L1 and L2 EV Charger Electric Vehicle Service Equipment Design Considerations

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ABSTRACT

This application report explains different auxiliary power tree architectures in an Electric Vehicle Service Equipment (EVSE) of AC level 1 and level 2 electric vehicle (EV) charging stations, relay or contactor drive using motor drivers, and contact weld detection.

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1 Introduction

Electric vehicles (EVs), including plug-in hybrid electric vehicles (PHEVs), receive energy from the electrical grid through EVSE, more commonly known as EV chargers. To facilitate the power delivery to the vehicle, the EVSE sits between a stable grid connection and the vehicle, as Figure 1 shows.

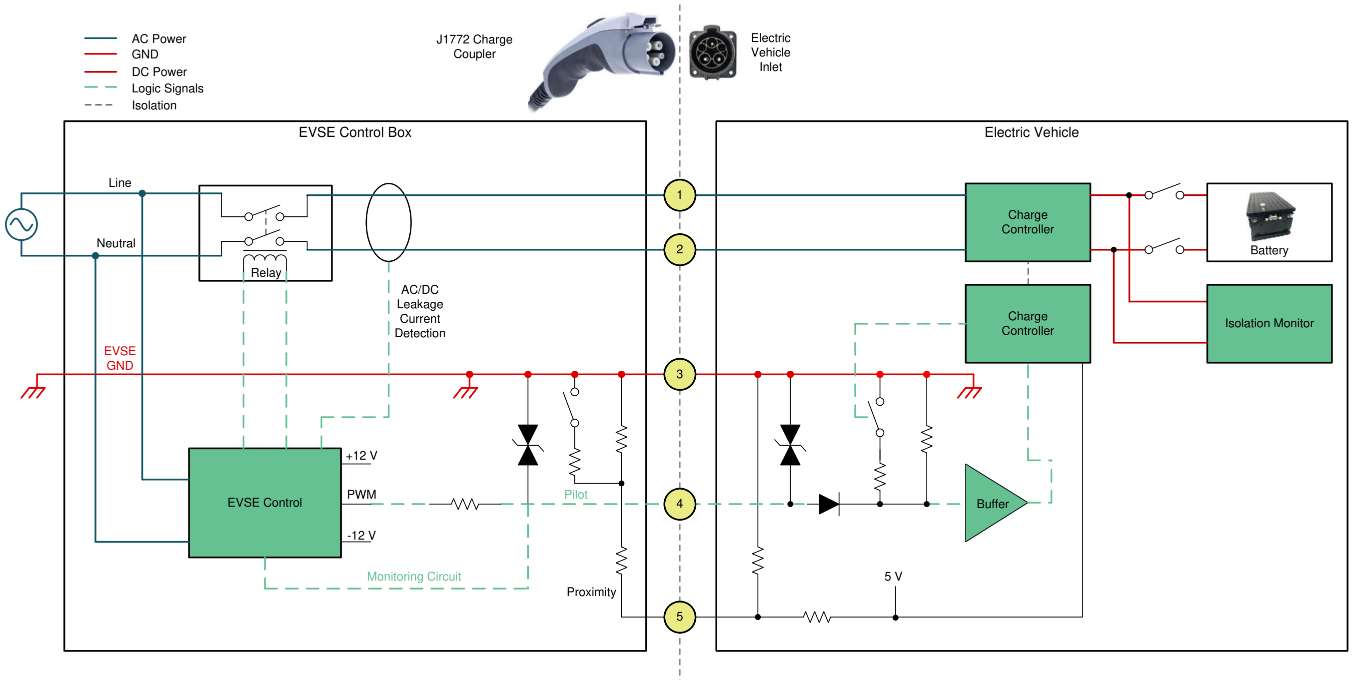
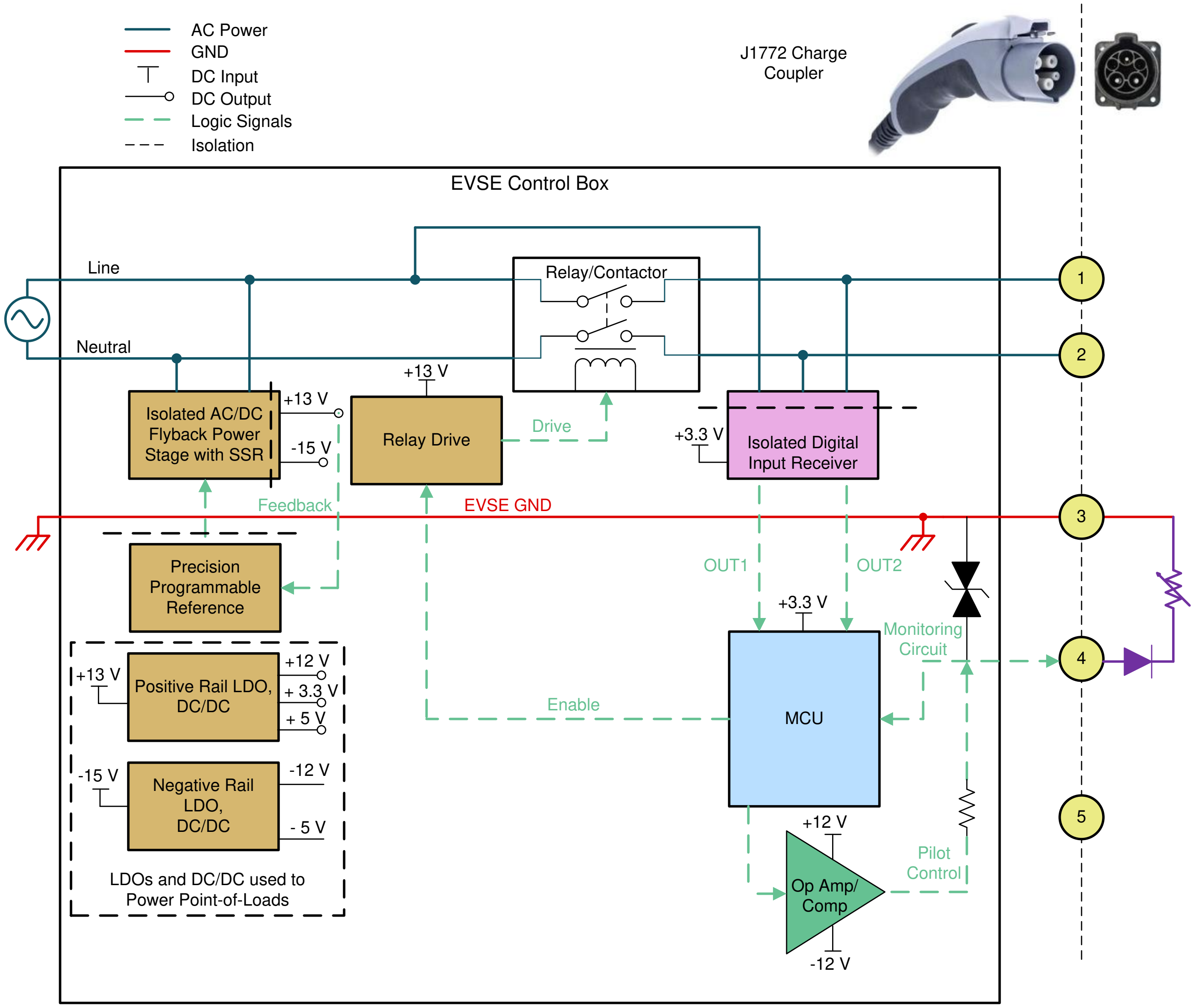


Figure 1. AC Level 1 and Level 2 System Configuration

The primary EVSE functionality includes:

- Regulated electrical current: Ensures that the optimal current is provided and falls within the maximum current the EV can handle.
- AC/DC residual current detection (RCD)
- Relay and contactor drive and latched contact detection
- Energy metering
- Automatic disconnect: Shuts off power when a fault is detected to avoid risks like battery damage, electrical shorts, or fires.
- Safety lock-out feature: Prevents current from flowing when the charger is not connected to an EV.

An EVSE control system mainly consists of auxiliary power stage, off-board AC/DC high-power stage (only in DC charging stations), energy metering, AC and DC residual current detection, isolation monitor unit, relays and contactors with drive, two-way communication, and service and user interfaces. Figure 2 shows the most common implementation of an EVSE in AC EV charging stations.



AC/DC leakage current detection sub-systems are not shown in this implementation.

Figure 2. Common Implementation of an EVSE in AC EV Charging Station

2 Auxiliary Power Tree Architectures in an EVSE

The auxiliary power tree in EVSE mainly consists of isolated AC/DC flyback power stage followed by linear regulators and DC/DC buck converters to generate I/O voltage, bipolar power rail for control pilot signal interface, and analog voltage for the different peripherals.

The isolated AC/DC flyback stage is based on the UCC28740 controller which provides constant-voltage (CV) using an optical coupler to improve transient response to large-load steps. Constant-current (CC) regulation is accomplished through primary-side regulation (PSR) techniques. This device processes information from the optocoupled feedback and an auxiliary flyback winding for precise high-performance control of the output voltage and current.

Figure 3 and Figure 4 highlight the implementation of low-cost variants of the power tree along with the peripheral requirements in an EVSE design.

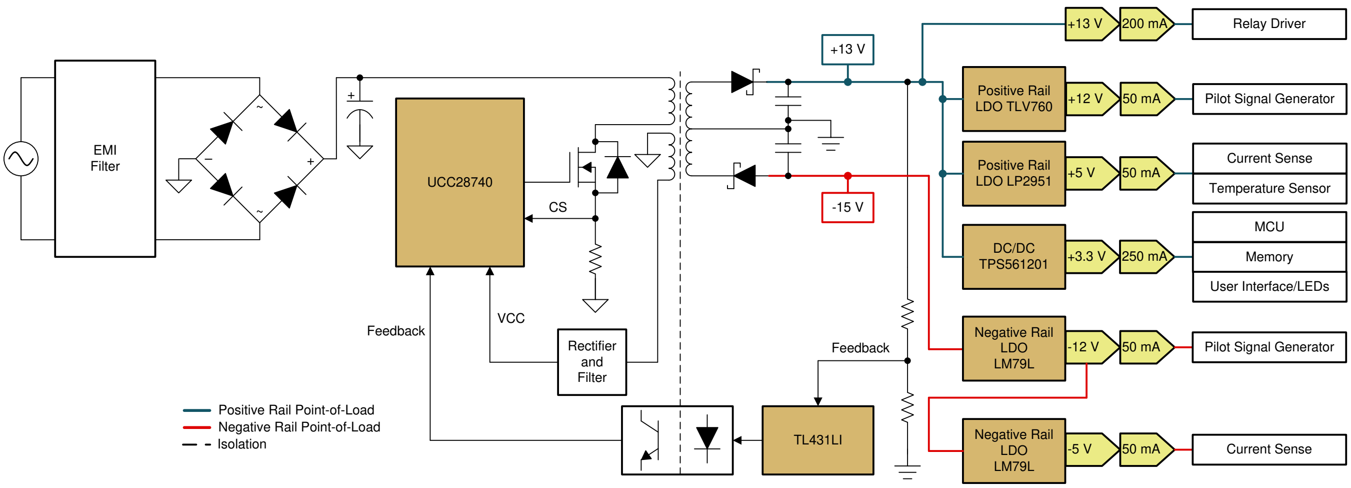


Figure 3. Multi-Output Flyback Followed by Low-Cost LDOs and DC/DC

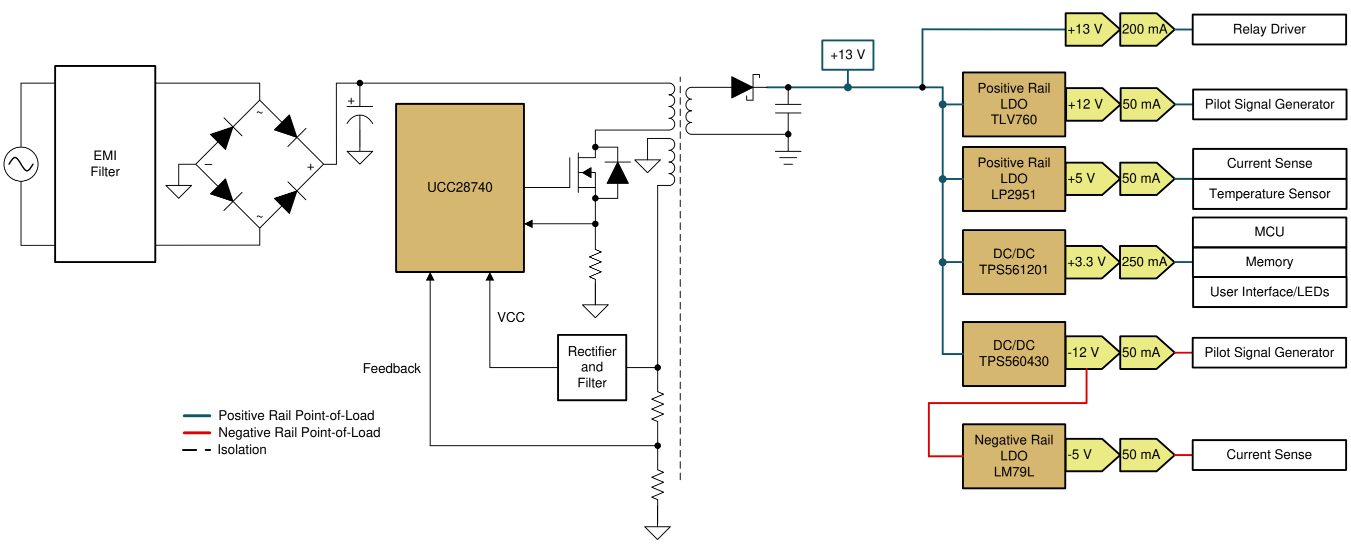


Figure 4. Single-Output Flyback Followed by Low-Cost LDOs and DC/DC

2.1 *Low Standby Power Tree to Meet ENERGY STAR®*

Most EV chargers typically remain in standby for 85% of their lifetime. ENERGY STAR certified EV chargers require, on average, 40% less energy on standby mode (that is, not charging a vehicle) than standard EV chargers do. By using an ENERGY STAR certified charger, consumers and businesses can reduce their charging costs significantly .

Figure 5 and Figure 6 highlight the implementation of low standby variants of the power tree along with the peripheral requirements in an EVSE design.

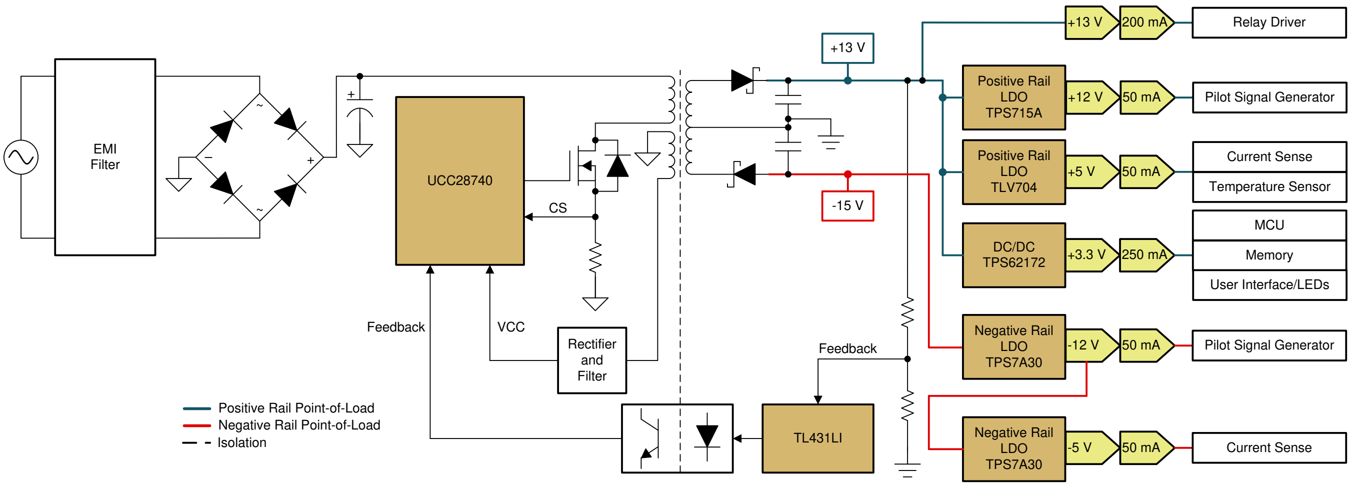


Figure 5. Multi-Output Flyback Followed by Low Standby LDOs and DC/DC

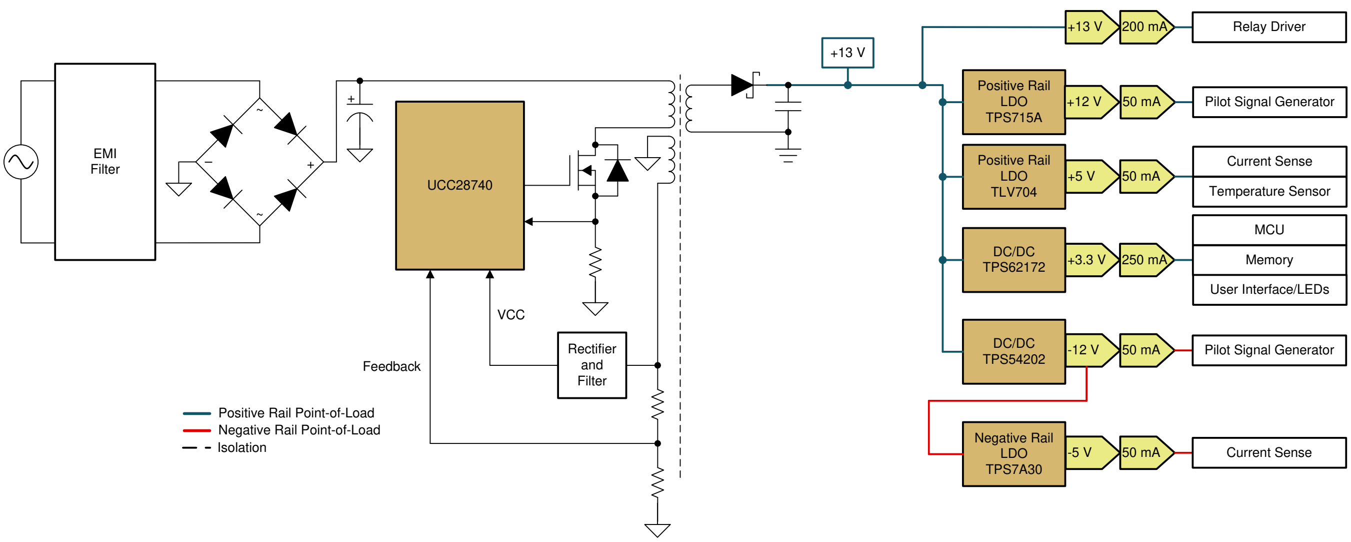


Figure 6. Single-Output Flyback Followed by Low Standby LDOs and DC/DC

3 Relay or Contactor Drive Using Half-Bridge Driver

An H-Bridge is two half-bridges joined together by a load. They are mainly used in applications where the voltage or current polarity applied to the load needs to be switched; for example, a latching relay. An H-Bridge also causes the current to re-circulate slower using the opposing MOSFET. Figure 7 shows how an H-Bridge can drive a conventional solenoid valve.

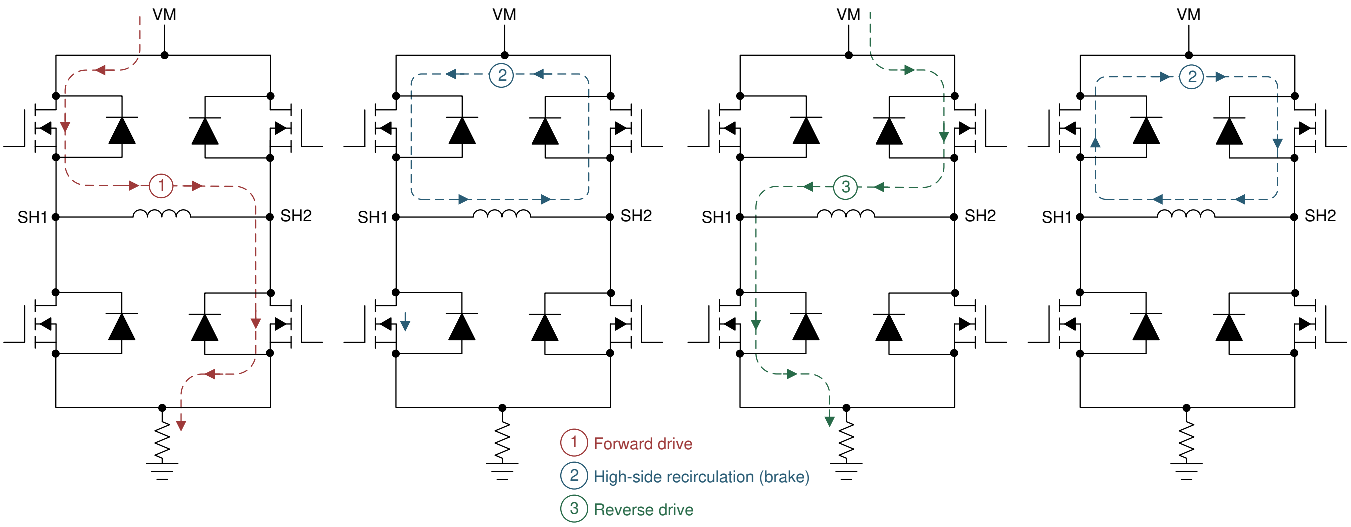


Figure 7. H-Bridge Configuration Utilized to Drive a Solenoid

This configuration enables the reduction of heat dissipation and improves thermal performance to increase efficiency over time. This drive topology also ensures fast discharge of the relay in case of contact welding faults due to arcing. The reliable integrated current control ensures that relays stay energized regardless of temperature. This configuration also protects both short-to-V_{SUPPLY} and short-to-GND scenarios.

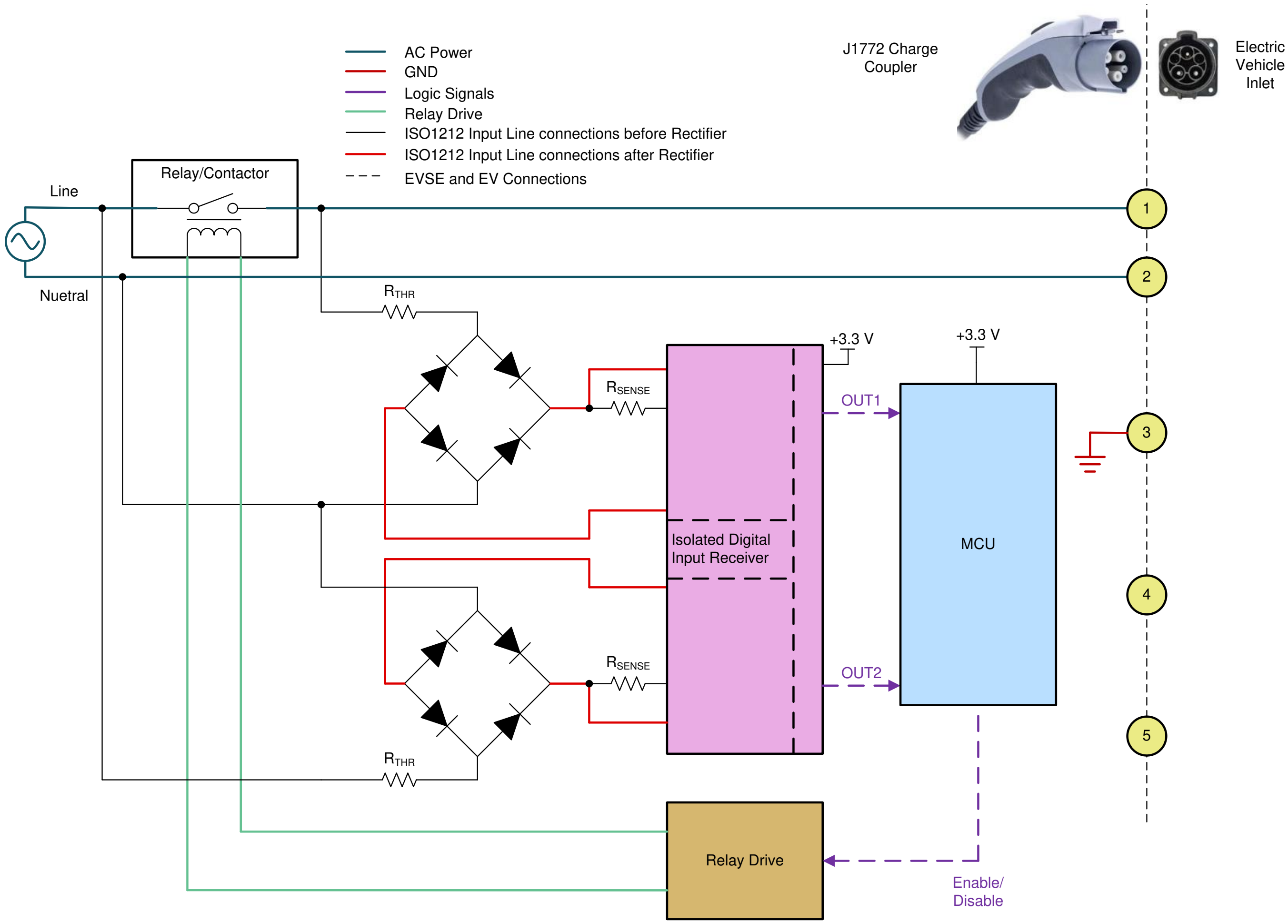
The DRV8816 motor driver helps drive the relay in single-phase AC EV charging applications to reduce thermal dissipation and fast discharge of the relay in case of contact with a welding fault.

The DRV8847 motor driver can drive relays like the Panasonic® HE-S in 3-phase AC EV charging applications. Using these motor-driver ICs can simplify the design and decrease the board size needed to accomplish this task.

4 Relay or Contactor Weld Detection

The detection of the voltage output of the primary relay is a major safety consideration. The contact between relay and contactor can result in arching and fuse them together supplying power to the charge coupler or plug even when the processor has disabled the relay drive stage. This is why verifying that the operation was completed correctly is crucial and should be done every time the relay is opened.

TI's ISO1212 device is a fully-integrated, isolated digital input receiver that helps implement this check by sensing or monitoring the line voltage. The ISO1212 receiver has an integrated current limit, is compliant to IEC 61131-2 Type 1, 2, and 3 characteristics, and is suitable for multichannel designs. Figure 8 shows the implementation of both channels of the digital input module with the ISO1212 for contact weld detection. The R_{SENSE} resistor controls the current limit, and the R_{THR} resistor controls the voltage transition thresholds. The outputs (OUT1 and OUT2) from the ISO1212 device are GPIO-level DC signals that are high when voltage is present and are fed directly into the MCU for fault detection.



Control pilot interface, auxiliary power tree, and AC/DC leakage current detection sub-system are not shown in this implementation.

Figure 8. ISO1212 Connections for Contact Weld Detection

Figure 9 and Figure 10 show the ISO1212 digital outputs and input line voltage in fault condition and the delay between the digital outputs of the ISO1212 device.

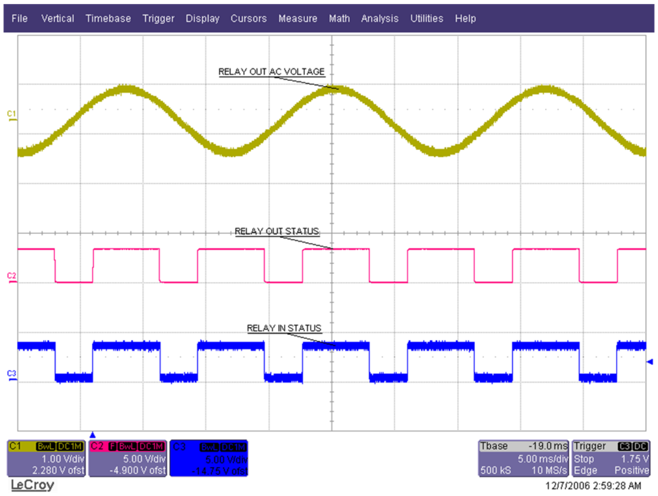


Figure 9. ISO1212 Digital Outputs and Relay Output Voltage When Relay is Closed

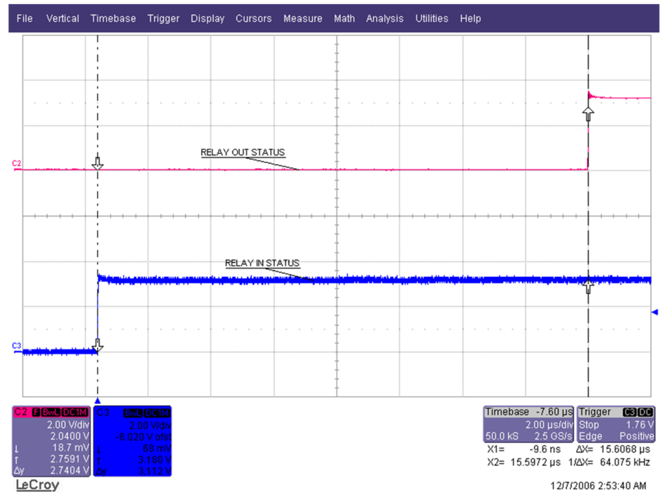


Figure 10. Delay Between Digital Outputs of ISO1212

5 Conclusion

The auxiliary power tree design includes multi-winding output or single winding flyback stage and low-cost or low-standby devices. Motor driver ICs such as the DRV8816 and DRV8847 can be an effective, efficient, and reliable solution to drive solenoids in single- and three-phase AC EV charging stations. Fully-integrated drivers such as the DRV8847 enable multiple solenoids with a single device, increase efficiency using PWM and reliability using current sense feedback. The ISO1212 device provides a modern solution for relay or contactor weld detection. Its integrated IEC 61131-2 input characteristics, voltage comparator with hysteresis, and precise current limit provides a space-effective solution for simplified, multichannel designs.

6 References

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (March 2020) to A Revision **Page**

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