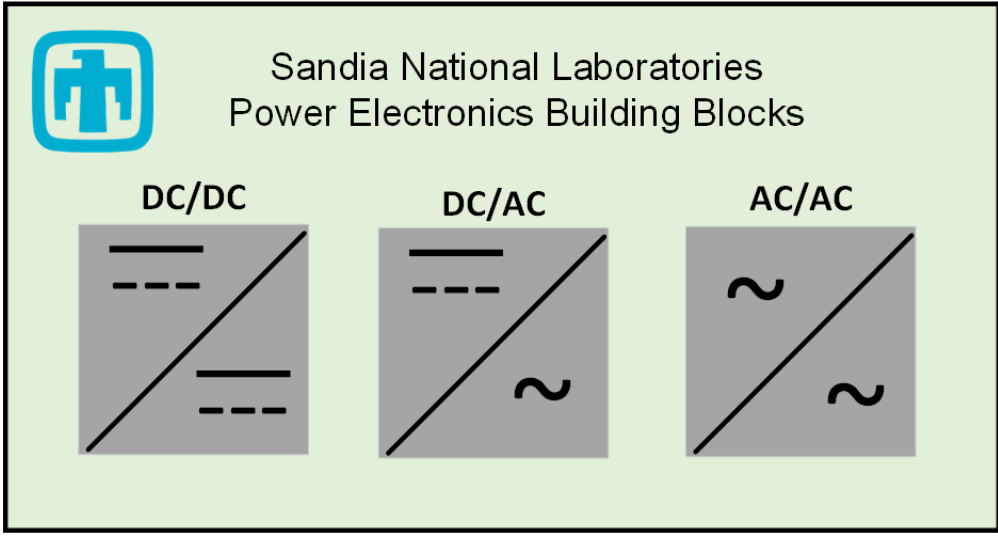*Sandia National Laboratories*

Open Source Software Platform for Modular Power Electronics for Energy Storage Systems

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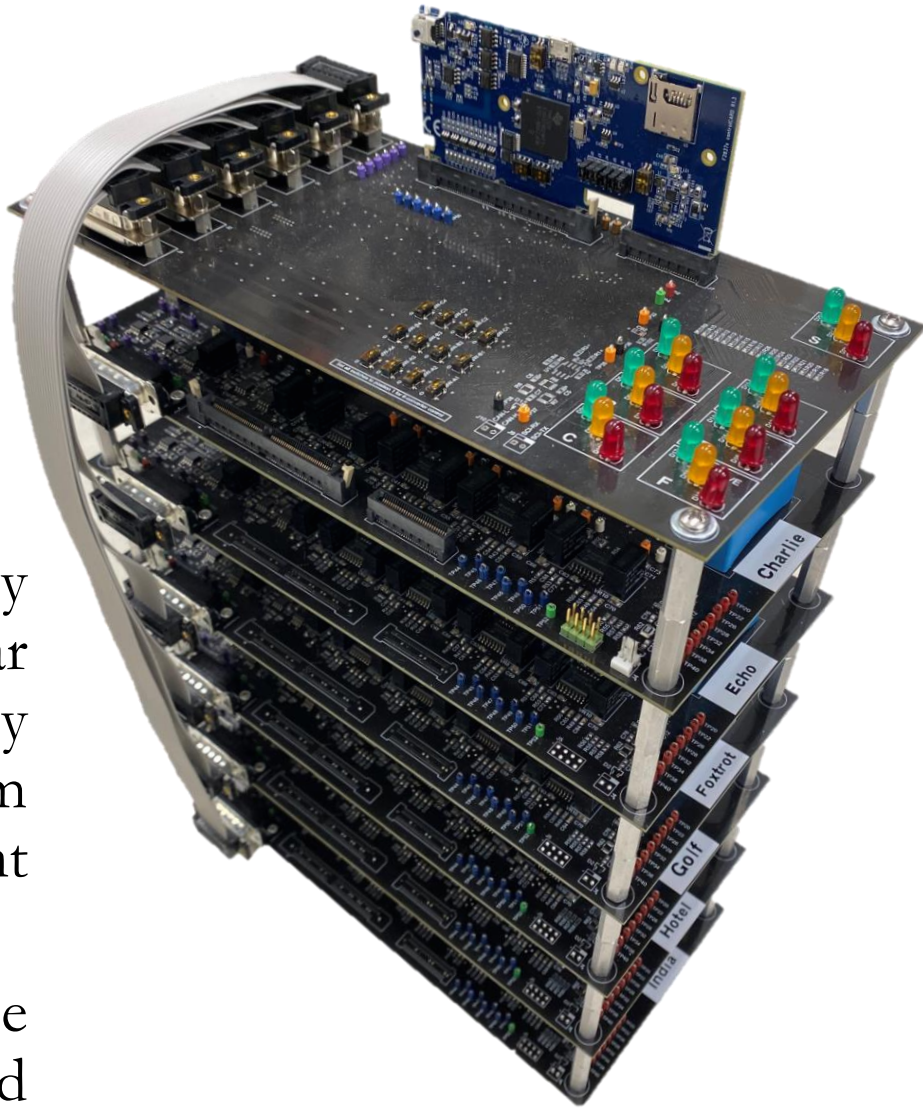
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Introduction

- The electrification of our energy landscape has placed power electronics at the center of energy conversion and therefore energy storage.

- Although current battery management systems (BMS) highlight important features like current/voltage protection, thermal management, health monitoring, and cell balancing, the systems remain suboptimal and are insufficient to realize the full potential of advanced energy storage beyond lithium chemistries.

- The next generation of power electronics for energy storage that are being developed at Sandia will provide an open source platform to facilitate advancement in key technologies like additional sensor integration, safety and reliability, and new battery chemistry performance characteristics.
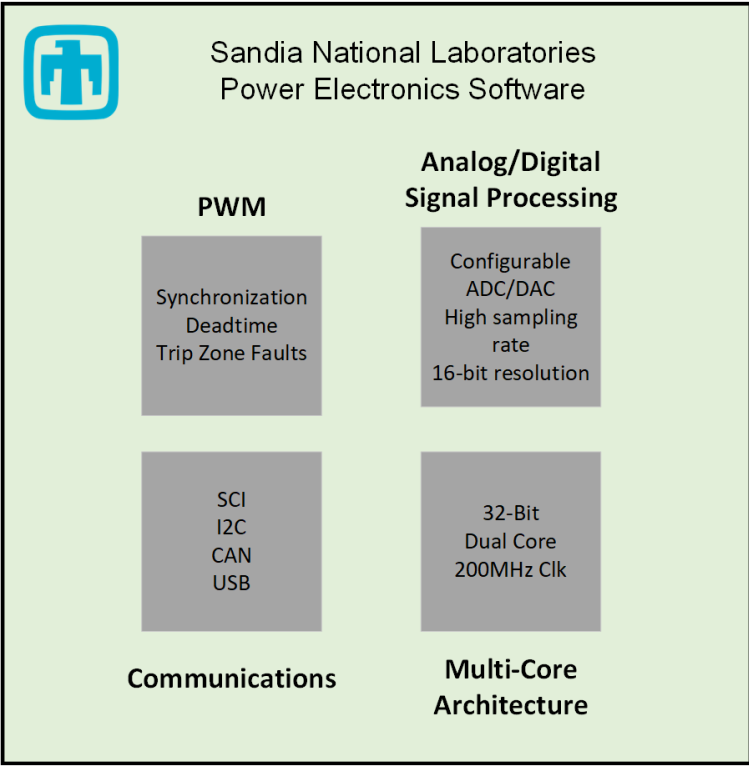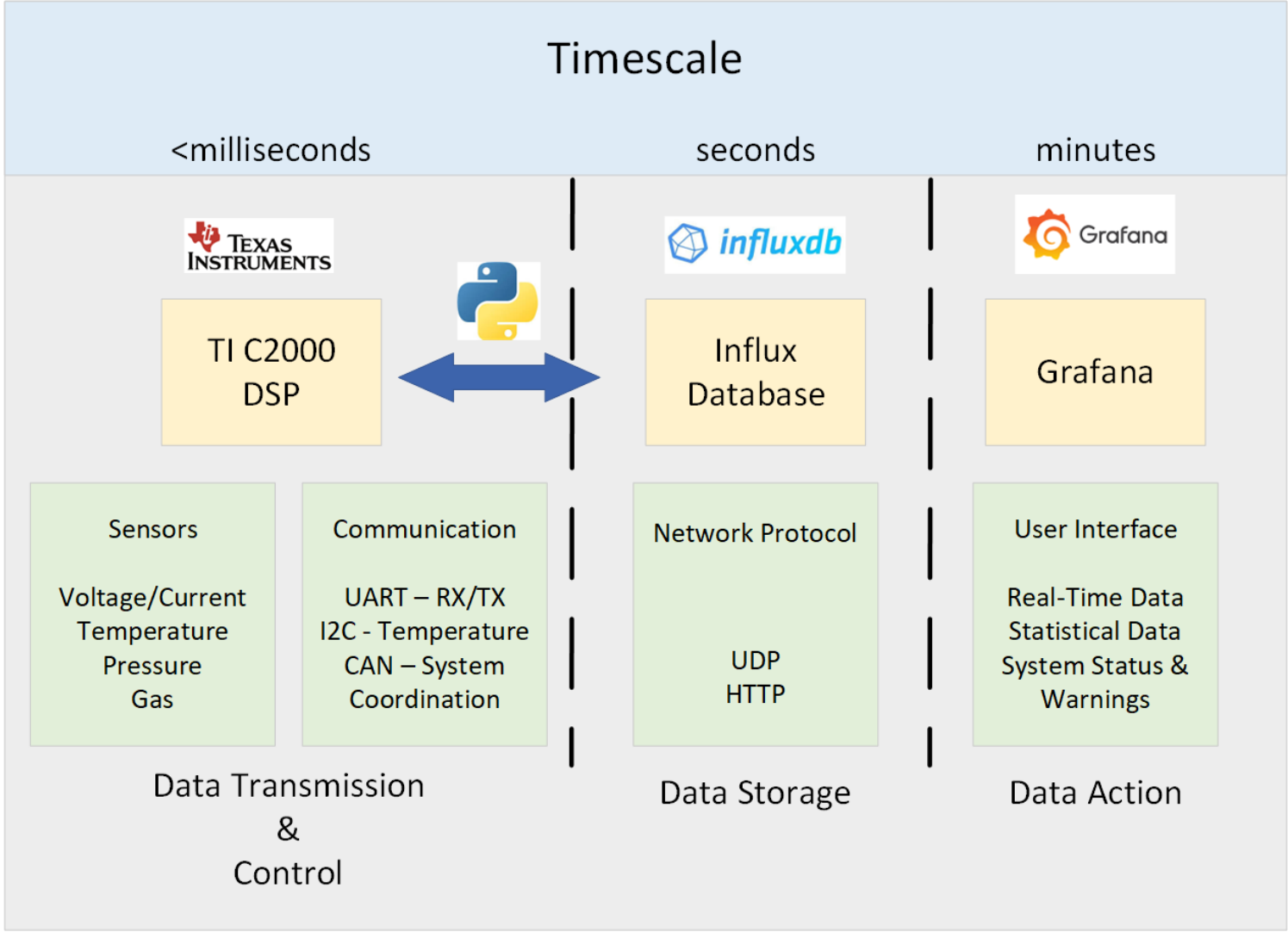
Power Electronics Building Blocks

- The DC/DC Dual Active Bridge topology (shown right) is one example of a modular topology that can interface directly to the battery cells and scale in a modular fashion. This system can configure in series or parallel to suit different battery needs.
- The simplest modulation scheme (single phase shift modulation) is used but more advanced controls offer critical features like hot swapping for ease of maintenance.
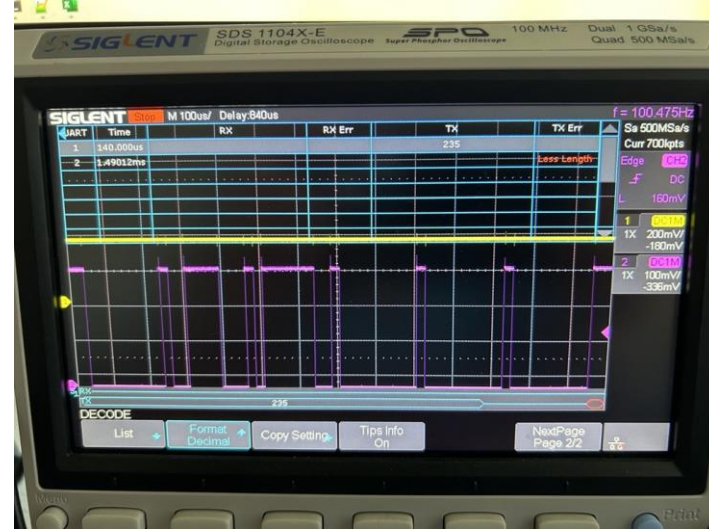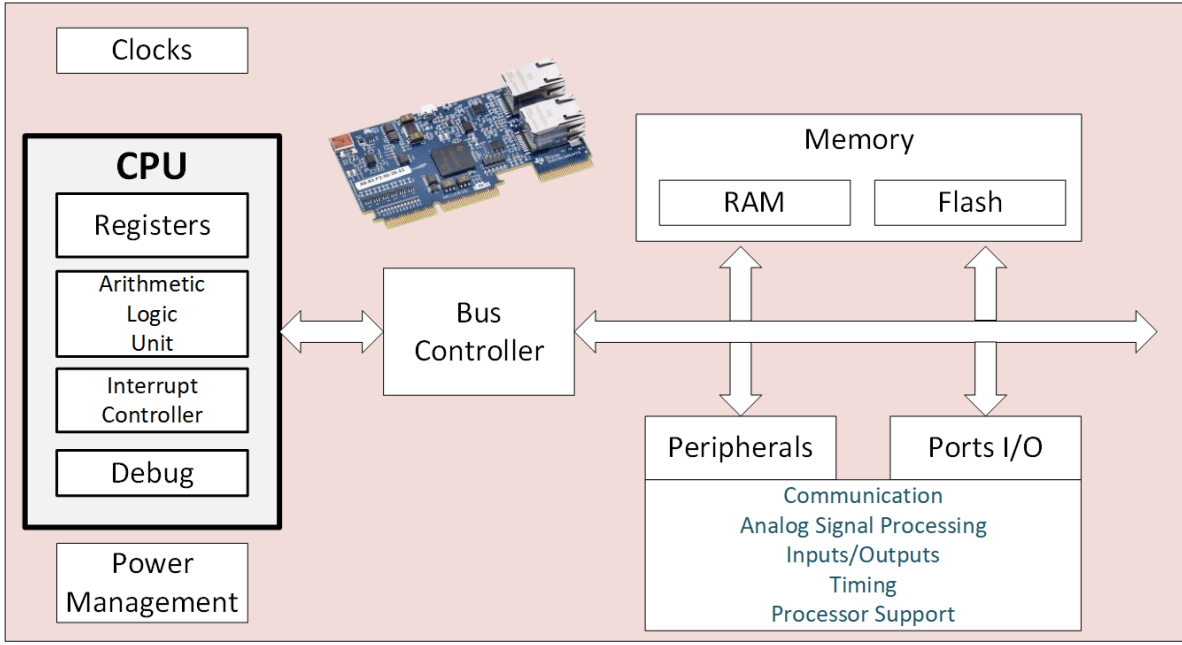
- The hardware building blocks also provide a testbed for advanced components like novel magnetic material and high power wide bandgap semiconductor modules.
- Safety and reliability are another critical aspect of advanced energy storage that serves our domestic grid modernization and security needs.
- Other advanced inverters (DC/AC) and Solid State Transformers (AC/AC) are also in development and testing at the Advanced Power Electronics Conversion Systems Lab (APEX).

Open Source Software Platform

- The software algorithms used in BMS for monitoring and control need to be highly **reliable, robust, modular, and scalable**. Bugs or failures in the software can lead to incorrect battery management, potentially causing safety hazards.
- In distributed BMS architectures, **communication latency** between different modules can affect the real-time monitoring and control capabilities, potentially leading to suboptimal performance or safety risks.
- Lack of **standardization** in BMS design and communication protocols has led to compatibility issues between different battery types and manufacturers, complicating integration and maintenance.

- Open source software platforms offer numerous advantages that can be particularly beneficial in research and development environments, such as community support and collaboration, transparency and security, innovation and rapid development, interoperability and standards compliance.
- Standard practice involves using a packaged code generation block from a high level simulation, such as Simulink or PLECS. However, a low-level programming strategy allows for great performance, efficiency, and control.
- Using Gitlab, the software development will be tracked, organized, and suitable for open source access upon testing validation.

Texas Instruments C2000 Real-Time Microcontroller

- The TI C2000 platform is the industry standard for enabling digital control of power, industrial, and automotive applications. Furthermore, it offers greater speed and controllability.
- The prepackaged control cards allow for easy integration and readily available from online suppliers.
- A high level structure of this microcontroller (above) has important features such as floating point processing for sensors, 32-bit architecture, a high speed 200MHz clock, and an enhanced PWM critical to power electronic control and switching strategies.
- An organized system of code block modules have been developed to support this next generation of power electronics R&D. This streamlines software development for advanced control techniques that have unique switching strategies, sensor integration, or communication protocols.

Data Management and Visualization

- InfluxDB is a popular open-source time series database designed for high-performance handling of time-stamped data, such as metrics, events, and real-time analytics. A database manager for InfluxDB would typically provide a range of features to facilitate the management, monitoring, and optimization of InfluxDB instances.

- Additional features include encryption and secure authorization methods, alerts on custom thresholds, and automatic data backup.

- Grafana is a powerful open-source platform for monitoring and observability, known for its ability to visualize time series data.

- InfluxDB and Grafana have a wide variety of users from IOT sensor arrays like smart homes, financial metrics, renewable energy installations, clinical patient monitoring, manufacturing processes and more.

- The serial interface of the C2000 DSP interfaces to InfluxDB via python scripts to feed the unique and customizable serial data to the database and visualization front end.

Summary & Future Work

- Software development is underway beginning with the critical features to support our rapid advancement of prototype power electronic converters for energy storage.

- Continued development will focus on digestible, functional code blocks for a diverse range of users to utilize for small to large prototype energy storage systems.

- Beyond the primary control features, additional software development is being made to address the important database management and user interface needs for the front end user.

- The database management aspect is particularly important for collecting data from diverse battery chemistries. It can act as a testbed for machine learning models that can be fed into higher level energy management systems.

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