New

**Biosirus**

**Opto-Sensor**

# Application Notes – Batteries, EVs, BESS

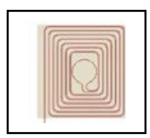
**(For details refer to the Opto-Sensor Temp & Strain Mapping System Brochure)**

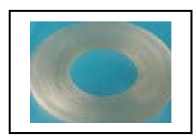
The performance of a battery cell/module/pack is dependent on the ambient temperature, internal cell temperatures, state of charge and the charge/discharge cycling requirements. Both high and low temperatures are bad for its performance and safety. This not only reduces its cycle-life but also causes swelling, stress-stiffening, deformation and even rupture. Hence, all tests and digital twinning efforts must include temperature and strain measurements.

**General Overview:**
Opto-Sensor is a two-part system consisting of (a) 19-inch rack mount unit and (b) optical fiber loops. Each unit can have up to 4 channels of dedicated fiber-loops where a single laser switches between each channel. A fiber loop can be dedicated to a single battery/cell/module test configuration while other fiber-loops can be placed in-situ into the test infrastructure permanently. Hence, a single Opto-Sensor unit can be used across multiple (even simultaneous) tests. The choice of the single-strand fiber and its jacketing (PVC, metal, etc.) is based on the application/mechanical requirement. The simplest fiber type is only hair-width. Also, a single channel fiber can be is spliced into "zones" and terminated as a contiguous fiber-loop. In multi-channel applications where the sampling rate is high (max 2 samples/minute) and the 3-D fiber length is very long (in kms), then a software adjustment is made to time-synchronize the various channel data-sets. Both temperature and strain measurements can be done on the same fiber.

**Creating a 3-D "wire-mesh" Profile:**
In most battery applications (test, real-time monitoring, digital twinning), the fiber needs to be "affixed" in 3-D shape around the test object (cell/module/pack/battery). For simple monitoring and charge/discharge applications, it could be a single fiber-loop for all inputs (ambient temp, under-hood ambient, cooling temp, battery temp, passenger cabin temp, air-conditioner temp, etc.). For destructive tests a two-channel system is best, where channel-1 is for the fixed test jig (ambient, cooling/enclosure/exhaust temperatures, other) and channel-2 fiber is for the battery only. In many cases a single fiber loop can be used for the entire battery/set-up, and can be spliced to create (a) 3-D wire-mesh for temp measurement and (b) a different fiber orientation for strain measurement (swelling, stress-stiffening, deformation). In addition, different "zones" can be created to identify different types of measurement points. The fiber placement is either mechanically secured or thermal-epoxied around the cell/module/pack faces to give its 3-D "wire-mesh". For large pouches and prismatic shapes (even as large as 30cm x 30cm x 2 cm cell size), the "wire-mesh" exercise is not a problem. For round cells it can be wrapped around to get both temperature and strain measurements.

**Temperature Measurement:**
The fiber is run in a circular/recursive contiguous loop to get the measurement points needed on each face (minimum say 5-6 cm/2.0-2.5 inches center-center resolution), noting that temperature measurement is still 1m apart on the fiber itself. The fiber bend radius depends on the fiber selected and can be as small as few cm. The fiber loop can be placed close to each other and there is no risk of any "coupling effect" or interference.





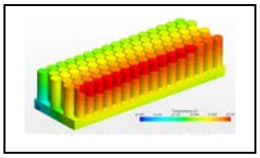
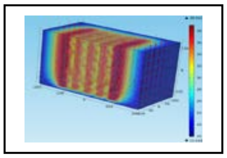
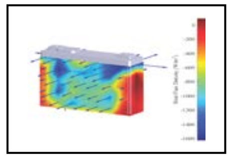
**Strain/Flex Measurements:**
While both the temperature and strain measurements can be done together in the same fiber, in some cases the fiber orientation for strain measurement may be different from that of temperature measurement and may force using its own separate fiber channel (separate from the temperature fiber). Strain measurements require the fiber to be epoxy/bonded along its entire length.

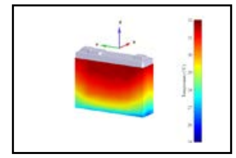
**Other Notes:**
The 19-in rack unit is independent of the applications. It is a fixed asset to the laboratory/factory/EV/BESS to be used across multiple tests. The fiber can be procured locally and is the only "consumable". Its selection (jacket type) for battery testing can be inexpensive. The copious data at max sampling rate of 2 samples/minute across all the data points (a function of the fiber length) can easily be stored in the unit. The max fiber loop length is 20 km. Pre-engineering services to obtain "wire-mesh" fiber positioning on a given sample is possible. *The best part is that only a few fiber connections are needed even for the most complex 3-D shape. It easily substitutes hundreds (if not thousands) of thermocouples.*

**A. OEM/Factory/Laboratory Applications:**

Such tests include measuring cell/modules/pack/battery in 3-D temperatures and strain profiles, for various charge-discharge test patterns by varying ambient temperature, battery loading and cooling temperatures. Often these tests are conducted indoors and the battery environment could be (a) **Adiabatic** (calorimeter or an insulated enclosure with no heat dissipation) and (2) **Isothermal** environment where cooling and heat transfer provisions are enabled. Adiabatic tests provide critical heat build up in the design while isothermal tests provide the heat extraction/flow parameters.

Note: While thermal runaway end-temperature rise can be observed (after the fact), recording transient temperature rise as thermal runaway occurs (say during a nail-penetration test) will not be possible.

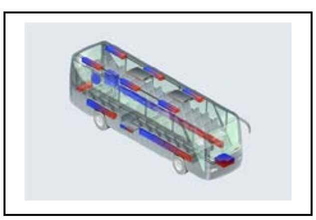
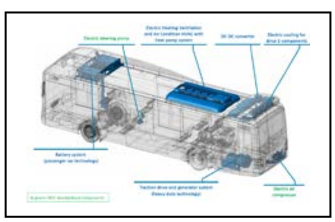
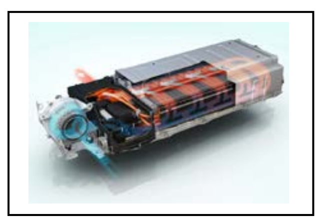
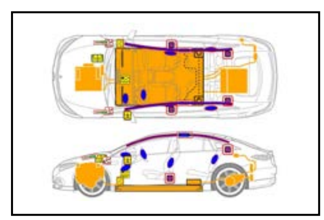
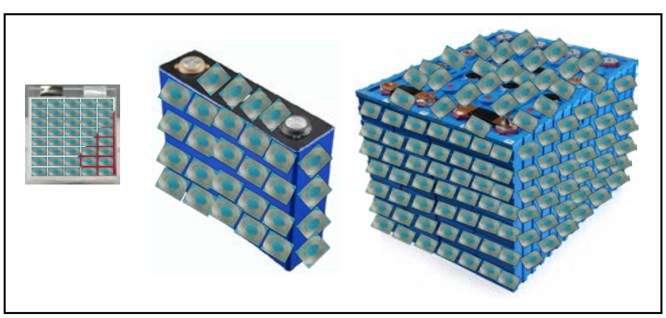
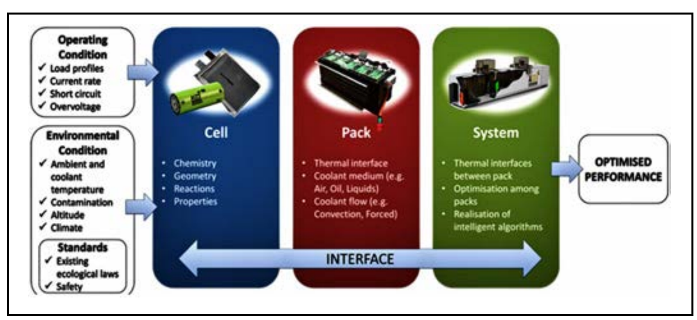


**B. BEV / BESS Digital Twinning Applications:**

In digital twinning applications the entire battery/charger system is set up and 3-D profiled (for thermal and/or strain) through load and temperature manoeuvres, to simulate real operating conditions. Such 3-D profile data-sets include not only the battery thermal profile but also ambient temperatures, cooling medium inlet/outlet temperatures and other auxiliary systems that may be varying to mimic actual operating conditions. This time-stamped, synchronized digital profile data-sets is then either used stand-alone for simulation and learning to understand operating limits and/or stored on-board EV or BESS computer systems to help predict and manage real-time operating situations.

**C. HEV / BESS Real-time Monitoring Applications:**

It is recommended that heavy-duty electric vehicles (HEVs) such as buses, trucks, mining equipment and large stationary battery energy storage systems (BESS) have on-board real-time thermal/strain mapping system to safeguard and manage such expensive assets from damage. In such a system a single fiber could be laid all-through the HEV/BESS enclosure including the battery packs to capture thousands of data points. Alarms and/or corrective actions can be enabled through output relay contacts. Principally, the optimal battery thermal management should include (a) operating/forecasted ambient temperatures; (b) charging/discharging time-series; (c) battery temperature (cell/module/pack); (d) battery SOC; (e) cooling input/output temperatures; (f) enclosure internal temperature; and (g) near-term expected load to be met.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