# Multi-Purpose Electronic Contactor Design with High-Side FET Driver, and Insulation Resistance Measurement

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**Abstract**

In today's world, lithium batteries, which can reach high power and energy capacity, have brought with them the need for precise and continuous monitoring and the need to take trustworthy measures. These electrochemical energy sources, which must operate within a safe range of voltage, current and temperature levels, have also been standardized with a series of regulations to protect property and public safety. In this study, an electronic contactor system capable of measuring insulation resistance has been developed to meet this safety requirement and facilitate compliance with the required standards. Insulation resistance measurement is a critical test for the safety, performance and longevity of lithium battery systems [1].

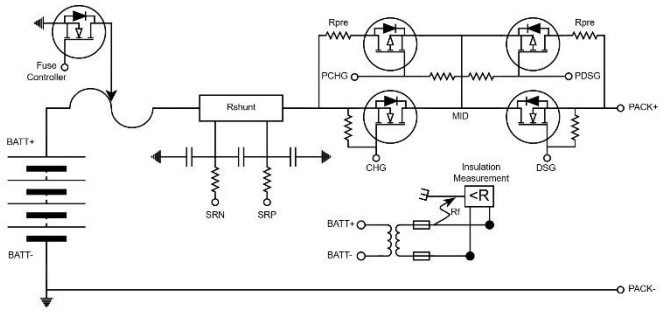


Fig 1. Schematic Design of Electronic Contactor

The study begins with the control of current flow, one of the three fundamental quantities when it comes to lithium batteries, and the measurement of the magnitude that allows us to decide when and how to control this current. Traditionally, the current flowing through the main current paths is controlled by electromechanical elements that connect or disconnect the power path when necessary, stopping the flow of current [2]. However, this method has a number of drawbacks and in order to take a more innovative approach in this work, a FET based control circuit is designed using high-side gate drivers for both charge and discharge directions and also for both pre-charge and pre-discharge paths [3, 4]. One of the better ways of current measurement is to use Hall effect sensors, but although this method provides isolation and high current measurement capability, the measurement accuracy may be degraded due to magnetic losses, air gaps and external interferences. In this study, a compact, low-cost, and integrated method is used to measure current using a high-power shunt resistor with differentially matched Kelvin connections and digital filters. This method uses high-resolution analog-to-digital converters (ADCs) to measure the current with high accuracy and can be used in SoX calculations to provide more accurate results.

In case of worst scenario such as crash, fire, external accident, the system may consist of fuse solutions such as eFuse, pyroFuse or DC fuse to ensure the power flow. Fast-acting power elements increase the functional safety level of the system and the compactness of the power path controllers [5].

**References**

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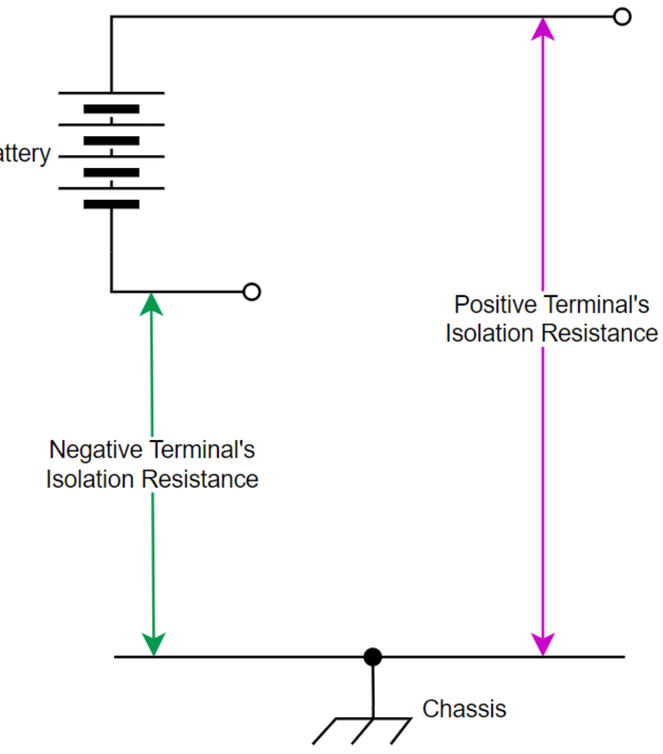
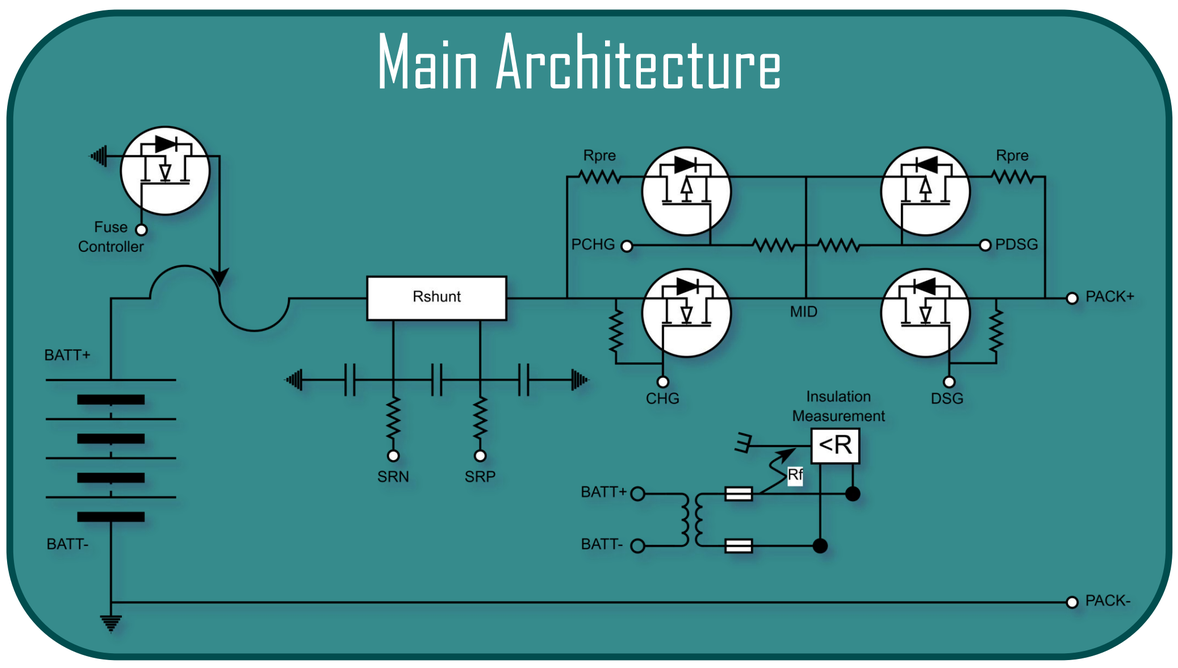
## Description

Lithium battery systems require precise monitoring for safety, performance, and regulation compliance. This study introduces an compact electronic contactor system which includes insulation resistance measurement, FET-based power path controller to enhance system safety and reliability.




## Methodology




- **FET-Based Switching for both charge/discharge & pre-charge/pre-discharge power paths.**
- **Insulation Resistance Measurement for enhanced safety**
- **High Accuracy Current Sensing using Kelvin-connected shunt resistors**
- **Compact and Low-Cost Design**
- **Fast-Acting Fuse Integration (eFuse, pyroFuse)**

## Technical Progress

This study addresses the limitations of traditional electromechanical contactors by implementing a high-side FET-based architecture for compact, bidirectional charge/discharge and pre-charge control. To enhance safety, real-time insulation resistance measurement enables early detection of leakage or breakdowns. A Kelvin-connected shunt with high-resolution ADC ensures accurate current sensing, with digital filtering improving SoX (SoC, SoH, SoP) estimations. Fast-acting protection elements like eFuse and pyroFuse provide immediate disconnection under fault or crash conditions, all within a compact, cost-effective design for automotive and industrial battery systems.

## Objectives

- ✓ Hall effect sensors are avoided due to magnetic interference risks.
- ✓ High-side gate drivers are used for bidirectional current path control.
- ✓ ADC + digital filtering enables precise current measurements for SoX algorithms.
- ✓ Safety-oriented fuse components enhance the **functional safety** of EV battery systems.

## Technology & Innovations

An innovative contactor system featuring high-side FET switching, real-time insulation resistance measurement, and precision current sensing enhances safety, accuracy, and compactness in lithium battery applications.

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