Mars Exploration Rover (MER) Power and Pyrotechnic Subsystem

Topic: **Spacecraft Power Systems and Performance**

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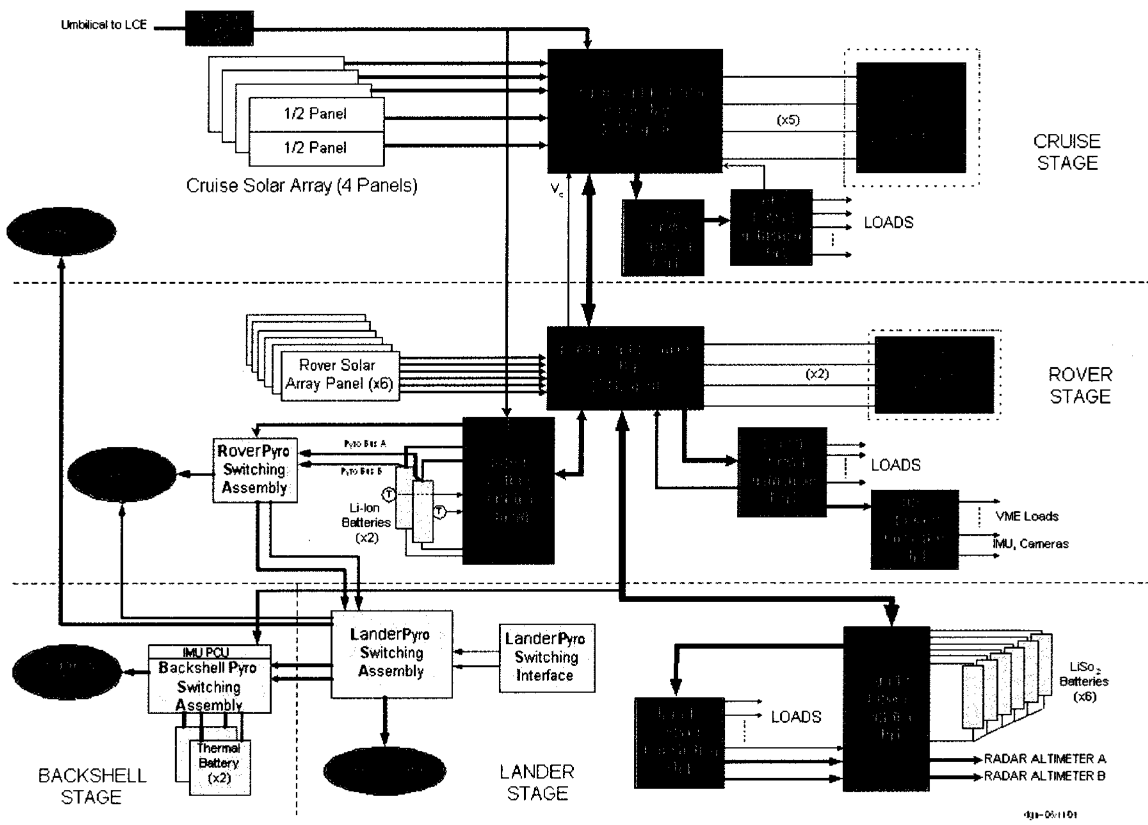
The Mars Exploration Rover Mission is the NASA mission to Mars during the 2003 launch opportunity. Two identical spacecraft MER A and MER B will launch in June and July of 2003 and arrive at Mars in January and February of 2004. These two spacecraft will deliver to the Martian surface two mobile platforms (Rovers) to perform remote sensing and in-situ experiments.

The mission architecture is based on the Pathfinder mission and consists of four main elements: 1) A Cruise Stage 2) An Entry Descent and Landing (EDL) system 3) A Lander Stage and 4) A Rover. Each mission element has unique power requirements, these requirements are satisfied by an integrated power system that is simple and optimizes the use of mass (see block diagram below).

MER POWER SUBSYSTEM FUNCTIONAL BLOCK DIAGRAM



The MER power system is based on a direct energy transfer system. Energy available from the Solar Array is used to power loads, charge the battery, or dissipated through the shunt radiators whilst maintaining an average bus voltage of 28 V.

Power Generation: Power generation is required during the cruise phase of the mission and during the landed phase of the mission. Each phase of the mission will be supported by separate solar arrays. From the time the spacecraft acquires sun at earth, until the turn-to-entry at Mars, power will be provided by a flat circular body mounted solar array on top of the Cruise Stage. The solar array consists of 4 fixed solar array quadrants, 2 quadrants may be switched open and half of the 3rd quadrant may be switched open. The solar array is based on GaAs triple junction cells with a cell size of approximately 4 cm X 6 cm and a thickness of 5.5 mm with a 3 mm thick cover glass. The array is sized to provide 300 watts to the spacecraft at Mars. The Rover array is mounted on the Rover RED (Rover Equipment Deck) , and on three primary deployable petals and two secondary deployable panels. The Rover cells are GaAs triple junction with 36 strings of 17 cells. They supply approximately 140 watts maximum power on the Mars surface at noon on sol 1.

Energy Storage: The baseline battery configuration was arrived at after several trades to optimize mass and still provide the pulse and steady state energy storage requirements. Energy storage for the mission will be provided by three sets of batteries. The three sets of batteries, based on different chemistries, optimally support the mission architecture. On the Rover, two eight cell 8 Ampere-hour secondary Li-Ion batteries, will provide energy for the launch, cruise, and the landed phases of the mission. The same Li-Ion secondary batteries will also power a pyrotechnic bus to support pyrotechnic events before and after EDL. During the EDL phase, two thermal batteries will support the Backshell pyrotechnic events. A set of six Lithium-Sulfur Dioxide (Li-SO_2) primary batteries, with a total capacity of 1200 Watt-hours, will support the loads from the time the spacecraft turns away from the sun to enter Mars until the end of the first Sol on the surface.

Power Electronics: The spacecraft bus operating voltage will range from 24 V to 34 V during all phases of the mission. Bus regulation will be accomplished by shunting solar array excess power. The Cruise Shunt Limiter Unit (CSLU), housed on the cruise stage, diverts power to the cruise shunt radiator based on voltage settings set at the Rover Shunt Limiter Unit (RSLU). The RSLU is housed on the Rover. The RSLU will also divert power to the Rover shunt radiator during the land portion of the mission. Charge control of the Li-Ion battery will be implemented by the Rover Battery Control Board (RBCB). The RBCB can control battery charge based on battery voltage and/or individual cell voltage. The RBCB will control battery charge by disconnecting the Rover batteries from the bus by the use of power FETs. During charge cells that reach a specified voltage limit will be by-passed until all cells are within a specified voltage range. If any cell reaches a slightly higher (also specified) voltage limit V_{cmd}, battery charge will be terminated. Similarly on discharge, the battery will be taken off—line based on a specified discharge voltage limit V_d. The voltage limits will be specified to minimize battery degradation based on battery ground test data. In addition to battery charge control, the RBCB also performs battery and solar array signal processing. Additional RBCB functions also include control of battery heater switching, and the generation of a wake-up signal based on solar array current or a wake-up timer. Several Power Electronics components are dedicated to orchestrate the 118 pyrotechnically activated events required by the mission. The Pyro subsystem design uses separate arm and enable relays commanded from fault tolerant switch interfaces. There are separate a and b pyro buses connected to the Li-Ion batteries (the a pyro bus from Li-Ion battery a and the b pyro bus from Li-Ion battery b). Pyro events during cruise, EDL and Sol 1 are deployed using the Lander Pyro Switch Interface (LPSIF) and the Lander Pyro Switch Assembly (LPSA). EDL events such as parachute deployment, heat shield separation and rocket firings are sent to the Backshell Pyro switch assembly through the LPSA. The Rover Pyro Switch Assembly (RPSA) which houses both the interface control and switching circuits activates Pyro events on Sol 2. As the spacecraft goes through the mission timeline, power sources and energy storage devices will be seamlessly interleaved. During the phase of the mission (from turn-to-entry to the end of Sol 1) when power is being provided by the Li-SO_2 primary batteries, bus power is maintained within regulation by the Lander Power Control Unit (LPCU). The LPCU provides for the monitoring and isolation of primary batteries as well as distributing power to various loads. On the Martian surface, the RBCB will provide low voltage regulated and isolated power to the Rover Electronics Module (REM) Loads. Loads outside the REM (cameras, motors, etc.,) will get regulated power from the Rover Power Converter Unit (RPCU). The RPCU regulates the power bus using commercial power converters of various power and output voltages.

Testing of all the units will be done at the component level followed by subsequent validation tests during various stages of subassembly and ultimately as part of the spacecraft verification.