Low Power FPGAs- Far Beyond Battery Life

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

SMART | CONNECTED | SECURE

FPGA

2022

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  - Low power FPGA
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- **Competitive Comparison on existing designs**
  - Reality-check of tools and models provided by different vendors
  - How can the benefit be proven for the client on their known territory?
  - Power Comparator
- **What‘s in for you?**
  ➔ Tool-demo to show on your customer‘s design

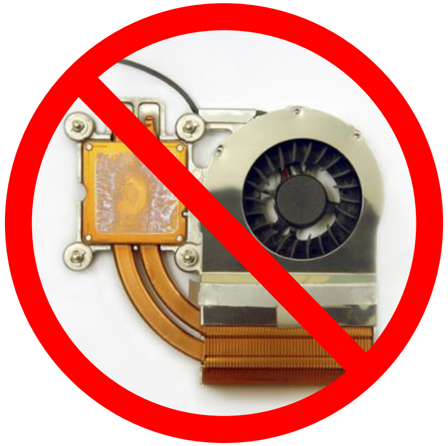
The Power Challenge

Why does Power Consumption Matter?

Why Power Consumption Matters

My Machine is Cable-Powered. Why Would I Care?

- **Power Consumption is way beyond „battery-life“**
  - Lower power = lower self heating
  - **No heat-sinks or fans**
    - Avoids cost and components that can fail
  - Smaller physical system-size and lower system cost
  - Longer device life-time due to lower junction temperature
  - Longer MTTF = lower FIT-rate
  - More features on power budget
- **Big 3**
  - Reduce Risk
  - Save Money
  - Make Money



https://www.microchip.com/en-us/about/blog/learning-center/low-power-system-saving-even-in-plug-in-devices

Lowest Power – Up to 50% Lower than Competitors

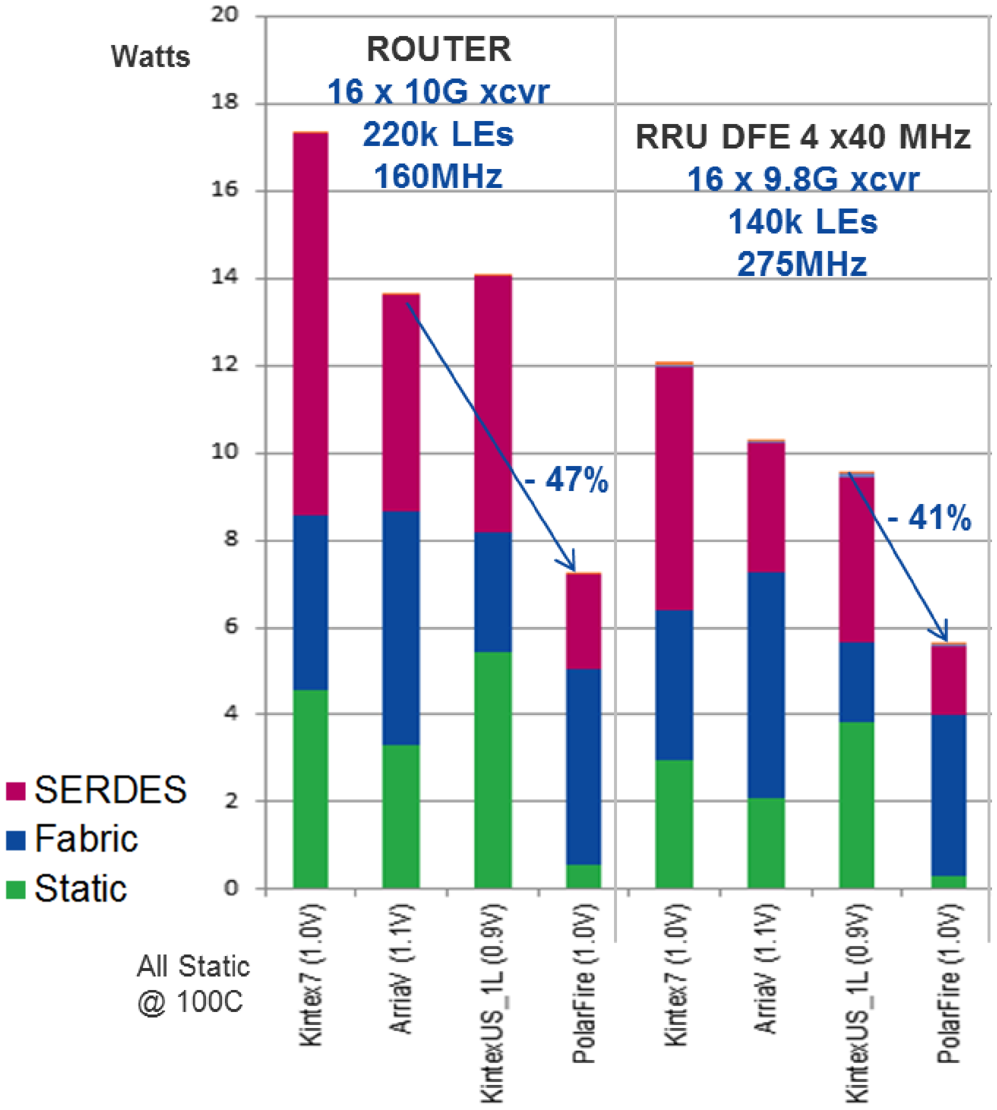
- **Enabling Application Performance at Significantly Lower Power**

Static power: **10x Reduction**

Transceiver power: **2x Reduction**

Total power up to 50% lower than best case competitor:

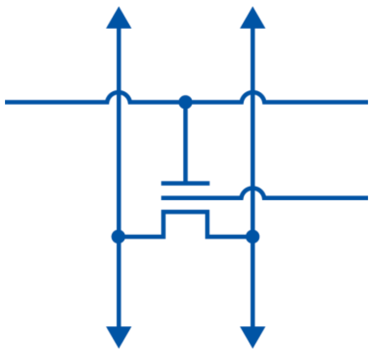
PolarFire® Customer: "$1.5/W in BOM cost saving due to power savings"



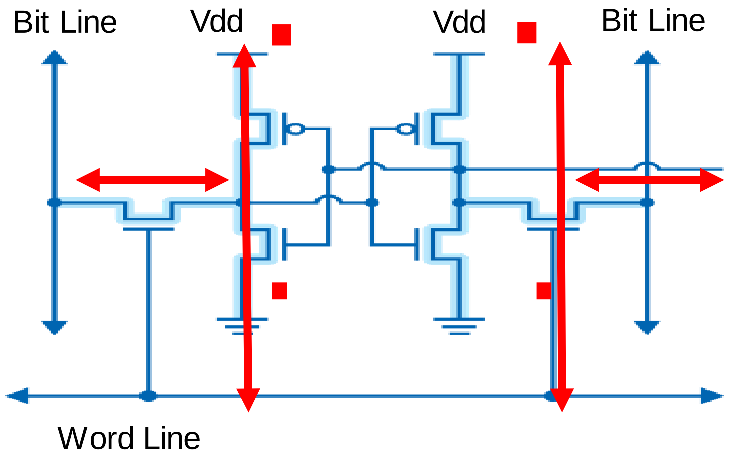
Significantly Lower Power Consumption

By Technology and By Design

Non-Volatile Cell



SRAM Cell



Non-Volatile memory: retains its state

1000x lower leakage per cell

Features: designed for LOW POWER

(Transceivers, Microprocessors, etc)

SRAM: must continually re-charge

Substantial leakage per cell

Features: designed for HIGH-END market

(and re-used for mid-range families)

Total Power Savings of 30-50% vs SRAM FPGAs

PolarFire Success – Based on Low Power

Smart Embedded Vision Designs

Thermal Cameras

Machine Vision

Microscope Cameras

Surveillance Camera

Portable Ultrasound

- **Low Power = less heating on IR-sensor ➔ less thermal noise**
- **Low Power + small footprint = smallest hi-res industrial camera**
- **Low Power + small footprint = new application market**

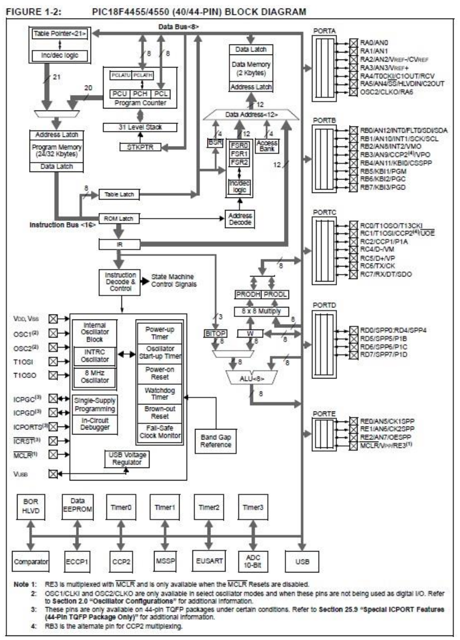
Microcontroller vs. FPGA

Design Approach – Use vs. Build

Architecture „Comparison“

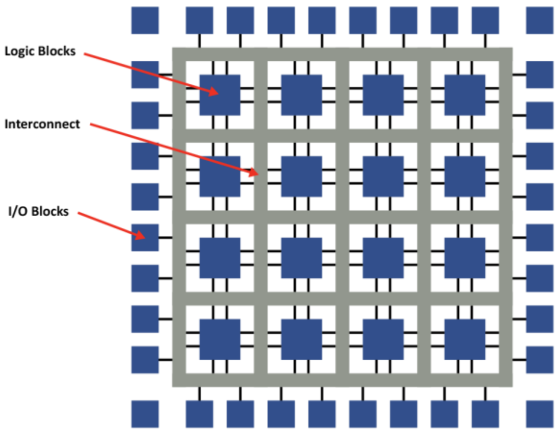
Microcontroller

- **Fixed** & defined architecture
- Controller-components are **used**



FPGA

- **Required** functionality is **built** using pre-defined „blocks“
- Some system-level components are present (clocks, DSP, etc.)



What is an FPGA?

I heard it is complex and expensive?

~~I learnt in uni that FPGAs are only used for prototyping and do not make sense in volume.~~

~~I heard that they are very complex and difficult to work with.~~

~~They are unreliable and cannot be used for proper applications.~~

- **Simple way to think about FPGAs = Lego for engineers**
  - Blocks of configurable logic that build up the larger function
- **SoC: FPGA with Processor System = Lego Mindstorm**

Architectural Flexibility

Influence on Power

- Based on design-content significant difference in power consumption
- Power estimation tools required and present for users
- Allow system-dimensioning of supplies and thermals under environmental conditions

Application Examples

Smart Vision

PolarFire® Success

Smart Embedded Vision Designs

Medical MRI

Machine Vision

Laser Measurement

Portable Ultrasound

Surveillance Camera

Smart Goggles

Thermal Cameras

Endoscope Camera

Deep Learning

X-Ray

Microscope Cameras

CoaXPress Camera

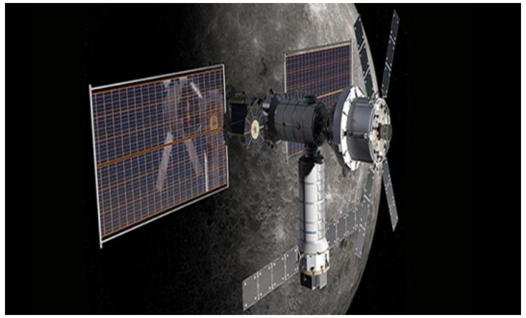
Medical Display

PolarFire has demonstrated success in broad-market Industrial Imaging end-equipment

Application Examples

Medical

Solving Problems in Medical Markets

Portable Imaging *Lowest Power, Small Packaging*	Reliability *Radiation Performance*	Security *Device and Data*
 Medical Eye Tracking  Portable Ultrasound  Medical Surgical	 Radiation Therapy  Satellite	 Secure Medical Infusion Pump  Tamper and Theft Proof Medical Infusion Pump

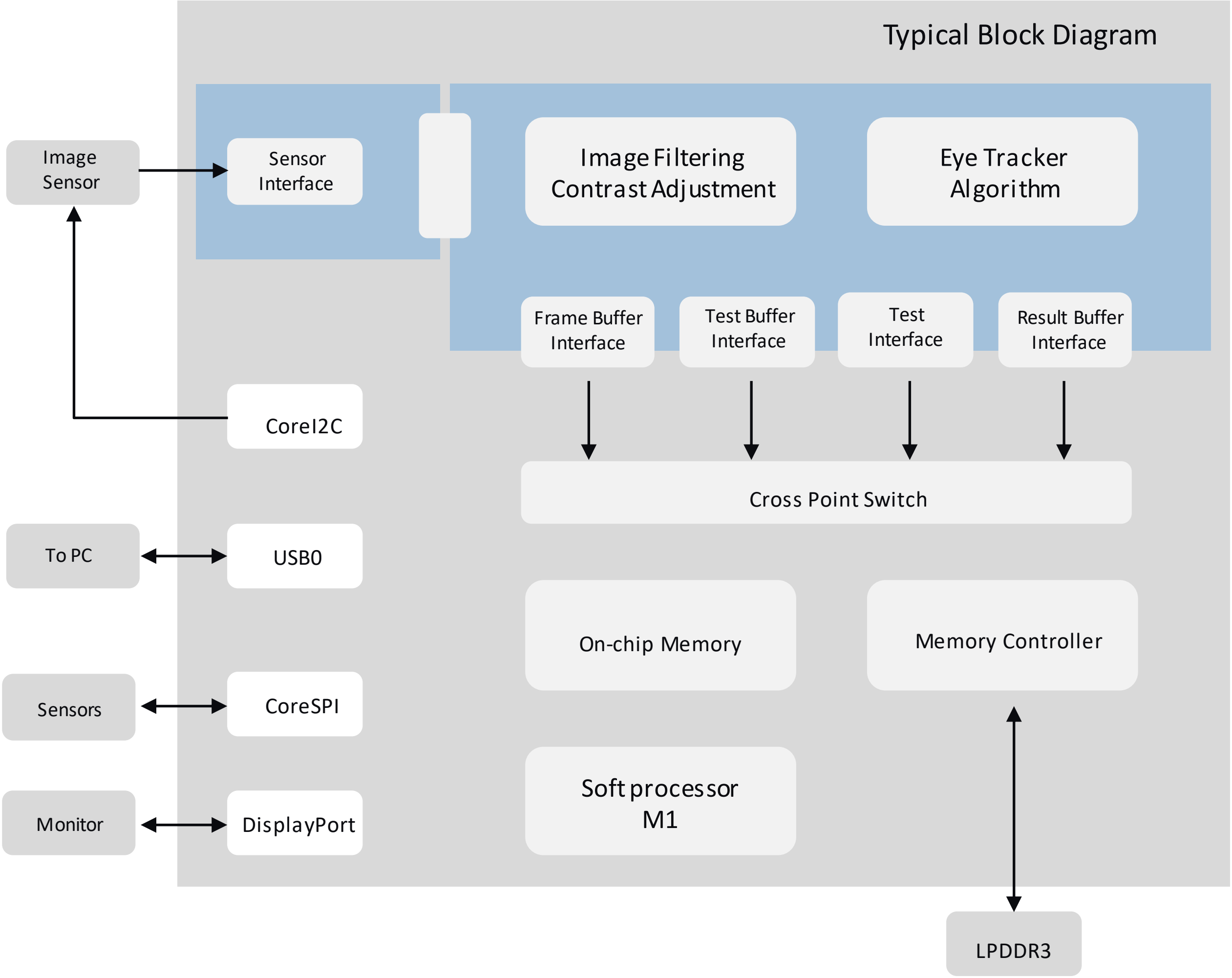
Portable Head-mounted Applications

Eye Tracking in Medical

Stereo vision

Virtual Reality Headset

PolarFire & SOC



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Application Examples

Imaging

Customers' LiDAR and Camera Applications

Structural and Civil Engineering

Industrial Lidar Solutions

High Resolution Industrial Solution

Customers’ Industrial Radar

Industrial Radar for Liquids

Industrial Radar for Solid Material

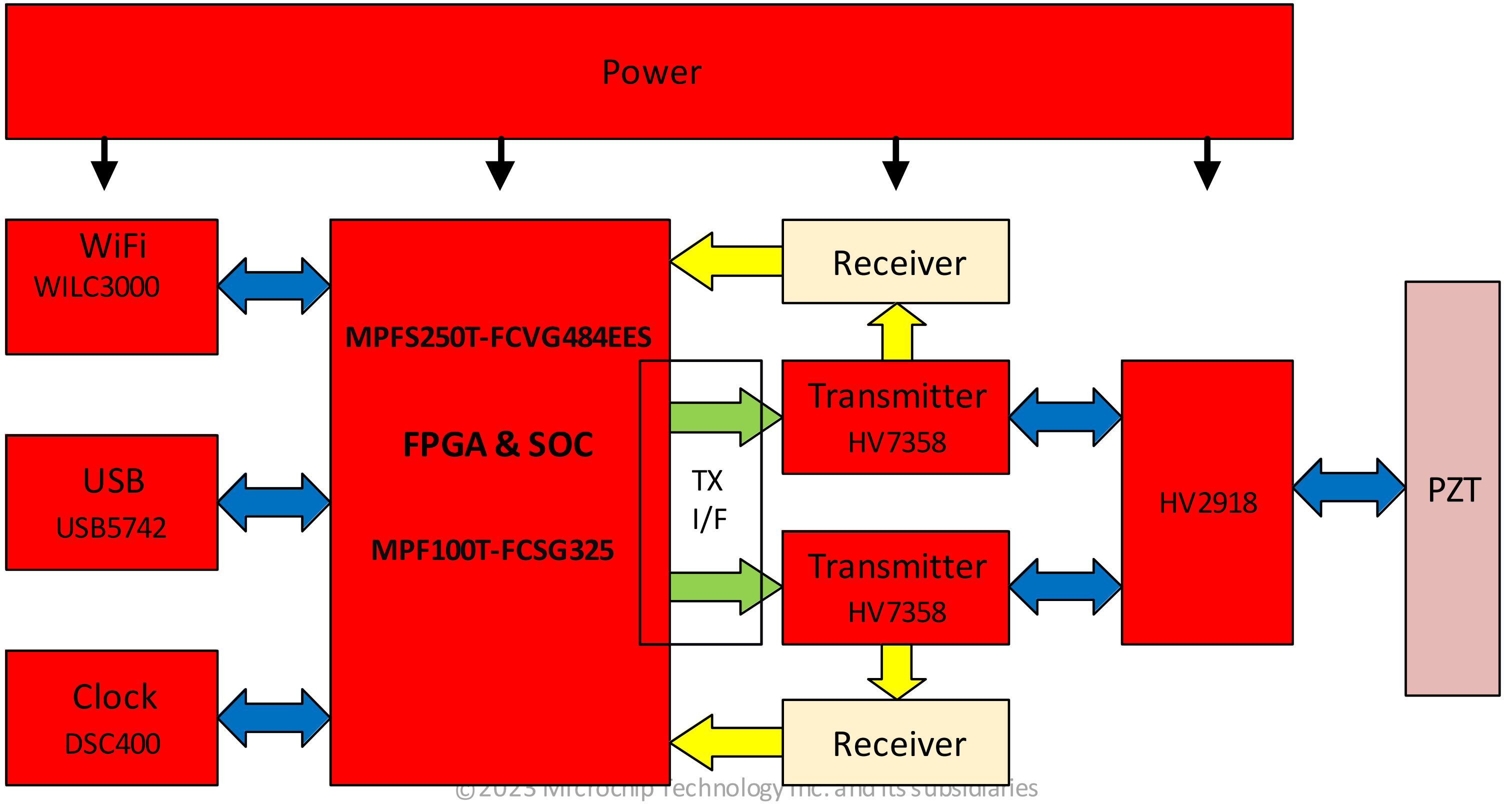
Self-sufficient Radar Sensor With Radio

- Combination of small size and low power
- Allow integration into tight and space/power constrained housings

Total System Solution for Ultrasound

Handheld Scanner Reference Design

- HV Pulser: HV7358 X 2
- HV MUX: HV2918 X 4
- FPGA: PolarFire & PolarFire SOC
- Clock generator: DSC400
- Power: MIC9131, MIC28514, MIC37102
- USB: USB5742
- WIFI: WILC3000



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Application Examples

Motor Control

Motion Control FPGA Applications Focus

FPGAs (High-end Multi-axis, multi-function), $5-$100 ASPs	Microchip Microcontrollers and Digital Signal Controllers (Single-axis – Hard to win with FPGAs), $0.5-$3.0 ASPs
	
Servo, Linear Drive Machine Tool, Needle Selection Machine, Robots, Industrial Drones, Medical Robots	Consumer, Induction Motor 1-axis, Power Tools, Consumer Drones, Sewing Machines

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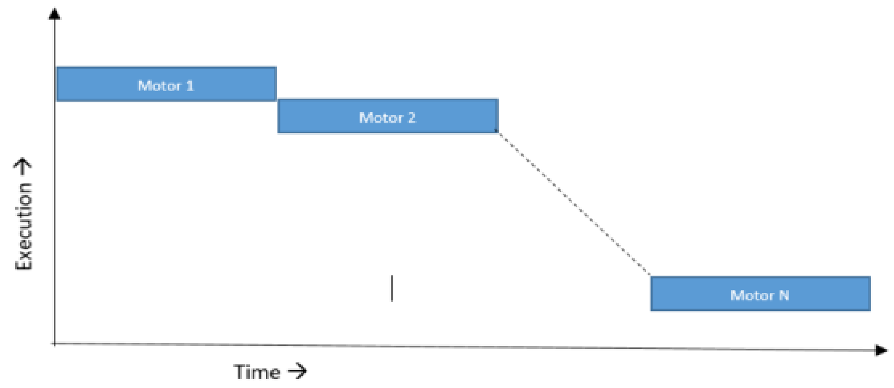
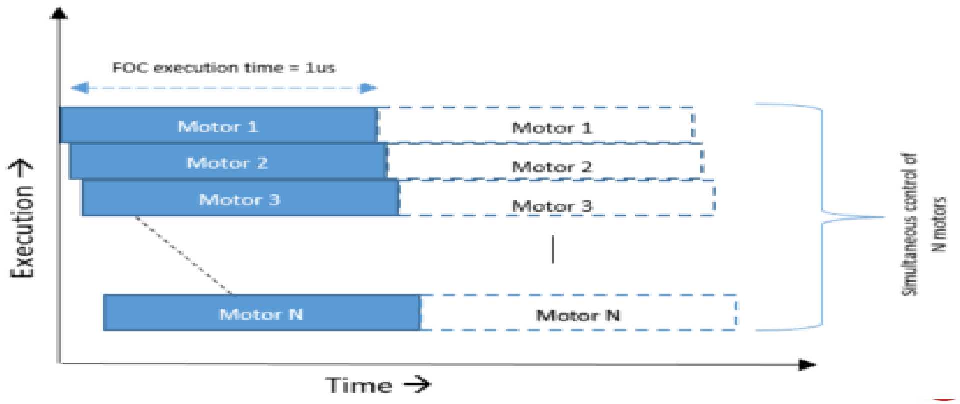
Advantages- FPGA Based Motor Control

Feature	MCU or DSP	SmartFusion2 SoC FPGA/IGLOO2 FPGA
Determinism	• Tasks run sequentially, with different execution times and interrupt-based priorities. Execution in ISRs are not always bounded.	• Tasks run in parallel. Execution time of each task is deterministic and always produces deterministic outputs
Reliability	• Vulnerable to single-event upset (SEU) and soft-errors at ground level	• SEU Immune
Security	• Need additional Crypto products for tamper protection, cloning, and overbuilding risks	• In-built security solutions (Supply chain security, Secure Boot-CPU™, M2M secure communications, Public Key Infrastructure, No overbuilding HSMs and Information assurance)
Scalability and Performance	• Demand a high switching frequency when using high-speed motors (**500 kHz for 2 µs FOC loop**) • Adding **motors not scalable** (>4 motors), complex ISR implementations required • Not flexible for platform development	• **1 µs FOC** loop achievable at lower frequencies • **TDM for FOC** can be used to control multiple motors (M2S010/M2S025- 4 motors M2S060 – 8 motors etc.) • FPGA platforms allow multi-motor/ communication/ encoder / memory support, for 15+ years end-product lifecycles





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Ordering The Motor Control Kit

Ordering Code	Description	Resale
SF2-MC-STARTER-KIT	SmartFusion2 dual-axis motor control starter kit	$899

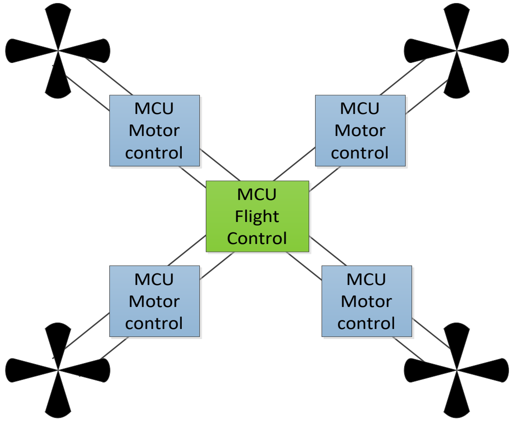
Motor Control Starter Kit

- Quick Start Card
- Starter board
- 1 BLDC motor
- 1 Stepper motor
- 24V power supply
- JTAG connector
- Mini USB cable
- Libero Gold edition
- FlashPro programmer

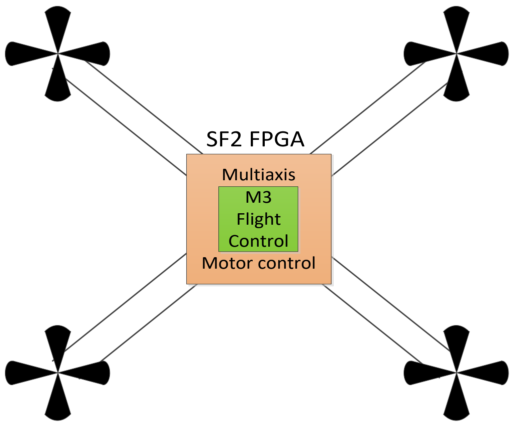
- **IP design project and GUI included**
- **IP VHDL and Verilog 'source code' available with license agreement and fee**
- **Support for:**
    - Libero software
    - IP and project customization via Design Services

Multi-axis Control in UAV/Drones

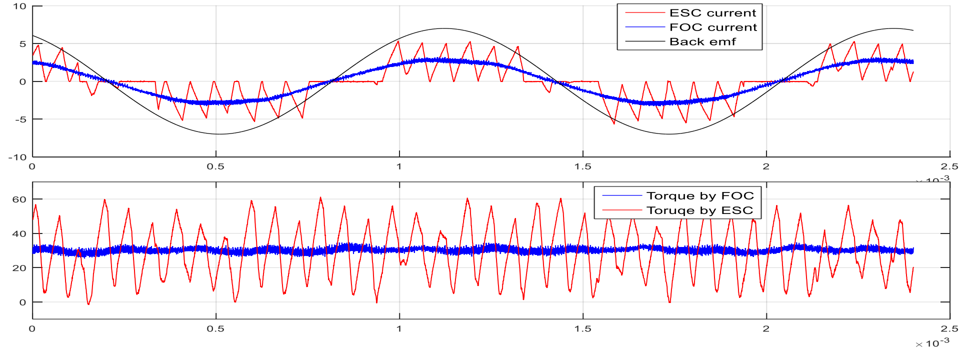
https://www.youtube.com/watch?v=7vNhXyX8hHY



- Total 5 MCUs required
- 1 for each motor and 1 for Flight control



- 1 SF2 is sufficient for total drone control
- Multi-axis motor control in FPGA
- Flight control in Cortex M3



- **Maximum efficiency and increased drone flight time by employing Field Oriented Control (FOC) of BLDC motors on FPGA to generates sinusoidal currents.**
- **Single FPGA for Multi-axis control and central flight control, the solution allows for stable gyros and**
- **Improved mechanical reliability due to improved noise and vibration parameters**

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The Power Challenge

Comparing Microchip Polarfire® and Competitor Y

Comparison On Power Estimators

But These are just Rough Estimations?

Rumour	Fact	Proof
This is just a simulation	If the models are good enough then it is ok	Whole FPGAs are simulated
Power estimation is very crude and unprecise	Accuracy depends on entered data	Don‘t believe it. ➔ See for yourself
Numbers are not trust-worthy	Significant effort put into tools => first touch for users	
One cannot directly compare	Tools very similar between vendors	

Checking Simulation vs. Reality

Do The Models Match „Enough"?

- **Requirement:**
  - Compare known designs on estimation and measurement
  - Application should be „similar", using same external interfaces
- **Approach**
  - Devices on boards are typical devices
  - Environmental conditions are measurable
  - If models are „good enough" then estimation and measurement will match

➔ Compare two boards and consider similarities and differences

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Checking Power Models in Reality

PolarFire® MPF300 vs. Competitor Y

- PolarFire MPF300:
  - 300.000 LUT4 & Flipflops
  - 12.7 Gbps transceiver

- Competitor Y
  - 203.800 LUT6, 407.600Flipflops
  - 12.5 Gbps transceiver
- Same design in both boards
  - 800 Block RAMs (set for 18 kb)
  - 4 Tranceiver at 10Gbps
  - 5277 LUT4 (PolarFire) / 4344 LUT6 (Competitor Y)

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Thermal Readings To Estimation Analysis

Do Reality and Simulation Match?

- **Measurements on boards should match temperature prediction from power estimation**
- **If that applies, then models are „accurate enough“**

→ Compare boards, results are shown in the following slides

Property	Microchip	Competitor Y
Device	FPGA	FPGA
FPGA-size	300 kLE	325 kLC
Internal RAM	800 LSRAM a 20kB	800 BRAM set to 18 kb

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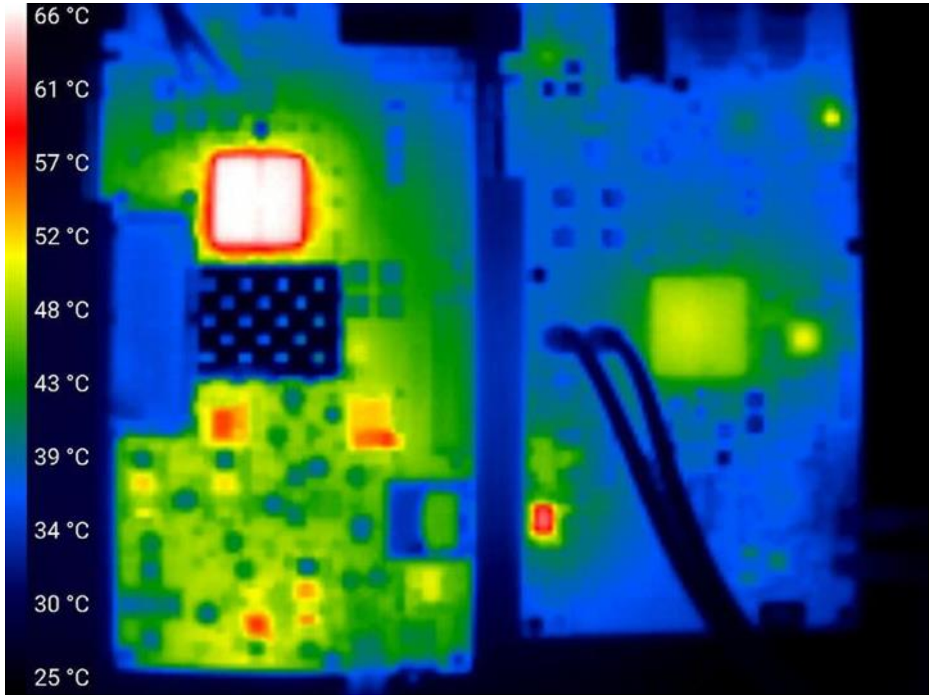
Power Evidence

Parallel Setup Under Identical Conditions

- **Operated at 30°C room-temperature**
- **PolarFire® MPF300 without heat-sink**
- **Competitor Y with small heat-sink**
- **Resulting temperature read with thermal camera and thermocoupler**
- **Measured temperature with thermocoupler:**
  - PolarFire: 45.7°C
  - Competitor Y : 62.1°C



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Thermal Readings on Boards

Reality and Simulation Match?

- Devices on boards considered as „typical“ devices
- Measurements on boards match temperature prediction from power estimation „enough“
- Models are „accurate enough“

→ Use Power Estimator to look at the bigger picture

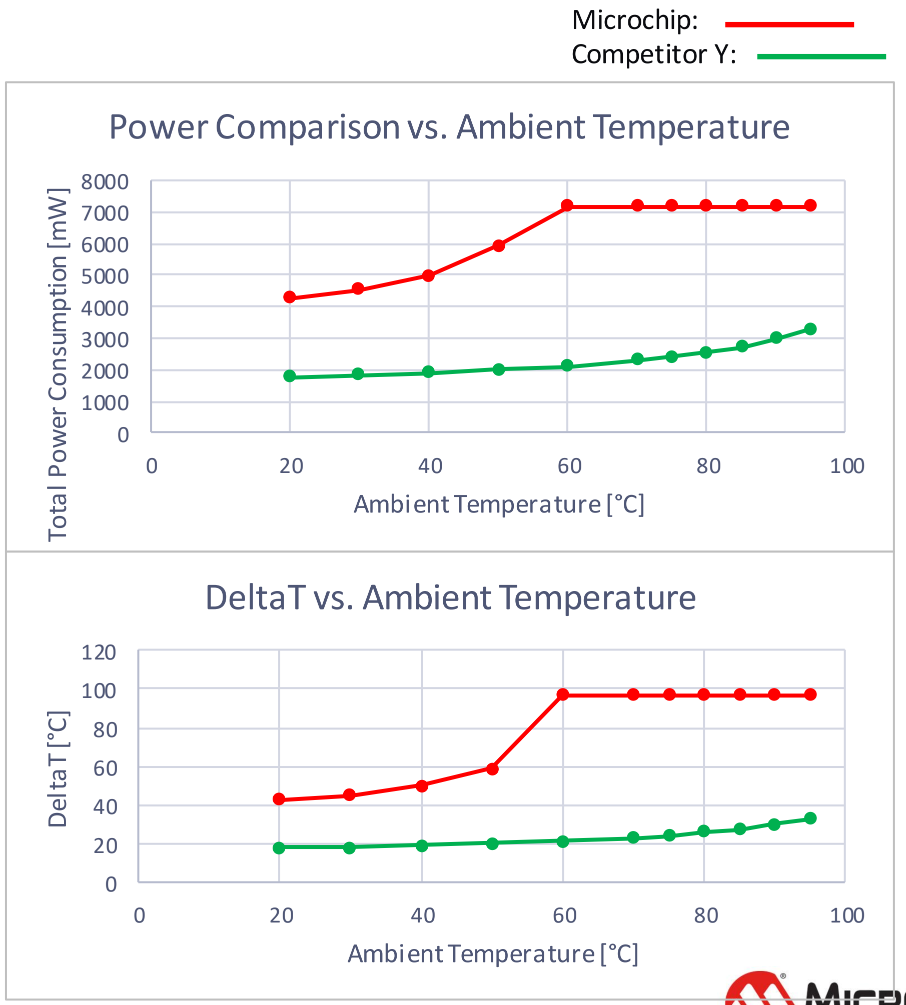
The Power Challenge

What Can „My Design“ Save in Power & How to Prove?

Thermal Sweeps

How To Do That?

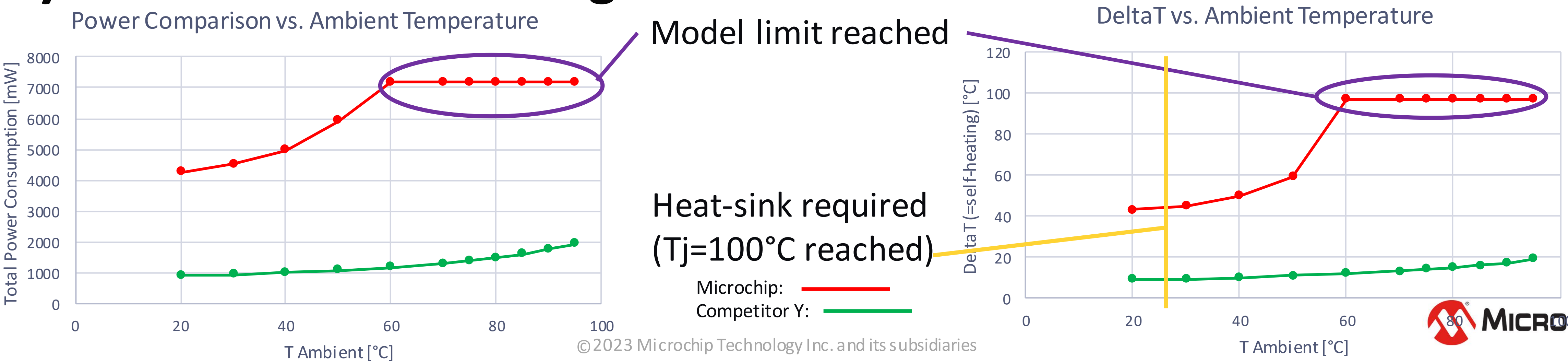
- **Power Comparator:**
  Excel-based competitive comparison
- **Use comparable devices**
- **Runs thermal sweep and creates diagrams**
- **Direct comparison on power and self-heating**



Estimate Converted Designs

Power Estimator Helps Winning on Power

- **Power estimators can be filled with**
  - Manually estimated design-resources
  - Exported data from implemented designs
  - Applies to both Microchip and Competitor Y
- **Temperature sweeps for typical and worst case**
- **Systems need to be designed for worst case**



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How To Estimate Correctly

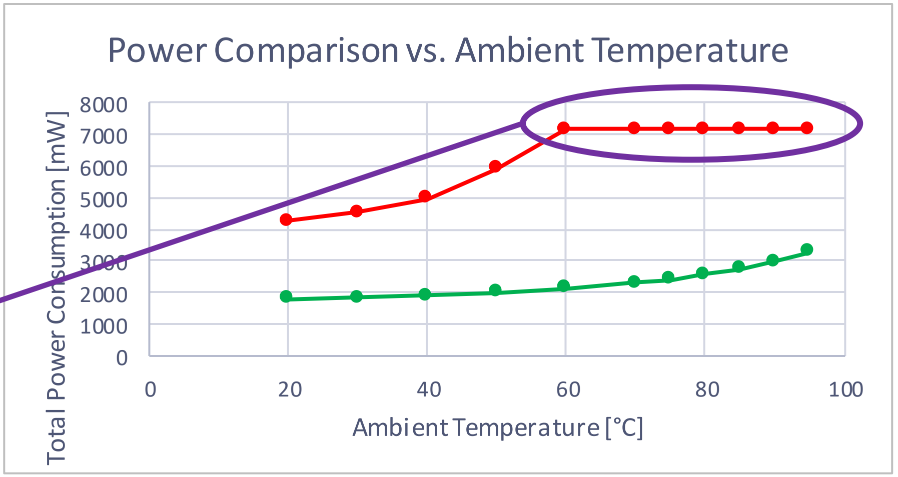
Get The Bigger Picture

- **Self-heating can be significant!**
  ➔ Use estimated junction temperature
- **Compare typical and worst-case devices**
  ➔ board must be designed for max
- **If available:**
  take exported data from implementation
- **Do temperature sweeps on ambient**
  ➔ graphs validate / invalidate data

Thermal Inputs	
Calculation mode	Estimated Tj
Ambient Temperature Ta (°C)	22.00
Theta JA	Custom Theta JA
Effective Θ_{JA} (°C/W)	8.20
Heat Sink	
Air Flow	
Custom Θ_{SA} (°C/W)	
Board Thermal Model	

Environment		
Junction Temperature	☐ User Override	
Ambient Temp		22.0 °C
Effective ΘJA	☑ User Override	8.7 °C/W
Airflow		
Heat Sink	None	
ΘSA		
Board Selection	Small (4"x4")	
# of Board Layers		
ΘJB		
Board Temperature		

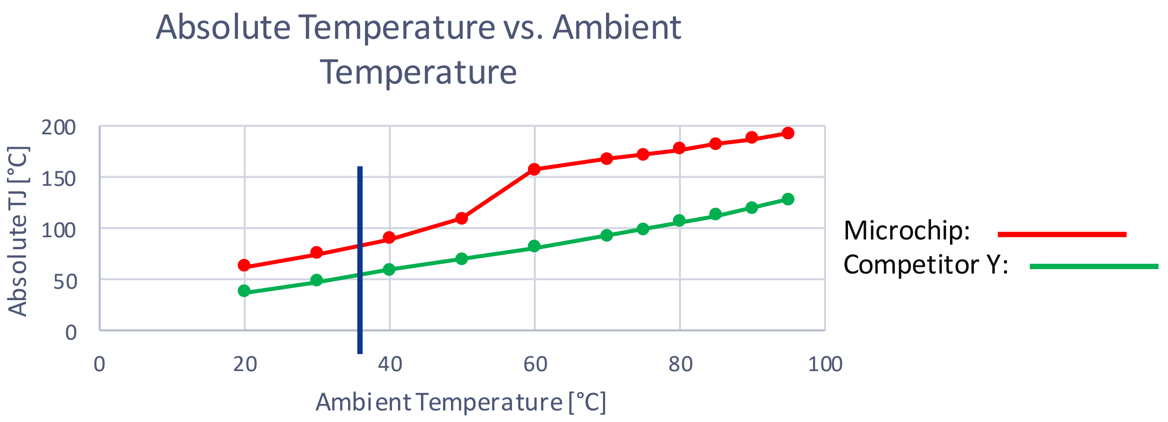
Remember?

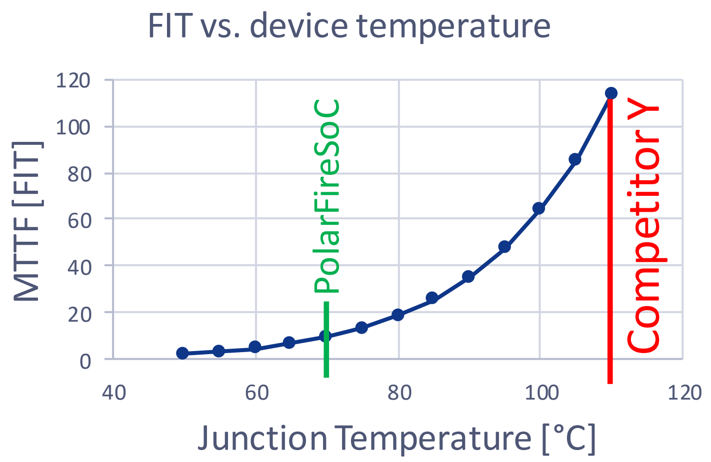


Thermal Sweep Results

What are Implications for the System?

- **Device aging**
  - T ambient = 50°C, Theta JA = 8.2 °C/W
  - Junction temperature PolarFire® SoC: 70°C, : 109°C





- **Resulting MTTF (assumed on identical test-hours)**
  - PolarFire SoC: ~10 FIT
  - Competitor Y : ~107 FIT
- **Lifetime expectations**
  - 110°C => 70°C, approximately 7x more life-time of electronic component!

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Your Design Estimates

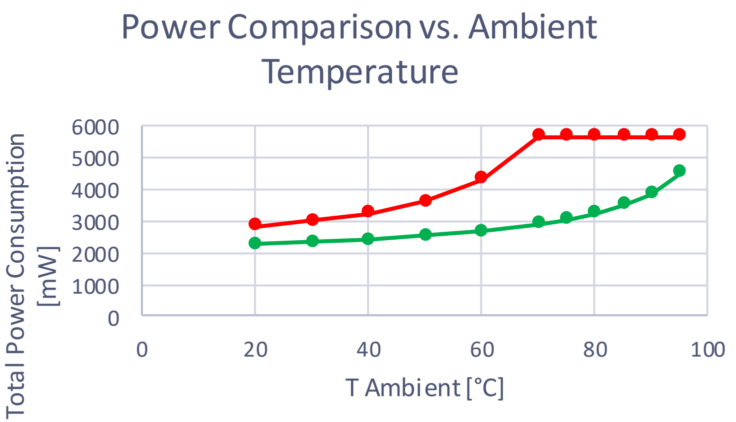
What Can You Save On Your Competitor Y Design?

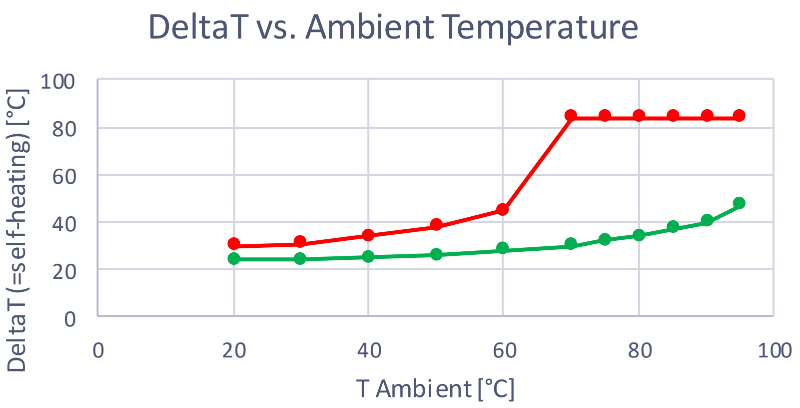
Estimate and Compare

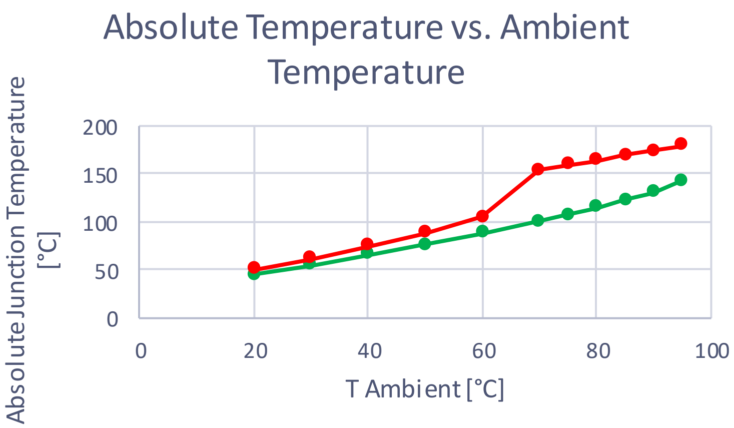
How Much can Your Design Benefit?

- **Temperature sweeps for typical/worst case on both architecture**
  - Either set tick-box for similar Theta JA or set in power estimators
- **Creation of diagrams**

Microchip:
Competitor Y:



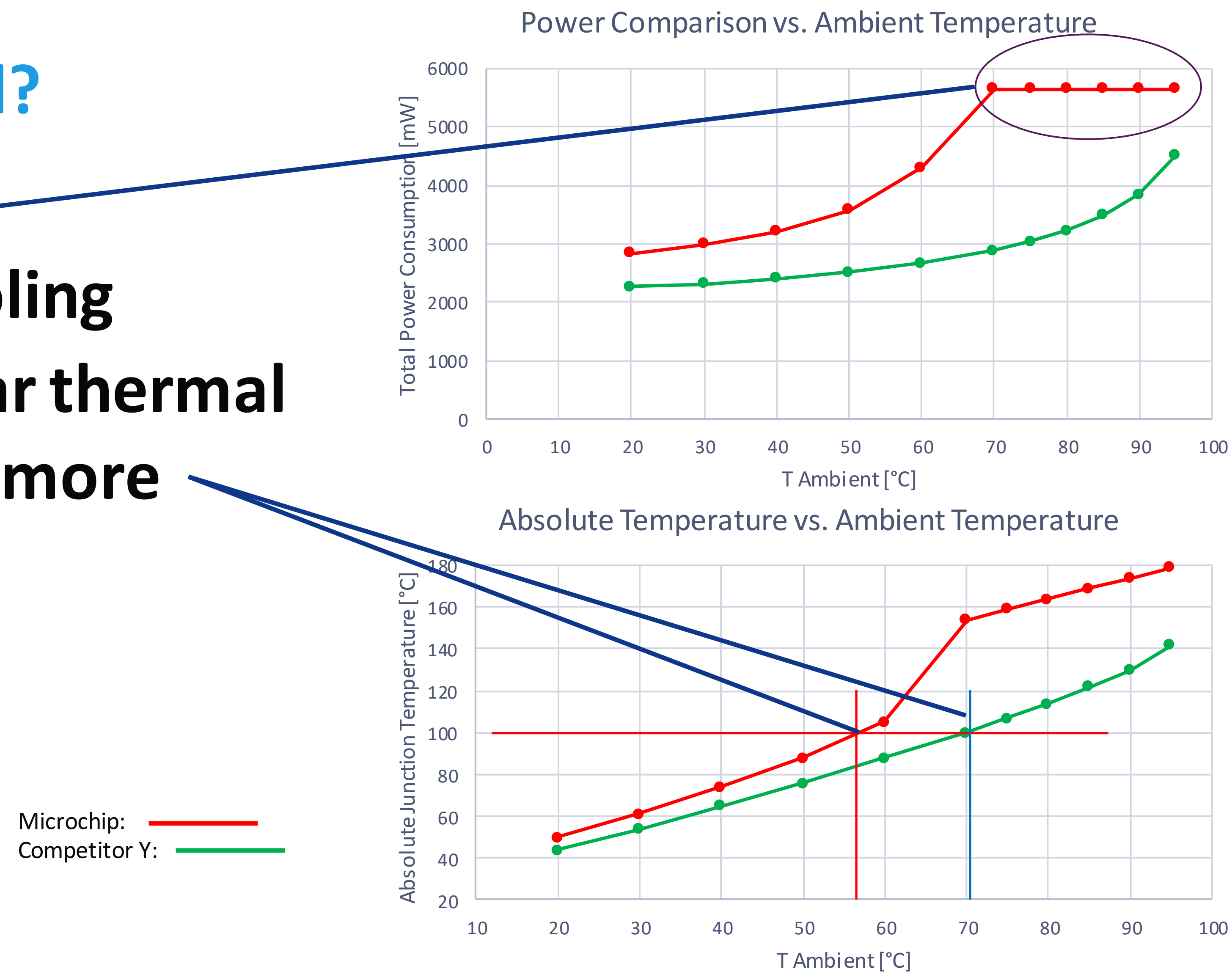




So What?

What do the Diagrams Tell?

1. **Model limit reached**
   => device will need cooling
2. **PolarFire® SoC at similar thermal conductivity has ~15°C more thermal margin**



Summary

What to do next?

Summary

What do the Diagrams Tell?

- **Microchip FPGAs provide significant power-advantage over competition**

- **Lower power = less trouble**
- **Significantly lower power = system benefit!**

Manual Data Entry Power Estimator

Similar Between all Vendors

- **Power estimation tools well known in FPGA community**
- **Design entry on tabs in Excel-Tool:**

Summary | Graphs | Snapshot | Current Breakdown | **Clock** | Logic | LSRAM | uSRAM | Math Block | IO | Transceiver | PLL & DLL | User | Release

- **Enter estimated logic for design:**

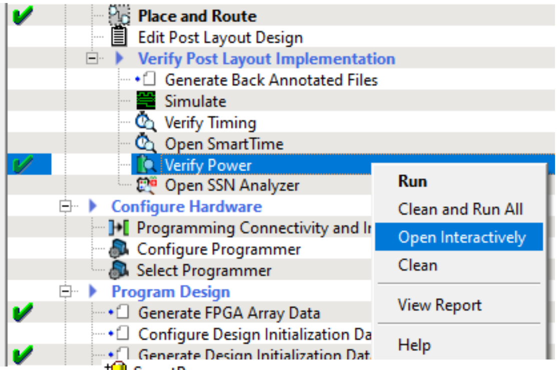
Name	Clock Frequency (MHz)	Number of DFF	Number of 4LUT	Design Complexity	Toggle Rate	Power (W)
				3.0	12.5%	0.000
				3.0	12.5%	0.000

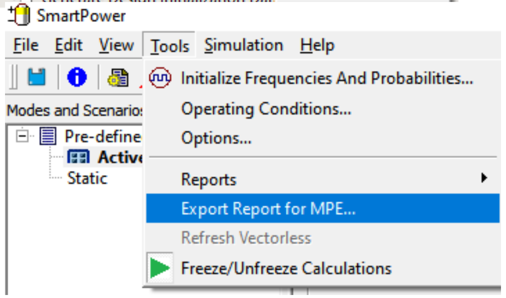
- **Do this for every basic component in FPGA fabric (Clock, Logic, internal RAM, Math-Blocks, IO, Transceiver, PLL)**

Exported Data Entry Microchip Power Estimator

Specific for Design, Good Accuracy

- **Power estimator allows change of environ-mental conditions**
- **Implement design in Libero SoC**
- **Open „Verify Power“ in interactive mode**
- **Menu: Tools\Export Report for MPE...**
  ➔ creates XML for import into MPE





- **Import XML into MPE**
  ➔ correct logic-sizes and toggle-rates are set

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Design Creation

MPF300 Video Kit

- **Design used on PolarFire® MPF300 is stripped down version of demo for MPF300-VIDEO-KIT**
  - VKPFH2RXTX.7z, available internally at Microchip
  - Send email to Martin.Kellermann@microchip.com
  - Design created in Libero 12.0