Toward Power Bus Standardization for NewSpace

(2021 SPW - PMAD WORKSHOP)

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Power Standardization - Building Blocks for the Future

Discussion

- Common Interfaces are desired to reduce the cost & schedule, and risk involved when implementing the Electrical Power System Blocks:
  - *Solar Array: Solar Cells, strings & arrays*
  - *Array Regulator: Convert the Array power to charge the Battery*
  - *Smart Battery: Li-Ion Cells, strings & packs, including protection, monitoring, & balancing*
  - *Power Distribution: Controlled delivery of energy to loads via resettable current limiters / breakers*
  - *Standardized I2C telemetry and command: Integral part of the Standard Block Interface*
- Once qualified, multiple Vendors can produce each Plug & Play Block, similar to existing ACS and Communication gear
- Two standard block sizes of 100W and 500W increments are forecast to be easily "snapped together" to support 200W to 2,000W payloads for SmallSat missions
  - *Parallel Blocks (module level) are utilized to provide increased robustness for power delivery*
- Standardization is typically higher in size & weight, and lower in power efficiency
  - *Trade off between standardization & point-design efficiency needs to be accepted by the community*
  - ***What enablers and impediments exist in making a standardized EPS block-based system reality?***

Standardization of EPS drives cost and schedules down, & increases robustness; SWaP is not the #1 goal

The Payload Customer is King, Queen, and Everything that Matters

Modularity allows standard power system blocks to be scaled for payload needs

- More focus from our Payload Customers on standard Bus systems (including power systems)
  - *Customers looking toward the community for guidance in reducing Cost, Schedule & Risk*

- Sole source procurements often drive schedule (and thus cost) by limiting choices
  - *Customers want flexibility and options for working around schedule slips*

- Spiral development of Payloads can require new / modified Bus subsystems to support changes
  - *Increases in power consumption and ACS Control Authority often occur*

- Launch vehicles drive space and weight allowability
  - *Emphasis and focus on driving no volume (☺) massless (☺ ☺), perfect efficiency (☺ ☺ ☺) designs*
    - Unobtanium of course but a goal
  - *Standardization is somewhat contrarian to a point-design highly-efficient system*

Standardization benefits include rapid response to Payload changing needs with modular blocks

Standards updates are needed for NewSpace

Robustness to accommodate standard designs using COTS

- Updated standards needed to consider lower "classical" reliability
  - *Higher focus on shorter missions - experimental (class D), demonstrations (class C), reliability at constellation level*
  - *Quicker understanding of failures, solutions, modification, and recovery*
  - *Drive quicker turn around from satellite concept to acquisition – allows technology updates and reduced obsolescence*
  - *Some work done at Aerospace – SmallSat Hub focus on considerations of design given classifications*
  - ***Class C & D systems can quickly become real missions***
- Example: Power standards update consideration
  - *American Institute of Aeronautics and Astronautics (AIAA) "Electrical Power Systems for Unmanned Spacecraft" standard is outdated*
    - Existing standards are not consistent with NewSpace model
    - Battery focus on outdated Ni-H2 based standards can drive PMAD in the wrong directions
    - High reliability focus not necessarily indicative of many of today's quicker, lower cost, but still reliable, missions
    - **As we drive toward smaller spacecraft, margins, growth assessment may not be as applicable**
- What work is in process toward standardization?
  - *Not quite as much community focus relative to SmallSat standard considerations*
  - *Aerospace SmallSat Hub is doing some work in this area of the corporation is involved*
  - *Common ICD for Solar Array , Array Regulator, Smart Battery, Power Distribution, Standardized telemetry and command interfaces*
  - *Larger vehicle standard may be a starting point for SmallSat methodologies*
    - Acquisition-based, from contract to SC design – SMC and commercial focus as an example -needed for many SmallSat program offices

Updated standards with respect to Lithium battery based PMAD systems, & mission classification needed

Modification to Standards

Some Aerospace TOR work to modify existing standards

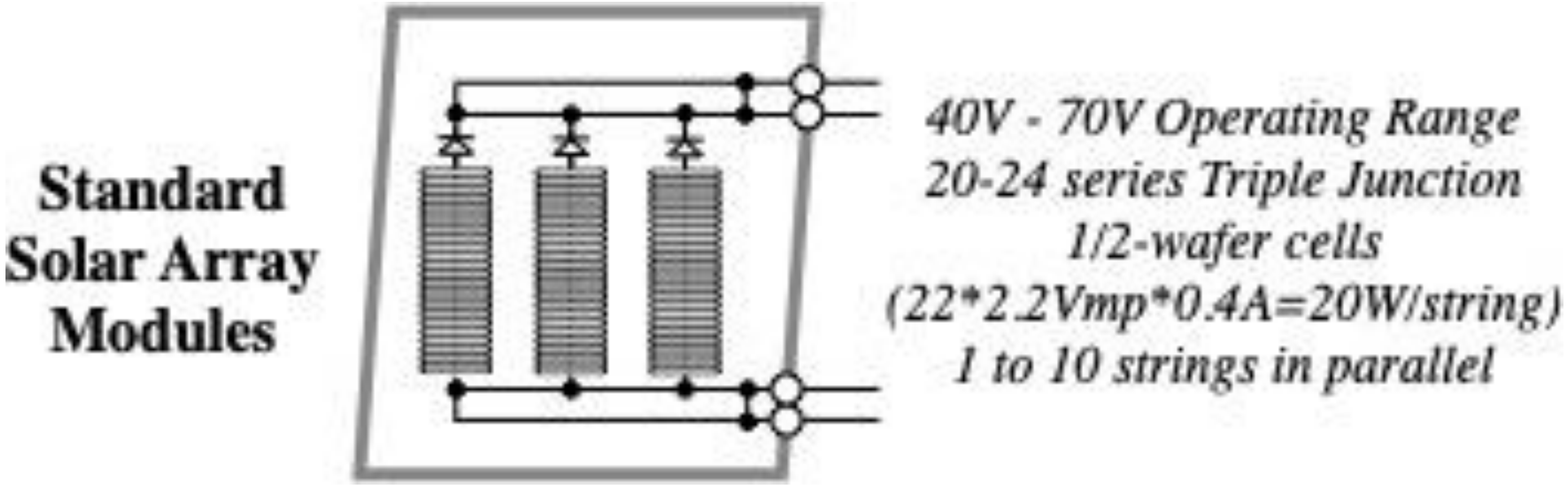
- Some Technical Operating Reports (TORs) exist and some are in progress which focus on NewSpace

- Lithium-Ion based & experimental/demonstration focused systems needs higher community focus with regard to standardization
  - *ICD and few requirements driven + Lots of testing – High focus on breadboarding and I&T program*

- **Standards can take multiple years to complete and can result in SmallSat standardization work becoming obsolete within a few years**

Consideration for update standards with respect to Lithium battery based PMAD systems, & mission classification

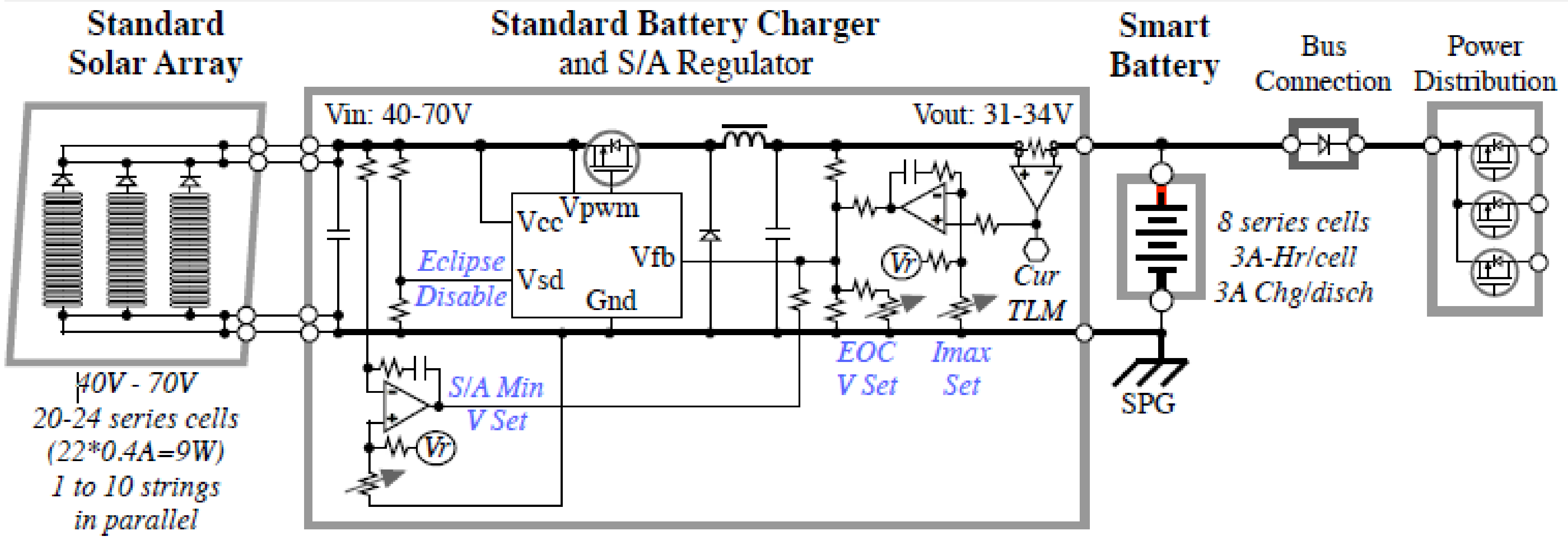
Solar Array Module (minimum of two per S/V) Requirements



- Electrical Power: Two (+) and two (-) wired “loop” connections for redundancy
  - *Open-circuit Voltage at Cold (-60°C) of 80V Maximum*
  - *Short-circuit Current at Hot (+100°C) of 2A (small) or 10A (Med) Minimum*
  - *Max Power Point at Operating Temperature (+60°C) of 40-60V*
  - *One Thermistor to report Array Temperatures*

100 & 500W versions for Small & Med Sat power from 100W to 2000W capability

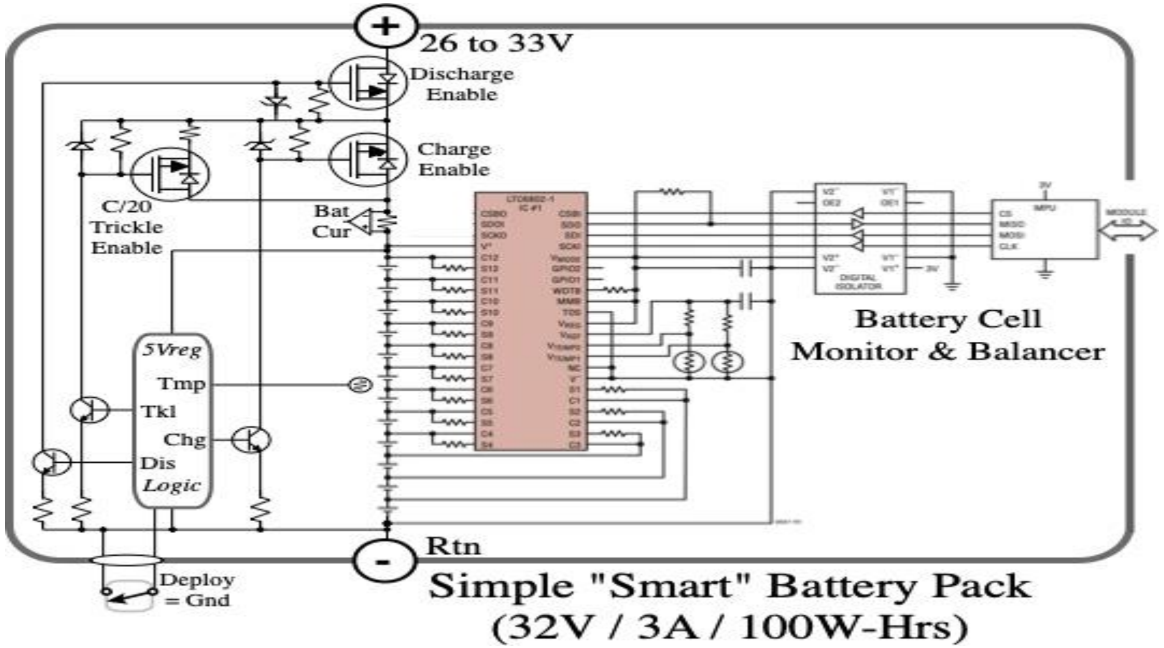
Battery Charger Module Interface Requirements



- Electrical Power: Two (+) and two (-) In & Out connections for redundancy
  - *Battery charge Voltage Set-Point adjustable from 31V Minimum to 34V Maximum*
  - *Output Current of 3A (small) or 15A (Med) Minimum to provide 1C charge current to Battery*
  - *Eclipse Disable power-saver (NOTE: Array regulator is powered from S/A – not Bus!)*
  - *Maximum Output Current Limiter set-point adjustable from Max to Max/2 Current*
  - *Charge Manager (Vsa Min, Veoc Max, Iout max) communications over I2C interface*

100 & 500W versions for Small &Med Sat power from 100W to 2000W capability

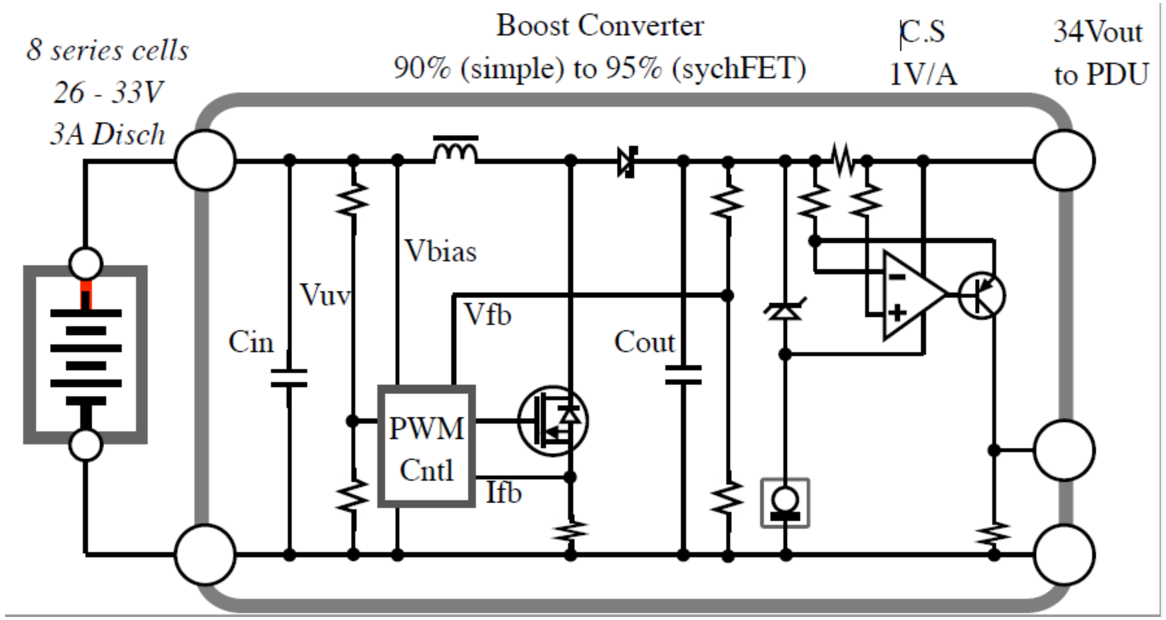
Smart Battery Module Interface Requirements

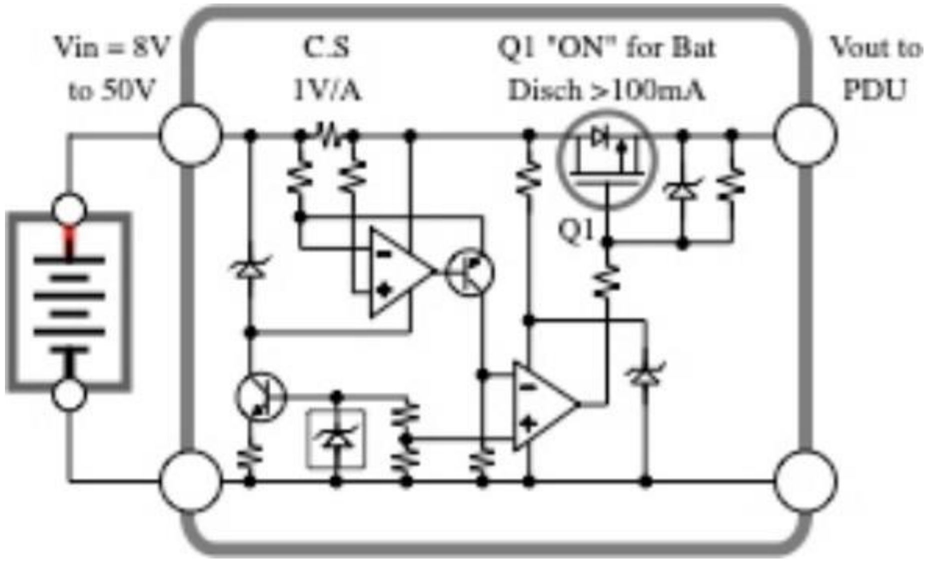


- Electrical Power: Two (+) and two (-) connections for redundancy
  - *Open-circuit fully charged Voltage of 33V Maximum*
  - *Discharge Current of 3A (small) or 15A (Med) Minimum for 1C nominal battery capability*
  - *Over- and under-Voltage disconnects to protect cells*
  - *Under-Temperature Charge Limiter at 0.1C to recover from dead-bus*
  - *Battery Cell Manager communications over I2C interface*

100 & 500W versions for Small &Med Sat power from 100W to 2000W capability

Battery Discharger / Distribution Module Interface Requirements

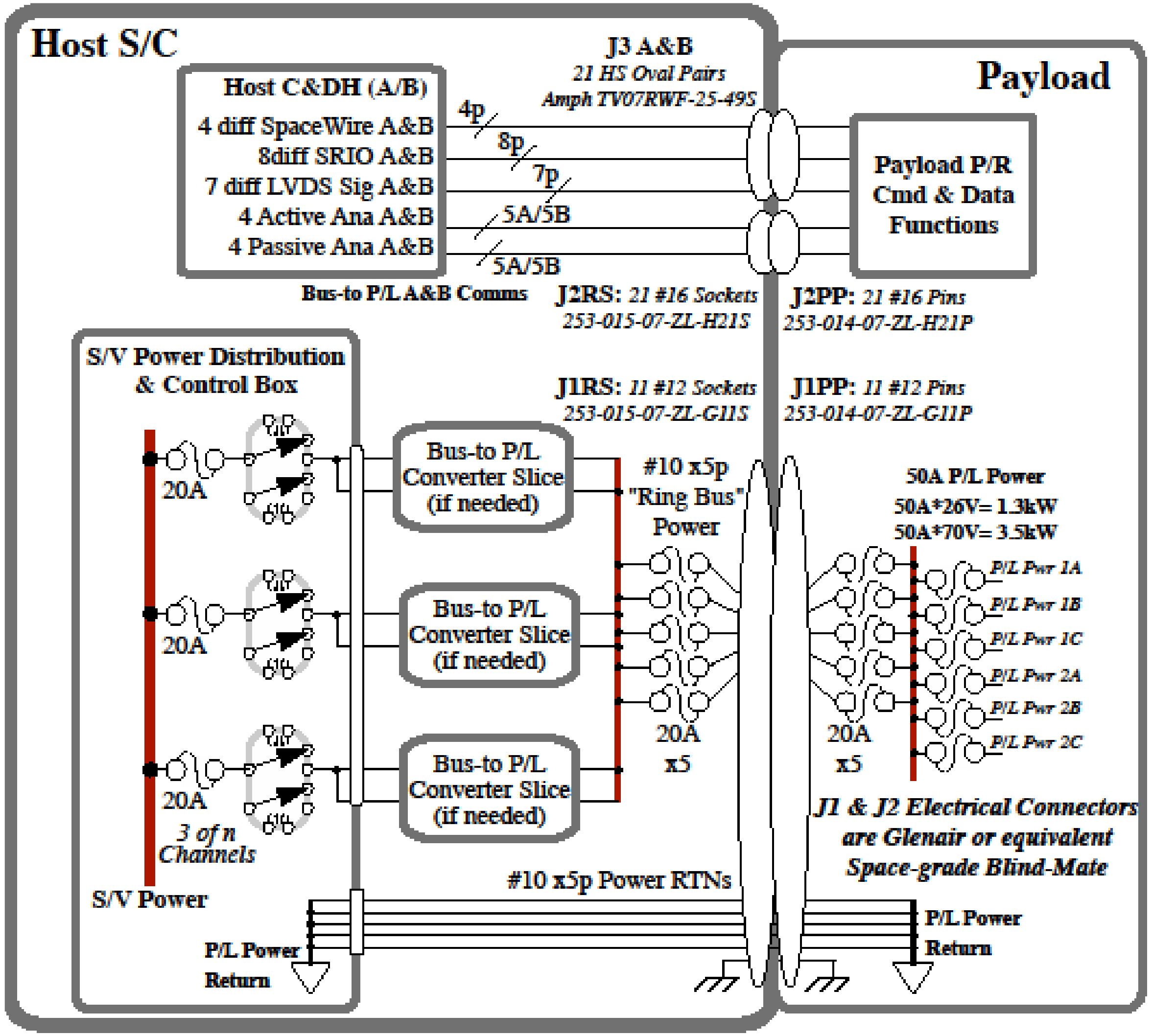




- Electrical Power: Two (+) and two (-) In & Out connections for redundancy
  - *Choice of Ideal Diode (Battery-on-Bus) or 34V Regulated Bus Voltage Modules*
    - Regulated Voltage set at 34V; adjustable 33.8 to 34.2V for Load Balancing, or Active Droop
  - *Output Current (100W, small) or (500W, Med) Minimum per parallel Module (2 minimum)*
  - *Load Manager (Vin, Vout, Iout) communications over I2C interface*

100 & 500W versions for Small &Med Sat power from 100W to 2000W capability

Bus-to-Payload common Interface Standards are also in development



Bus-to-Payload Electrical Interface
04/02/2021 P. J. Carian

- **Electrical Power:** Fused parallel Power "Ring Bus" wires move the Main Bus from the Bus to the Payload with single-fault tolerance
  - *A single connector provides Bus Power*
  - *Any single Short or Open wire will not impact P/L power delivery*
- **C&DH:** Command, Telemetry and Data Interface sized and populated to meet P/L Requirements
  - *Accommodation for two High-Speed Serial Buses (SRIO & SpaceWire)*
  - *Eight Basic LVDS signaling paths*
  - *Four Active & Four Passive P/L discrete TLMs with one common Return for each set*
  - *Standard Mil-38999 connectors specified*

Defining the minimum set of electrical connections is a challenge, but agile Customers are demanding it

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It takes a village to raise our NewSpace Environment – Looking toward the future