

P/O/E/T/S

CENTER FOR POWER OPTIMIZATION OF
ELECTRO-THERMAL SYSTEMS

Designing a Graphical User Interface for the Power Module Optimization Tool PowerSynth

Joshua Mitchener, Imam Al Razi, Yarui Peng

jmitchen@uci.edu, ialrazi@uark.edu, yrpeng@uark.edu

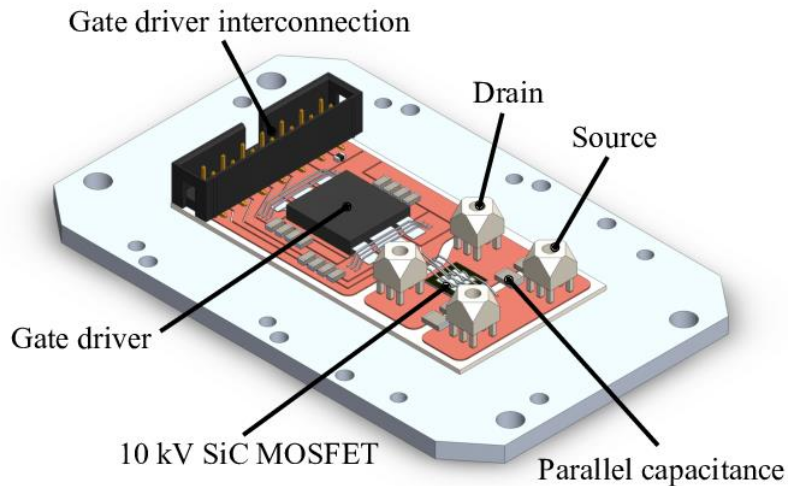




Overview of MCPM Design



- ❑ **Power electronics are everywhere**
 - electric vehicles, personal computers, solar panels, etc.
- ❑ **A power module's layout is crucially tied to its performance**
 - optimize electrical, thermal, and mechanical capabilities
- ❑ **Design flow of multichip power modules (MCPMs) is usually an arduous manual process**

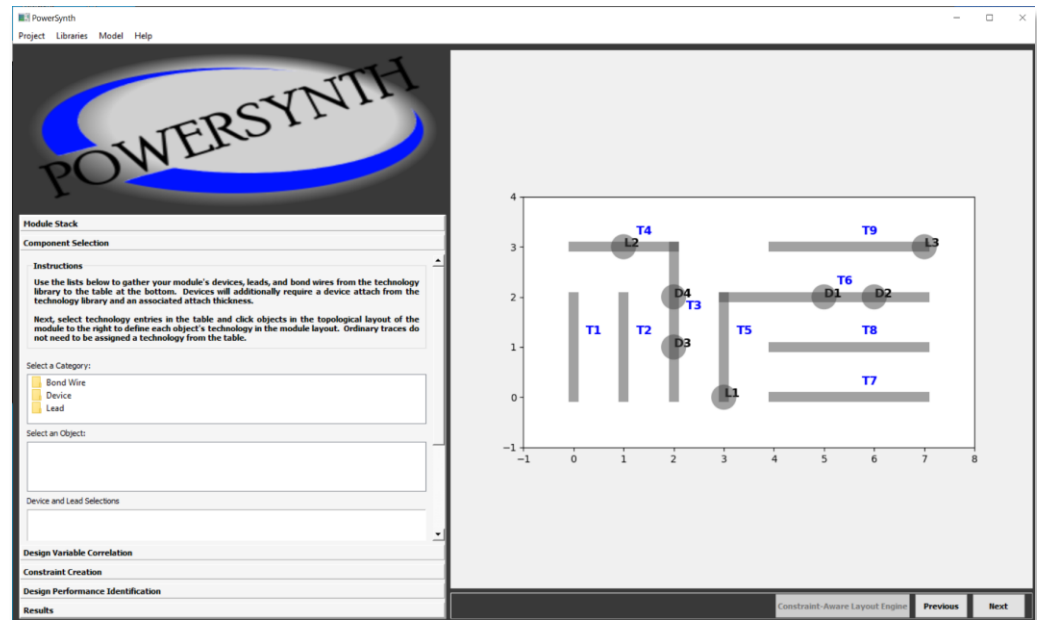




PowerSynth As A Service (PSaaS)



- ❑ **PowerSynth is a software tool for the design and layout of multi-chip integrated power modules**
 - combines layout synthesis with design optimization
 - performs orders of magnitude faster than existing tools
- ❑ **New version of PowerSynth is currently in development**
 - more advanced algorithms
 - hierarchical layout engine
 - support for 3D layouts



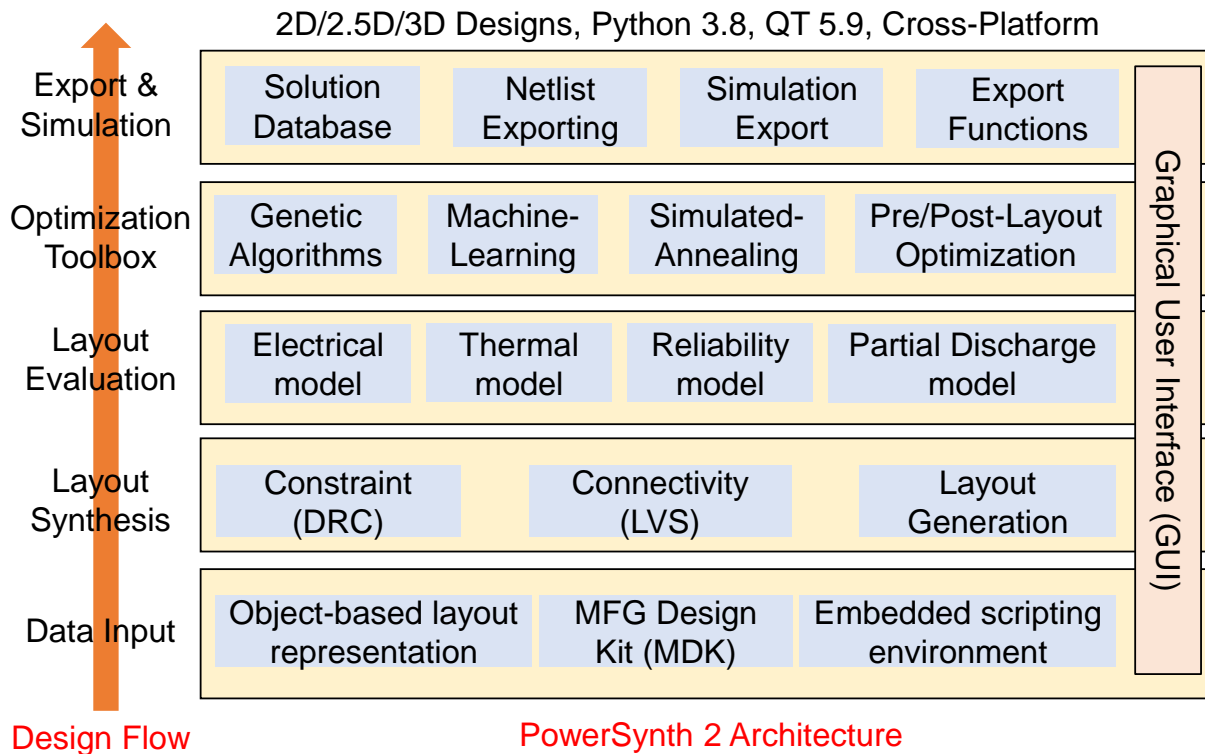
PowerSynth 1.4



PowerSynth 2 Features



- **Material Design Kit (MDK) and Layer stack parameterization**
- **Constraint-aware layout engine to generate DRC-clean layouts**
- **Fast, accurate and reduced-order electrical and thermal model.**
- **Electro-thermal reliability optimization**
- **Easily export design solutions to FEA tools**

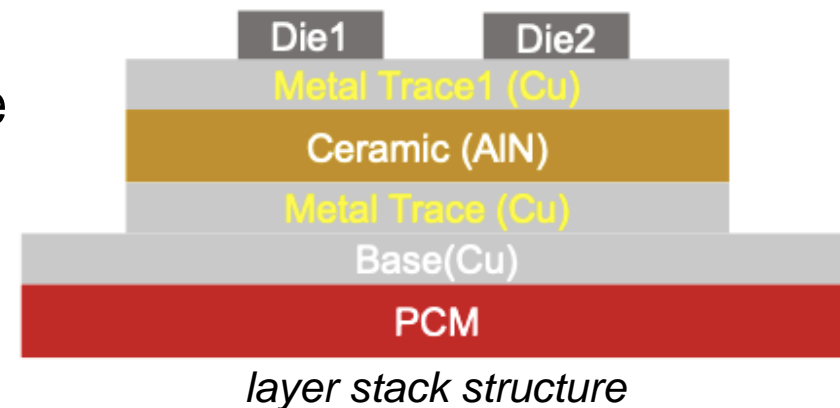




Contributions to PowerSynth



- ❑ **Two-step electro-thermal reliability optimization methodology:**
 - layer stack optimization
 - placement and routing optimization
- ❑ **Fast, accurate transient thermal model for PowerSynth to predict thermal cycling behavior with phase change material (PCM)**
- ❑ **A comparative study of using PCM to reduce thermal cycling stress**
- ❑ **Reliability Performance metrics include:**
 - Electrical: power loop inductance
 - Thermal: maximum transient temperature





Command Line Design Flow



- ❑ **User inputs paths to settings/macro script files**
- ❑ **Prompts user to change the constraints file**
- **Limitations of command line version:**
 - requires large amount of setup for user
 - challenging for new users to figure out file setups
 - required specific formatting of files is prone to error

```
PowerSynth 1.9
-----PowerSynth Version 1.9: Command line version-----
Please enter the file path for settings.info file: C:\PowerSynth1.9\settings.info
Please enter the file path for the macro.txt script: C:\PowerSynth1.9\Sample_Projects\Test_Cases\Half_Bridge_1\half_bridge_macro.txt
Loading settings file
C:\PowerSynth1.9\tech_lib\Material\Materials.csv
Settings loaded.
settings.GMSH C:\PowerSynth1.9\gmsH-2.7.0-Windows
loading material from csv
C:\PowerSynth1.9\tech_lib\Material\Materials.csv
Loading macro file
Trace orientation is included, mesh acceleration for electrical evaluation is activated
run the optimization
initializing ....
Starting Characterization
Checking for existing cached file
found a cached version!
Checking for existing cached file
found a cached version!
Checking for existing cached file
found a cached version!
Checking for existing cached file
found a cached version!
init api
Updated Performance Values for: Layout_0
-- {'Inductance': 8.162326511290683, 'Max_Temperature': 400.0241663133596}
Min-size 30.0 36.0
```

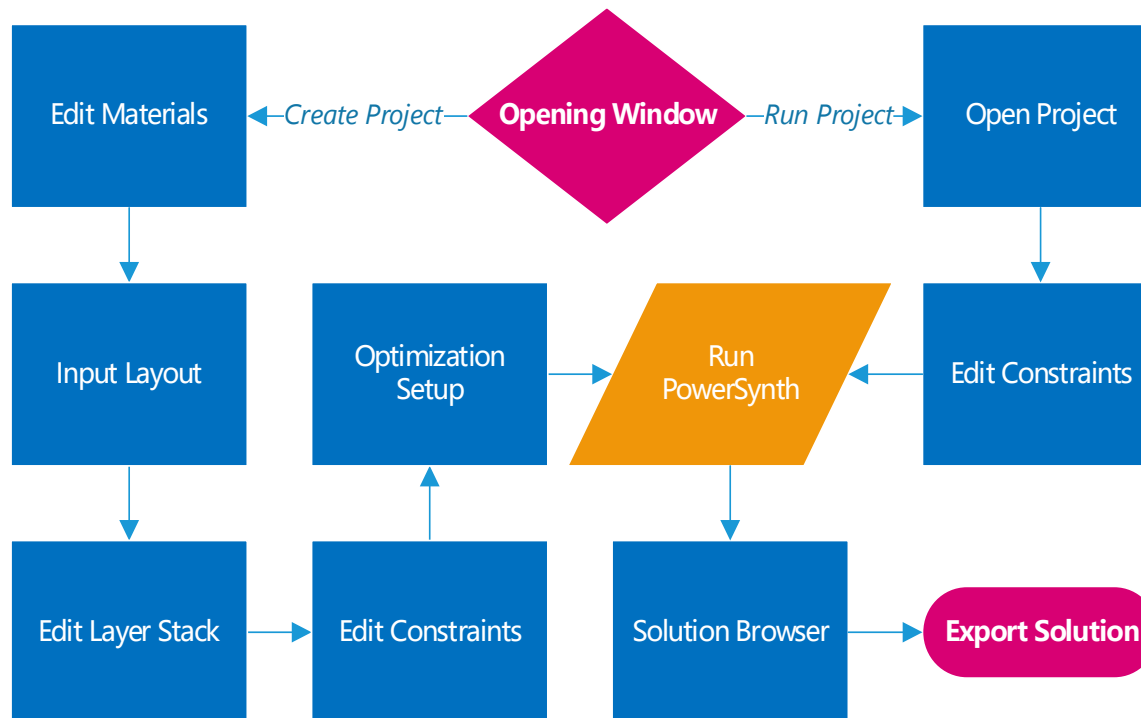
PowerSynth 1.9 (Command line only)



Graphical Interface Design Flow



- ❑ **Two main flows: create new project or run existing project**
 - functional, simplistic design of windows
- ❑ **GUI automatically generates many required input files**
 - significantly eases process for new users





Project Configuration



- ❑ Opening window allows to run existing or create a new project
- ❑ Materials list can be edited via the MDKEditor
 - default materials are pre-loaded

The image shows two screenshots from the PowerSynth software. The top screenshot is the 'Edit Materials' dialog box, which asks 'Would you like to edit the materials list? If not, the default materials will be used.' It has two buttons: 'Edit Materials List' and 'Use Default Materials'. The bottom screenshot is the 'MDKEditor' window, which displays a table of materials with columns for Name, Type, Young Modulus, Poisson's Ratio, Melting Temperature, and Density(Solid). The table lists 12 materials, including Cu, AlN, Al, BiPbSnIn, Ga, PureTemp 29, SiC, brass, solder, titanium, vacuum, and zinc.

Name	Type	Young Modulus	Poisson's Ratio	Melting Temperature	Density(Solid)	D
1 Cu	Conductor	1.10E+11	0.37		8900	
2 AlN	Conductor	3.44E+11	0.24		3260	
3 Al	Conductor	6.90E+10	0.33		2700	
4 BiPbSnIn	PCM	0	0	57	9060	82
5 Ga	PCM	0	0	29.8	5903	60
6 PureTemp 29	PCM	0	0	29	940	85
7 SiC	Semiconductor	4.10E+10	0.14	0	3100	
8 brass	Conductor	1.01E+11	0.34		8600	
9 solder	Conductor	6.90E+10	0.4		8000	
10 titanium	Conductor	1.25E+11	0.33		4500	
11 vacuum	None	0	0			
12 zinc	Conductor	1.15E+11	0.33		7140	

MDKEditor



Structure Configuration



- ❑ User must now input paths to the layer stack, the layout script, and the bondwire setup files
- ❑ Editors for the layer stack and constraints will be provided
 - constraints file is also automatically generated

Please edit the values in the layer_stack.csv file, then click continue.

	Name	Origin	Width	Length	Thickness	Material	Type	Electrical
1	Baseplate	0,0	53	57	1	copper	p	F
2	Bottom_Metal	5,5	43	47	0.2	copper	p	G
3	Ceramic1	5,5	43	47	0.835	Al_N	p	D
4	I1	5,5	43	47	0.2	copper	p	S
5	C1		43	47	0.18	None	a	C

layer stack visualization

Initial Structure and Layout@peng-srv2

Path to layer_stack

Path to layout_script

Path to bondwire_setup

Reliability Constraints:

Design configuration

Edit Constraints@peng-srv2

Please edit the values in the constraints.csv file, then click continue.

	MinHorEnclosure	MinVerEnclosure	MinHorSpacing	MinVerSpacing	
EMPTY					
power_trace					
bonding wire pac					
Via					
power_lead					
MinWidth	1	1	0	2.0	3.0
MinLength	1	1	0	2.0	3.0
MinHorExtension	1	1	0	2.0	3.0
MinVerExtension	1	1	0	2.0	3.0

constraints visualization



Model Configuration



❑ User selects how to run PowerSynth:

- Initial layout optimization
- Layout solution generation only
- Layout optimization/evaluation

❑ Direct user to the customized macro script window

- electrical/thermal setups only included if necessary
- automatically generates macro script once completed

Macro Script Setup:
Floor Plan: 40 by 40
Plot Solution:

Layout Generation Setup:
Layout_Mode: fixed-sized solutions
Number of layouts: 25
Seed: 10
Optimization Algorithm: NG-RANDOM
Number of Generations: 100

Open Electrical Setup | Open Thermal Setup

Run Powersynth

Electrical Setup
Model Type: PEEC
Measure Name:
Measure Type: inductance

Device	Options
1 D1	Drain to Sou

Add Device
Remove Device

Select a source: L1
Select a sink: L5
Frequency (kHz): 10000
Path to trace_orientation: Open File
Path to parasitic_model: Open File

Continue

Thermal Setup
Model Select: TSFM
Measure Name:

Device	Power
1 D1	10

Add Device
Remove Device

Heat Convection: 1000
Ambient Temperature: 300

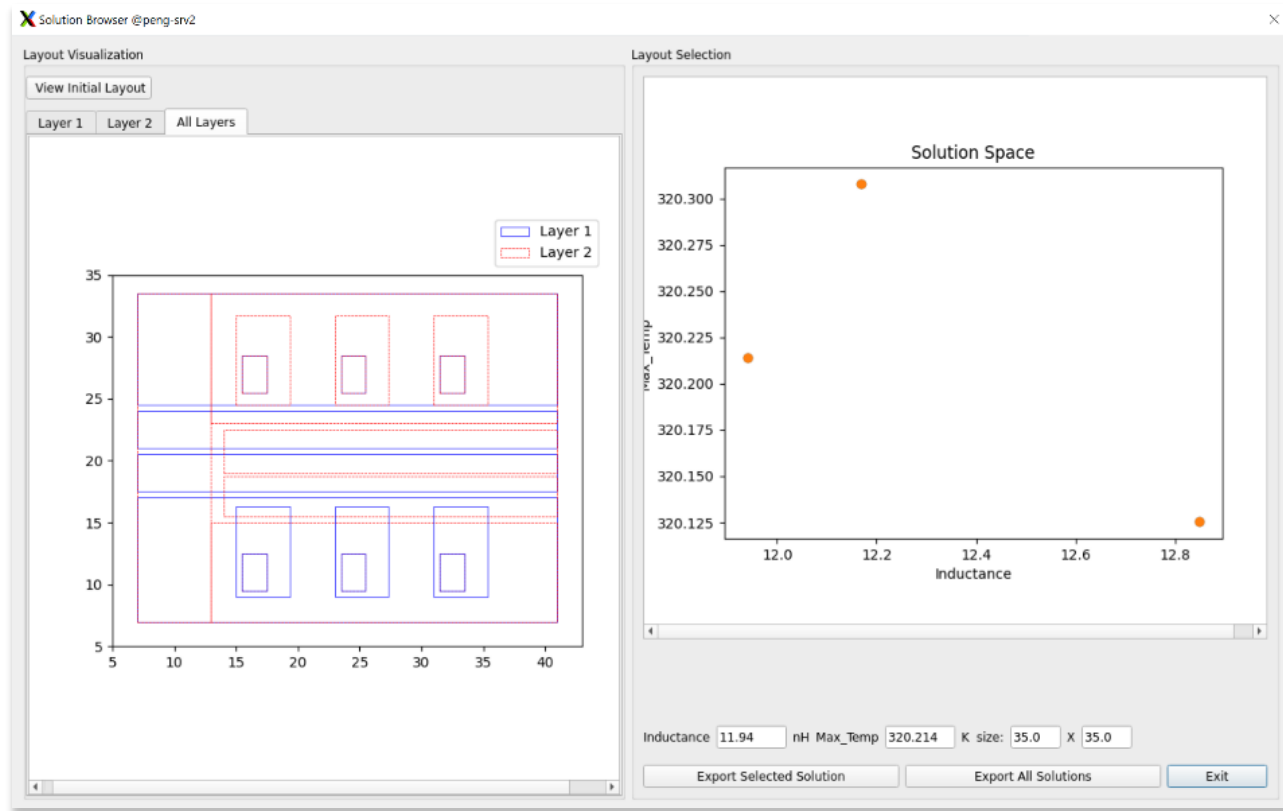
Continue



Layout Visualization



- ❑ PowerSynth is ran with all given input and solutions are generated
- ❑ User can compare and browse solutions by clicking on the graph
 - individual or all solutions may be exported in an FEA-friendly format





REU as an Educational Experience



In-person research is highly valuable

- virtual opportunities lack effective networking and communication
- insufficient work-life balance

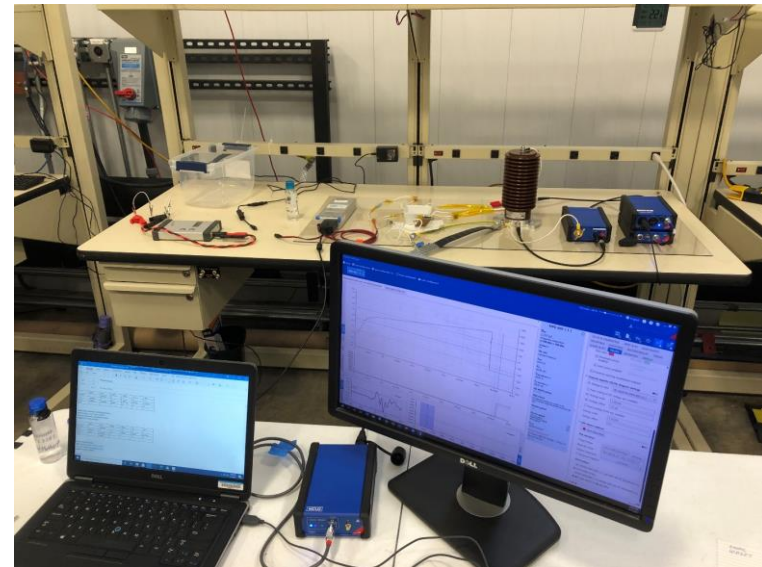
REUs (Research Experiences for Undergraduates) provide opportunity to work outside major

- American educational system is not built for experimentation of fields
- leads to student dissatisfaction and career anxiety

Undergraduate research acts as a preview of careers in academia



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ARKANSAS





Conclusions and Future Work



Conclusions:

- As a reliability-aware design tool, PowerSynth can further reduce design efforts and engineering time with MCPMs
- New GUI improves user interaction and design efficiency with PowerSynth through visualization
- The interface should improve the design flow for both new and advanced users
- REU programs create a highly valuable and supportive experience that allows students to explore their interests at a crucial time in their development

Future Work:

- Visualization of hierarchical structure of layouts
- Integrating MDKEditor to edit layer stack
- Custom layout editor to generate layout script files



Questions?

For more information, please visit the E3DA Lab Website:

<https://e3da.csce.uark.edu/>