A Modular, High-Power, Radiation-Hardened, DC-DC Converter with Decentralized Control

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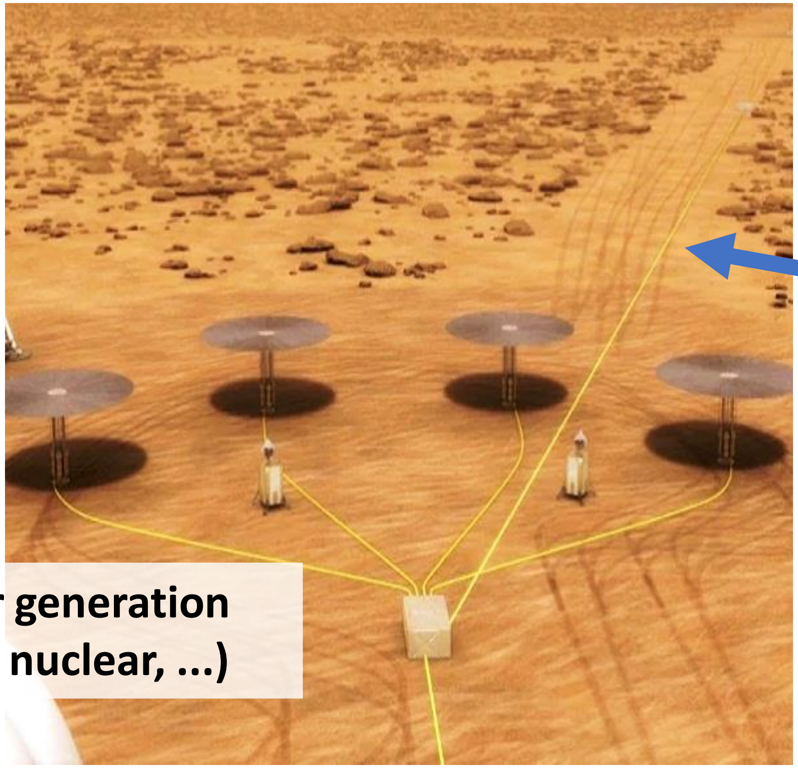
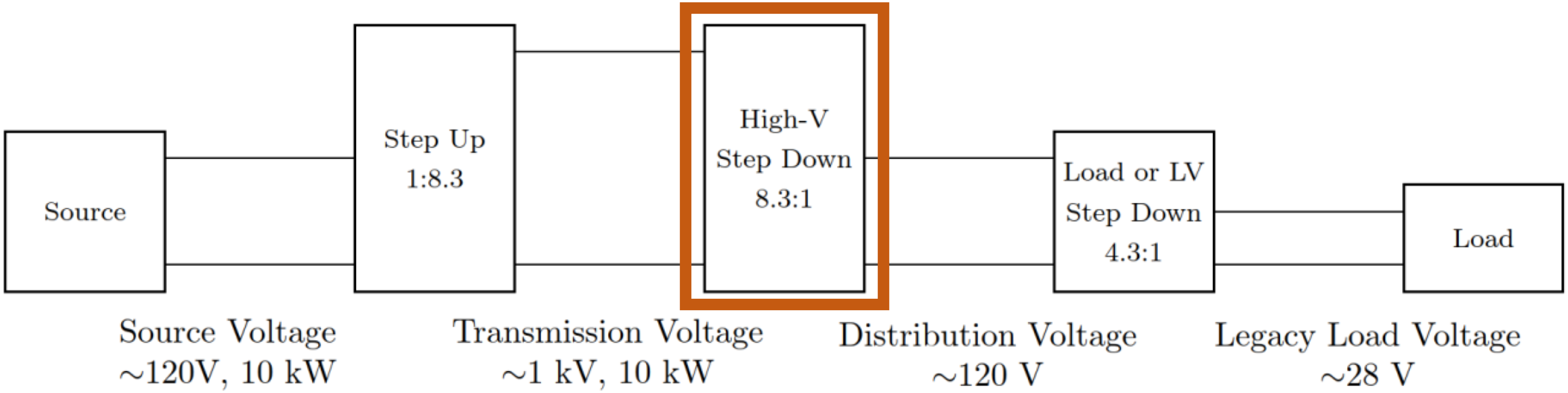
Space Power Workshop - Aerospace

Powering lunar/Martian habitats



A Martian power concept (courtesy NASA)

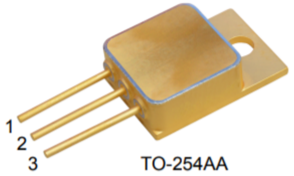
Adopt high transmission voltage to reduce cable weight



Silicon outlook fairly grim

STRH100N10

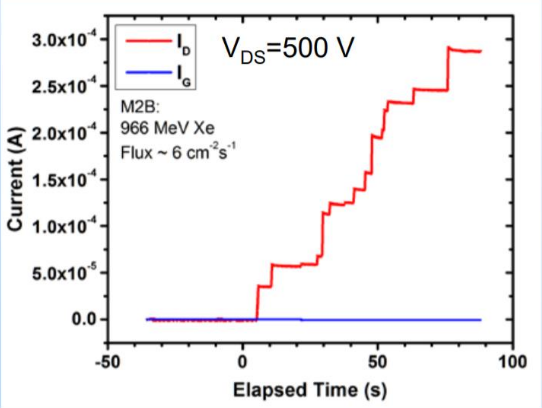
Rad-Hard 100 V, 48 A N-channel Power MOSFET



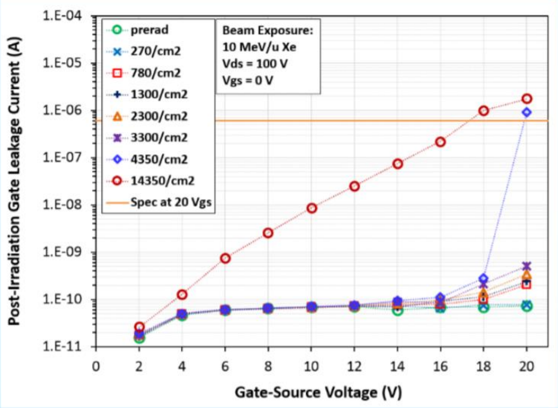
Features

V_{DS}	I_D	$R_{DS(on)}$ typ.	Q_g
100 V	48 A	30 mΩ	135 nC

Silicon Carbide not much better



1200V MOSFET biased at 500V: increasing permanent drain leakage current with ion fluence

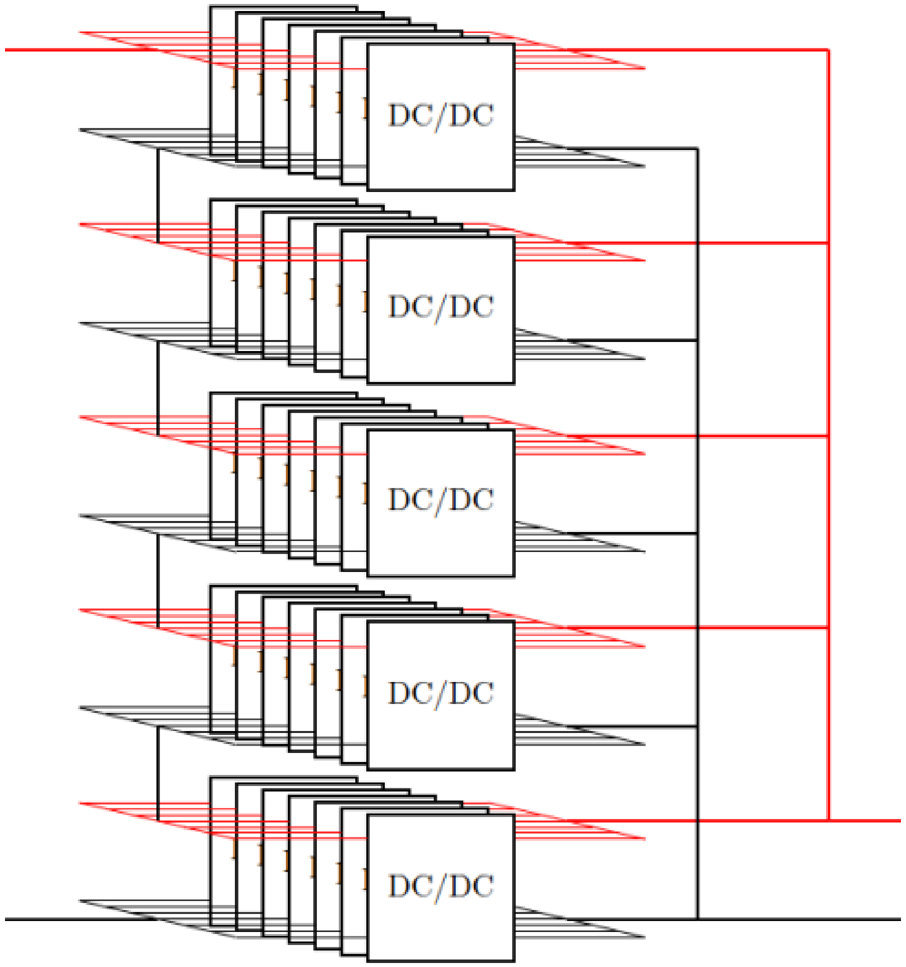


Same part type at 100V: permanent degraded gate leakage current with ion fluence (as measured post-irradiation)

We need…

1) a modular architecture to stack low-voltage modules into a high-voltage stack

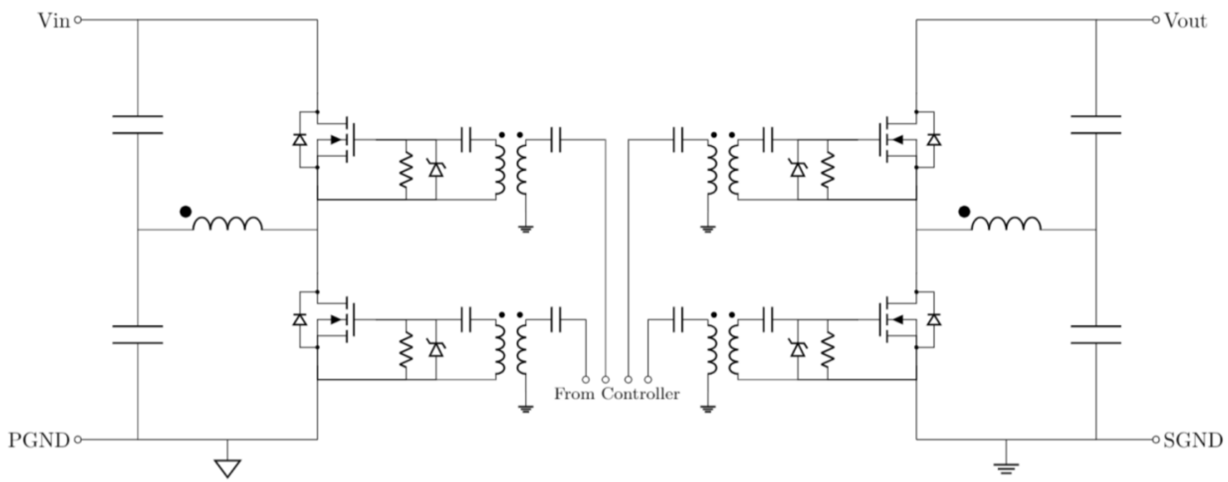
2) a rad-hard IC technology for sophisticated control with low die area and power consumption

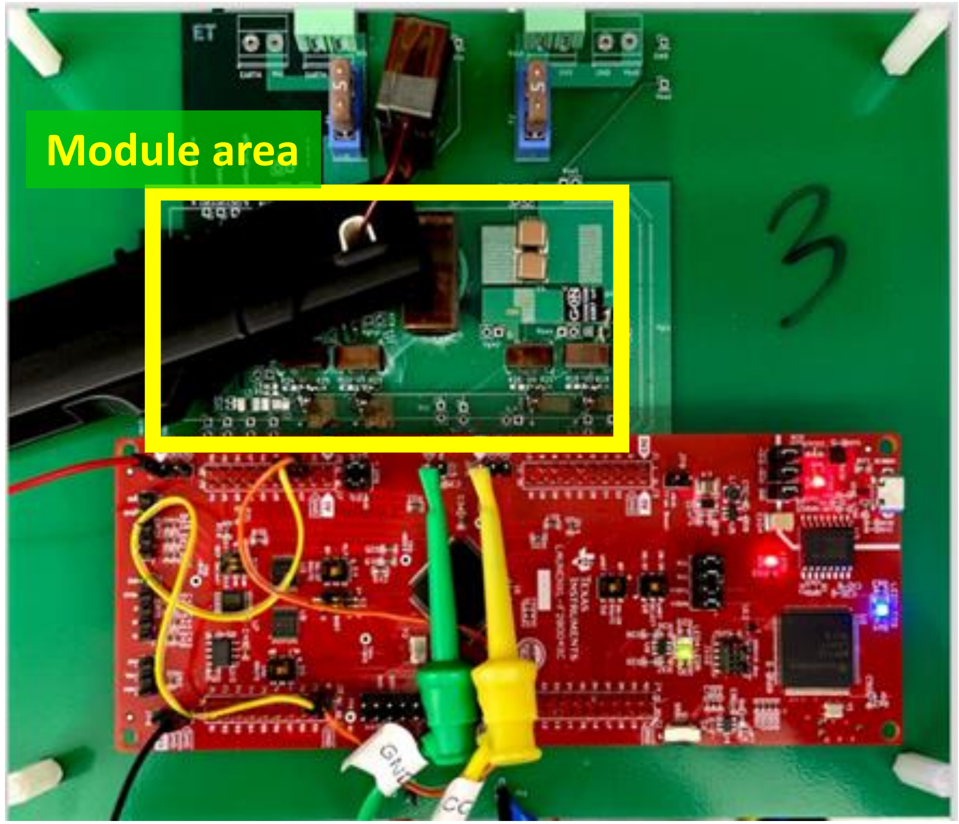


Benefits of modularity, space/terrestrial

- Handle high voltage (with low-V parts with better FOM)
- Handle high current
- Ability to shed modules for high efficiency
- Operate at high-frequency
- Lightweight modules easy to handle, ship, assemble
- Large surface area for conducting heat
- Access to inexpensive low-power parts with high production volumes
- Ability to operate through failures, repair/replace without downtime

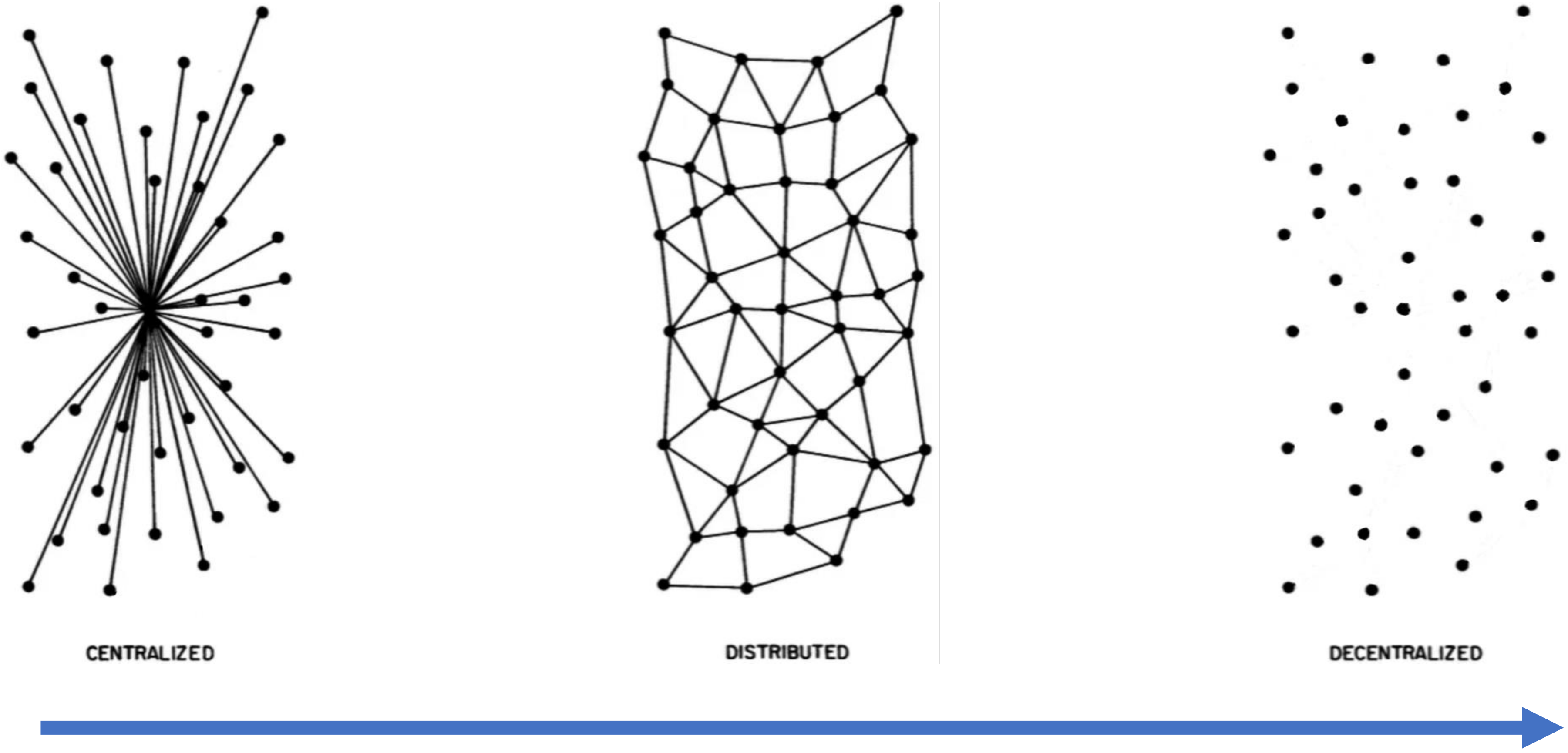
High-frequency, phase-shift controlled modules





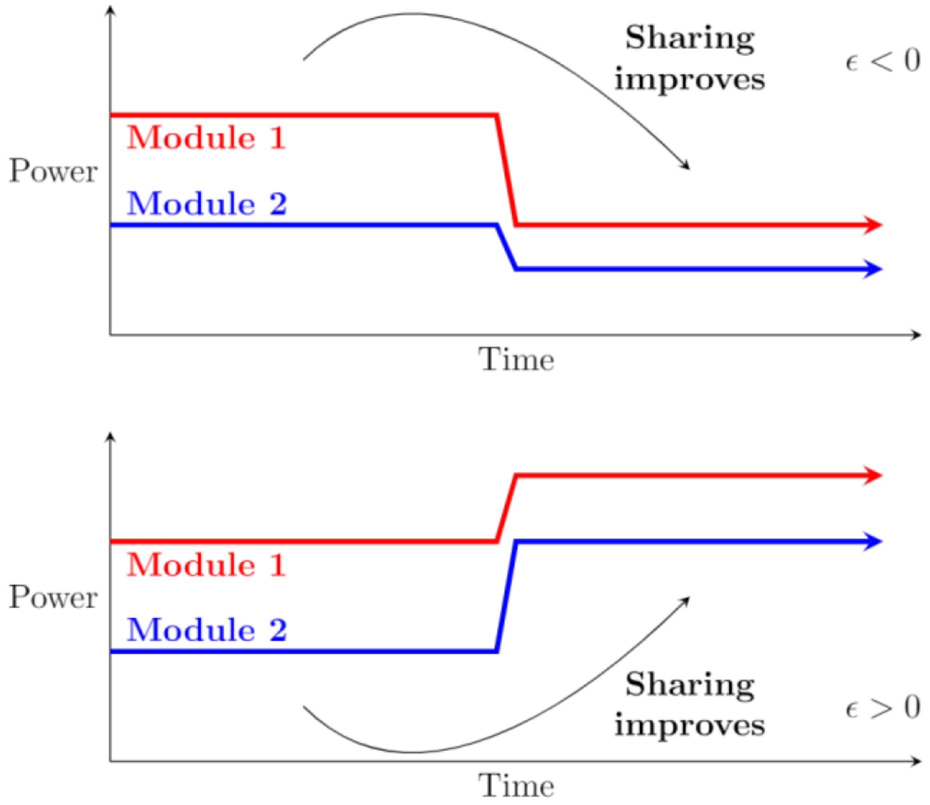
One module > 100 W/in^3
1 MHz

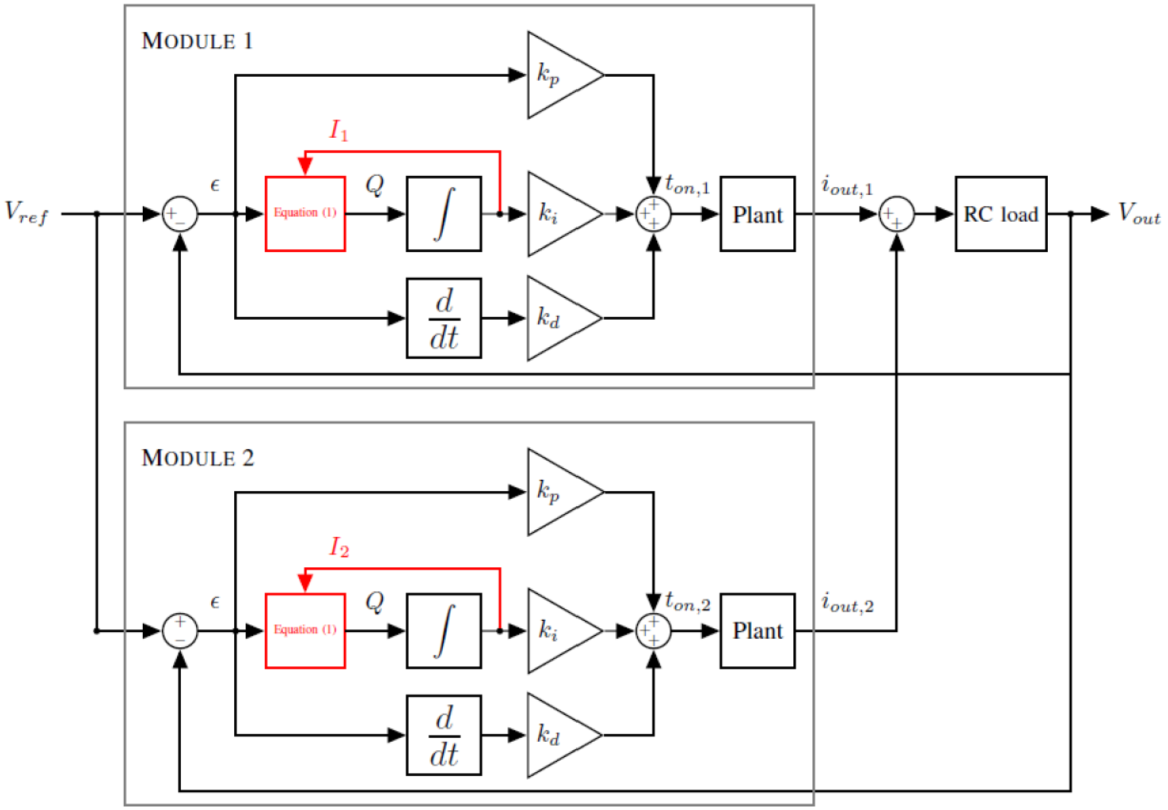
Key to modularity – decentralized control



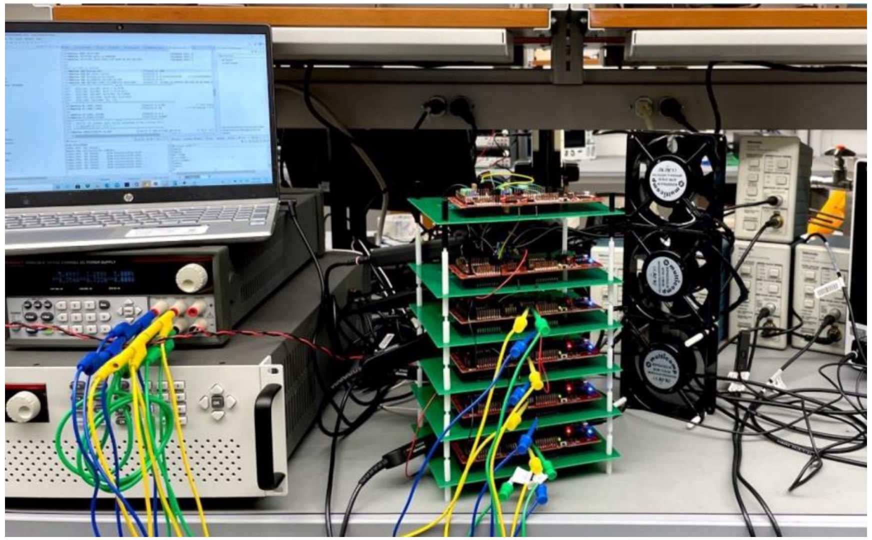
Fewer interconnects, greater resilience, truer "modularity"

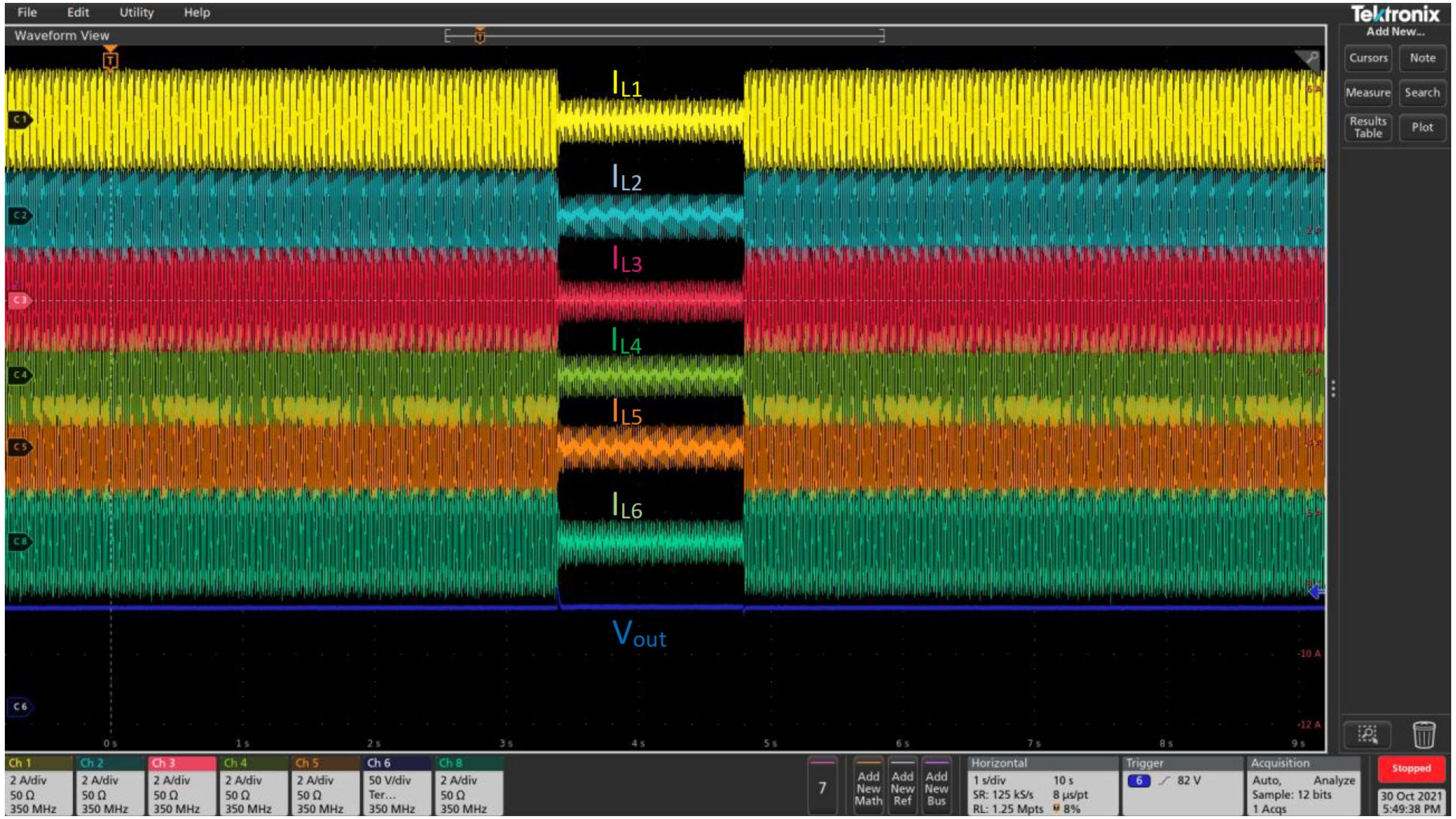
A decentralized power-sharing controller



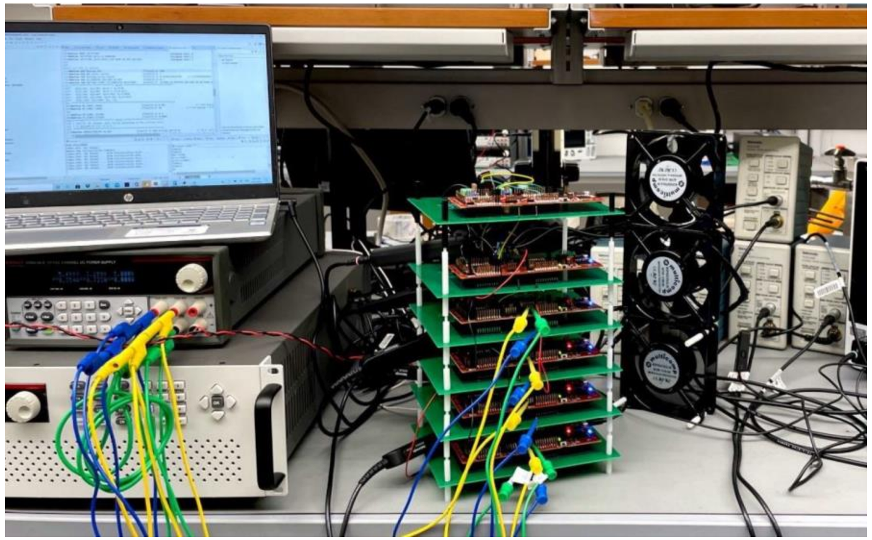


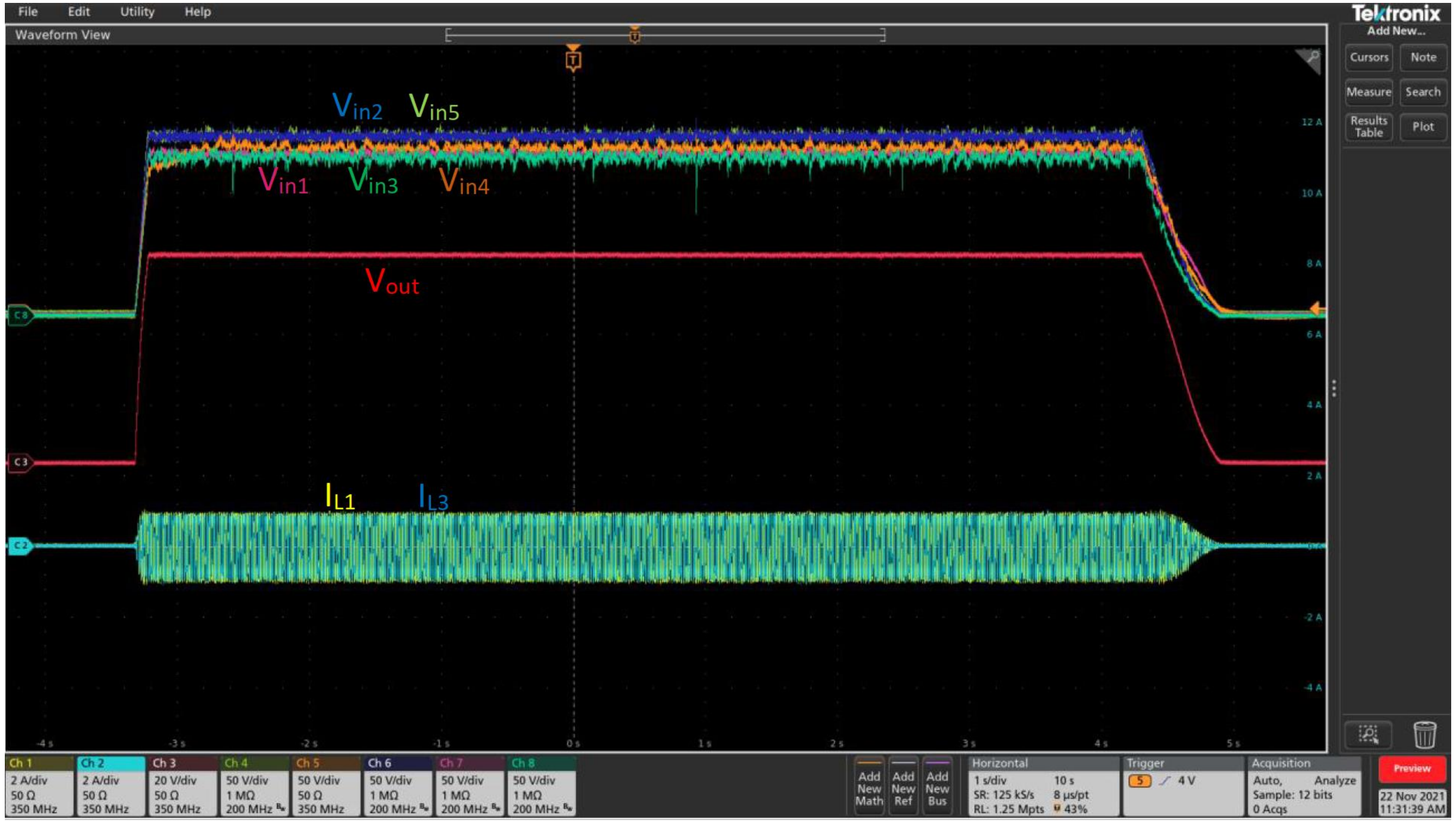
Input-parallel-output-parallel 6 modules



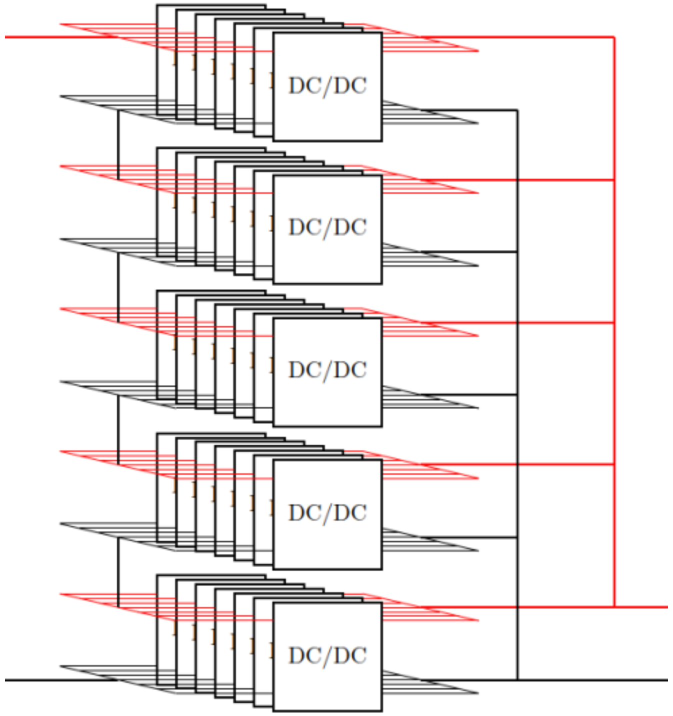


Input-series-output-parallel 5 modules

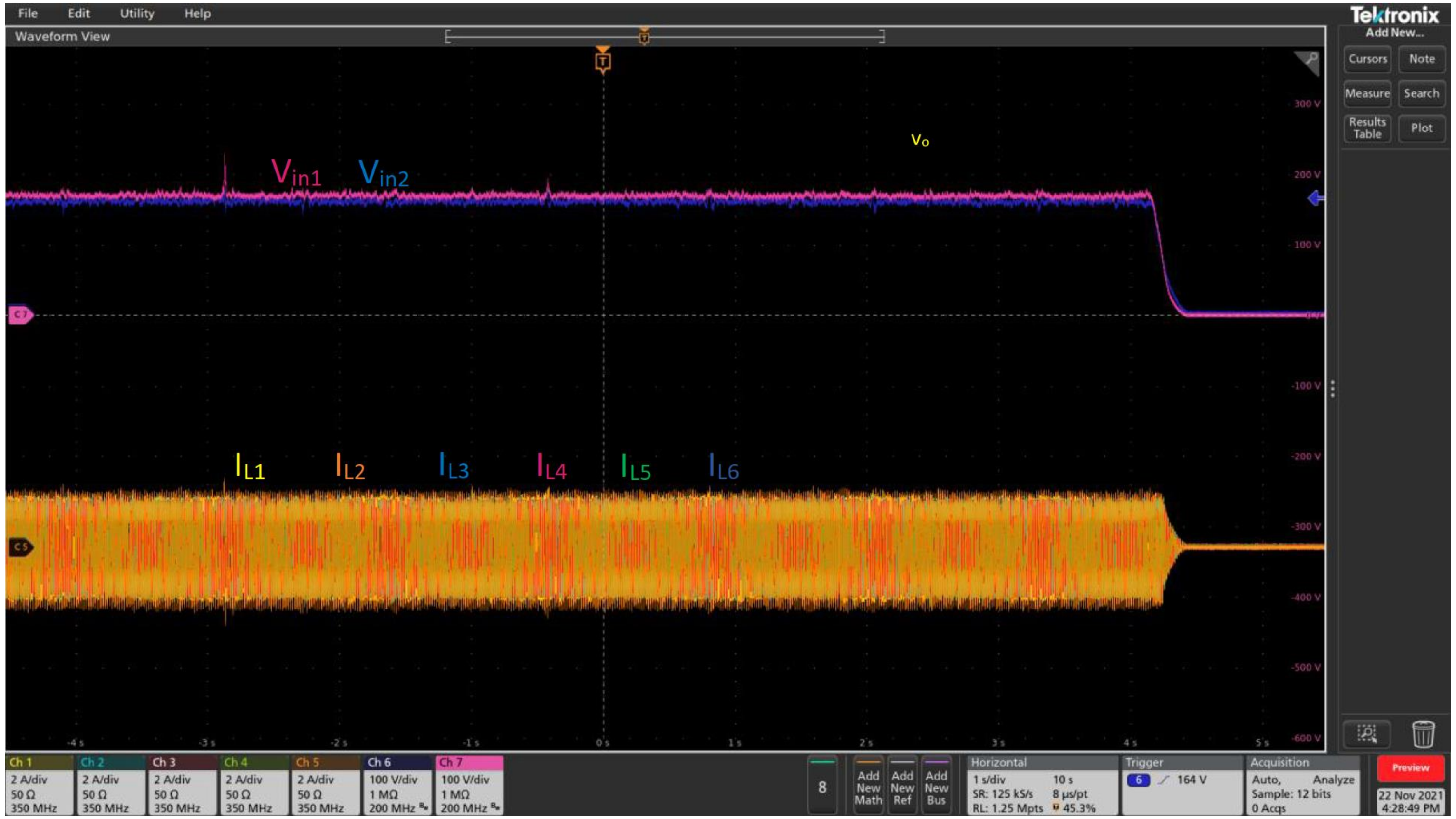




Input-series-parallel-output-parallel 6 modules



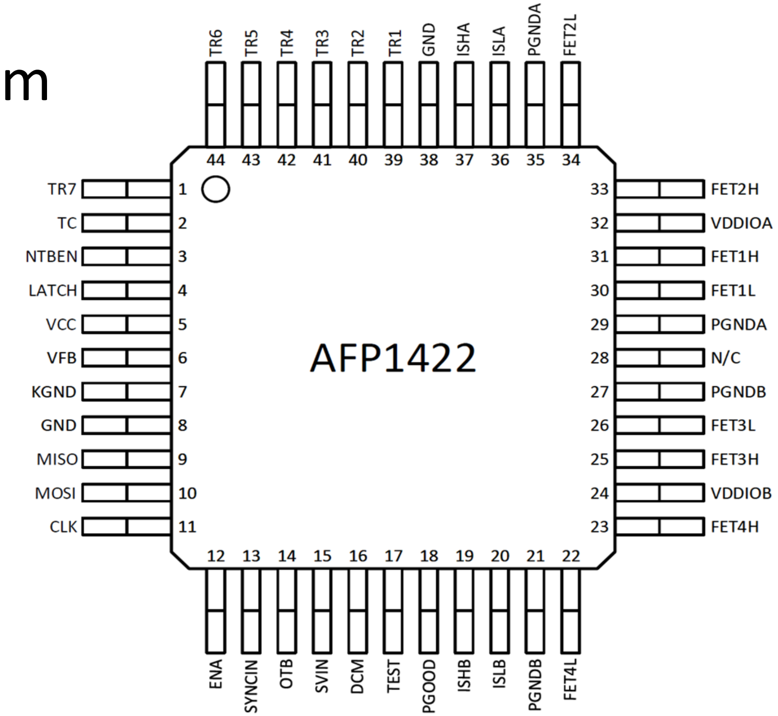
3 wide, 2 tall on input



What about the controller IC?

Controller IC requirements

- Capable of controlling four transistor phase shift bridge
- Able to implement more complex power sharing algorithm
- High immunity to single event effects
- High immunity to TID induced drift



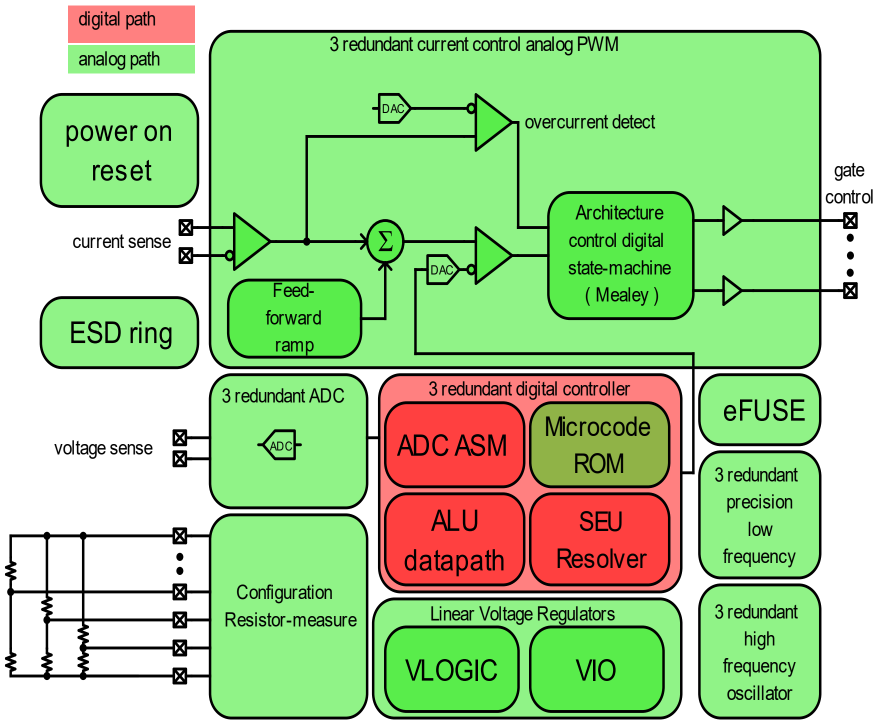
AFP1422 AKA "Jensen" PWM power controller already meets many of the hardest requirements

- Capable of controlling four transistor phase shift bridge
- Able to implement more complex power sharing algorithm
- High immunity to single event effects
- High immunity to TID induced drift

Already Implemented

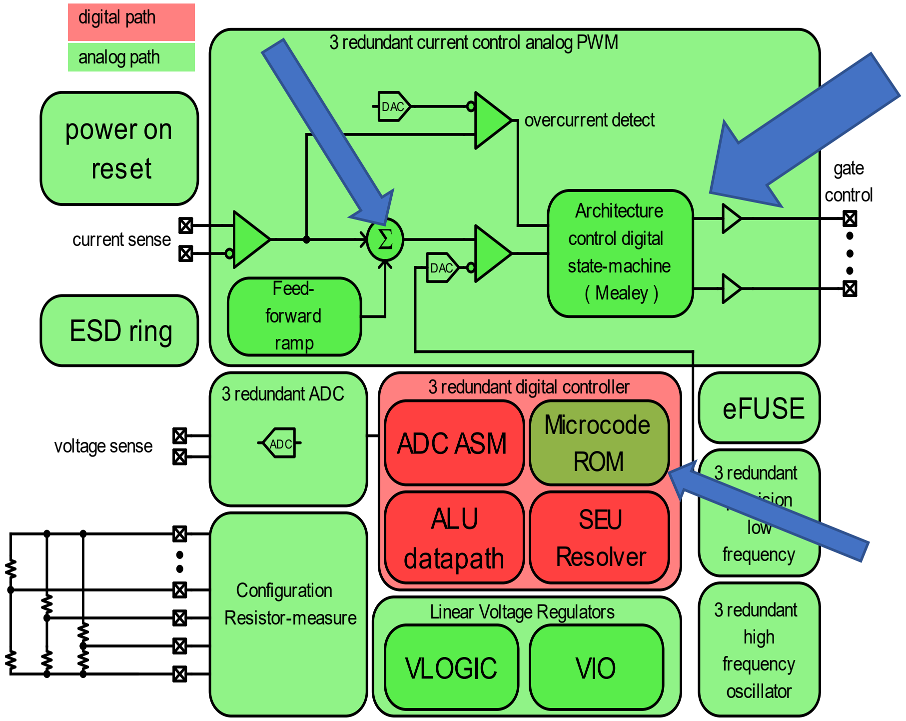
ROM code change

Requires minor design change



Minimal spin of AFP1422 AKA "Jensen" power controller will meet all requirements

- Requires removal of current sense from PWM control, adjustment of gains
- Requires a change in the Mealey state machine that controls the FETs to implement phase shift
- Requires change in ROM code that implements control algorithm to implement power sharing phase shift

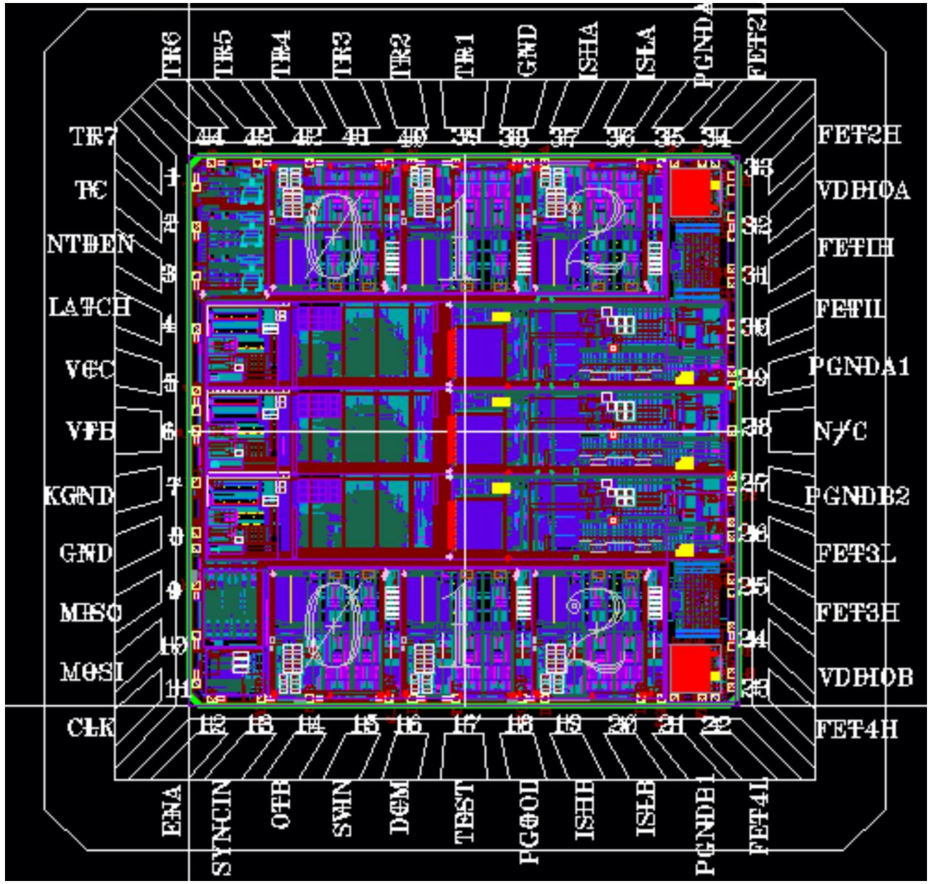


Current status:

- ROM code conversion of algorithm implementation from general purpose floating-point DSP to Jensen custom rad-hard enhanced fixed-point DSP is under way.

- First pass of Mealey state machine modifications already implemented.

- Expect tapeout of first pass complete prototype power sharing phase shift controller in Q1 2023



Acknowledgements

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Thank You