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A Burn-in test station for the ATLAS Tile-calorimeter Phase-II low voltage power supply transformer-coupled buck converters

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ATLAS EXPERIMENT

The ATLAS Tile Calorimeter

The Tile-Calorimeter (TileCal) is a sampling calorimeter which forms the central region of the Hadronic calorimeter of the ATLAS experiment. It performs several critical functions within ATLAS such as the measurement and reconstruction of hadrons, jets, hadronic decays of τ -leptons, and missing transverse energy. It also participates in muon identification and provides inputs to the Level 1 calorimeter trigger system. TileCal is composed of 256 wedge-shaped modules which are arranged azimuthally around the beam axis. A module consists of alternating steel (absorber) tiles and plastic scintillating tiles (active medium) with a Super Drawer (SD) housing the Front-End (FE) electronics and the Photomultiplier tubes located on its outer radius.

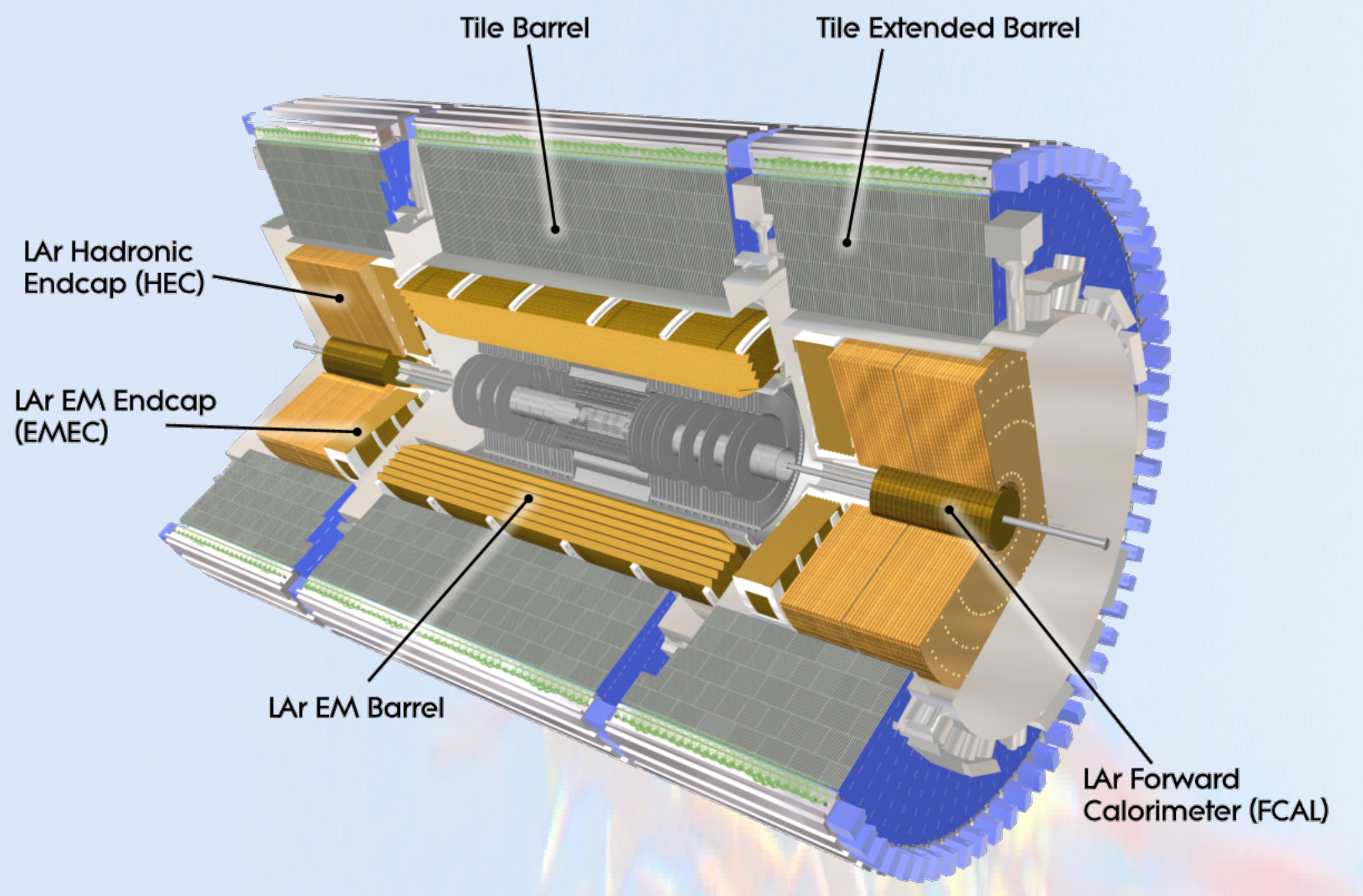

Fig. 1 The ATLAS inner-barrel. https: // cds. cern. ch/ record/ 1095927

Low-Voltage Power Supply

Function: Provides low voltage power to the front-end electronics of the SDs. A Low-Voltage Power Supply (LVPS), of which there is one per TileCal module, steps down 200 VDC, received from off-detector high-voltage supplies, to the 10 VDC required by the front-end electronics. The LVPS's location can be seen in in Fig.1 where they are housed within shielding (blue boxes) attached to the outer radii of the Tilecal modules. An LVPS consists of an Embedded Local Monitoring Board (ELMB), a Fuse board, a water-cooled heatsink, and eight transformer-coupled buck converters (Bricks). The Bricks make use of an isolated primary (see Fig.2) and secondary side. The secondary side contains an LC Buck, LC filter stage and the output. The Bricks monitor their input and output voltages, currents as well as two temperatures (T_2, T_3). The Tristate signal input is used to switch an individual Brick on/off.

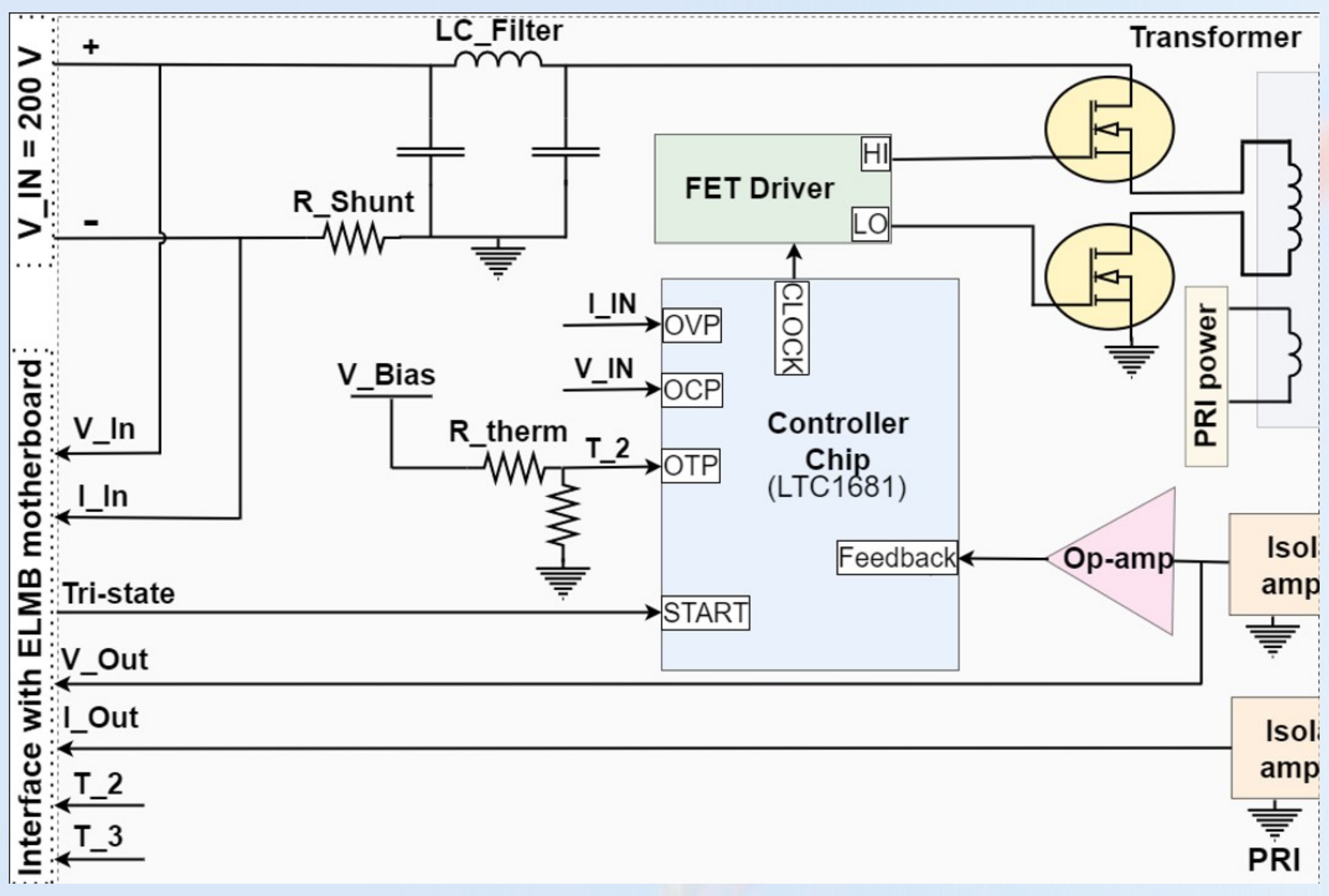

Fig.2 The isolated primary side of a Brick.

Phase-II Upgrade Production: The TileCal Phase-II upgrade requires the replacement of 256 LVPSs. This corresponds to 2048 Bricks (Plus approx. 10% spares). The production is equally divided between WITS and UTA and will take place over the next three years. Quality assurance testing, of which Burn-in testing forms a part, is to be undertaken as part of the manufacturing process.

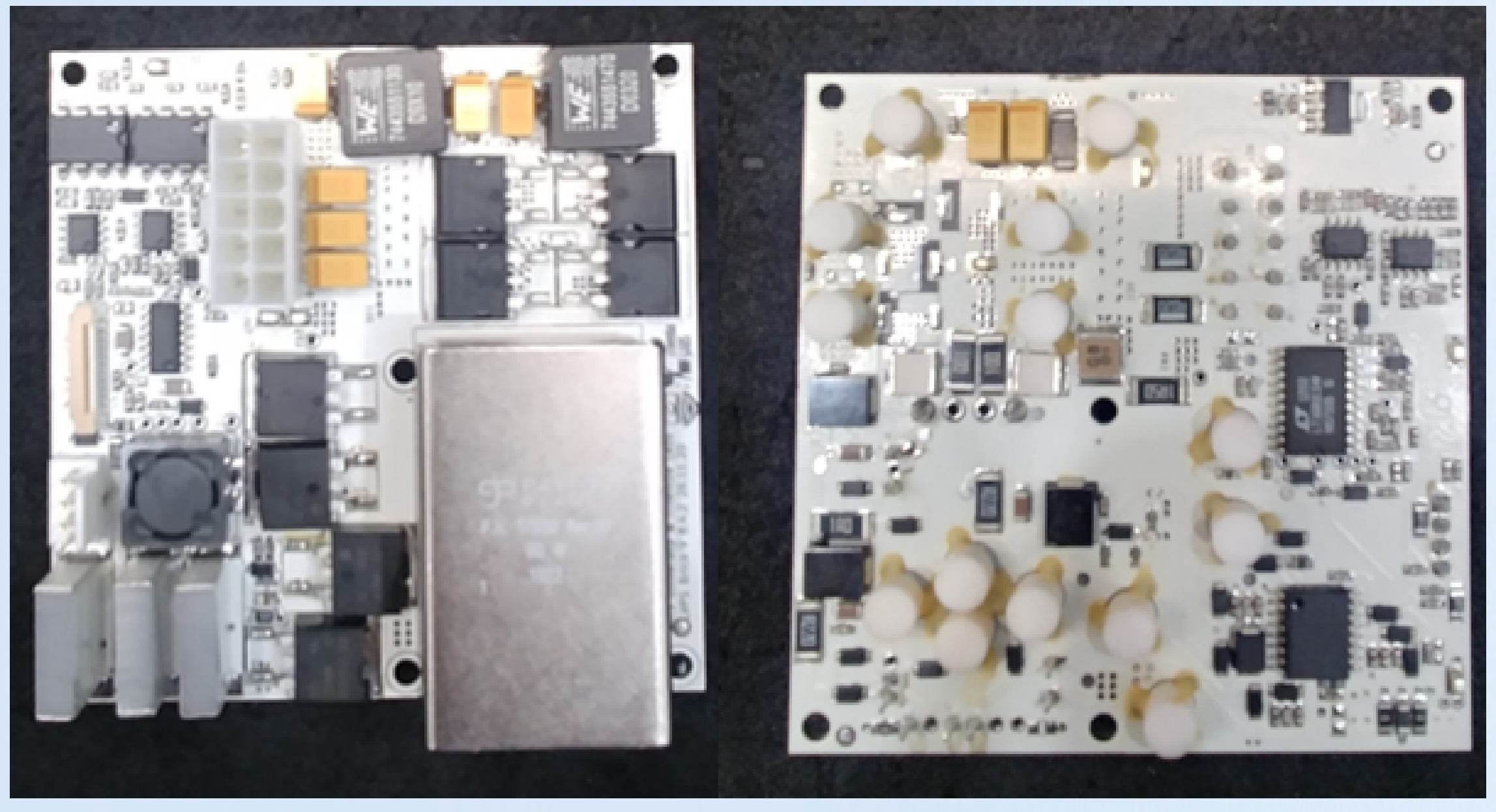

Fig.3 A top (Left) and bottom (Right) view of a WITS high-efficiency LVPS Brick.

Burn-in Motivation

Access to the Bricks is limited to approximately once per year. Therefore, any Bricks which fail will result in a portion of a module being offline for a commensurate time emphasizing the importance of the Brick reliability. To maximize this we are required to minimize their failure rate. The failure rate of electronics can be represented by a "Bathtub" curve (Fig.3). Observe the undesirable failure rate within the infant mortality region. Burn-in testing serves to address this by performing accelerated ageing of the Bricks. The accelerated aging causes Bricks that would fail during their early lifetime to fail immediately thereby effectively screening out the infant mortality failures.

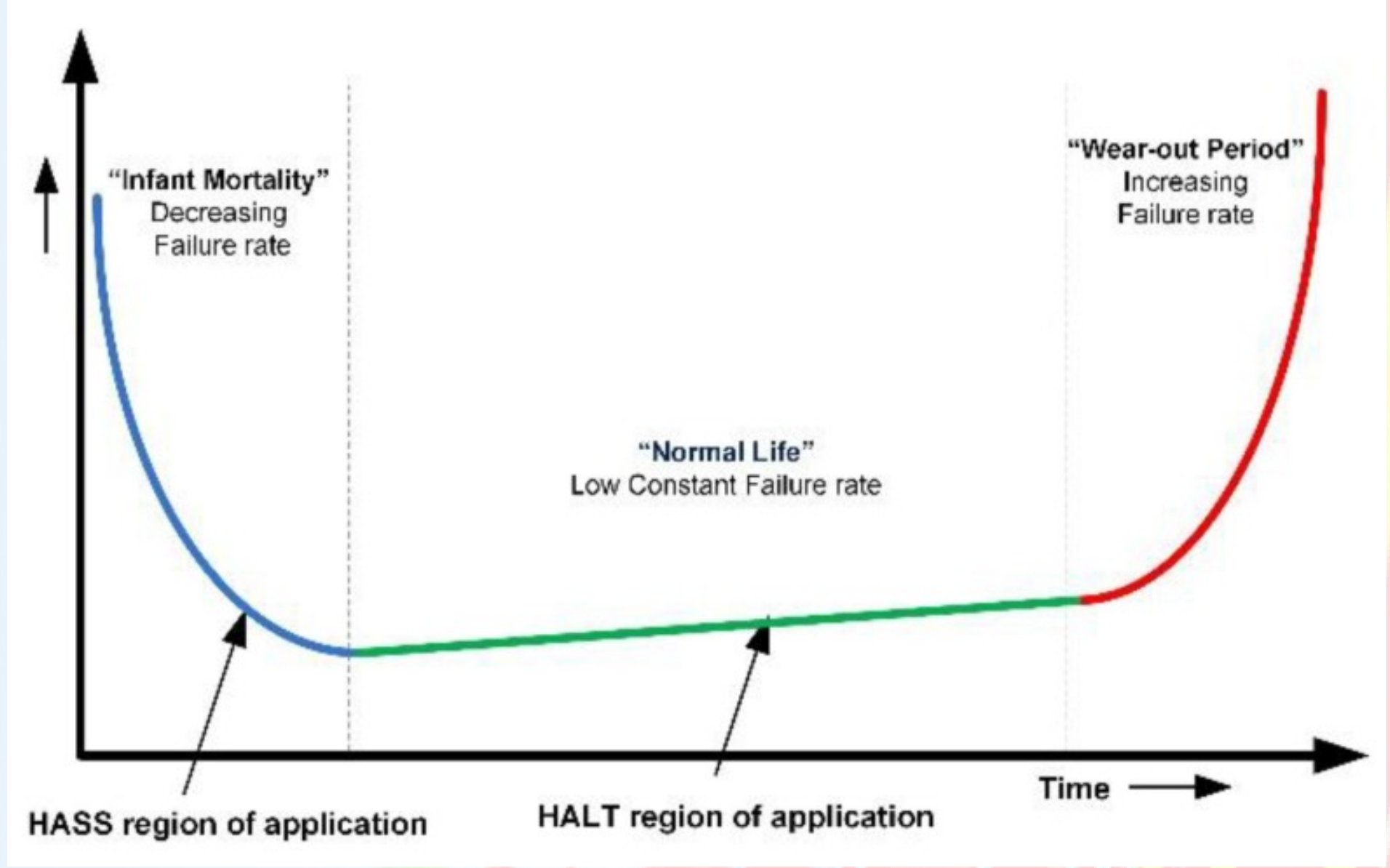

Fig.4 A Bathtub curve illustrating the failure rate as a function of time for electronic products. Muhammad.N et al. doi:10.3390/mi11030272

Burn-in Procedure

The purpose of the Burn-in procedure is to accelerate aging of the Bricks. This is achieved by operating the Brick within a sub-optimal environment (increased temperature and load) thereby stimulating similar failure mechanisms which appear during normal operation. The Bricks operating temperature is increased by reducing the cooling capacity of the heatsinks (Cooling plates) to which they are attached.

Burn-in operating parameters

The Burn-in parameters are higher than nominal to ensure accelerated aging but have to remain below the limits imposed by the Bricks protection circuitry.

- Run-time = 8 hours
- Operating Temperature of Bricks = 60° C
- Load = 5 A

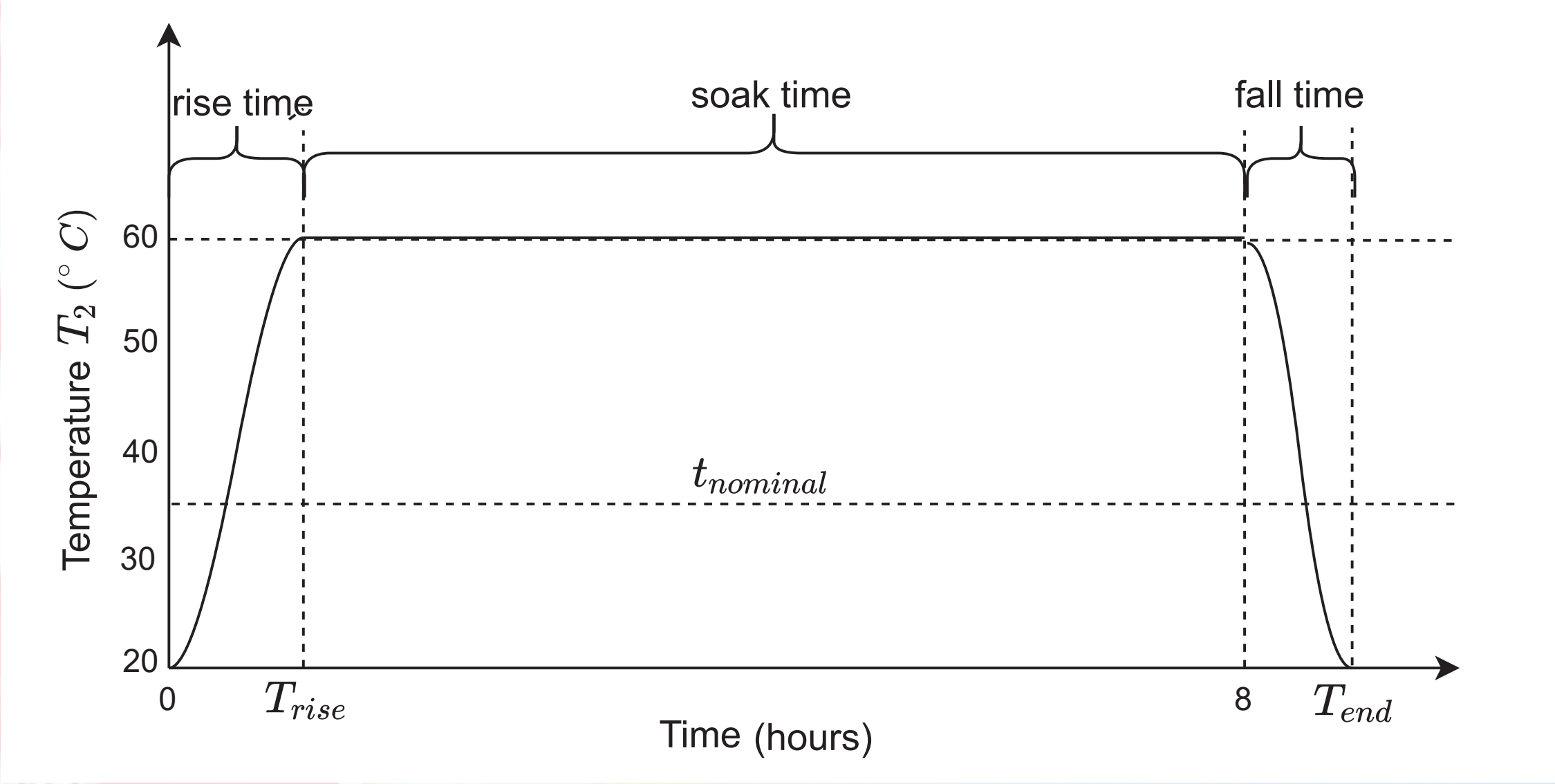

Fig.5 Generalized Phase-II Brick burn-in procedure thermal profile

Burn-in test Station

As depicted in Fig.6, the Burn-in station hardware is composed of a Personal Computer (PC), a 200 VDC High-Voltage (HV) power supply, various custom Printed Circuit Boards (PCBs) designs, electronic components, connectors, wiring, Cooling Plates (CP), a water-chiller, and a mechanical chassis known as the test-bed. The PCBs are subdivided into four types, the Main Board (MB), the Brick Interface Board (BIB), the Load Interface Board (LIB) and the Dummy Load Board (DLB).The burn-in station comprises a MB (x1) responsible for communicating to the BIBs (x8) and LIBs (x2) through an application-specific control and monitoring program developed in LabVIEW. The BIBs interface between the Main board and the eight Bricks undergoing burn-in. They digitize performance metric analog signals (such as output voltage) received from the Bricks. The BIBs are also used to switch the Bricks on/off and act as a switch for the 200 VDC input to a Brick.

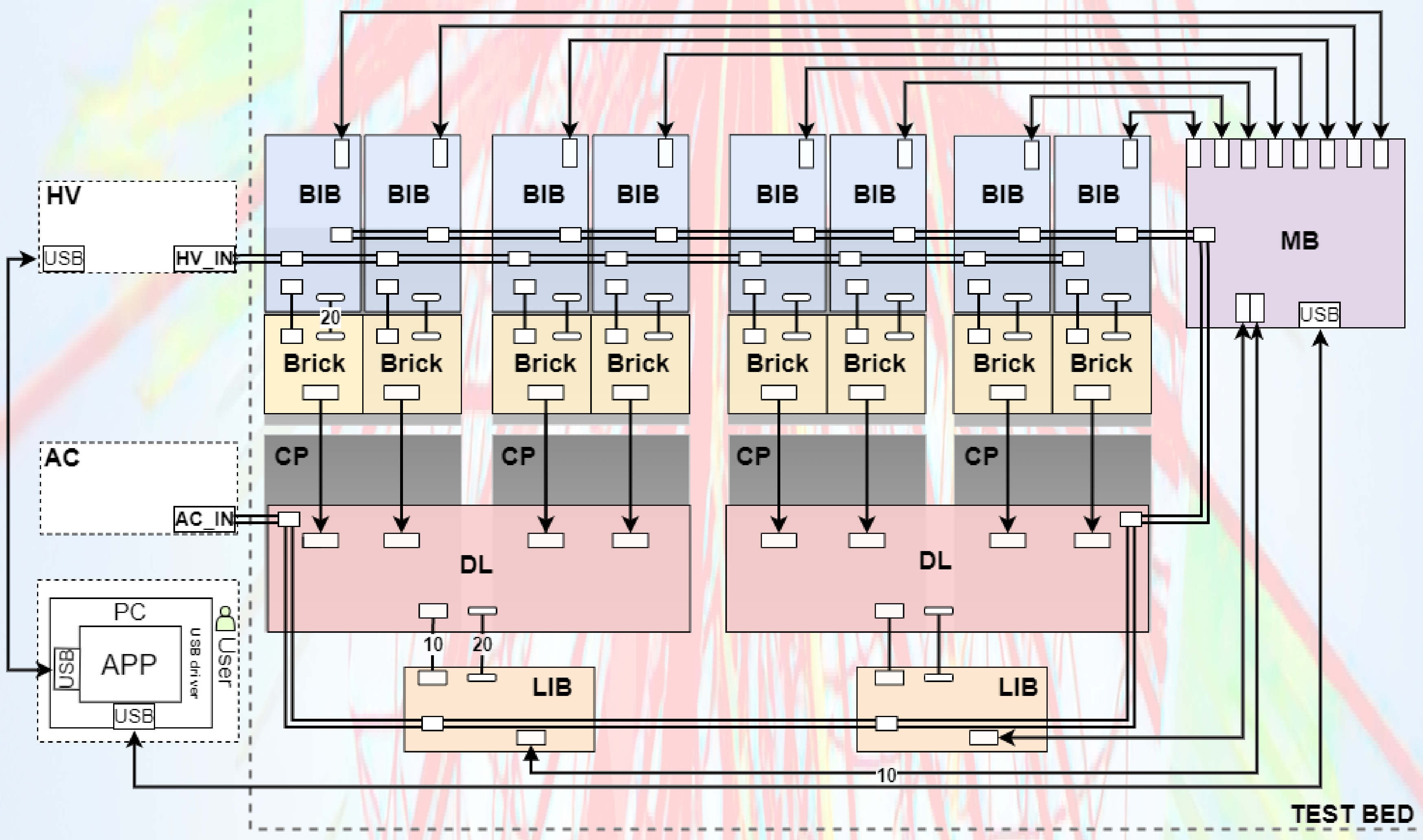

Fig.6 Block diagram illustrating the burn-in station. Adapted from diagram by S. Moeyedi.

Load Interface Boards (LIB) interface between the MB and Dummy-Load (DL) boards. As with the BIBs they digitize performance measurements obtained from the DLs (voltage and current of the brick output measured at the DL).The LIBs also control the load current of a Brick via Voltage-Controlled Current Sink (VCCS) located on the DLs. The DLs make use of 4 VCCS that use high precision op-amps and N-channel MOSFETs which are affixed to the CPs to dissipate the heat generated.

Preliminary Burn-in results

The Burn-in station is in a mature stage. To date preliminary testing of the hardware and software has commenced with favourable results being observed. As can be seen in Fig. 7 (left) the burn-in temperature parameter is being met with the hot spot being measured resulting from the primary-side MOSFETs. It is worth noting that the thermistor (with associated temperature T_2) utilized for the on-Brick measurements is located adjacent to these MOSFETS and is utilized in the Bricks Over Temperature Protection (OTP) circuitry. The T_2 temperature monitored during the burn-in procedure is illustrated in Fig.7 (middle). The burn-in temperature is stable with a mean value of $60.69°C$ and standard deviation of $\sigma = 0.19°C$.

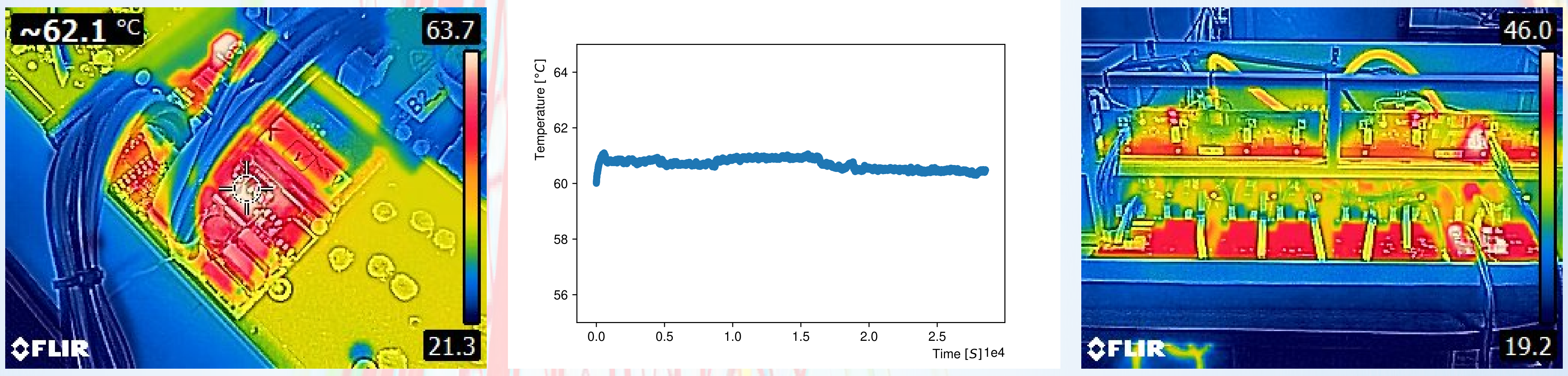

Fig.7 Thermal image of a Brick undergoing burn-in where the target is centered on the primary side MOSFETs (left). A temperature stability plot of an LVPS Brick undergoing Burn-in testing (middle). Thermal image of a burn-in station undertaking burn-in of a Brick (Right).