Protecting Test Equipment During EV Battery Testing

APPLICATION NOTE

KEITHLEY
A Tektronix Company

Tektronix®

Introduction

We are expecting more out of our battery packs for EV and energy storage than ever before. These packs are able to output hundreds of amps and volts and the power requirements are continuously increasing as the market for batteries grows into larger applications such as aviation and transport. Strict testing is necessary to ensure that every pack meets our requirements for capacity, charge time, safety, and lifespan. This means that quality test equipment is a crucial tool for battery manufacturers.

Batteries are considered unlimited power sources in testing. A common power source like a power supply has output impedance that limits the amount of power generated at a time. The power supply is unable to exceed a certain maximum voltage or current, and the power output is limited to a certain specified wattage. Unlimited power sources, such as batteries or line voltage from the outlet on the wall, have very low impedances that do not limit the output. When these devices are shorted, the output can increase until something fails in the circuit to stop the event.

When an unlimited power source is allowed to output freely during testing, the device itself and the test equipment can be damaged. This may lead to costly equipment replacement, loss of inventory, and interruptions to the manufacturing process. In worst case scenarios, operators and nearby equipment can be exposed to harmful shock or fire. Therefore, it is important to consider protections for equipment when designing and implementing a test system - both to prevent an event from occurring and to protect the equipment from damage in case an event does occur.

Identifying Risk

High energy events can quickly damage the test equipment or the device. Damage could be limited to a single component that burns out or fails to meet specification. More serious events, such as electric arcs, can occur when the circuit is exposed to extremely high current or voltage. An electric arc occurs when the energy is large enough that the air breaks down into conductive plasma. The current in an arc is not limited, so arcs with unlimited power sources are especially dangerous. The discharge of energy through the air causes extreme heat and fire that can lead to widespread damage on the test system.

The first step in protecting a test system is to identify situations that expose the test system to high current or voltage. Start with identifying the limits of your test equipment and your device. Most electrical test and measurement devices are equipped with some internal protection, and the maximum signal level for that protection is specified in the datasheet. These limits must be considered first, as they are not adjustable. Board traces, wire gauge, and connector ratings will also limit signal levels, although these sometimes can be changed to match the circuit requirements. Once you have identified the limits of the components in your circuit, consider the lowest limits. This will be the threshold for damage.

Also examine your circuit for the highest current and voltage potential that could be present. Most high current events occur when the circuit is shorted, but high voltage events can occur even when little to no current is present in the circuit. This is often the case for testing open circuit voltage, a common battery test. Look for critical areas in the test circuit where a short or an open would cause high output, like the output terminals of a battery pack. Areas where test leads or touch down points are close together, or where the voltage between terminals in a switch is very high, may also have potential to cause damage.

Prevention Before Protection

The best thing we can do when setting up a test system that has the potential to be exposed to damaging signal levels is to prevent those levels from occurring in the first place. Many of these are simple considerations that can save your test equipment.

- Use properly rated cables and connectors. Improperly rated cables can overheat, melt the insulation and cause shorts.
- When connecting open wire ends (such as wires to a screw terminal block), use ferrules or collets to prevent stray wires from touching.
- When making connections to the circuit, ensure that there is space to make a proper touch down and that any automated equipment is calibrated properly so the terminals do not make incorrect connections.
- In circuits that involve switching, use break-before-make switching to ensure that the previous circuit is disconnected before the next circuit is closed.
- Regularly maintain test systems. Check insulation for cracks and wear, cable harnesses for strain, and any connectors for loose connections.

Fuses

Sometimes, even with the best prevention, high energy events can still occur. Therefore, we must consider protection mechanisms to prevent damage in the case of exposure. Damage from high current is most often prevented using fuses. A fuse contains a small metal strip or wire that breaks when the current is large enough. When the fuse breaks the circuit is no longer complete and the damage is stopped. If there is no fuse in the system, the current will flow until another component in the system fails, becoming an unintentional fuse.

Most test equipment contains fuses to prevent some damage, but these may not be enough to prevent other damage. In addition, some fuses are not user-replaceable; requiring the instrument to be sent to a service center for repair. For EV and energy storage applications, most packs are capable of hundreds of amps, so external fuses should be used.

There are several factors to consider when choosing a fuse. An improperly rated fuse can fail to prevent damage to other devices or can allow an arc after opening. Fuses are designed to prevent either current overloads, where the current increases above a set level and remains there, or current short-circuits, also called surges, where the current increases very rapidly but may not remain at that high level. When choosing a fuse, keep the following specifications in mind:

- The rated current should be close to, but not less than, the normal operating current in the circuit. The fuse will open if the sustained current is above this value.
- The rated voltage should be larger than the open circuit voltage exposed to the fuse once it opens. This prevents arcs after the circuit is opened.
- The interrupt rating should be larger than the maximum short circuit current that the circuit could be exposed to. This ensures that the fuse breaks safely without additional damage.

The response time will depend on the fuse need. Fast-acting fuses respond better to surges in the current and should be used when trying to protect against short circuit situations. Time-delay or slow-blow fuses break after the current rating has been exceeded for a certain period and should be used for circuits that may experience quick spikes in current that are normal for operation. The I^2T specification is also used to represent the speed of the fuse opening and how much energy will be passed as the fuse opens.

Fuses should be placed in line to the current path such that the entire current must pass through the fuse. For a multichannel system, there can be many current paths and a fuse should be on each unique current path such that the entire system is protected. Typically, the fuse should be placed as close to the source as possible to protect as much of the rest of the system as possible. Fuses should not be placed on connections to ground, as this can create shock hazards or other failures if the entire system is suddenly disconnected from ground. The ratings for the fuse should keep in mind the limits of test equipment. This is especially important for switching systems, which often have a maximum power rating that cannot be exceeded. Using a fuse that allows more energy to pass before opening will damage the switch.

For more information on proper fuse sizing, consult the fuse manufacturer.

Common Mode Voltage

Damage from high voltage occurs when a device terminal is exposed to a higher potential with respect to ground or with respect to a related terminal. For battery testing, test equipment is often exposed to high common mode voltages. Measurement devices such as digital multimeters (DMMs) make differential voltage measurements or measure the difference between input HI and input LO. Each of these terminals is referenced to ground. Common mode voltage is the voltage difference between ground and the LO terminal. The measurement device can be damaged if this voltage difference is too high, regardless of the maximum voltage level. The specifications for maximum common mode and normal mode voltage can be found in your instrument's datasheet.

Batteries are floating voltage potentials, meaning there is a voltage potential between the two electrodes, but that potential is not referenced to ground. When making an open circuit voltage measurement on a battery pack, the placement of the reference ground can expose the DMM to high common mode voltage. For example, if we place the

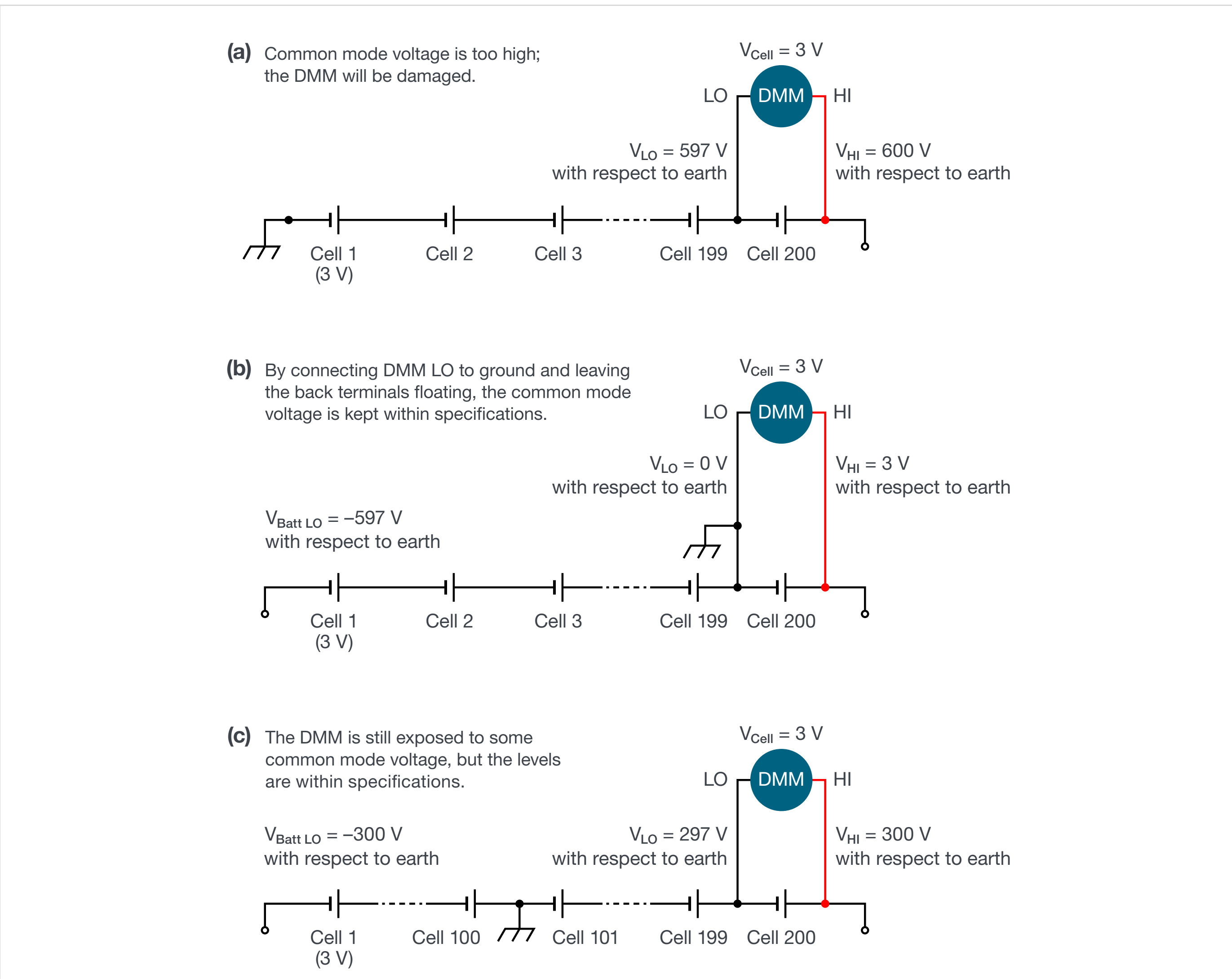

Figure 1 (a) Measuring open circuit voltage on cells in series with earth ground connected to end of pack leads to high common mode voltage. (b) Connecting the earth ground to DMM LO prevents exposure to high common mode voltage. (c) Wiring the earth ground to the center of the pack reduces common mode voltage to within specification.

ground on the low potential end of 200 3 V cells connected in series, the measurement on cell 200 puts the LO terminal of the DMM at 597 V, which will damage a DMM with a maximum 500 V common mode specification. This is shown in **Figure 1a**.

We can help protect the DMM terminals by choosing a location for the earth ground point that prevents any high voltage potentials on the terminals. The ground could be hardwired to LO as shown in **Figure 1b**, or there could be a set ground point dividing the pack as shown in **Figure 1c**.

When grounding sections of a battery pack beware of ground loops. A ground loop can occur when there are multiple grounded points in the circuit that form an undesired path for current to flow. To avoid risk of shorts from multiple grounding points, consider using an isolation switch to isolate part of the battery pack from the active testing circuit.

When handling common mode voltage, keep in mind that the battery potential will change according to the location of the ground points. This may mean that portions of the battery pack that were previously at safe potentials could be at hazardous potentials later in the test. Always be aware of the potentials on the battery pack to avoid operator injury.

Floating battery potentials are not the only source of common mode voltages. Insulators on equipment, such as conveyer belts carrying the pack, can have static charge build up. This static charge can lead to high common mode voltages if it causes the battery pack to float away from earth ground or if the charge discharges through the measurement LO terminal. High resistance bleed resistors can help prevent this by allowing any built-up charge to dissipate.

Common mode voltage is also a critical factor for switching systems. Switch cards contain many measurement pathways on a single card. In this case, we are not only concerned with the voltage between high and low or low and ground, but also the voltage potential between each of the channels and ground and the channels with each other. A channel can be exposed to a voltage potential even when open, and moving the ground point will expose the channels to varying levels during the test procedure. It may be necessary to use a high voltage capable card to ensure that the card can handle all potentials. For more information on common mode voltage during open circuit voltage testing, see the application note Methods to Measure Open Circuit Voltage on a Battery Pack.

Conclusion

Testing with unlimited energy sources such as large battery packs can expose your test system to very high voltages and currents in the event of a failure. Considering the possibility of failure proactively and implementing methods to prevent shorts and identify points of high potentials can save time and money during the testing process.

Contact Information:

Australia 1 800 709 465
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3530-8901
Canada 1 800 833 9200
Central East Europe / Baltics +41 52 675 3777
Central Europe / Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400 820 5835
India 000 800 650 1835
Indonesia 007 803 601 5249
Italy 00800 2255 4835
Japan 81 (3) 6714 3086
Luxembourg +41 52 675 3777
Malaysia 1 800 22 55835
Mexico, Central/South America and Caribbean 52 (55) 88 69 35 25
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
New Zealand 0800 800 238
Norway 800 16098
People's Republic of China 400 820 5835
Philippines 1 800 1601 0077
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea +82 2 565 1455
Russia / CIS +7 (495) 6647564
Singapore 800 6011 473
South Africa +41 52 675 3777
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2656 6688
Thailand 1 800 011 931
United Kingdom / Ireland* 00800 2255 4835
USA 1 800 833 9200
Vietnam 12060128

*** European toll-free number. If not accessible, call:** +41 52 675 3777

Rev. 02.2022

KEITHLEY
A Tektronix Company

Find more valuable resources at TEK.COM

093022 SBG 1KW-73953-0