# Programmable Power Converters and Measurements for PHIL and Power Systems Prototyping


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Powering your R&D

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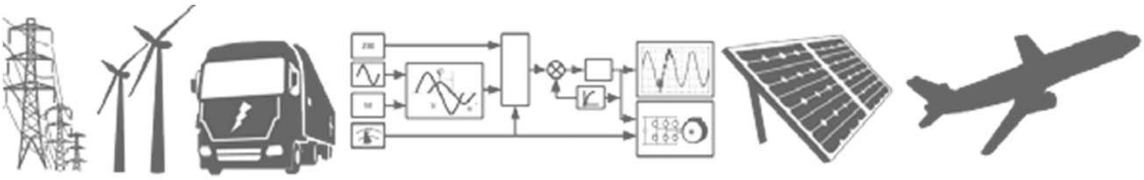
## triphase - Building a more-electric future...

The 21st century is becoming an ever-more electric one, Growing numbers of devices require electrical energy as their main power source. Ever more devices are capable of generating and storing electrical energy. Electric cars start to replace petrol ones. Sun and wind make up a fast growing part of our power diet. Battery technologies store ever more energy in a smaller volume. Leveraging these trends to improve our daily lives requires us to provide engineers with the tools to freely explore, realise and test ideas. This is where Triphase comes in.

## triphase - Solutions for research and test

Triphase tools and solutions aim at helping both research engineers and test engineers.

- We provide research engineers with open and scalable power converter and measurement systems to build smart grids and microgrids.
- We provide research engineers with test benches and open, reprogrammable inverter systems to prototype advanced motor drive controls and test new motor and inverter designs.
- We provide research and test engineers the platform, power amplifiers and measurements to build power-hardware-in-the loop test setups.
- We provide test engineers with easy-to-use but flexible power converters for DC and AC testing. This includes applications such as battery and PV panel testing.



## triphase - Products and technologies

### PMx programmable power

Triphase PMx encompasses a range of power converters and amplifiers for AC and DC research and test.

### DPS open and scalable platform

Triphase DPS is a platform for building large-scale power conversion and measurement systems.

# About PMx

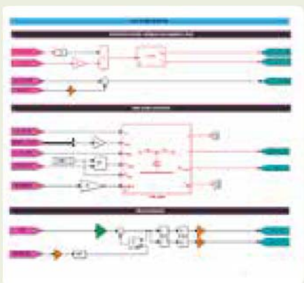
## PMx Modular, Programmable Power Modules

Triphase PMx is a modular power converter platform offering 15 and 90 kW building blocks for AC, DC and motor drive applications. PMx modules can synchronize with one another and work together as parts of a larger system. This allows power levels into the MW range, easy setup of multi-node power routers and management of complex energy flows. PMx systems feature an open data, open software architecture. All PMx measurement data is user-accessible. Moreover, they are programmable as to adapt to your particular needs.

## PMx Key Features

- Modular and scalable system architecture. This enables a wide range of configurations and applications, including four-quadrant motor controls and multi-channel bidirectional DC/DC, AC/DC and AC/AC applications.
- Easy and safe to use. Minimal time is required for configuration and setup. PMx comes in IP22 enclosures and include all necessary measurements and safety features.
- Open and fully programmable. Users can adapt PMx behaviour to suit their particular needs, if necessary by reprogramming existing controls or by adding new ones.

## Multi-Module Software Applications



PMx systems come with high-performance software that can span multiple PMx modules, facilitating advanced energy and power management. Available software modules include

- Bidirectional AC and DC voltage and current sources for load and source emulation.
- Motor controls for induction motors, PMSMs and doubly fed induction generators (DFIG).

## User-friendly Application Development

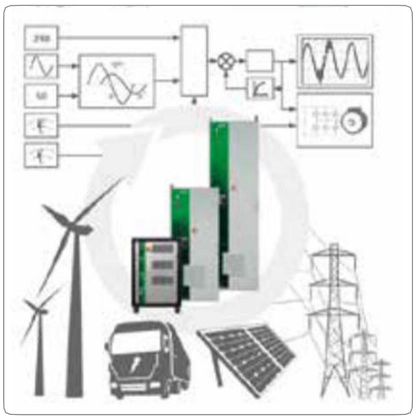
For application development, Triphase adheres to proven, easy-to-use engineering environments and open source standards. This way, we aim to empower PMx users to develop their own applications.

- Matlab/Simulink™ graphical programming for developing real-time control algorithms.
- Python for test automation and automated data processing.
- HTML5 for browser-based user interfaces.

# PMx Application Areas

## Micro- and Smart Grid Equipment

PMx is a multi-purpose power system that can emulate and interface with a wide variety of loads and sources. PMx real-time inter-component communication enables advanced energy and power management. Multiple units can be synchronized and controlled and monitored from a single real-time controlunit.

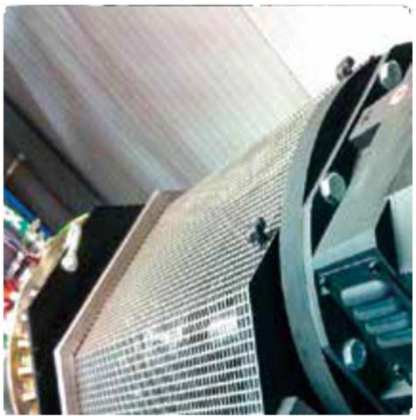


## PHIL - Load and Source Emulation

PMx power modules can be programmed to serve as high-performance power amplifiers as well as load and source emulators. They enable you to test your device under close-to-reality conditions. User-friendly operator and engineering interfaces support easy automation and customization of test procedures.

## Test Systems for PV, Batteries and Grids

PMx offers hard- and software modules to test and emulate, amongst others, batteries, PV systems and AC grids. PMx can handle applications up to 1 MW.The built-in scripting interfaces facilitate advanced test automation. Triphase systems are intended both for lab use, field tests and end-of-line testing.



## E-Motor Test benches

PMx is able to power e-motor testbenches into the MW range. It supports motor drives with up to 12 synchronized output phases. Moreover, the open programming interface enables rapid motor drive control prototyping. As such, PMx simplifies development and test of e-motors as well as the associated innovative controlstrategies.

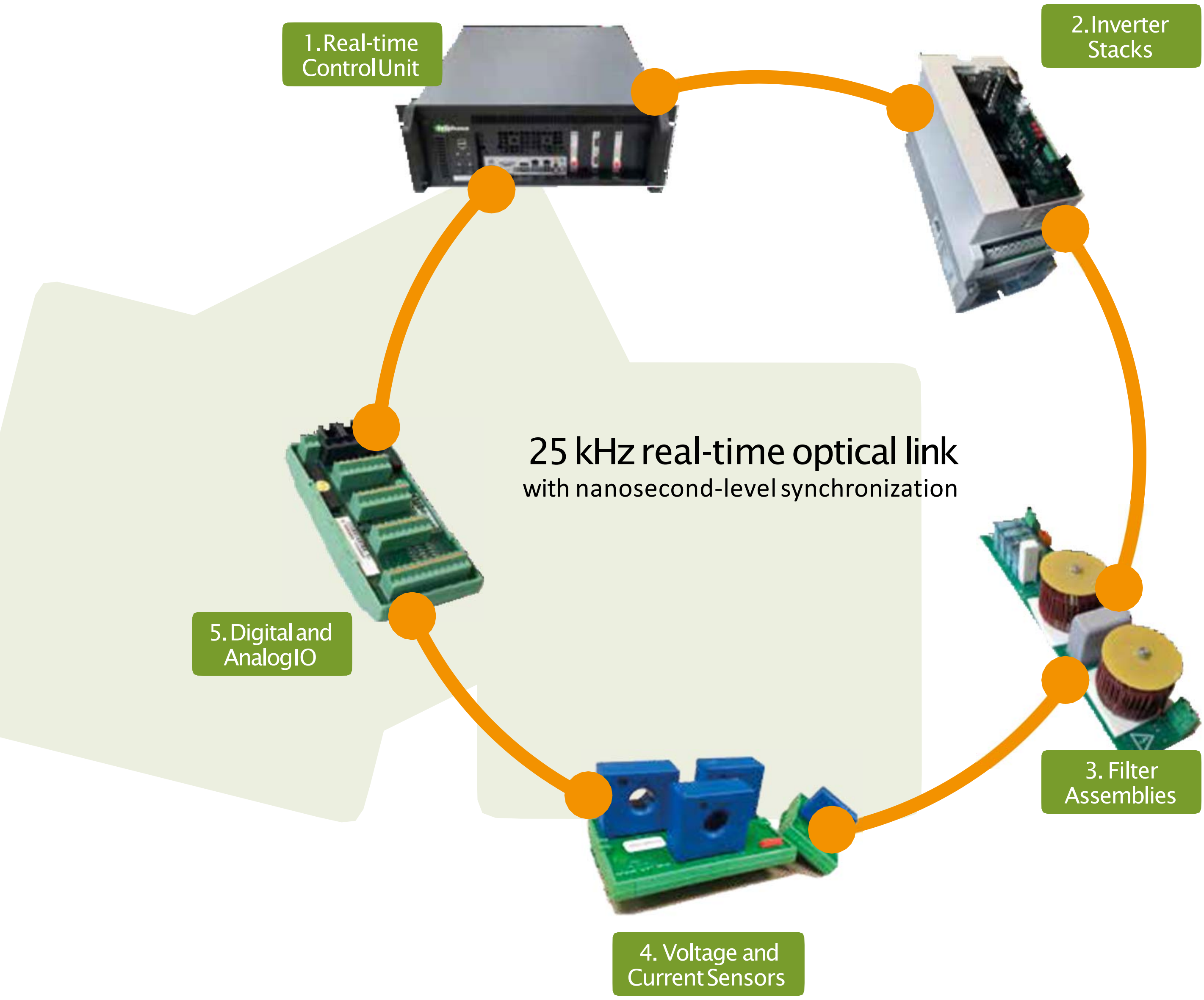
# About DPS

## DPS Platform for Open and Scalable Power Conversion and Measurement

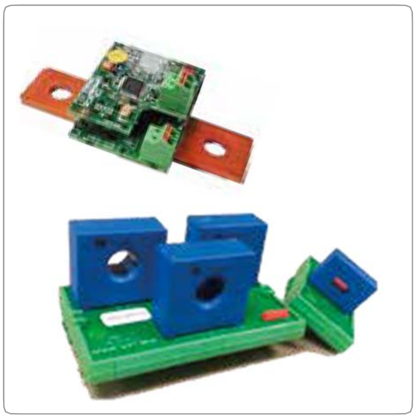
The Triphase Distributed Power System (DPS) platform connects and synchronizes clusters of power sensors, inverter stacks, filter assemblies and general-purpose I/O to a real-time optical network backbone. DPS features centralized control and processing on a single real-time target (RTT). DPS is ideally suited for high-end, multi-node power conversion and measurement applications.

### Key Features

- Multi-node power conversion and measurement
- Reliable, industrial-grade components
- Centralized monitoring and control
- Robust data acquisition and communication
- Nanosecond-level synchronisation
- Rapid control prototyping with PWM-level access
- Continuous and event-based data logging
- Open programming and communication interfaces



# DPS Application Areas



## Large scale power measurement

DPS enables the setup of synchronized, multi-node, distributed measurement setups. DPS supports a wide range of industrial current and voltage sensors. All raw data is centralised and made accessible on the real-time control unit and can be processed freely.

## Educational Laboratories

Education is key for a more electrical future. Triphase provides affordable and flexible packages for teaching courses on motor drives, AC/DC and DC/DC converters as well as power systems control.

## Rapid Control Prototyping

Reduce your effort for the design and rapid prototyping of complex power and mechatronics systems. DPS PC-based control units are open and easy-to-program. DPS features control rates up to 25 kHz. Support for a wide range of networked IO and third-party fieldbus systems ensure that your system is wired and running in no time.

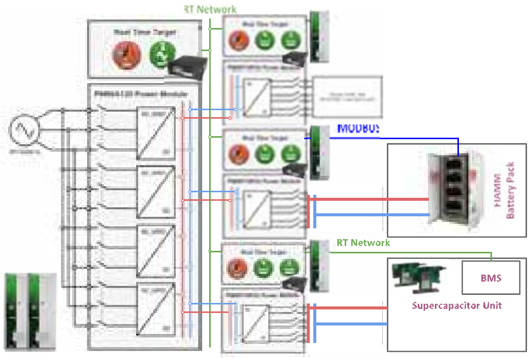
## Multi-Node Power Electronics Control

Develop, prototype and test novel converter topologies such as multilevel , dual active bridge or matrix converters. With DPS you can tap into industrial components with maximum flexibility.

## Success Stories

### Energy Storage Test Bed for Newcastle University, UK

The test bed connects multiple battery and super-capacitor packs to the main grid. At the heart of the setup is a Triphase PM90 multi-node converter system. It consists of a 360 kW bidirectional active frontend a three 90 kW bidirectional DC/DC converters. All converters connect to a joint DC bus, enabling the exchange of energy between all sources, sinks and storage elements connected to the system. As such, it is a multi-node power router.




The testbed consists of:

- 2 x 180 kW programmable active front-ends
- 3 x 90 kW programmable DC/DC converters
- A large supercapacitor system
- Several batteries
- 4 x real-time control units

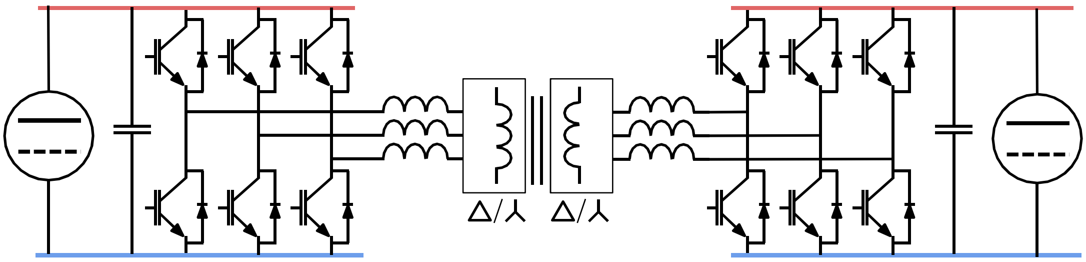
One of the main advantages of this facility is its high degree of flexibility allowing fast and easy integration of a multitude of existing electrical energy storage systems, their combinations and even the emulation of novel and emerging technologies. It is built around a high-performance, fully reprogrammable platform allowing us to study in detail a wide range of phenomena associated with the operation and control of grid-connected energy storage and develop relevant solutions.

Haris Patsios
Science Central - Newcastle University, UK

For more information on Science Central, see http://www.ncl.ac.uk/sciencecentral/

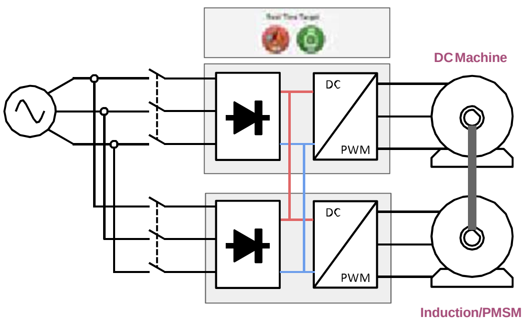
## 3-phase Dual Active Bridge Prototype for TUEindhoven

Triphase DPS was used to prototype a dual active bridge converter. TUEindhoven researchers created a DPS network connecting two 90 kW power stacks and several measurements. Minimizing time-to-hardware, they could focus on the development of the magnetics and validation of the concept. New control strategies were implemented and tested on the Triphase RCP control target.



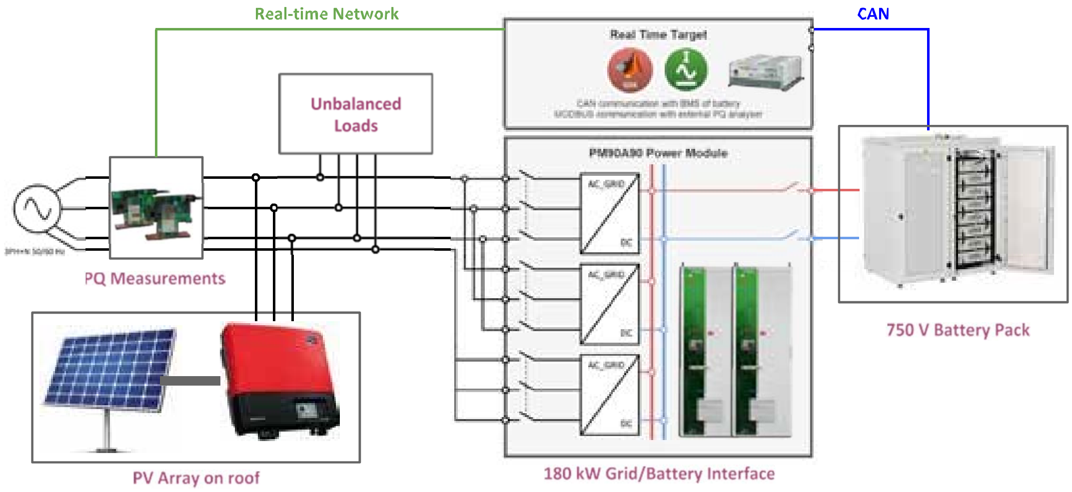
## Educational Lab for TUEindhoven

For its teaching classes, Eindhoven university realized 8 fully programmable motor test beds. Each test bed comprises a separately excited DC machine and either an induction motor or a PMSM. Motors are controlled using Triphase DPS inverters. During laboratory sessions students use the setup to practice motor identification and control. They perform experiments to determine rotor and stator characteristics and to tune control parameters. In advanced classes, they develop their own motor controls from scratch.



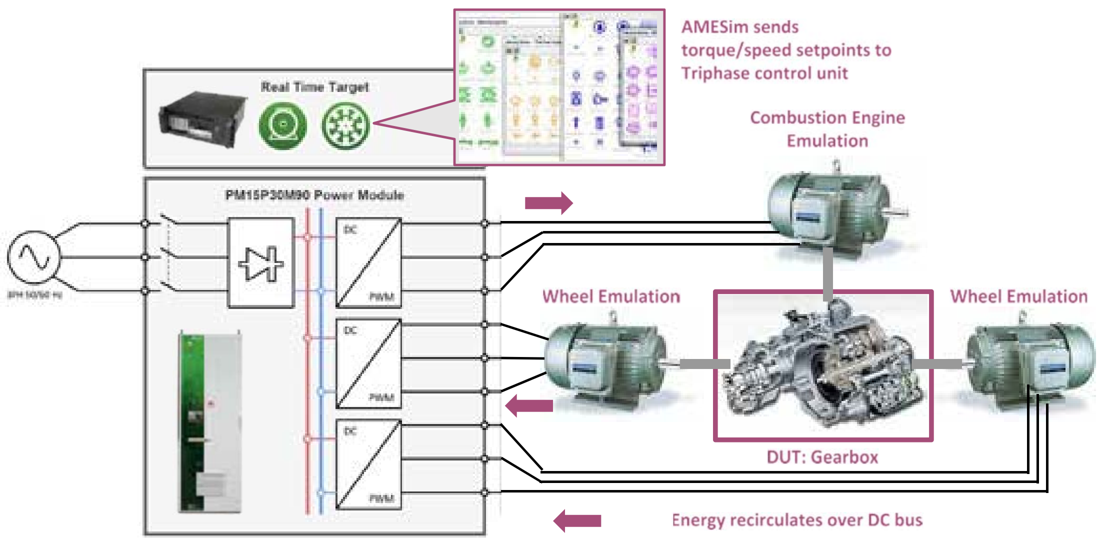

## Grid-integration of renewables for Meta PV

The MetaPV test setup, installed in the Belgian city of Sint-Truiden, connects a 60 kWh LiOn battery to the main grid. It is programmed to buffer the fluctuations from a PV installation. At the heart of the setup is a Triphase PM90 multi-converter system. It consists of three 90 kW sections that can be configured both as a 270 kW 3-phase, 3-wire grid frontend or as a 180 kW, 3-phase, 4-wire frontend. The PM90 sections facilitate a bidirectional exchange of energy between the battery and the grid.



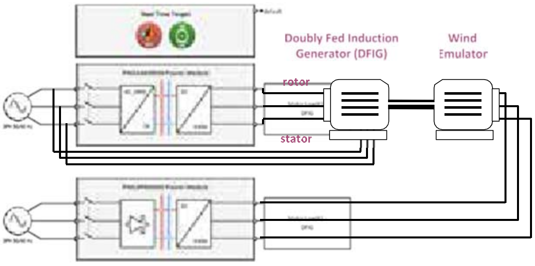

## Testbench for CVT with hybrid simulation for Siemens LMS

A CVT power-hardware-in-the-loop testbench was realized for Siemens LMS. The test bench integrates AMESim real-time simulation models with power hardware. With the CVT as the device under test, the Triphase system controls 3 electrical motors to emulate the combustion engine and the wheels.



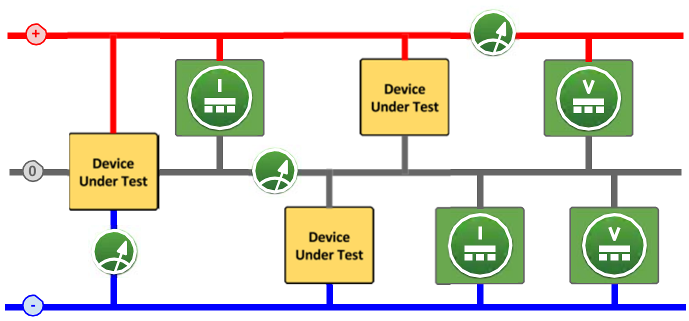
## DFIG Test Bench for University of Valencia, Spain

The University of Valencia, Spain, uses a Triphase-delivered electromechanical test bench for windmill emulation and control. The test bench features a doubly-fed induction generator (DFIG) facing an induction motor. The setup is controlled by a PMx converter system. The converter system contains a four-quadrant motor drive for DFIG control and a two-quadrant motor drive for load motor control. The converter system is fully reprogrammable. It comes with open, Simulink-based control algorithms for both DFIG and load motor control. Users can study the algorithms and use them for their own developments. Test runs are automated through the Python scripting interfaces. This boosts productivity in dealing with repetitive and time consuming tasks.




## Smart Programmable Load and Source for more-electric aircraft testing

Triphase delivered a multi-functional power module for the Cleansky more-electric aircraft test bench. The power module can act both as a source and as a load. It covers both DC and 400 Hz AC applications. DC applications include battery emulation, fuel cell emulation and emulation of hydro-electric and electromechanical actuators. AC applications include 400 Hz grid and load emulation. The system builds on an open and flexible software platform. As such, the entire system can easily be reprogrammed and is capable of running a Triphase- as well as user-developed application programs.




**Learn more on how PMx and DPS is used by our customers at triphase.com/applications.**

## References

Triphase is an important partner for the Maurice Hancock laboratory at Imperial. Their unique technology allowed us to build a very flexible Smart Grid test environment. Researchers at Imperial can now perform experimental validation of concepts for power converter control strategies quickly and easily instead of relying on simulation only.

**Tim Green, Professor of Power Engineering, Imperial College, London**

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