replacing mechanical relays or contactors. Compared to mechanical relays, SSRs are more reliable, lighter, and smaller in size. Since there are no mechanical moving contacts, there is no audible noise or physical circuit wear out. As a result, the TPSI3050-Q1 creates a reliable cost-effective isolation solution.

- **Disable Switches Quickly**
  One key feature of the TPSI3050-Q1 is its ability to disable switches quickly. This can be useful to protect in events such as overheating or overcurrent. The response time of the TPSI3050-Q1 is less than 3us while relays are often in the range of 1-50ms (depending on the armature and force of the spring).

- **Generates Secondary Bias Supply**
  TPSI3050-Q1 generates its own secondary bias supply from the power received on its primary side. The secondary side provides a regulated floating supply rail of 10V for driving a variety of power switches shown in Figure 4 such as dual back-to-back power switches for AC applications, single power switches for DC applications, various types of SCRs, and more.

TPSI3050-Q1 in High Voltage Pre-charge Circuits

Figure 4 shows the TPSI3050-Q1 connected to a pre-charge circuit that has MOSFET switches. In this example, TPSI3050-Q1 operates with an EN signal, and low voltage supply between $V_{DDP}$ and $V_{SSP}$ on the primary side. On the secondary side, the $V_{DRV}$ pin connects to back-to-back MOSFETs in a common source configuration. When EN pin is logic high, TPSI3050-Q1 will signal information from the primary side to the secondary side to assert $V_{DRV}$ high. Similarly, when EN pin is logic low, $V_{DRV}$ would be driven low.

Conclusion

A pre-charge circuit can be used to prevent stress and damage to the electric system by implementing a resistor and a switch to limit in-rush current. The TPSI3050-Q1 can replace traditional pre-charged contactors for a more reliable, smaller, and more responsive Solid State Relay solution compared to mechanical contacts which can wear out over time.

---

**Figure 4. TPSI3050 in Application**
IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2022, Texas Instruments Incorporated