

Vivado Design Suite Tutorial

Power Analysis and Optimization

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Revision History

The following table shows the revision history for this document.

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I ab 1

Power Analysis and Optimization **Tutorial**

This tutorial introduces the power analysis and optimization use model recommended for use with the Xilinx[®] Vivado[®] Integrated Design Environment (IDE). The tutorial describes the basic steps involved in taking a small example design from RTL to implementation, estimating power through the different stages, and using simulation data to enhance the accuracy of the power analysis. It also describes the steps involved in using the power optimization tools in the design.



VIDEO: The Vivado Design Suite Quick Take Video: Power Estimation and Analysis Using Vivado shows bow the Vivado Design Suite can help you to estimate power consumption in your design and reviews best practices for getting the most accurate estimation.

VIDEO: The Vivado Design Suite QuickTake Video: Power Optimization Using Vivado describes the factors 0 that affect power consumption in an FPGA, shows how the Vivado Design Suite helps to minimize power consumption in your design, and looks at some advanced control and best practices for getting the most out of Vivado power optimization.

Software Requirements

This tutorial requires the latest Vivado Design Suite software is installed. For installation instructions and information, see the Vivado Design Suite User Guide: Release Notes, Installation, and Licensing (UG973).

For hardware power measurement of 7 series devices, the tutorial requires Texas Instruments Fusion Design Power Designer software, which can be downloaded from the following location: http://www.ti.com/tool/fusion_digital_power_designer

For hardware power measurement of UltraScale[™] devices, the tutorial requires Maxim Digital Power Tool software, which can be downloaded from the following location:

https://www.maximintegrated.com/en/products/power/switching-regulators/ MAXPOWERTOOL002.html



Hardware Requirements

Supported operating systems to run the Vivado Design Suite, and memory recommendations when using the Vivado tools, are described in the Vivado Design Suite User Guide: Release Notes, Installation, and Licensing (UG973).

Hardware Requirements for 7 Series Devices

- The hardware power measurements for 7 series devices (needed in Lab 4: Measuring Hardware Power Using the KC705 Evaluation Board), require a Xilinx Kintex®-7 FPGA KC705 Evaluation Kit. You can find information on the Evaluation Kit at this location: Xilinx Kintex®-7 FPGA KC705 Evaluation Kit
- For power measurements through TI Power Regulators (needed in Lab 4: Measuring Hardware Power Using the KC705 Evaluation Board), use the Texas Instruments USB Interface Adapter. You can find information on the USB Interface Adapter at this location:

www.ti.com/lit/ml/sllu093/sllu093.pdf

Hardware Requirements for UltraScale Devices

- The hardware power measurements in UltraScale devices (needed in Lab 5: Measuring Hardware Power Using the KCU105 Evaluation Board), requires a Xilinx Kintex[®] UltraScale[™] FPGA KCU105 Evaluation Kit. You can find information on the Evaluation Kit at the following location: Xilinx Kintex UltraScale FPGA KCU105 Evaluation Kit
- For power measurements through Maxim Digital Power Tool (needed in Lab 5: Measuring Hardware Power Using the KCU105 Evaluation Board), use the Maxim Power interface adapter. You can find information on the interface adapter at the following location: https:// www.maximintegrated.com/en/products/power/switching-regulators/ MAXPOWERTOOL002.html

Locating Tutorial Design Files

1. Download the reference design files from the Xilinx website:

ug997-vivado-power-analysis-optimization-tutorial.zip

2. Extract the zip file contents into any write-accessible location.

This tutorial refers to the location of the extracted ug997-vivado-power-analysisoptimization-tutorial.zip file contents as <Extract_Dir>.

IMPORTANT! You will modify the tutorial design data while working through this tutorial. Use a new copy of the original data each time you start this tutorial.



The ug997-vivado-power-analysis-optimization-tutorial.zip file includes a readme file which contains the details and version history of the design files along with the folders of 7 series and UltraScale design files.

7 Series Tutorial Design Files

You can find a separate 7 series folder containing the 7 series tutorial design files in the contents of the zip file.

The following table describes the contents of the 7 series tutorial design files:

Directories/Files	Description
/src	Contains the design HDL and testbench for the functional simulation.
/src/dut_fpga.v	Top module for the design.
/src/bram_tdp.v	Other design blocks - synthesized module.
/src/bram_top.v /src/dut.v	
dut_fpga_kc705.xdc	Contains clocking and timing constraints for the design.
/src/testbench.v	Testbench for simulating the design.

UltraScale Device Tutorial Design Files

You can find a separate UltraScale[™] folder containing the UltraScale device tutorial design files in the contents of the zip file.

The following table describes the contents of the UltraScale device tutorial design files:

Directories/Files	Description	
/src	Contains the design HDL and testbench for the simulation.	
/src/dut_fpga.v	Top module for the design.	
/src/dut.v	Other design blocks.	
/src/Cascade_bram.v		
/src/Noncascade_bram.v		
/src/bram_top_cascade.v		
/src/bram_top_noncascade.v		
/src/bram_tdp_cas.v		
/src/bram_tdp_noncas.v		
dut_fpga_kcu105.xdc	Contains clocking and timing constraints for the design.	
/src/testbench.v	Testbench for simulating the design.	

Table 1: Example table



Lab 2

Running Power Analysis in the Vivado Tools

Introduction

In this lab, you will learn about the Power Analysis and Optimization features in the Vivado[®] IDE. The lab will take you through the steps of project creation and power analysis at the synthesis stage, using the Vivado Report Power feature in vectorless mode. It will also demonstrate using the SAIF file generated from behavioral simulation for Vivado report power analysis.

You will analyze power in the Vivado IDE. Then you will examine some of the major features in the Power window and closely examine some power specific Tcl commands. You will also learn to create a Switching Activity Interchange Format (SAIF) file by simulating the design in the timing simulation stage using both the Vivado simulator and Questa Advanced Simulator.

You will also learn how to achieve Power Optimization after <code>opt_design</code> in the Vivado IDE. You will examine the power optimization report and selectively turn power optimizations ON or OFF on specific signals, nets, modules, or hierarchy.

Step 1: Creating a New Project

To create a project, use the New Project wizard to name the project, to add RTL source files and constraints, and to specify the target device.

Note: Throughout this tutorial, Xilinx[®] 7 series example design is used to explain the process of configuring, implementing, estimating the power through different stages, and using simulation data to enhance the accuracy of the power analysis. For UltraScale[™] device design, most of the steps are similar to 7 series. Additional information, wherever necessary, is provided for UltraScale devices.



On Linux, do the following.

- 1. Go to the directory where the lab materials are stored:
 - cd <Extract_Dir>/7_series (for 7 series devices) or
 - cd <Extract_Dir>/UltraScale (for UltraScale devices)
- 2. Launch the Vivado IDE: vivado

A	Vivado 2021.1	+ _ 3 ×
Eile Flow Tools Window Help Q- Quick Access		
		£ XILINX.
Quick Start Create Project > Open Project > Open Example Project >	Recent Projects Project_1 Project_1 Promovular/Desktopsproject_1	
Tasks Manage IP > Open Hardware Manager > Vivado Store >		
Learning Center	·	
Tcl Console		? _ 🗆 🖒 X
)°

On Windows, do the following.

3. Launch the Vivado IDE by selecting Start → All Programs → Xilinx Design Tools → Vivado 2021.x → Vivado 2021.x (x denotes the latest version of Vivado 2021 IDE).

As an alternative, click the Vivado 2021.x Desktop icon to start the Vivado IDE.

The Vivado IDE Getting Started page contains links to open or create projects and to view documentation.

- 4. In the Getting Started page, click **Create New Project** to start the New Project wizard.
- 5. Click **Next** to continue to the next screen.



A-New Project			
Project Name Enter a name for yo	our project and specify a directory where the project data files will be stored.		A
Project name:	power_tutorial1		0
Project location:	C:Nivado_power_tutorial		0
Create project	ct subdirectory		
Project will be cre	reated at: C:/vivado_power_tutorial/power_tutorial1		
•	< Back Next >	Elnish	Cancel

- 6. In the Project Name page, name the new project power_tutorial1 and enter the project location (C:\Vivado_Power_Tutorial). Make sure to check the Create project subdirectory option and click Next.
- 7. In the Project Type page, specify the type of project to create as **RTL Project**, make sure to uncheck the **Do not specify sources at this time** option, and click **Next**.
- 8. In the Add Sources page:
 - a. Set Target Language to Verilog and Simulator language to Mixed.
 - b. Click the Add Files button.
 - c. In the Add Source Files dialog box, navigate to the <Extract_Dir>/7_series/src directory for 7 series devices or <Extract_Dir>/UltraScale/src for UltraScale devices.
 - d. Select all of the Verilog (.v) source files, and click OK.
 - e. In the Add Sources page, change the HDL Source For the ${\tt testbench.v}$ file to Simulation only.



+.	[::]	+ +					
	Index	Name	Library	HDL Source For		Location	
0	1	bram_tdp.v	xil_defaultlib	Synthesis & Simulation	٠	C:/vivado_power_tutorial/7_series/src	
	2	bram_top.v	xil_defaultlib	Synthesis & Simulation		C:/vivado_power_tutorial/7_series/src	
0	3	dut.v	xil_defaultlib	Synthesis & Simulation	*	C:Nivado_power_tutorial/7_series/src	
	4	dut_fpga.v	xil_defaultlib	Synthesis & Simulation	٠	C:/vivado_power_tutorial/7_series/src	
	5	testbench.v	xil_defaultlib	Simulation only	٠	C:/vivado_power_tutorial/7_series/src	
	opy <u>s</u> our	add RTL includ ces into project es from subdiri			IS	<u>C</u> reate File	

- f. Verify that the files are added and **Copy sources into project** is checked. Click **Next**.
- 9. In the Add Constraints (optional) page, click Add Files and select dut_fpga_kc705.xdc in the file browser. In the directory structure, you will find the dut_fpga_kc705.xdc file below the /src folder.

For UltraScale devices, select dut_fpga_kcu105.xdc in the file browser. In the directory structure, you will find the dut_fpga_kcu105.xdc file below the /src folder.

- 10. Click Next to continue.
- 11. In the Default Part page, click **Boards** and select Kintex-7 KC705 Evaluation Platform for 7 series or Kintex UltraScale KCU105 Evaluation Platform for UltraScale devices. Then click **Next**.

TIP: When you specify a board, you are also specifying the part you are targeting for your design, in this case an xc7k325tffg900-2 FPGA for 7 series or xcku040-ffva156-2-e FPGA for UltraScale devices.

12. Review the New Project Summary page. Verify that the data appears as expected, per the steps above, and click **Finish**.

Note: It might take a moment for the project to initialize in the Vivado IDE.



power submit [Chinedo power	storisk'power_tutoriall/power_tutorialLogs] - Vivodo 2017.3		0.0
The Eq. Lion Tools R	indose Lagaul gaw galp Qr Datch Access		Ready
■, + + 0 0 X	▶, # 0 Σ % # #		E Oetault Laeaul
Now Navagelos 🗧 8 🤉	PROJECT BARACER - power_information		?
Y PROJECT NANAGER	Sources 2 - D D X	Project Summary	7.0 S X
O Swittings Add Bources	Q 2 0 + 0 0	Settings 1.4	
Canguage Temptales Ø IP Catalog	Concentration (1) Out of the second (1)	Projectioner power Microsoft Projectiocater Criterios Jacobspower Microsoft Productionaly: Kiteso 7	
 PINTEGRATOR Greate Block Design Open Block Design Germania Block Design 	Benecky Lizzeisz Campis Order	Propertia ant kineter 2022/00 E-assuation Platform bioCh325/thg900-02 Top models name: date topa Target language: liveling Simulation language: liveling	
Y SARLATION Nan Simalakin	Properties 7	Boald Part Display name - Kintee-7 KG726 Busication Platform	5557676777
 RTL ANALYSIS Open Distorated Design 	Sarked are object to see programme	Board anthrane alline.com Is/73/5part/1.5 Connections Researchere anth Researchere anth URL several for comite/103	
 SYNTHESE Ratification 		Ecard oveniew: Kinte 7 KC715 Exclusion Platform	#1.1777
> Open Sutherbed Design	Tol Console Mexicages Log Reports Design Russ. ×		? _ 0 0
MPLEMENTATION Run Implementation Open implementation	Q. Ξ. ÷ 14 ≪ >> + % Name Constraints Status Whit THS WHS ~ D syntl_1 constraint Not stated D imp[_1 constraint Not stated	THS THAT THAT WAY Fare Routes LUT IF BRUES UNAN USY Stat Elegand	Shalegy Veado Synthesis Debadle (W Veado Implementation Debu
PROCRAW AND DEBUG If Convrats Bitstream			
> Open Hardesare Manager	8		

13. In the Settings dialog box (**Tools** → **Settings** → **Tool Settings** → **Project**), enter the tutorial project directory in the Specify project directory field, so that all reports are saved in the tutorial project directory. Then click **OK**.

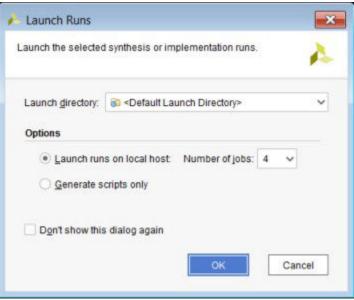
2-	Project		2
Project Settings General	Specify various settings related to project	ts.	,
Simulation	Default Project Directory		
Elaboration Synthesis Implementation Bitstream	Start in directory (C:/Users/venkal)	as)	
Fool Settings	Specify project directory: C:/pro		
Project	Target Language		
IP Defaults Source File Display WebTalk	Verilog VHDL		
Help	Reopen last project on startup		
 Text Editor 3rd Party Simulators 	Number of recent projects to list:	10 🗘	
> Colors	Number of recent directories to list	15 🗘	
Selection Rules Shortcuts Strategies > Window Behavior	Number of recent files to list	10 ‡	
_			

Now, the design is ready for synthesis.



Step 2: Synthesizing the Design

1. Click **Run Synthesis** in the Flow Navigator. In the Launch Runs dialog box that appears, click **OK**.



2. The Synthesis Completed dialog box appears after synthesis has completed on the design.



3. Open the synthesized design by selecting **Open Synthesized Design** in the Synthesis Completed dialog box and clicking **OK**.





Step 3: Setting Up the Report Power

The Vivado IDE allows you to specify input data to the Report Power tool to enhance the accuracy of the power analysis.

In the Vivado IDE, you can configure thermal, environmental, and power supply options to mimic the board level settings as closely as possible. For information on setting these options, see the *Vivado Design Suite User Guide: Power Analysis and Optimization* (UG907).

- 1. In the main menu bar, select **Reports** \rightarrow **Report Power**.
- 2. Examine the Environment tab in the Report Power dialog box.

Res <u>u</u> lts name:	power_1					C
Environment	Power Supply	Switching 9	Output			
Device Setting	S					î
Temp grad	le:	extended	~]		
Pro <u>c</u> ess:		maximum	~			
Environment S	ettings					
Output Loa	d:		0 ‡	pF	[0 - 10000]	
Unctio	n temperature:		25.679	°C		
Ambient te	mperature:	-	25 🌲	°C		
Effectiv	e ƏJ <u>A</u> :		1.42	2 °C/W	[0 - 100]	
Airflow:		250	~	LFM		
<u>H</u> eat sink:	<u>H</u> eat sink:		um Prof 🗸			
ϑSA:			°C/W	[0 - 100]		
<u>B</u> oard sele	ction:	medium (10"x"	10") 🗸			
Number of	board layers:	12to 15 (12 to 1	5 Layer 🗸			
JB:		1	2.5 🌲	°C/W	[0 - 100]	
C Board tom	o o roturo:		nc 🔺		1 55 4001	~
Legend						

3. In the Environment tab, set Process to **maximum** for a worst case power analysis. Examine the Power Supply tab.



IMPORTANT! By default, Vivado Report Power uses nominal values for voltage supply sources. Voltage is a large factor contributing to both static and dynamic power. For the most accurate analysis, ensure that actual voltage values are entered for each supply. Similarly, ensure temperature and other environmental factors match actual operating conditions.

lesylts name:	power_1				
Environment	Power Supply		Switching	Output	
Settings					
Vccint:	1.000 ‡	v	[0.970 -	1.030}	î
Vccaux	1.800 \$	v	[1.710 -	MICHT.	
Vcco <u>3</u> 3:	3.300 \$	v	[3.000 - 3		
Vcco25:	2.500 🗘	v	(2.380 -)	2.630]	
Vcco <u>1</u> 8:	1.800 🌲	v	[1.710 -	1.900]	
Vcco1 <u>5</u> :	1.500 ‡	v	[1.430 -	1.580]	
Vcco135:	1.350 🗘	v	[1.300 -	1.400]	
Vcco12	1.200 🌻	v	[1.140 -	1.260J	
Vccaux_io:	1.800 ‡	v	[1.710 -	1.890}	
Vccbra <u>m</u> :	1.000 ‡	v	[0.970 -	1.030]	
MGTAVcc:	1.000 🌲	۷	[0.950 -	1.050]	
MGTAVII:	1.200 🗘	v	[1.140 -	1.260]	
MGTVccaux	1.800 🌻	۷	[1.710 -	1.890]	
MGTZVccl:	1.075 ‡	v	[1.050 -	1.100)	
Legend	+				~

4. In the Switching tab, expand **Constrained Clocks** and examine the constrained clocks in the design.

, **IMPORTANT!** Make sure all the relevant clocks in the design are constrained. All the design clocks must be defined using *create_clock* or *create_generated_clock* XDC constraints, so that Report Power recognizes the clocks.

Default toggle rate is set to 12.5% and Default Static Probability is set to 0.5. This will be applied to primary input ports (non-clock) and block box outputs.



stimate power c	onsumption based	d on the netli	st design and	1 part xc7k325t	tg900-2.	
Results name:	power_1					
Environment	Power Supply	Switching	Output			
Simulation Se	ttings					
Simulation	activity file (.saif):	1]
Default Activit	y Settings					
Default tog	gle rate:	12.5	[0 - 100]			
Default Sta	tic Probability:	0.5	[0.0 - 1.0]			
Enable Rate S	ettings					
		Static Proba	bility	Toggle Rate		
BRAM Port	Enable:		[0.0 - 1.0]		[0 - 100]	
BRAM Writ	e Enable:		[0.0 - 1.0]		[0 - 100]	
Bidi Outpu	Port Enable:		[0.0 - 1.0]		[0 - 100]	
Toggle Rate S	ettings					
		Static Proba	bility	Toggle Rate		
Primary Ou	itputs:		[0.0 - 1.0]		[0 - 100]	
Logic						
Register	s:		[0.0 - 1.0]		[0 - 100]	
Shift Reg	gisters:		[0.0 - 1.0]		[0 - 100]	
Distribut	ed RAMs:		[0.0 - 1.0]		[0 - 100]	
LUTs:			[0.0 - 1.0]		[0 - 100]	
DSPs:			[0.0 - 1.0]		[0 - 100]	
Block R/	Ws:		[0.0 - 1.0]		[0 - 100]	
GTs						
RX Data			[0.0 - 1.0]		[0 - 100]	
TX Data:			[0.0 - 1.0]		[0 - 100]	
 Constrained 	Clocks					
Clock			Period			
sys_clk_in_p			5 ns			
clk_0			5 ns			
clkout0			10 ns			

- 5. In the Output tab of the Report Power dialog box, specify the **Output text file** as power_1.pwr.
- Specify the Output XPE file as power_1.xpe. After creating this file when Report Power runs, you can import the file and results into the Xilinx Power Estimator. For information on importing the file in to the Xilinx Power Estimator, see the Xilinx Power Estimator User Guide (UG440).
- Specify the RPX file to write the results of the Report Power command. The saved RPX file
 can be reloaded using the Reports → Open Interactive Report command to provide
 interaction/cross-probing with the open design.



Report Power	onsum	ption base	d on the netlis	t design and	part xc7k325	tfg900-2.	×
Results name:	powe	er_1					0
Environment	Powe	er Supply	Switching	Output			
Output text file	0	power_1	pwr			¢	
Output XPE file	e:	power_1	xpe			C	
J Output RP	X file:	C:/proj/p	ower_1.rpx			C	

Legends in Report Power Tool

The following legends appear consistently in the Report Power tool:

- **Constraint:** Displays when the nets are defined as clock with timer constraints. The defined frequency of a clock determines the switching activity.
- Stimulation: Displays when the nets with switching activities are derived from simulation's .saif file.
- User Defined: Displays when the nets with user set switching activities are derived from set_switching_activity power Tcl command.
- Estimated: Displays when the nets with switching activities are generated by report_power vectorless propagation engine.
- **Default:** Displays when the nets include default switching activities. If you use set_switching_activity on input port nets or on internal nets before running report_power (vectorless propagation), the report tool displays the default.



Step 4: Running Report Power

1. Click **OK** on the Report Power dialog box.

This runs the report_power command.

2. Examine the power report, power_1, generated in the Power window in the Vivado IDE.

Note: Due to continuous accuracy improvements in the Vivado tools, the actual power numbers you see might be slightly different than the ones that appear in the following figures.

Power		7 _ 0 2 3
a ¥ ≑ c ∎"	Summary	
Setings Summary (1.379 W) Power Supply V Ulication Details Hierarchical (0.918 W) Clocks (0.011 W) State (0.051 W) Date (0.051 W) Clock Reate (0 W) SetReate (0 W) SetReate (0 W) Logic (0.011 W) ERVM (0.714 W) Clock Manager (0.117 W) KD (0.004 W)	Power estimation from Synthesized netlist Adduly derived form constraints files, simulation files or vectories analysis. Note: these early estimates can change after implementation. Total On Chip Power: 1.379 W Junction Temperature: 27.4 °C, Thermail Margin: 57.6 °C (30.3 W) Effective 2UA: 1.3 °C.W Power supplied to off-chip devices: 0.W Confidence level: 8654 um Launch Power Constraint Addiagr to find and fix invalid switching activity	

- 3. Examine the power breakdown in the power report by block type (Logic, BRAM, I/O, etc.).
- 4. Examine the power supply breakdown in the Power Supply view.

Power							? _ D 2
Q 😤 单 C 🕍 "	Power Supply						🔂 Getault 🛛 Calculate
Sellings	Supply Source	Voltage (v)	Total (A)	Dynamic (A)	Static (A)		
Summary (5.379 W)	Vecint	1.000	1.041	0.745	0.295		
Power Supply	Voceux	1.800	0.152	0.067	0.085		
 Utilization Details 	V00033	3 300	0.042	0.000	0.042		
Herarchical (0.918 W)	Voco25	2.500	0.000	0.000	0.000		
Clocks (0.011 W)	Vcco18	1.800	0.000	0.000	0.000		
 Signala (0.061 W) 	Vcco15	1500	0.000	0.000	0.000		
Date (0.061 V/)	Veco135	1350	0.000	0.000	0.000		
Clock Enable (0 W)	Voco 12	1.200	0.000	0.000	0.000		
SeoReaet (0 W)	Vocaux_io	1.800	0.000	0.000	0.000		
Logic (0.011 W)	Vocbram	1.000	0.065	0.054	0.013		
BRAM (0.714 W)	MGTAVec	1.000	0.000	0.000	0.000		
Clock Manager (0.157 W)	MGTAVI	1.200	0.000	0.000	0.000		
VO (0.004 W)	MGTVccaux	1.800	0.000	0.000	0.000		
	Vocado	1.800	0.030	0.000	0.030		

5. Examine the hierarchical breakdown of the power in the **Utilization Details** → **Hierarchical** view.

a 🛛 e c 📕 "	Q 📱 Hierarchical									
Setings	Utilization	Name	Clocks (W)	Signals (W)	Data (W)	Logic (W)	BRAM (W)	Clock Manager (W)	MICH (W)	NO (W)
Summary (1.370 W)	 E 0.918 W (67% of total) 	agat_tub 🎉								
Power Supply	 Compared 0.795 W (58% of total) 	(tut) tub 📳	0.009	0.061	0.061	0.011	0.714	<0.001	<0.001	<0.001
Utilization Details	> 🔲 0.079 W (6% of total)	🗐 gen_dutj0] br	0.001	0.005	0.006	0.001	0.071	=0.001	<0.001	-0.001
Hierarchical (0.918 W)	> 0.079 W (0% of total)	🗿 gen_dut(1).br	0.001	0.005	0.006	0.001	0.071	<0.001	<0.001	-0.001
Clocks (0.011 W)	> 0.079 W (0% of total)	gen_dut(2).br	0.001	0.005	0.006	0.001	0.071	<0.001	<0.001	<0.001
 Signals (0.051 W) Dats (0.051 W) Clock Enable (0 W) 	> 0.079 W (5% of total)	gen_dut(3).br	0.001	0.005	0.006	0.001	0.071	+0.001	<0.001	-0.001
	> 0.079 W (0% of total)	I gen_dut[4].br	0.001	0.006	0.006	0.001	0.071	<0.001	<0.001	+0.001
	> 0.079 W (5% of total)	al gen_dut(6).br	0.001	0.006	0.006	0.001	0.071	+0.001	+0.001	+0.001
SebReset (0 W)	> 0.079 W (6% of total)	📓 gen_dul(8) br.	0.001	0.006	0.006	0.001	0.071	*0.001	+0.001	-0.001
Logic (0.041 W)	> 0.079 W (5% of local)	gen_dul(?).br	0.001	0.006	0,006	0.001	0.071	+0.001	+0,001	-0.001
BRAW (0.714 W) Clock Manager (0.117 W)	> 0.078 W (8% of total)	🧾 gen_dut(ii) br	0.001	0.006	0.006	0.001	0.071	*0.001	+0.001	-0.001
	> @ 0.079 W (8% of total)	📓 gen_dul(9) br	0.001	0,006	0.006	0.001	0.071	+0.001	+0.001	+0.001
UC (0.004 W)	\$ <0.001 W (<1% of fotal)	Lesf Cells (8)								
	0.124 W (9% of total)	E Leaf Cells (18)								



6. Examine the Clocks view and the various Signals views (Data, Clock Enable, and Set/Reset).

Q 🔮 🖨 C 📕 "	Q 🔮 Clocks								Constr	aint 🗄	Calculated
Settings	Utilization	Name	Frequency (MHz)	Buffer	Clock Buffer Enable (%)	Enable Signal	Bel Fanout	Sites	FanoutiSite	Type	
Summary (1.379 W)	 E 0.011 W (1% of total) 	🙀 dut_fpga									
Power Supply	> 0.009 W (1% of Islar)	J cikoutó	100.000	NA	NA	NAVA	842	611	1.378	NIA	
 Utilization Details 	> 10.002 W (<1% of lotal)	∫ dk_0	200.000	NIA	NIA	NA	2	2	1.000	NØ.	
Hierarchical (0.918-W)	> 1<0.001 W (<1% of total)	_ sys_dk_in_p	200.000	NIA	N/4	NA	2	2	1.000	NiA	
Clocks (0.011 W)											
Signals (0.061 W)											
Data (0.061 W)											
Clock Enable (0.W)											
SetReset (0 W)											
Logic (0.011 W)											
BRAM (0.714 W)											
Clear Manager () 417740											
Clock Manager (0.117 W)											
UD (8 004 W)											

Step 5: Viewing the Power Properties

This step shows how you can get the display of static probability and toggle rate for a signal in property window.

- 1. Note the total power (Total On-Chip Power) in the Power Report Summary view.
- 2. Click the Set/Reset item in the Power Report.
- 3. Click on the dut/dut_reset signal.

wer											?
2 ₹ ♦ C 📕 "	QI	SetReset							Attribute	Estimated	Calculated
Settings	Utilization	Name	Signal Rate (Mtr/s)	% High	Fanout	Slice Fanout	Clock	Logic Type			
Summary (1.370 W)	~ DW	Gil dut_fpga									
Power Supply	0.W	_f_dut/dut_reset	0.000	0.000	530	0	clkout0	FFLUT			
Utilization Details	0 W O	J led_OBUF	0.000	100,000	3	0	clkout0	FEIIOLUT			
Hierarchical (0.918 W)											
Clocks (0.011 W)											
✓ Signals (0.061 W)											
Data (0.061 W)											
Clock Enable (0.W)											
Set/Reset (0 W)											
Logic (0.011 W)											
BRAM (0.714 W) Clock Manager (0.117 W)											
UD (8 004 W)											

4. Note that there is a Power view in the Net Properties window that displays net properties for the dut/dut_reset signal. Click on Load Power Properties to get the power information the first time.



Legend: Estimated	⇔ ⇒ 0
Toggle rate: 0.0 % Static probability: 0.0	
Static probability: 0.0	
Legend: 📃 Estimated	
Edit Properties	

5. Note the Toggle rate is 0% and the Static probability is 0 for the dut/dut_reset signal, which indicates that reset is always deasserted in the design.

Step 6: Editing Power Properties and Refining the Power Analysis

Assume the reset is asserted for 10% of the cycles in this design. Switching activity can be set accordingly to re-estimate the power.

- 1. In the Net Properties window, click the **Edit Properties** button.
- 2. In the **Edit Power Properties** dialog box, change the Toggle rate to 4% and the Static probability to 0.1.

et power properties for du	t_reset.	
Output		
Toggle rate:	4.000 🗘	%
		0.0 - 1.0]
Static probability:	0.1 🌲 [0.0 - 1.0]

- 3. Click OK.
- 4. In the Net Properties window, observe that the Toggle Rate and Static Probability values turn a different color to indicate that they are user defined.



Net Properties	? _ D .7 ×
.F dut_reset	+ - O
Output	
Toggle rate: 4.0 % Static probability: 0.1	
	Edit Properties
General Properties Connectivi	Power Aliases Cell Pins Nodes Tiles Pips

You can also observe the equivalent Tcl command executed in the Tcl Console.

cl Console x Micessajos Log Reports Design Runs Power	5 – D D
Q. 茶 ゆ 川 田 麗 首	
Command: report power -file Cr/DorshNMm/power 1.pwr -xpc Cr/DorshNMm/power 1.apc -rpm Cr/peo//power 1.rpm -mame power 1 Running Vector-Leas Activity Propagation	^
Pinished Numming Vector-less Activity Propagation 0 Infos, 0 Warnings, 0 Critical Warnings and 0 Errors encountered.	
report_power completed successfully ret switching sciivity -topple rate 4.000000 -static probability 0.100000 [pet sets dis/dut reset]	
and have a state of the second state of the se	
•	3
Igpo a Tel command here	

- 5. Rerun Report Power (**Reports** \rightarrow **Report Power**).
- 6. Change the Output text File and Output XPE File in the Output tab to **power_2.pwr** and **power_2.xpe** respectively.
- 7. In the Switching tab, set Switching Activity for Resets: to None. Then click OK.
- 8. In the Power window, note the change in total power reported in the power_2 report compared to the power_1 report. The total power has decreased due to the change in the Signal Rate for the dut/dut_reset signal. Because the signal is a reset signal, an increase in its activity will significantly reduce the activity of other signals in the design. The Signal Rate of the dut/dut_reset signal is now color coded as being User Defined in both the properties window and the Set/Reset view of the Power Report.

You can also observe the equivalent Tcl command executed in the Tcl Console.

a 🗄 🔹 C 📕	Q 🛨 SetReset							1000	User Defined	Atribute	Calculated
Settings	Utilization	Name	Signal Rate (Mh/s)	% High	Fanout	Slice Fanout	Clock	LogicType			
Summary (1.358 W)	\$<0.001 W (<1% of total)	apd_tub 80									
Power Supply	1 <0.001 W (<1% of total)	_f_dut/dut_reset	4.000	10.000	630	Þ	clacut0	FFLUT			
Utilization Details	ow	J led_OBUE	0.000	100.000	3	0	clazat0	FEBOLUT			
Hierarchical (0.898 W)											
Clocks (0.0111W)											
→ Signals (0.065 W)											
Data (0.065 W)											
Clock Enable (0 W)											
BetReset (<0.001 W)											
Logic (0.01 \V)											
BRAM (0.71W)											
Clock Manager (0, 117 W)											
BO (0.004 W)											

Xilinx recommends you to double-check the signal rates and percentage high (%High) values of high impact I/O ports, control signals (such as resets and clock enables) and high fanout nets. This is an opportunity to guide the Report Power tool to the right estimation scenario.



See the Vivado Design Suite User Guide: Power Analysis and Optimization (UG907) for more information on switching activity.

TIP: In Tcl, use the *set_switching_activity* command to change the signal rate and static probability of signals and use *report_switching_activity* to query the values that were set on the signals.

 \bigotimes IN as

IMPORTANT! Switching activity can also be specified in terms of toggle rate. Toggle rate is always associated with a clock. The primary ports can be associated with a specific clock using the set_input_delay and set_output_delay commands. If no clock association is found, Report Power will associate the ports with respect to the capturing clock.

For a clock of 100 MHz and a toggle rate of 4, the equivalent signal rate will be 4 MTr/s (signal_rate = toggle_rate * Freq = 4×100 MHz).

Step 7: Running Functional Simulation with SAIF Output

Now that you have created a Vivado Design Suite project for the tutorial design, you can set up and launch the Vivado simulator to run post-synthesis functional simulation. Simulation will generate a switching activity values file (SAIF) that will enable you to do more accurate power estimation on your design.

- 1. In the Flow Navigator, click **Settings** to open the Settings dialog box and set the simulation properties in Simulation section.
- 2. In the Simulation section of Settings dialog box, note that the following Simulation defaults are automatically set for you based on the design files:
 - Simulator language: Mixed
 - Simulation set: sim_1
 - Simulation top-module name: testbench
- 3. In the Elaboration tab of Simulation section, make sure the xsim.elaborate.debug_level is set to **typical**, which is the default value.



Q	Simulation									
Project Settings	Specify various	settings assoc	iated to Simula	tion			· · ·			
General										
Simulation	Target simulate	or:	Vivado Simul	ator			~			
Elaboration Synthesis	Simulator lang	uage:	Mixed							
Implementation	Simulation set		🚞 sim_1	~						
Bitstream	Simulation top	module name:	testbench				0			
Tool Settings Project	🗹 Clean up si	mulation files								
IP Defaults	Compilation	Elaboration	Simulation	Netiist	Advanced					
Source File	xsim.elat	orate.snapshot	E .							
Display WebTalk	xsim.elat	orate.debug_le	vel		typical		~			
Help	xsim.elab	orate relax				2				
> Text Editor	xsim.elab	orate.mt_level			auto		~			
3rd Party Simulators	xsim.elat	orate.load_glbl								
> Colors	xsim.elat	orate.rangeche	ck							
Selection Rules	xsim.elab	orate.sdf_delay	(sdfmax		~			
Shortcuts Strategies	xsim.elat	oorate.xelab.mo	re_options							
> Window Behavior	Select an opti	on above to see	a description	ofit						
-										

- 4. In the Simulation tab enter the SAIF file name as power_tutorial_func.saif for xsim.simulate.saif. Observe that the xsim.simulate.runtime is 1000 ns.
- 5. Click OK.





Specify various s Target simulator: Simulator langua		iated to Simula		******		**				
		Vivado Simul								
Simulator langua		vivauu oimus			~					
	age:	Mixed	Mixed							
Simulation set:		📾 sim_1	~							
Simulation top m	testbench	6								
Clean up sim	ulation files									
Project IP Defaults Compilation Elaboration				Advanced						
xsim.simul	ate.tcl.post									
xsim.simul	ate.runtime			1000ns	0					
xsim.simul	ate.log_all_sig	gnals		×.						
xsim.simul	ate.custom_tc	10								
xsim.simul	ate.wdb									
xsim.simul	ate.saif_scope	9								
xsim.simul	ate.saif			power_tutorial						
xsim.simul	ate.saif_all_si	gnals		0						
xsim.simul	ate.xsim.more	_options								
xsim.simulate. SAIF filename	saif									
	Clean up sim Compilation xsim.simul xsim.simul xsim.simul xsim.simul xsim.simul xsim.simul xsim.simul xsim.simul xsim.simul	xsim.simulate.tcl.post xsim.simulate.tcl.post xsim.simulate.log_all_si xsim.simulate.custom_tcl xsim.simulate.wdb xsim.simulate.saif_scope xsim.simulate.saif xsim.simulate.saif_all_si xsim.simulate.saif_all_si	Clean up simulation files Compilation Elaboration Simulate. Simulate.tcl.post xsim.simulate.log_all_signals xsim.simulate.custom_tcl xsim.simulate.saif_scope xsim.simulate.saif xsim.simulate.saif_all_signals xsim.simulate.saif_alll_signals xsim.simulate.saif_all_signals xsim.sim	Clean up simulation files Compilation Elaboration Simulation Netlist xsim.simulate.tcl.post xsim.simulate.log_all_signals xsim.simulate.custom_tcl xsim.simulate.saif_scope xsim.simulate.saif xsim.simulate.saif xsim.simulate.saif_signals xsim.simulate.saif_signals xsim.simulate.saif_all_signals xsim.simulate.s	Clean up simulation files Compilation Elaboration Simulation Netlist Advanced xsim.simulate.tcl.post xsim.simulate.log_all_signals xsim.simulate.custom_tcl xsim.simulate.saif_scope xsim.simulate.saif xsim.simulate.saif_all_signals xsim.simulate.saif_all_signals xsim.simulate.saif_all_signals xsim.simulate.saif_all_signals xsim.simulate.saif_all_signals xsim.simulate.saif_all_signals xsim.simulate.saif	Image: Compilation files Simulation Netlist Advanced Compilation Elaboration Simulation Netlist Advanced xsim.simulate.tcl.post 1000ns Image: Compilation files Image: Compilation files xsim.simulate.tcl.post 1000ns Image: Compilation files Image: Compilation files xsim.simulate.log_all_signals Image: Compilation files Image: Compilation files Image: Compilation files xsim.simulate.custom_tcl xsim.simulate.saif_scope Image: Compilation files Image: Compilation files xsim.simulate.saif Image: Compilation files Image: Compilation files Image: Compilation files xsim.simulate.saif_scope Image: Compilation files Image: Compilation files Image: Compilation files xsim.simulate.saif_all_signals Image: Compilation files Image: Compilation files Image: Compilation files xsim.simulate.saif_all_signals Image: Compilation files Image: Compilation files Image: Compilation files xsim.simulate.saif_all_signals Image: Compilation files Image: Compilation files Image: Compilation files xsim.simulate.saif Image: Compilation files Image: Compilation files Image: Compilation files				

With the simulation settings properly configured, you can launch the Vivado simulator to perform a post-synthesis functional simulation of the design.

Note: The power reporting and analysis are not performed at the RTL level. They are performed at the gate level.

6. In the Flow Navigator, click **Run Simulation** \rightarrow **Run Post-Synthesis Functional Simulation**.

Run Simulati	on
	Run Behavioral Simulation
✓ RTL ANALYSI	Run Post-Synthesis Functional Simulation
> Open Elat	Run Post-Synthesis Timing Simulation
Y SYNTHESIS	Run Post-Implementation Functional Simulation
Run Synth	Run Post-Implementation Timing Simulation

When you launch the Run Post-Synthesis Functional Simulation command, the Vivado simulator is invoked to run the simulation.



cope × Sources.		- 0	23	Objects	?	× D O _	Untitled 1		2 🗆 0
Q <u>*</u> ¢			¢	Q		0	Q 🖬 @ @ 💥	- H H	et et infini at inti
lame	Design Cont	Block Type		Name	Value	Date T. C			1,000.030
testbench	testbench	Verilog N.,		The sys_clk_p	0	Logic	Name	Value	0 ns 400 24
> 🔒 dut_togs	dut_togs	Verilog M.		Ti sys_dk_n	1	Logic	5)5_6K_0		0 ns
🖬 qibi	pibi	Verilog M.		bal 🧬	1	Logic	W ass. ck.n	1	
				Va pass	1	Logic	lik ted	1	
				> N WATCHDD	100000	Array	Té pass	the second	
								000186a0	(010)8650

After the simulation completes, click \mathbf{x} at the top right corner to close the simulation window.

Step 8: Incorporating SAIF Data into Power Analysis

The SAIF output file requested in the simulation run is generated in the project directory. This SAIF file is used to further guide the power analysis algorithm.

1. Ensure the SAIF file requested is generated. Check to see that the SAIF file requested in the simulation settings prior to running simulation appears in this directory:

```
<project_directory>/power_tutorial1/power_tutorial1.sim/sim_1/
synth/ func/power_tutorial_func.saif
```

- 2. In the Flow Navigator window, click on Open Synthesized Design to expand options.
- 3. From the Synthesized Design options, select Report Power.
- 4. In the **Report Power** dialog box, set the Results name to **power_3**.
- 5. In the Output tab of Report Power dialog box, make the following changes:
 - Set the Output text File to power_3.pwr
 - Set the Output XPE File to power_3.xpe
- 6. In the Environment tab of Report Power dialog box, make sure that the Process is set to **maximum**.
- 7. In the Switching tab of Report Power dialog box, specify the SAIF file location.



imate power ci	onsumption base	d on the neti	st design an	d part xc7k325	ffg900-2.
es <u>u</u> lts name:	power_3				
nvironment	Power Supply	Switching	Output		
Reset swit	ching activity befor	re report pow	er		
Switching Activ	ity for Resets:	None	~		
Simulation Set	ttings				
Simulation	activity file (.saif):	(/sim_1/sy	nähäuncipow	er_tutorial_tun	c.salf 🕢 …
Default Activity	y Settings				
Default tog	gie rate	12.5	[0-100]		
Default Sta	tic Probability.	0.5	[0.0 - 1.0]		
Enable Rate Se	ettings				
		Static Prob	ability	Toggle Rate	
BRAM Port	Enable		[0.0 - 1.0]		[0 - 100]
BRAM Write	e Enable:		[0.0 - 1.0]		[0 - 100]
Bidi Output	Port Enable:		[0.0 + 1.0]		[0~100]
Toggle Rate Se	ettings				
		Static Prob	ability	Toggle Rate	
Primary Ou	tputs:		[0 0 - 1 0]		[0 - 100]
Logic					
Register	5		0.0 - 1.0]		(0 - 100)
	uisters:		[0.0 - 1.0]		[0 - 100]
Shift Reg					

8. Click **OK** in the Report Power dialog box.

The $report_power$ command runs, and the Power Report power_3 is generated in the Power window.

Power			5 - D 5 3
Q 🗄 单 C 📕	Summary		
Settings Summary (1332 V0) Power Supply • Uttanton Detats Herarchica (0858 V7) October (045 V7) • Signate (0.045 V7) Ottate (045 V7) Citeck Enable (=0.001 V7) Settings (=0.005 V7) Logic (=0.005 V7)	Power estimation from Synthesized netlist. Activity derived from constainin files, simulation files or vicionisis analysis. Note fields with softwards and durings after implementation. Total On-Chip Power: 1.332 W Junction Temperature: 27.4 °C Thermit Margins 57.5 °C (20.3 W) Effective 3JA: 1.8 °C.W Power supplied to off chip devices: 0 W Conflores level light	On-Chip Power 0.869 W (65%) Cons 0.900 W (1%) Cons 0.900 W (1%)	
BRAM (0.585 W) Clock Manager (0.117 W) W0 (0.065 W) >> >> >>	and a which is start,	Dexter Stanc: 0.463 W (20%)	



Note: The SAIF annotation results are displayed in the Tcl Console. Make sure that all the design nets are matched with simulation nets, to achieve better accuracy by including Simulation data. For 7 series devices, the number of design nets and simulation nets may vary due to various reasons. The most common reason is that their hierarchical separators are different. Sometimes, the simulation nets may be lower down in the hierarchy level. However, they should match 100%.

Example: INFO: [Power 33-26] Design nets matched = 1894 of 1894



9. Go to the I/O view in the Power window. Note that all the I/O port activity data has been set from simulation data we specified. The data is color coded to indicate activity rates read from the simulation output file.

QIOCH	Q ¥ 10							13	Sim	latio	n 🖩	Cor	strail	nt i	Calculated
Settings	Utilization	Name	10 Type	VO Standard	Drive Strength	Input Pins	Output Pins	Bidir Pins		-			-		Signal Rate.
Summary (1.332 W)	 10.005 W (1% of total) 	🗿 dut_fpga													
Power Supply	0.004 W (<1% of total)	₽ sys_dk_in_p	HP	DIFF_SSTL.	NA	1	0	D	la.				4		400.00
 Utilization Details 	> 10.001 W (<1% of total)	tmc_out	HR	LVCM0833	12.000	0	10	0		-		-	-	-	1.00
Hierarchical (0.889 W)	1<0.001 W (<1% of total)	2 golo_out_pass	HR	LVCM0833	12.000	0	1	0	2	-		-	- 440	-	1.00
Clocks (0.01 W)	0.001 W (<1% of total)	- led	HP	LVCMD815	12.000	0	1	0		1.5		14		12	1.00
Clock Enable (<0.001 W) SetReset (<0.001 W) Logic (0.003 W) BRAM (0.815 W) Clock Hanager (0.117 W) Ko (0.005 W)															

10. Note the difference in total power numbers (Total On-Chip Power in the Summary view) between a pure vectorless run in the power_1 results versus with the post synthesis functional simulation data in the power_3 results. Also note that the dut/dut_reset signal rates are overwritten by simulation SAIF data.

Power										? 0 7 ×
Q X 0 C M	Q 🔮 SetiReset								Simulation	Calculated
Settings	Utilization	Name	Signal Rate (Min/s)	% High	Fanout	Slice Fanout	Clock	Logic Type		
Summary (1.332 W)	> 1 <0.001 W (<1% of total)	🕅 dut_fpga								
Power Supply	1 40.001 W (41% of total)	. dut/dut_reset	1.000	26.250	530	0	cikout0	FF LUT		
~ Utilization Details	0 W	F led_OBUF	1.000	73.740	3	0	cikout0	FF VO LUT		
Hierarchical (0.859 W)										
Clocks (0.01 VII)										
Signals (0.043 W)										
Data (0:043 W)										
Clock Enable (<0.001 W										
SelfReset (<0.001 W)										
Logic (0.009 W)										
BRAN (0.685 W)										
Clock Manager (0.117 W)										
NO (0.005.10)										
(
power_1 × power_2 × po										



Step 9: Implementing the Design

This tutorial helps you understand power analysis with and without power optimization. In this step, you will run Implementation without power optimization.

- 1. In the Flow Navigator, right-click Implementation and select Implementation Settings.
- 2. In the Opt Design settings, select the NoBramPowerOpt option for -directive and click OK.

Q	Implementation					
Project Settings	Specify various settings as	ssociated to Imple	mentation		P	
General					*********	
Simulation	Constraints					
Elaboration	Second Second					
Synthesis	Default constraint set	constrs_1 (active)		~	
Implementation	Options					
Bitstream	(1. 4 .0000)				^	
> IP	Run report UltraFas					
Tool Settings	Incremental compile:					
Project	incremental complie.					
IP Defaults	Strategy: 🙏 Vivado Implen		mentation Defaults	s* (Vivado Im	× 🖬	
Source File					_	
Display	Description:					
WebTalk	YOpt Design (opt_des	sign)				
Help	is_enabled		2			
> Text Editor	tcl.pre					
3rd Party Simulators	tcl.post				***	
> Colors	-verbose					
Selection Rules	-directive		NoBramPower	Opt		
Shortcuts	More Options		Explore ExploreArea			
> Window Behavior	YPower Opt Design ()	ower_opt_design	ialArea			
 Window Benavior 	is_enabled		AddRemap			
	tcl.pre		RuntimeOptimiz NoBramPowerC			
	tcl.post		ExploreWithRen			
	More Options		Default			
	YPlace Design (place	_design)			~	
	-directive Opt design directive.					
· · · · · · · · · · · · · · · · · · ·					1	
?)		OK	Cancel	Apply	Restore	

- 3. In the Flow Navigator, click **Run Implementation**.
- 4. When Save Project dialog box is displayed to save the project before launching implementation, click **Don't Save**.



ementation?
dut_fpga_kc705.xdc
n't Save Cancel

Conclusion

In this lab, you have learned how to set the power analysis in the Vivado. In lab 2, you will learn about the timing simulation and its effect on the power analysis.





Lab 3

Running Timing Simulation and Estimating Power

Introduction

In this lab, you will learn about generating a SAIF file after running a timing level simulation using the Vivado[®] simulator and Questa Advanced Simulator. The lab will take you through the steps for SAIF file creation, running timing simulation, and estimating power using the SAIF data.

Step 1: Configuring and Running the Timing Simulation using Vivado Simulator

1. In the Implementation Complete dialog box, select **Open Implemented Design** and click **OK** to open the implemented design. When prompted to save the project before opening an implemented design, click **Don't Save**.

Now you are ready to set up and launch the Vivado simulator to run post implementation timing simulation. You will set the timing simulation properties in the Vivado IDE, then run the timing simulation.

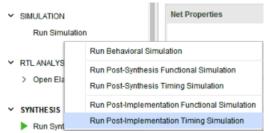
- 2. In the Flow Navigator, click **Settings** and select the **Simulation** to set the timing simulation properties. In the Settings dialog box, note that the following defaults are automatically set:
 - Simulation set: **sim_1**
 - Simulation top-module name: testbench
- 3. In the Elaboration tab, make sure that debug_level is set to **typical**, which is the default value.
- 4. In the Simulation tab, set the SAIF file name xsim.simulate.saif to **power_tutorial_timing_xsim.saif**.
- 5. Set the xsim.simulate.saif_scope to testbench/dut_fpga.
- 6. Observe that the simulation run time xsim.simulate.runtime is 1000ns.
- 7. Click OK.



pecify various settings as arget simulator:	Sociated to Simulation	000000000000000000000000000000000000000		<u></u>
na n menungkakanan Keneralahan menungkakanan	Vivado Simulator			
				*
imulator language:	Mixed			~
imulation set	🛱 sim_1			~
imulation top module nar	me: testbench			0
Clean up simulation file	es			
Compilation Elaborati	on Simulation Netlist	Advanced		
xsim simulate runtim	e	1000ns		61
xsim.simulate.log_al	l_signals*	ignals*		
xsim.simulate.custor	m_tcl			
xsim.simulate.wdb				
xsim.simulate.sait_s	cope	testbench/dut_	fpga	0
xsim.simulate.saif*		power_tutorial		0
unios alexidade a sit. a	0.sleaste			~
	ne			
	Clean up simulation file Compilation Elaborati xsim.simulate.runtim xsim.simulate.log_al xsim.simulate.custor xsim.simulate.saif_s xsim.simulate.saif_ xsim.simulate.saif_ xsim.simulate.saif_ xsim.simulate.runtime	imulation top module name: testbench Clean up simulation files Compilation Elaboration Simulation Netlist xsim.simulate.runtime xsim.simulate.log_all_signals* xsim.simulate.custom_tcl xsim.simulate.salf_scope xsim.simulate.salf_scope xsim.simulate.salf_scope	imulation top module name: testbench Clean up simulation files Compilation Elaboration Simulation Netlist Advanced xsim.simulate.runtime 1000ns xsim.simulate.log_all_signals* xsim.simulate.custom_tcl xsim.simulate.salf_scope testbench/dut_ xsim.simulate.salf_scope testbench/d	imulation top module name: testbench Clean up simulation files Compilation Elaboration Simulation Nettist Advanced xsim.simulate.runtime 1000ns xsim.simulate.log_all_signals* xsim.simulate.custom_tcl xsim.simulate.salf_scope testbench/dut_fpga xsim.simulate.salf_scope xsim.simulate.salf_scope xsim.simulate.salf_scope xsim.simulate.salf_scope xsim.simulate.salf_scope xsim

With the simulation settings properly configured, you can launch the Vivado simulator to perform a timing simulation of the post implemented design.

8. In the Flow Navigator, click **Run Simulation → Run Post-Implementation Timing Simulation**.



9. After the Vivado simulator has finished simulating the design, ensure that the SAIF file requested has been generated. Check to see that the SAIF file requested in the simulation settings prior to running simulation appears in this directory:

```
<project_directory>/power_tutorial1/power_tutorial1.sim/ sim_1/
impl/timing/power_tutorial_timing_xsim.saif
```



Q	Design Unit	Block Type	۰	Q		0		the last has been	and the second second second	
estbench	Design Unit	Phone Phone				w	0 8 6 6 3		the states of the second secon	4
		DOCK Sype		Name	Value	Data T. ^				1,000.000 20
	testbench	Verlog M.		Va sys_ck_p	0	Logic	Name	Value	15 mil 1600 mil	
> 🔒 duLipga	duLlpga	Venlog M.		14 sys_dk_n	1	Logic	la sys. dk. p	0	0 m 800 m	A
🛢 gibi	gibi	Verlog M.		Tá led	1	Logic	la sys_clk_n	1		
				G pasa	1	Logic	le led	10		
				> 👒 WATCHDO .	100000	Array	le pasa	15		

Step 2: Running Report Power in Vectorless Mode

1. In the Flow Navigator, select **Open Implemented Design** → **Report Power** to open the Report Power dialog box.

You can also select **Reports** \rightarrow **Report Power** from the main menu.

2. In the Report Power dialog box, Environment tab, make sure the Process is set to **maximum** and click **OK**.

The Report Power command creates a power report under the power_1 tab in the Power window.

3. Note the total power (Total On-Chip Power) in the power report Summary page.

Q X O C "	Summary							
Settings Summary (1.545 W) Power Supply Vikitation Details Hierarchical (1.08 W) Clocks (0.022 W) Clocks (0.022 W) Data (0.223 W) Clock Enable (0 W)	Power analysis from Implemented r derived from constraints lice, simuli vectoriess analysis. Total On-Chip Power: Junction Temperature: Thermal Margin: Effective 3JA Power supplied to off-chip devices.	1.545 W 27.7 °C 57.3 °C (30.1 W) 1.8 °C/W 0 W	On-Chip Pov 70%	21%	Clocks: Signals: Logic: BRAM: MMCM:	0.022 W 0.022 W 0.223 W 0.009 W 0.705 W 0.117 W	(2%) (21%) (1%) (65%) (11%)	
SetFRead (~0.001 W) Logic (0.008 W) BRAM (0.705 W) Clock Manager (0.117 W) I/O (0.004 W)	Confidence level: <u>Launch Power Constraint Advisor</u> to invalid switching adfivity	Medium 9 find and fix	30%	Device	Static: 0.4	0.004 W	(0%) %)	

Vectorless analysis is done based on default switching activity specification on the primary ports and the design clocks.

Refer to the Vivado Design Suite User Guide: Power Analysis and Optimization (UG907) for more information on vectorless power analysis.



Step 3: Running Report Power with Vivado Simulator SAIF Data

The project directory contains the SAIF output file requested in the previous timing simulation run. We use this SAIF file to further guide the power analysis algorithm.

- 1. From the main menu, select **Reports** \rightarrow **Report Power**.
- 2. In the Report Power dialog box, specify the SAIF file location in the Switching tab.

The SAIF file, which was requested in the simulation settings prior to running timing simulation, should appear here:

```
<project_directory>/power_tutorial1/power_tutorial1.sim/ sim_1/
impl/timing/power_tutorial_timing_xsim.saif
```

3. Click **OK** in the Report Power dialog box.

After the Report Power command completes, the Power windows displays power report power_2.

In the Tcl console, observe that the SAIF file is read successfully and that 100% of the design nets are matched. This assures you that the generated SAIF file is correct and matched with all design nets.

Q X + C *	Summary		
Settings Settings Summary (1.405 W) Power Supply Utilization Details Hierarchical (1.019 W) Clocks (0.021 W) Data (0.182 W) Data (0.182 W) Clock Enable (*0.00 SetReset (~0.001 W) Longs: 0.006 W)	Power analysis from implemented netlist. Activity derived from constraints files, simulation files or vectories analysis. Total On-Chip Power: 1.485 W Junction Temperature: 27.6 °C Thermal Margin: 57.4 °C (30.2) Efficitive 3/k 1.8 °CW Power supplied to off-chip devices 0 W Confidence level High	On. Chip Power Opnamic: 1.019 W (69%) Opnamic: 0.021 W (25%) Opnamic: 0.021 W (25%) Signals: 0.021 W (15%) Example: 0.065 W (57%) MMCAI: 0.117 W (25%) 128% MCCAI:	
Eogic (0.008 W) BRAM (0.685 W) Clock Manager (0.117 W WO (0.005 W) 	_aunch Booper Constrant Advisor to find and fix invalid switching activity × power_2 ×	Device Static: 0.466 W (31%)	

- 4. Note the change in total power (Total On-Chip Power in the Summary view) in the power_2 report compared to the power_1 report. The total power estimated in the report generated with SAIF file data will be different than the total power estimated in the vectorless run (power_1 results).
- 5. Examine the summary and block level (On-Chip Power) power distribution in the Summary view of the power report.
- 6. Go to the **Utilization Details** → **Signals** → **Data** view in the power report. Note that all the Signal Rate data has been set from simulation data the SAIF file provided.

The data is color coded to indicate activity rates read from the simulation output file.



lower						? _ 0	810
q ₹ ♦ C »	Q 😤 Data			1	Simulat	ion 🗌 Calcu	later
Settings	Utilization	Name	Signal Rate (Mtr/s)	% High	Fanout	Silce Fanout	CI
Summary (1.485 W)	 Image: Second Sec	🗿 dut_fpga					
Power Supply	1 0.001 W (<1% of total)	_f_dul/gen_dul(9).bram_top_inst/addr_a(1)	73.000	63.935	34	34	d
Utilization Details	0.001 W (<1% of total)	f dutigen_dut[9].bram_top_instladdr_b[11]	73.000	36,049	34	34	d
Hierarchical (1.019 W)	1 0.001 W (<1% of lotal)	f dutigen_dut[1].bram_top_inst/bram_inst/mem_reg_2_0_i_2_n_0	74.000	36.001	16	16	c
Clocks (0.021 W)	1 0.001 W (<1% of total)	f dutigen_dut[9].bram_top_inst/bram_inst/mem_reg_0_0_i_3_n_0	73.000	36.011	16	15	d
~ Signals (0.182 W)	1 0.001 W (<1% of total)	_f_dutigen_dut[1].bram_top_instladdr_b(16)	73.000	63.934	37	35	c
Data (0.182 W)	10.001 W (<1% of total)	_f_dutigen_dut(9).bram_top_instladdr_b(3)	73.000	36.049	34	34	0
Clock Enable (<0.00	1 0.001 W (<1% of total)	f dutigen_dut[9].bram_top_instibram_instimem_reg_0_0_i_4_n_0	73.009	35.019	16	15	c
SetReset (<0.001 W	0.001 W (<1% of total)	J dutigen_dut[8].bram_top_inst/bram_inst/mem_reg_2_0_i_1_n_0	72.000	36.000	16	16	0
Logic (0.008 W)	1 0.001 W (<1% of total)	J dubigen_dut[2].bram_top_inst/addr_b(0)	73.000	63.934	34	34	0
BRAM (0.685 W)	10.001 W (<1% of total)	J dutigen_dut[9].bram_top_inst/bram_inst/mem_reg_2_0_i_2_n_0	74.000	36.001	16	16	c
Clock Manager (0.117 W	1 0.001 W (<1% of total)	/ dutigen_dut(9).bram_top_instladdr_b(0)	73.000	63.934	34	34	c
VO (0.005 W)	1 0.001 W (+1% of Iotal)	_f_dul/gen_dut(2).bram_top_insl/addr_b(5)	73.000	63.936	34	34	

7. In the Summary view of the power_1 report (the report generated by the vectorless analysis), click on **Confidence level** (the following figure).

The Confidence Level is a measurement of the accuracy and the completeness of the input data that the Report Power uses while performing power analysis.

Notice that the Confidence Level is High for the vectorless analysis because less than 25% of internal nodes are user specified for **Internal Activity**.

Power							? _
Q ¥ ¢ C *	Summary						
Settings Summary (1.545 W) Power Supply V Utilization Details Hierarchical (1.08 W Clocks (0.022 W) V Signals (0.223 W) Data (0.223 W) Clock Enable (C SetReset (<0.0	Power analysis from Implemented netlist, derived from constraints files, simulation files, vectoriess analysis. Total On-Chip Power: 1.545 Junction Temperature: 27.7 Thermal Margin: 57.3 Effective 8JA 1.8 °C Power supplied to off-chip devices 0 W Confidence level Media	11es or 5 W 7C (30.1 W) 7AV	70%	Power Dynan 21% 65%	Nic 1.0 Clocks: Signals: Logic: BRAM: MMCM: V/O:	080 W (70 0.022 W 0.223 W 0.009 W 0.705 W 0.117 W 0.004 W	(2%) (21%) (1%) (55%) (1%) (0%)
Logic (0.009 W) BRAM (0.705 W) Clock Manager (0.1 WO (0.004 W)	k (0.009 W) Launch Power Constraint Advisor to find an Invalid switching activity k Manager (0.1		Confidence Level Details × te: High Design is routed ty: High User specified more than 95% of clocks				
impl_1 (saved) × powe	<u>r_1 ×</u> power_2 ×	I/O Activity: Internal Activit Characterizati	r	High User specifie Medium User specifie nodes High	d more than 95% d less than 25% s are Productio	% of inputs 6 of internal	

8. In the Summary view of the power_2 report (the report generated by the analysis for which you specified a SAIF file as input), click on **Confidence level** (the following figure).

Notice that the Confidence Level has increased to High, because more than 25% of internal nodes are user specified for **Internal Activity**.



Q Ŧ	¢ C	33	Summary						
			Summary						
Power S Utilizatio Hier: Cloc Sign I	y (1.485 W) upply n Details archical (1.1 ks (0.021 V als (0.182 Data (0.182 Clock Enab	119 () V) W) e (*	Junction Temperature: 27.6 Thermal Margin: 57.4 Effective 3JA: 1.8 Power supplied to off-chip devices 0.9	files or 15 W 5 °C 1°C (30.2 W) 1°C/W	69%	ower Dynan 18% 67%	Clocks: Signals: Logic: BRAM: MIMCM:	0.021 W 0.021 W 0.182 W 0.008 W 0.685 W 0.117 W	%) (2%) (18%) (1%) (67%) (12%)
Set/Reset (<0.0	Confidence level: High						(0%) ×		
Logic (0.008 W) Launch Power Constraint Advisor to BRAM (0.685 W) invalid switching activity Clock Manager (0.1 WO (0.005 W) impl_1 (saved) × power_1 × power_2 ×		Launch Power Constraint Advisor to find invalid switching activity	Design State: Clock Activity:	e High Design is routed					
		powe	_1 × power_2 ×	VO Activity Internal Activity	User specified r				
				Characterization			are Production		

Generating a SAIF File using Questa Advanced Simulator

The following steps will take you through the process of SAIF file creation, running timing simulation, and estimating power using the SAIF data using Questa Advanced Simulator.

IMPORTANT! Make sure the Vivado Design Suite knows where to pick up the Questa Advanced Simulator tool. You can either:

Manually set the path to ModelSim/Questa Advanced Simulator using the *\$PATH* environment variable

or

In the Vivado IDE, click **Tools** \rightarrow **Settings** \rightarrow **Tool Settings**, and define the path to the Questa Advanced Simulatoron the 3rd Party Tools page.

Make sure the Default Compiled Library Paths points to a valid location for the compiled Xilinx simulation libraries.

To create new compiled libraries:

- 1. In the 3rd Party Simulators page, specify the compiled library path for Questa Advanced Simulator in the **Questa** field under Default Compiled Library Paths. Enter the **Compiled library location** specified during the compiled library generation. It should point to the compile_simlib directory.
- 2. Click **OK** to define the path and generate compiled libraries.



Q	3rd Party Simula		
Project Settings General Simulation		ths and default compiled library paths. Default compiled w project creation.	ibrary path will be 💋
Elaboration	Install Paths		
Synthesis Implementation	ModelSim:		
Bitstream	QuestaSim:	G:/gensys/gensys/questa/10.5c/win32	··· ·
> IP	IES:		
Tool Settings Project	VCS:		
IP Defaults	Riviera:		***
Source File	ActiveHDL:		
Display WebTalk	Default Compiled	Library Paths	
> Text Editor	ModelSim:		
3rd Party Simulators	Questa:		
 Colors Selection Rules 	IES:		
Shortcuts	VCS:		
Strategies > Window Behavior	Riviera:		
	ActiveHDL:		

Step 1: Configuring and Running Timing Simulation in Questa Advanced Simulator

Now you are ready to set up and launch the Questa Advanced Simulator to run postimplementation timing simulation. You will set the timing simulation properties in the Vivado IDE, and run the timing simulation

- 1. In the Flow Navigator, right-click **Simulation** to select **Simulation Settings**. Set the timing simulation properties.
- 2. In the Simulation Settings tab, set the Target simulator to **Questa Advance Simulator**.
- 3. Click **Yes** to change your target simulator to Questa Advanced Simulator.



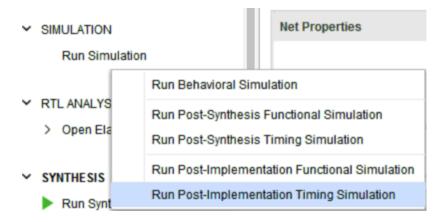
Targ	et Simulator
?	Questa Advanced Simulator requires that Xilinx libraries are pre-compiled. You can compile Xilinx simulation libraries by going to tools menu and clicking on compile simulation libraries. Make sure that the compiled library location in simulation settings menu is pointing to the correct file. To confirm the status of the compiled libraries run report_simlib_info Tcl command. OK to change your target simulator to 'Questa Advanced Simulator'?
	Yes No

- 4. Set the questa.simulate.saif to power_tutorial_timing_questasim.saif.
- 5. Set the questa.simulate.saif_scope to testbench/dut_fpga.
- 6. Note that the questa.simulate.runtime is **1000ns**.

Q	Simulation				N		
Project Settings	Specify various settings assoc	iated to Simulation					
General Simulation	Target simulator:	Questa Advanced Simu	ator		~		
Elaboration	51.157404 (0.0544) (1.1674)			~			
Synthesis	Simulator language:	Mixed					
Implementation	Simulation set						
Bitstream	Simulation top module name:	testbench			0		
Tool Settings	Clean up simulation files						
Project	Compiled library location:	i:/akasha/tmp/Tutorial/re	ad_salt/project_3	/project_3.cache/compile_simlib/questa	0		
IP Defaults							
Source File	Compilation Elaboration	Simulation Netlist	Advanced				
Display	4						
WebTalk	questa.simulate.log_all_	signals*		2			
> Text Editor	questa simulate custom	_do					
3rd Party Simulators	questa.simulate.custom	_udo					
> Colors	questa.simulate.custom	_wave_do					
Selection Rules	questa.simulate.sdf_dela	ау	sdfmax	sdīmax			
Shortcuts	questa.simulate.leee_wa	amings					
Strategies	questa.simulate.saif_sci	ope*	testbench/dut_fpga				
> Window Behavior	questa simulate.salf*		power_tuto	rial_timing_questasim_saif			
	questa simulate vsim mo	questa simulate vsim more_options					
	questa.simulate.saif* Specify SAIF file						
2)			ок				

- 7. Click **OK**. With the simulation settings properly configured, you can launch the Questa Advanced Simulator to perform a timing simulation of the design.
- 8. In the Flow Navigator, click **Run Simulation → Run Post-Implementation Timing Simulation**.





A separate Questa Advanced Simulator GUI opens and starts simulating the design.

9. After the Questa Advanced Simulator has finished simulating the design, make sure the SAIF file requested has been generated. Check to see that the SAIF file requested in the simulation settings prior to running simulation appears in this directory:

```
<project_directory>/power_tutorial1/power_tutorial1.sim/ sim_1/
impl/timing/power_tutorial_timing_questasim.saif
```

Step 2: Running Report Power in Vectorless Mode

IMPORTANT! If SAIF based report_power has already been run in this session, run the reset_switching_activity -all command in the Tcl Console. This will clear the SAIF data in the power engine from the earlier runs.

- 1. Close any open Report Power views.
- In the Flow Navigator, select Implemented Design → Report Power to open the Report Power dialog box.

Alternatively, select **Reports** \rightarrow **Report Power** in the main menu.

- 3. In the Report Power dialog box, make the following settings:
 - Specify the Results name as **power_1**.
 - In the Environment tab, set the Process to maximum.
 - In the Switching tab, leave the Simulation activity file empty.
- 4. Verify that all the input settings are correct and click OK.

The Report Power command creates a power report under the power_1 tab in the results windows area. Note that the total power for vectorless analysis runs with default switching rates.



Q 🗄 🖨	Summary						
Settings Summary (1.485 W) Power Supply Utilization Details Hierarchical (1.019 Clocks (0.021 W) Signals (0.182 W) Data (0.182 W) Clock Enable (Set/Reset (<0 (Logic (0.008 W) BRAM (0.685 W) Clock Manager (0.1 VO (0.005 W)	Power analysis from Implemented derived from constraints files, simu vectorless analysis. Total On-Chip Power: Junction Temperature: Thermal Margin: Effective 3JA Power supplied to off-chip devices Conflidence level: Launch Power Constraint Advisor 1 invalid switching activity	1.485 W 27.6 °C 57.4 °C (30.2 W) 1.8 °C/W : 0 W High	On-Chip Pox 69%	Dynam 18% 67%	Clocks: Signals: Logic: BRAM: MMCM: VO:	0.021 W (69%) 0.021 W (2%) 0.182 W (18%) 0.008 W (1%) 0.685 W (67%) 0.117 W (12%) 0.005 W (0%) 166 W (31%)	

Step 3: Running Report Power with Questa Advanced Simulator SAIF Data

The SAIF output file requested in the simulation run has been generated under the project directory. We use this SAIF file to further guide the power estimation algorithm.

- 1. In the main menu bar, select **Reports** \rightarrow **Report Power**.
- 2. In the Report Power dialog box, specify the SAIF file location in the Switching tab.

The SAIF file, which was requested in the simulation settings prior to running simulation, should appear here:

```
<project_directory>/power_tutorial1/power_tutorial1.sim/ sim_1/
impl/timing/power_tutorial_timing_questasim.saif
```

3. Click **OK** in the Report Power dialog box.

The Report Power command runs, and the Power Report power_2 is generated in the Power tab of the results windows area.



		רקם_?
Q ₹ ♦ C "	Summary	
Settings Summary (1485 W) Power Supply Utilization Details Hierarchical (1.019 W) Clocks (0.021 W) > Signals (0.182 W) Data (0.182 W) Clock Enable (=0.00	Power analysis from Implemented netlist. Achity derived from constraints files, simulation files or vectoriess analysis. Total On-Chip Power: 1.485 W Junction Temperature: 27.6 °C Thermal Margin: 57.4 °C (30.2 W) Effective 3JA 1.8 °C/W Power supplied to off-chip devices: 0.W	67% BRAM: 0.685 W (67%)
Clock Enable (3000 SetReset (0 W) Logic (0.068 W) BRAM (0.685 W) Clock Manager (0 117 W VO (0.005 W)	Confidence level: High Launch Power Constraint Advisor to find and fix invalid switching adwity	31% Image: Characterized and Characterized a

- 4. In the Tcl console, observe the read_saif results. This shows the percentage of design nets matched with simulation SAIF. This is important for accurate power analysis.
- 5. Go to the **Signals** → **Data** view in the Power Report and scroll to the right. Note that all the Signal Rate data is set from simulation SAIF data that you provide.

The data is color coded to indicate activity rates read from the Simulation output file.

			Simulation Calculati				
Settings	Utilization	Name	Signal Rate (Mtr/s)	% High	Fanout	Slice Fanout	1
Summary (1.485 W)	✓ ■ 0.182 W (12% of total)	😫 dut_fpga					
Power Supply V Utilization Details Hierarchical (1.019 W) Clocks (0.021 W)	8 0.001 W (<1% of total)	J dutigen_dut[9].bram_top_inst/addr_a[1]	73.000	63.935	34	34	¢
	0.001 W (<1% of total)	J dut/gen_dut(9).bram_top_inst/addr_b(11)	73.000	36.049	34	34	¢
	0.001 W (<1% of total)	J dut/gen_dut[1]bram_top_inst/bram_inst/mem_reg_2_0_i_2_n_0	74.000	36.001	16	16	4
	0.001 W (<1% of total)	dut/gen_dut(9).bram_top_inst/bram_inst/mem_reg_0_0_i_3_n_0	73.000	36.011	16	16	3
~ Signals (0.182 W)	10.001 W (~1% of total)	<pre>_ dut/gen_dut[1].bram_top_inst/addr_b[18]</pre>	73.000	63.934	37	35	
Data (0.182 W)	10.001 W (<1% of total)	J dut/gen_dut(9).bram_top_inst/addr_b(3)	73.000	36.049	34	34	
Clock Enable (<0.00	10.001 W (<1% of total)	f dut/gen_dut(9).bram_top_inst/bram_inst/mem_reg_0_0_i_4_n_0	73.000	36.019	16	16	,
Set/Reset (0 W)	\$ 0.001 W (<1% of total)	_f_dut/gen_dut(8) bram_top_inst/bram_inst/mem_reg_2_0_i_1_n_0	72.000	36.000	16	16	
Logic (0.008 W) BRAM (0.685 W)	8 0.001 W (<1% of total)	f dut/gen_dut[2].bram_top_inst/addr_b[0]	73.000	63.934	34	34	
Clock Manager (0.117 W	10.001 W (<1% of total)	J dutigen_dut(9) bram_top_instibram_instimem_reg_2_0_i_2_n_0	74.000	35.001	16	16	
UD (0.005 W)	0.001 W (<1% of total)	∫ dut/gen_dut(9) bram_top_inst/addr_b(0)	73.000	63.934	34	34	1
PO (0.000.11)	8 0.001 W (<1% of total)	dut/gen_dut[2] bram_top_inst/addr_b[5]	73.000	63.936	34	34	T
	0.001 W (~1% of total)	f dut/gen_dut(9),bram_top_inst/bram_inst/mem_reg_2_0_i_1_n_0	72.000	35.000	16	16	
	10.001 W (<1% of total)	J dut/gen_dut(9).bram_top_inst/addr_b(16)	73.000	63.934	37	36	D
	8 0.001 W (<1% of total)	dut/gen_dut(8).bram_top_inst/bram_inst/mem_reg_0_0_i_4_n_0	73.000	35.019	16	16	T
	0.001 W (+1% of total)	J dut/gen_dut(2).bram_top_inst/addr_b[1]	73.000	63.936	34	34	

6. Note the change in total power (Total On-Chip Power in the Summary view) in the power_2 report compared to the power_1 report. The total power estimated in the report generated with SAIF file data will be different than the total power estimated in the vectorless run (power_1 results).

Conclusion

In this lab, you have learned how to generate a SAIF file after running a timing level simulation using a Vivado Simulator and Questa Advanced Simulator.



In Lab 3, you will learn about basic hardware power measurement technique using the KC705 Evaluation Board and correlating the hardware power numbers with the numbers generated by Vivado Report Power.





Lab 4

Measuring Hardware Power Using the KC705 Evaluation Board

Introduction

In this lab, you will learn about basic hardware power measurement technique and correlating the hardware power numbers with the numbers generated by Vivado[®] Report Power using KC705 evaluation board for 7 series devices. The lab will take you through the steps for setting up the hardware measurement, programing a bit file using Vivado Hardware Manager and power measurement through Texas Instruments (TI) Fusion Design Software. It also includes Junction Temperature reading from Vivado System Monitor.

Step 1: Generating a Bit File from the Implemented Design (Non-Power Optimization)

- 1. In the Vivado Design Suite, open the 7 series implemented design.
- 2. In the Flow Navigator, click Generate Bitstream.

The Bitstream Generation Completed dialog box appears after the bitstream has been generated.





1 Bitstream (Generation successfull	y completed.
lext		
🔿 <u>V</u> iew Repo	rts	
Open Hard	lware Manager	
O Generate N	lemory Configuration F	File
Don't show thi	s dialog again	
	ок	Cancel

3. Select **Open Hardware Manager** in the Bitstream Generation Completed dialog box and then click **OK** to open the Hardware Manager.

Step 2: Setting Up the KC705 Evaluation Board

IMPORTANT! This project is created for the KC705 Rev 1.0 Evaluation Board. The pin constraints are set based on this Evaluation Board. If you are using any other revisions, update the XDC file $dut_{fpga_kc705.xdc}$ with the correct pin constraints.

- 1. Connect the Digilent cable (or Platform USB Cable) for programming.
- 2. Connect the TI USB Interface Adapter to the PMBus port on the KC705 Evaluation Board.
- 3. Connect the Power cable.





4. Install the TI Fusion Digital Power Designer software on the PC from this location.

Step 3: Setting Up the Fusion Digital Power Designer Software

- 1. Power ON the KC705 Evaluation Board.
- 2. Open the Fusion Digital Power Designer.

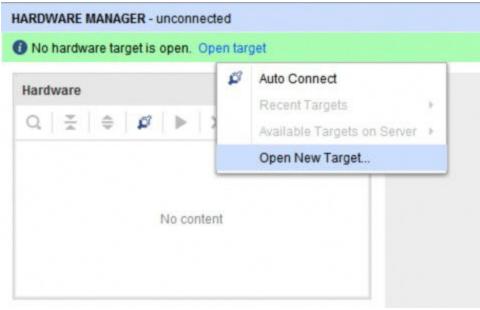
The software detects the USB adapter and brings up the GUI.



Device Tools	Hep	UCD9248 @ Address 523 - Rail #1
ifigure	Vout Config Sout, Vin, Temp Config Other Config Phase, Rail Config GP30 Config	
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Auto write on rail or device change Discard Changes Econe RANI To Plash esto ne Flash to RAM war Reactor w Nortkae Ceory Rail/Design	Sub Sub <th>Woldsey Setgenere, Hangten, and Limits Vac: Mass: 1.600 € V Ouw Faulti 1.100 € V 15.0 € F Oww Faulti 1.100 € V 10.0 € % Norgin Hight 1.000 € V 5.0 € F West: 1.000 € V 5.0 € F Ward: 1.000 € V 5.0 € F Margin Hight 0.500 € V 5.0 € F Under Ware: 0.500 € V -10.0 € F</th>	Woldsey Setgenere, Hangten, and Limits Vac: Mass: 1.600 € V Ouw Faulti 1.100 € V 15.0 € F Oww Faulti 1.100 € V 10.0 € % Norgin Hight 1.000 € V 5.0 € F West: 1.000 € V 5.0 € F Ward: 1.000 € V 5.0 € F Margin Hight 0.500 € V 5.0 € F Under Ware: 0.500 € V -10.0 € F
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) Soft Start) Soft Stop) Both Show call Abels	Dentce Raf # Raf hame Yout PG De PG DF On Delay Rate Off Delay Pall Dependencies (Prect	Over Current LV: 0.870 (1)/2 V -13.0 (1)/2 % 00 LV Response (v) Power Good Drc 0.900 (2)/2 V -10.0 (2)/2 % %
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external Show external Vitadi sources	U LCD242 & £ 24 2 14 2 14 2 1500 1200 1277 0.0 5.0 5.0 1.0 10 10 10 10 20 20 00 1, 10 1 20 1 10 10 10 10 10 10 10 10 10 10 10 10	Turn On Timing Turn Off Timing Turn On Delayi 0.0 ± ms Rise Time: 5.0 ⊕ ms
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Status	Niget with an interview of the second s	

Step 4: Programming the Bitstream

- 1. Power up the KC705 Evaluation Board.
- 2. In the Vivado Hardware Manager, click **Open Target** in the green alert bar and select **Open New Target**.



3. In the Open New Hardware Target wizard, click **Next** to go to the Hardware Server Settings.





- 4. Select the server to which the board is connected.
 - If the board is connected to the local PC, select Local server and click Next.
 - If you are connecting to a remote server, see Connecting to a Hardware Target Using hw_server in the Vivado Design Suite User Guide: Programming and Debugging (UG908).

When the hardware is detected successfully, the part information will be displayed in the Open New Hardware Target wizard.

5. Verify the part information, then click **Next** then click **Finish**.

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	ID Code		specify the Instr					
Name xc7k325t_(ID Code	IR Length 6	specify the Instr					

6. In the Hardware window, right-click the part and select **Program Device**.



Hardware ?	- ?		5 ×
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Name	Sta	atus	
 Iocalhost (1) 	Co	onnec	ted
✓ ■● xilinx_tcf/Digilent/2102033373	Op	en	
 v xc7k325t_0 (1) 	Pr	noran	
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		c	Add Configuration Memory Device Boot from Configuration Memory Device Program BBR Key Clear BBR Key
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xc7k325t_0 Name: xc7k325t_0		c	Add Configuration Memory Device Boot from Configuration Memory Device Program BBR Key Clear BBR Key Program eFUSE Registers
xc7k325t_0 Name: xc7k325t_0 Part xc7k325t		c	Add Configuration Memory Device Boot from Configuration Memory Device Program BBR Key Clear BBR Key Program eFUSE Registers
xc7k325t_0 Name: xc7k325t_0 Part xc7k325t ID code: 33651093		c	Add Configuration Memory Device Boot from Configuration Memory Device Program BBR Key Clear BBR Key Program eFUSE Registers
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xc7k325t_0 Name: xc7k325t_0 Part: xc7k325t ID code: 33651093 IR length: 6 Status: Programmed	¢		Add Configuration Memory Device Boot from Configuration Memory Device Program BBR Key Clear BBR Key Program eFUSE Registers Export to Spreadsheet

- 7. Select the bit file <project_dir>/power_tutorial1/power_tutorial1.runs/ impl_1/ dut_fpga.bit and click Program.
- 8. After the program completes successfully, select **XADC (System Monitor)** in the Hardware window, right-click and select **Dashboard**, and then select **New Dashboard**.
- 9. Click **OK**. The System Monitor window opens and plots die temperature (junction temperature) in the graph window.



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### **Step 5: Measuring the Hardware Power Rails**

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- 1. In the Fusion Digital Power Designer, select a rail in the Configure view and click **Monitor**.

2. Configure the parameters to be monitored. An Output Power graph will be plotted in the Monitor window.



Fre Device Loois	Halp				UCD5248 @ Address 53d	-1al #1
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) Configure	Castrolius (058) © Hgh O Lav	10				
Monitor	Operation - Rail #1					and the second
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3. Repeat the steps above to monitor the power information for each rail supplied to the device. Note that rail information is displayed in terms of regulator address.

			KC70	5 (UCD9248)	
device	rail	purpose	voltage	IOUT_CAL_GAIN	IOUT_CAL_OFFSET
	1	VCCINT	1.0V	0xEBDC	0x8000
52	2	VCCAUX	1.8V	0xEBDC	0x8000
52	3	VCC3V3	3.3V	0xEBDC	0x8000
	4	VADJ	2.5V	0xEBDC	0x8000
	1	VCC2V5	2.5V	0xEBDC	0x8000
-	2	VCC1V5	1.5V	0xEBDC	0x8000
53	3	MGT_AVCC	1.0V	0xEBDC	0x8000
	4	MGT_AVTT	1.2V	0xEBDC	0x8000
	1	VCCAUX_IO	1.8V	0xEBDC	0x8000
	2	VCCBRAM	1.0V	0xEBDC	0x8000
54	3	MGT_VCCAUX	1.8V	0xEBDC	0x8000
	4	N/A	N/A	N/A	N/A

4. Note the Junction Temperature value either from the Vivado Hardware Manager or from the Fusion Digital Power Designer.



## Step 6: Estimating Vectorless Power with Junction Temperature

For further Power Analysis, you can use the measured Junction Temperature and other thermal settings to feed into Vivado Report Power for better accuracy.

- 1. In the Vivado Design Suite, open the tutorial project and click **Open Implemented Design** to display the implemented design.
- 2. In the Tcl Console, run the following command to reset any user defined or SAIF file defined settings:

```
reset_switching_activity -all
```

- 3. From the main menu, select **Reports**  $\rightarrow$  **Report Power**.
- 4. In the Environment tab of the Report Power dialog box, enter the **Junction Temperature** value supplied by the hardware power measurement.
- 5. Set the Process to maximum.
- 6. In the Switching tab, make sure the Simulation activity file (.saif) is blank.
- 7. Click OK.





Res <u>u</u> lts name:	power_1						8
Environment	Power Supply	Switching	Output				
Device Setting	js						
Temp grad	de:	extended		v			
Process:		maximum		~			
Environment	Settings						
Output Loa	ad:		0	*	pF [0	- 10000]	
Junctio	on temperature:		34	*	°C		
Ambient te	mperature:		25	*	°C		
Effectiv	ve ðJ <u>A</u> :		1	.42	•CW [0	- 100]	
Airflow:		250		~	LFM		
<u>H</u> eat sink:		medium (M	edium Prof	~			
9SA:			2.4	4 7	*C/W [0	- 100]	
Board sele	ection:	medium (10		~			
	f board layers:	12to15 (121	o 15 Layer				
alB:			2.5		*CW [0		
Board tem	perature:		25	*	*C [-5	5 - 100]	
Legend							

8. In the Power Report, observe that the power numbers increase slightly as compared to the vectorless power analysis using a default junction temperature value. Note that the Junction Temperature is now color coded as being user defined in the Power Report.



Q ₹ ♦ "	Summary			
Settings Summary (1.576 W) Power Supply > Utilization Details Hierarchical (1.01) Clocks (0.024 W) > Signals (0.232 W) Data (0.232 W) Clock Enable (	Power analysis from implemented r derived from constraints files, simul vectoriess analysis. Total On-Chip Power: Junction Temperature: Thermal Margin: Effective &JA: Power supplied to off-chip devices:		On-Chip Pon 65%	Dynamic         1.017 W (85%)           23%         Clocks:         0.024 W (2%)           Signals:         0.232 W (23%)           Logic:         0.016 W (2%)           61%         BRAM: 0.624 W (61%)           MMCM:         0.117 W (12%)
Set/Reset (0 W Logic (0.015 W) BRAM (0.624 W) Clock Manager (0: WO (0.004 W)	Confidence level: Launch Power Constraint Advisor to invalid switching activity	Medium find and fix	35%	1296         UO:         0.004 W         (0%)           Device Static:         0.559 W         (35%)

9. Similarly, you can overwrite the Junction Temperature setting and do a SAIF based power analysis. Note the power numbers measured and estimated on non-power optimized design.

### Conclusion

In this lab, you have completed a Vivado Report Power analysis on post-synthesis and postimplementation netlist designs without Power Optimization. You also experimented with hardware power measurement using the KC705 Evaluation Board and with reading Junction Temperature for software analysis.

In lab 4, you will learn to experiment with hardware power measurement using the KCU105 Evaluation Board and with reading Junction Temperature for software analysis.





Lab 5

# Measuring Hardware Power Using the KCU105 Evaluation Board

### Introduction

In this lab, you will learn about the basic hardware power measurement technique and correlating the hardware power numbers with the numbers generated by Vivado[®] Report Power using the KCU105 evaluation board for UltraScale+[™] devices. The lab will take you through the steps for setting up the hardware measurement, programing a bit file using the Vivado Hardware Manager and power measurement through the Maxim Digital Power Tool. It also includes the Junction Temperature reading from the Vivado System Monitor.

### Step 1: Generating a Bit File from the Implemented Design

- 1. In the Vivado Design Suite, open the UltraScale[™] Implemented design.
- 2. In the Flow Navigator, click Generate Bitstream.
- 3. When prompted to Save project before generating bitstream, click Don't Save.

The Bitstream Generation Completed dialog box appears after the bitstream has been generated.



Bitstream	m Generation Completed
() Next	Bitstream Generation successfully completed.
O	View Reports
0	Open Hardware Manager
O	Generate Memory Configuration File
Don	't show this dialog again
	OK Cancel

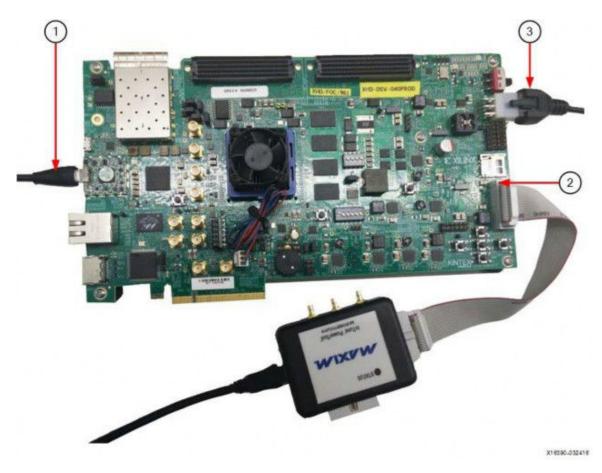
4. Select **Open Hardware Manager** in the Bitstream Generation dialog box and click **OK** to open the Hardware Manager.

### Step 2: Setting up the KCU105 Evaluation Board

**IMPORTANT!** This project is created for the KCU105 Rev B Evaluation Board. The pin constraints are set based on this Evaluation Board. If you are using any other Revisions, update the XDC file  $dut_fpga_kcu105.xdc$  with the correct pin constraints.

- 1. Connect the Digilent cable (or platform USB Cable) for programming.
- 2. Connect the MAXPOWERTOOL002# Interface Adapter to the PMBus port on the KCU105 Evaluation Board.
- 3. Connect the power cable.





4. Install the Maxim Digital Power Designer software on the PC from this location.

### Step 3: Configuring the Maxim Digital Power Tool Software

- 1. Power on the KCU105 Evaluation Board.
- 2. Open the Maxim Digital Power Tool. The software detects the Interface adapter and brings up the GUI.



Deshboard	Ov0A	0x08	( 0x0F	( dell	0e12	0614	0x15	0x16	Oe16	0.16	
10000000	MAX15301	MAX15308AADO	MAX15303AA00	MAX15303A400	MAX15301	MAX1530BAADO	MAX15303AA00	MAX15303A400	MAX15303A400	MAX15301	
SMBus Address	Ov04	80x0	OvOf	(611	Ox12	0x14	Oct 5	0016	0x18	0x16	Output Voltage Plots
Product	MAX15301	MAX15303A400	MAX15309A400	MAX15303AA00	MAX15301	MAX15303AA00	MAX15303A400	MAX15303A400	MAX15303AA00	MAX15301	0x3A-3MAX16301
Survere Revision	4018	4196	4196	4196	4018	4196	4196	4196	4196	4018	6 0e18:MAX15363
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PMBus Enable				1.1	12	3				-	e *
Input Voltage (V)	11.422	11.459	11.469	11.484	51.406	11.484	11.484	11.484	11.469	11.406	Voort (V)
Output Voltage (V)	0.95	1,80	0.95	1.80	1.90	1.20	1.00	1,20	1.80	3.30	·
Output Current (4)	0.96	0.14	0.30	0.00	0.01	0.03	0.36	-0.01	0.00	0.69	
Switching Frequency (kHz)	401	000	600	600	002	801	603	599	600	601	0 1280
Internal Temperature (*C)	46	49	43	49	45	47	45	42	46	45	
External Temperature ("C)	42	48	43	45	47	44	43	36	4b	49	
Duty Cycle (%)	7.43	14.41	6.85	14.06	3158	8.97	7.88	8.96	1198	27.28	System Sequencing
Bratikod											11
Power Good	0	0	0	0	0	0	0	0	0	0	10
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On Delay Time (ms)	4 56	11.00	7.82	19.75	24.84 🔹	24.88	10/09 🔹	15.22	19.75	1.00	
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Off Delay Time (ms)	24.97 🚖	1437 😩	19.88 🚖	7.96 🛫	511 🗘	5.11	19,88 🚖	14.78	10.23	a) 90.06	Stæt låp
Olf Fall Time (ms)	2.02	2.32 💠	1.77 🚖	232 🕂	235 💠	1.88 💠	1.83 🔹	1.85 🛧	234	2.13	Search For Device: Save Contigurat

### **Step 4: Programming the Bitstream**

- 1. In the Vivado Hardware Manager, click **Open Target** in the green alert bar and select **Open New Target**.
- 2. In the Open New Hardware Target wizard, click **Next** to go to the Hardware Server Settings page.
- 3. Select the server to which the board is connected.
  - If the board is connected to the local PC, select Local Server and click Next.
  - If you are connecting to a remote server, see Connecting to a Hardware Target Using hw_server in the Vivado Design Suite User Guide: Programming and Debugging (UG908).

When the hardware is detected successfully, the part information will be displayed in the Open New Hardware Target dialog box.

4. Verify the part information, then click **Next** and **Finish**.



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1	ices (for unknow		, specify the Inst	dd Xilinx Virtual ( nuction Registe				
Hardware Devi Name • xcku040 (	ID Code	IR Length	, specify the Inst					

5. In the Hardware Devices window, right-click the part and select **Program Device**.





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localhost (1)		Connected			
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v (i) xcku040_0 (1)		Not programm			
😼 SysMon (System Moni		Hardware Device Properties Ctrl+			
		Program Device			
		Verify Device			
	C	Refresh Device			
		Add Configuration Memory Device			
		Boot from Configuration Memory Device			
		Boot from Conliguration Memory Device			
		Program BBR Key Clear BBR Key Program eFUSE Registers			
rdware Device Properties					
xcku040_0					
Name: xcku040_0		Export to Spreadsheet			
Part: xcku040					
D code: 13822093					
R length: 6					
Status: Not programmed					
rogramming file					
Programming file:					
Probes file:					

- 6. Select the bit file from the implementation runs directory of the project created in Lab 2 for the UltraScale[™] design (<project_dir>/power_tutorial2/ power_tutorial2.runs/impl_1/ dut_fpga.bit) and click Program.
- 7. After the program completes successfully, select **XADC (System Monitor)** in the Hardware window, right-click and select **Dashboard**, and then select **New Dashboard**.

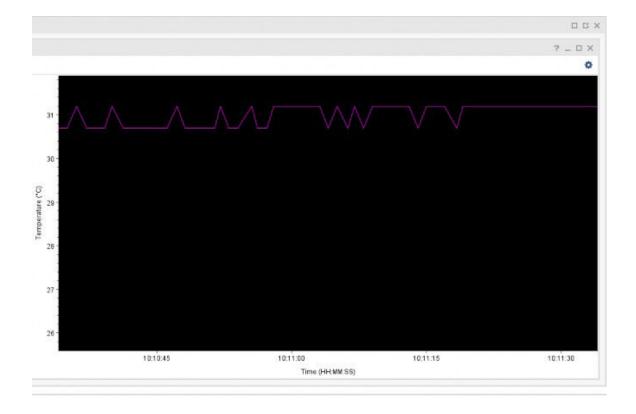


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Name		Status	60		-01	
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✓ ✓ ✓ ✓ xilinx_tcf/Digilent/2102	518450	Open	hboard Options	Temp 31.2°C		
v () xcku040_0 (1)		Not programm	ooar			
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	·				_	
System Monitor Core Properties	?	_ 0 6 X				
		11 11 22				
SysMon	+	• • •				

8. Click **OK**. The System Monitor window opens and plots die temperature (junction temperature) in the Graph Window.







### **Step 5: Measuring the Hardware Power Rails**

	0 0x12 0x14 MAX15301 MAX13	0x08 MAX15303AA00 NAX15303AA00 MAX15303AA00	Dashboard OrDA MAX15301
		PMBus Command   Permissions   Tools	onfiguration   Monitor   Faults Set
Device States			Basic Settings
Output Voltage (V) 0.950	0.950 🌘	Vourt (V)	
Input Voltage (V) 11.875	0.996	Vout Margin High (V)	
Output Current (A) 3.18	0.903 🚭	Vout Margin Low (V)	
Switching Frequency (kitz) 400	400 🖶	Switching Frequency Set Point (kHz)	
Internal Temperature (*C) 49	40.063 😭	Over Current Limit (A)	
External Temperature (*C) 42	0.452 🚔	Power Good On (V)	
Duty Cycle (NJ 7.54	0.805 📮	Power Good Off (V)	
Siatus O			Startup/Shutdown Times
User Calibration	4.98	On Delay Time (ms)	
EXT_TEMP_CAL m 1003	2.02 🚖	On Rise Time (ms)	
EXT_TEMP_CAL-b 0.0	24.97 🚖	Off Delay Time (ms)	
	2.02	Off Fall Time (ms)	
IDUT_CAL_GAIN (#D) 0.55			
IOUT_CAL_OFFSET (A) 119		C Margin High, Act on Faults	Operation Mode
Advanced Configuration			) Margin High, Ignore Faults ) Normal
Advanced Configuration		Margin Low, Act on Faults Tostate Stop	) Margin Low, Ignore Faults I Soft Stop

D. .. ۰. tion. 1.

- 2. In the Configuration tab, you can observe the basic settings and device status.
- 3. Click **Monitor** tab to observe the voltage and current plots.



Dashboard	0x0A MAX15301	0x08 MAX15303AA0	0x0F MAX15303440	0x11 MAX153034400	0x12 MAX15301	0x14 M4X15303AA0	0x15 MAX15303AA00	0x10 MAX13303	0x18 MAX153034	0x18 MAX15301		
Infiguration Monito	Faults Set	PMBus Command   Pe	missions   Tools					1221010-0000				
arameters	a second			doress 0x04								
Configur	Minn	-	-	Vout (V)	Min: 0.950 Max	x: 0.950 Avg: 0.950	E.		VIN (V):	Min: 11.875 Max: 11.8	75 Avg: 11.875	
	On/Off Config	Cw16	20		Netter YOUT	FALST LINET		E	- VIN	····· VIN FAULT LIN		
Vor	e Command (V)	0.950						18				
	Vout Max (V)	1.045	1.5					12 -			60 / 10 / 10 / 10 / 10 / 10 / 10 / 10 /	
	Iout Cal Gain	0.55	U 10					E s		-		
Parame	ters	ei.						5.				
	Input Voltage (V	1 11.875	0.5				-	1				********
c	utput Voltage (V	1 0.950	0.0	900	1922						100 10	
0	Natput Current (/	1 1.20		900	010 Sarr	sza npie	933 3	140 00	900	510 Sample	920 93	
Switching	Frequency (kH	1 401		lout (A):	Min: 3.203 Max	: 3.344 Avg: 3.262			Internal Temperal	ture (C): Min: 48.563 (	Max: 48,625 Avg: 4	3.608
Internal	Temperature (*C	1 48	- C	- KUT	IOUT FA	NULT LIMIT		- 3	TEMPERATURE	TEMP FAUL	TUNT	
Esternal	Temperature (*	1 43	43					Q 120				
	Buty Cycle (3	7.53										
Statu	• 0		5 ¹¹ 199 ₂₇					internal temperature 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0				
	54	alt Warning	<u>9</u> 20					11fer				_
Vous Un	ider Voltage	0 0	10					an en				
lout C	Iver Current	0 0						- 10 C				
Vin C	Ver Voltage	0 0	0	800	912	929	830 84	0 0	890 800	610	920	850
Vin Un	ider Voltage	0 0			Sem	iple				Sample		
Vout C	Ver Voltage	0 0					St	op Platting				

4. Repeat the steps mentioned above to monitor the power information for each rail supplied to the device.

*Note:* The rail information is displayed in terms of Regulator address.

RAIL	VOLTAGE	PMBUS ADDR
VCCINT	0.95V	0x0A
VCCAUX	1.8V	0x0B
VCCBRAM	0.95V	0x0F
VCC1V8	1.8V	0x11
VADJ_1V8	1.8V	0x12
VCC1V2	1.2V	0x14
MGTAVCC	1V	0x15
MGTAVTT	1.2V	0x16
MGTAVCCAUX	1.8V	0x18
UTIL_3V3	3.3V	0x1B

#### Table 2: Rail Information

5. Note that the junction temperature value from the Vivado Hardware Manager (System Monitor).



## Step 6: Estimating the Vectorless Power with Junction Temperature

For further Power Analysis, you can use the measured Junction Temperature and other thermal settings to feed into Vivado Report Power for better accuracy.

- 1. In the Vivado Design Suite, open the tutorial project and click **Open Implemented Design** to display the implemented design.
- 2. In the Tcl Console, run the following command to reset any user defined or SAIF file defined settings.

```
reset_switching_activity -all
```

- 3. In the main menu bar, select **Reports**  $\rightarrow$  **Report Power**.
- 4. In the Environment tab of Report Power dialog box, enter the Junction Temperature value supplied by the hardware power measurement.
- 5. Set the Process to maximum.
- 6. In the Switching tab, make sure that the Simulation activity file (.saif) is blank.
- 7. Click OK.





Res <u>u</u> lts name:	power_1		8
<u>Environment</u>	Power Supply	Switching Output	
Device Settings			
Temp grade	e:	extended 🗸	
Process:		maximum	
Environment Se	ettings		
Output Load	t:	0 🗘 pF [0 - 10000]	
✓ Junction	temperature:	34 🗘 °C	
Ambient ten	nperature:	25 🗘 °C	
Effective	€J <u>A</u> :	1.42 °C/W [0 - 100]	
Airflow:		250 🗸 LFM	
Heat sink:		medium (Medium Prof 🗸	
9SA:		2.4 🗘 °C/W [0 - 100]	
Board selec	tion:	medium (10"x10") 🗸	
Number of t	ooard layers:	12to15 (12 to 15 Layer 🗸	
୫JB:		2.5 🗘 °C/W [0 - 100]	
Board temp	erature:	25 🗘 °C [-55 - 100]	
Legend			

8. In the Power Report, observe that the power numbers increase slightly as compared to the vectorless power analysis using a default junction temperature value.

Note that the Junction Temperature is now color coded as being user defined in the Power Report.



Settings     Power analysis from Implemented netlist. Activity derived from constraints files, simulation files or vectorises analysis.     On-Chip Power       * Utilization Details     Total On-Chip Power:     3.063 W       * Utilization Details     Total On-Chip Power:     3.063 W       * Utilization Details     Total On-Chip Power:     40.0 °C       * Utilization Details     Total On-Chip Power:     40.0 °C       * Utilization Details     Total On-Chip Power:     40.0 °C       * Utilization Details     Utilization Chip Power:     60%       * Utilization Details     Utilization Chip Power:     60%       * Utilization Details     Utilization Chip Power:     60%       * Signals (0.385 W)     Effective 3JA     1.4 °C/W       * Dower supplied to off-chip devices:     0 W       * Settreset (0 V     Confidence level:     Medium	• • • • »			
Summary (3.063 W)     Power analysis from implemented netitist, Activity vectoriess analysis.     On L hip Power       > Utilization Details     Total On-Chip Power:     3.063 W       > Utilization Details     Total On-Chip Power:     3.063 W       > Unitication Details     Total On-Chip Power:     3.063 W       > Signals (0.385 W)     Diffective 8JA     1.4 "C/W       > Data (0.385 W)     Effective 8JA     1.4 "C/W       Power supplied to off-chip devices:     0.W       SettReset(0 V)     Confidence level:	Q ₹ ♦ C ″	Summary		
Utilization Defaults         Total On-Chip Power:         3.063 W         60%         6%         6%         6%         1         Clocks:         0.114 W         (8%)           Clocks:         0.114 Within Temperature:         40.0 °C         60%         5%         21%         5%         5igmals:         0.385 W         21%         5%         5%         21%         5%         5%         21%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%         5%		derived from constraints files, simulation files or	On-Chip Pov	
Hierarchical (185 Clocks (0.114 W)         Total On-Chip Power:         3.063 W         60%         21%         Clocks:         0.114 W         (8%)           Signata (0.385 W)         Thermal Margin:         60.0 °C (39.4 W)         5%         Signata:         0.385 W         Logic:         0.089 W         (5%)           Data (0.385 W)         Effective 3J.A         1.4 °C/W         60%         Effective 3J.A         1.4 °C/W           Clock Enable         Power supplied to off-chip devices:         0 W         IMMCM:         0.122 W         (7%)           SettReset (0 V)         Confidence level:         Medium         40%         7%         10C:         0.04 W         (7%)	Power Supply	vectoriess analysis.		Dynamic: 1.850 W (60%)
SetReset (0 V         Confidence level:         Medium         40%         7%         UC:         0.024 V(         (%)	Clocks (0.114 W) ~ Signals (0.385 W)	Junction Temperature: 40.0 °C Thermal Margin: 60.0 °C (39.4 W) Effective 3JA: 1.4 °C/W	60%	21%         Citocks:         0.114 W         (6%)           5%         Signats:         0.385 W         (21%)           Logic:         0.089 W         (5%)
Logic (0.889 W) Launch Power Constraint Advisor to find and fix BRAM (1.132 W) Invalid switching activity Device Static: 1.213 W (40%)	Set/Reset (0 V Logic (0.089 W)	Confidence level: Medium Launch Power Constraint Advisor to find and fix	40%	7% UO: 0.004 W (0%)

9. Similarly, you can overwrite the Junction Temperature setting and do a SAIF based power analysis.

### Conclusion

In this lab, you have learned to experiment with hardware power measurement using the KCU105 Evaluation Board.

In lab 5, you will learn about using the Power Optimization features in the Vivado IDE.



Lab 6

### Performing Power Optimization

### Introduction

In this lab, you will learn about using the Power Optimization features in Vivado[®] for 7 series devices. The lab will take you through the steps for invoking Power Optimization after synthesizing the design. It will also guide you on how to use the power optimization report, make decisions and selectively turn off power optimization on signals, blocks, and hierarchies.

**TIP:** When you run Implementation on your design, the Vivado tools may perform block RAM power optimizations by default during opt_design. These optimizations will not affect performance, and will have little impact on area and run time. In the previous Lab, the default block RAM power optimization was disabled (Step 9 of Lab 1) by setting a NoBramPowerOpt directive to opt_design.

### Step 1: Setting Up Options to Run Power Optimization

- 1. In the Flow Navigator, right-click Implementation and select Implementation Settings.
- 2. In the Project Settings dialog box, select Implementation tab to make the following settings:
  - In the Opt Design settings, set the **-directive** option to **Default**.

Block RAM optimization runs in the Default setting for Opt Design during Implementation. Block RAM optimization was disabled in the previous lab. It is now re-enabled when the design runs Power Optimization.

• In the Power Opt Design settings, check the is_enabled box.

This ensures Power Optimization runs after opt_design. Enabling the **Power Opt Design** option prior to place_design results in a complete power optimization to be performed. This option yields the best possible power saving from the Vivado tools.



Q	Implementation					
Project Settings	Specify various settings ass	sociated to Implement	ation			
General	******					
Simulation	Constraints					
Elaboration Synthesis	Default constraint set:	active	)	~		
Implementation	Options					
Bitstream	Options	g== ;				
> IP	is_enabled		1	^		
Tool Settings	tcl.pre					
Project	td.post			***		
IP Defaults	-verbose					
Source File	-directive*		NoBramPowerOpt	~		
Display	More Options					
WebTalk	Y Power Opt Design (po	wer_opt_design)				
Help	is_enabled		<b>v</b>			
> Text Editor	tcl.pre					
3rd Party Simulato	tcl.post					
> Colors	More Options					
Selection Rules				~		
Shortcuts Strategies > Window Behavior	is_enabled Optionally run this step as	part of the flow. This	step optimizes design to maximize pow	er saving.		
window Benavior 🧹						

- 3. Click OK.
- 4. In the Create New Run dialog box, click **Yes** to Properties for the completed run 'impl_1' have been modified. Do you want to preserve the state of 'impl_1' and apply these changes to a new run?.

I_1' have been	modified. ply these changes	to a new run?
Yes	No	Cancel
	impl_1' and ap	N_1' have been modified. impl_1' and apply these changes <u>Y</u> es <u>N</u> o

- 5. In the Create Run dialog box, set the **Run Name** to impl_2.
- 6. Click OK.
- 7. In the Flow Navigator, select **Run Implementation**. Click **Don't Save** when the Save Project window pops up to save both Synthesis and Implementation constraints.



ika Save	Project			*
?	Save projec	t before launchir	ng implementation?	
Data to	Save			
	-		trs_1 - dut_fpga_kci	
(*	Implement	led Design - con	strs_1 - dut_fpga_k	1705.Xuc
		S <u>a</u> ve	Don't Save	Cancel

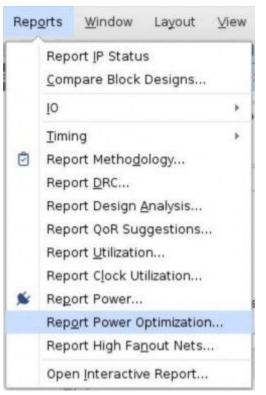
You are running Implementation with Power Optimization turned on.

8. In the Implementation Completed dialog box, select **Open Implemented Design** and click **OK**. Click **Don't Save** when the Save Project window pops up to save both Synthesis and Implementation constraints.

## Step 2: Running report_power_opt to Examine User/Design Specific Power Optimizations

- 1. In the Flow Navigator, select Implemented Design.
- 2. From the main menu, select **Reports**  $\rightarrow$  **Report Power Optimization**.





The Report Power Optimization dialog box appears, as shown in the following figure.

Report Power C	Optimization	
Report power optimi	zation.	4
Results <u>n</u> ame:	power_opt_1	0
Export to file:	Output file format	TXT () XML
✓ Open in a new		Dur O Bur
(?)	ок	Cancel

- 3. Enter power_opt_1 for the Results name.
- 4. Ensure that the **Open in a new tab** option is checked.
- 5. Click **OK**. Alternatively, execute the following command in the Tcl Console:

report_power_opt -name power_opt_1



- 6. Observe the report power_opt_1 is generated in the Power Opt window. When the report opens, the Summary view is displayed in the report.
- 7. In the Summary view, note that 50% of the block RAMs are clock gated by the tool during power optimization.

Create	New Run			×
?	Properties for the completed ru Do you want to preserve the sta on't show this dialog again			s to a new run?
		<u>Y</u> es	<u>N</u> ₀	Cancel

8. In the Power Optimization Report, select **Hierarchical Information** → **BRAMs** → **Tool Gated BRAMs** and observe the block RAM cells and its CE ports which are gated by the tool during the power optimization.

### Step 3: Running report_power to Examine Power Savings

- 1. In the main menu bar, select **Reports**  $\rightarrow$  **Report Power**.
- 2. In the Report Power dialog box, make the following settings
  - Specify the Results name as power_1.
  - In the Environment tab, make sure the Process is set to **maximum**.
- 3. Click **OK**. Alternatively, in the Tcl Console execute this Tcl command:
- 4. In the Summary view of the Power Report, observe an approximately 100-200mW power savings compared to the non-optimized power run in the previous lab.

You can generate a bitstream to program the hardware and measure its power, to observe the power saving in hardware. See Lab 4: Measuring Hardware Power Using the KC705 Evaluation Board for hardware power measurement instructions.



ower			? _ 🗆 ? )
Q <u>∓</u> ♦ C "	Summary		
Settings Summary (1.48 W) Power Supply	Power analysis from implemented netlist. Activity derived from constraints files, simulation files or vectoriess analysis.	On-Chip Po	Dynamic: 1.017 W (59%)
Utilization Details Hierarchical (1.017 Clocks (0.024 W) Signals (0.232 W) Data (0.232 W Clock Enable (	Total On-Chip Power:         1.48 W           Junction Temperature:         27.6 °C           Thermal Margin:         57.4 °C (30.2 W)           Effective & JA:         1.8 °C/W           Power supplied to off-chip devices:         0 W	69%	23%         Cłocka:         0.024 W         (2%)           Signala:         0.232 W         (2%)           Logic:         0.016 W         (2%)           BRAM:         0.524 W         (51%)           MMCM:         0.117 W         (12%)
SetReset (0 V) Logic (0.016 W) BRAM (0.624 W) Clock Manager (0	Confidence level: Medium Launch Power Constraint Advisor to find and fix invalid switching activity	31%	12%         INO:         0.004 W         (0%)           Device Static:         0.463 W         (31%)

## Step 4: Turning Off Optimizations on Specific Signals and Rerunning the Implementation

In this step you will learn how to turn off the power optimization on specific block RAMs.

IMPORTANT! Power optimization works to minimize the impact on timing while maximizing power savings. However, in certain cases, if timing degrades after power optimization, you can identify and apply power optimizations only on non-timing critical clock domains or modules using the *set_power_opt* XDC command.

See the Vivado Design Suite User Guide: Power Analysis and Optimization (UG907) for more information on the  $set_power_opt$  command.

Assume that this block RAM is in the critical path:

dut/gen_dut[0].bram_top_inst/bram_inst/mem_reg_0_0

This step makes sure the tool does not gate this block RAM.

1. In the Tcl Console, type this command:

```
set_power_opt -exclude_cells [get_cells dut/gen_dut[0].bram_top_inst/
bram_inst/mem_reg_0_0]
```

This will prevent the tool from gating this block RAM.

- 2. From the Flow Navigator choose Run Implementation, which in turn reruns power_opt_design.
- 3. Click **Save** in the Save Project dialog box to save the synthesized design and implemented design constraints before launching implementation.



🕹 Save	e Project 🥃
?	Save project before launching implementation?
Data to	
5	Synthesized Design - synth_1 - constrs_1 - dut_fpga_kc705.xdc
	Implemented Design - impl_1 - constrs_1 - dut_fpga_kc705.xdc
	Implemented Design - impl_2 - constrs_1 - dut_fpga_kc705.xdc
	Save Don't Save Cancel

Also, select **Implemented Design – impl_2** in the Save Constraints Conflict dialog box to save the changes in constraints from the set_power_opt command.

E Sav	e Constraints Conflict	×
Chang	There are unsaved changes to constraints set 'constrs_1' in multiple editors. Please choose which changes to save. es to Save	
	<ul> <li>Synthesized Design - synth_1</li> <li>Implemented Design - impl_1</li> <li>Implemented Design - impl_2</li> </ul>	
	OK Car	icel

4. In the Implementation Completed dialog box, select **Open Implemented Design** and click **OK**.

### Step 5: Running report_power_opt to Examine Tool Optimizations Again

- 1. In the main menu bar, select **Reports**  $\rightarrow$  **Report Power Optimization**.
- 2. In the Report Power Optimization dialog box, type in the Results name as **power_opt_2**. Alternatively, execute this Tcl command in the Tcl Console:

report_power_opt -name power_opt_2



3. In the generated report power_opt_2 in the Power Opt window, display Tool Gated BRAMs.

Power Opt				? _ [] 귀 >
QIEC	Q. Tool Galed BRAMs			
General Information	Cell Name	CE Port	CE Net Name	
Summary	mem_reg_0_0 (RAME36E1)	ENARDEN	dutigen_dut(0) bram_top_inst/bram_inst/mem_reg_0_0_ENARDEN_cocolgate_en_sig_2	
Recommendations	mem_reg_0_0 (RAME36E1)	ENEWREN	dutigen_dut(0).bram_top_inst/bram_inst/mem_reg_0_0_ENEWREIV_coopdgate_en_sig_11	
~ Hierarchical Information	mem_reg_0_1 (RAMB36E1)	ENARDEN	dutigen_dut(0] bram_top_inst/bram_inst/mem_reg_0_1_ENARDEN_cooolgate_en_sig_3	
~ ERAMs	mem_reg_0_1 (RAMB36E1)	ENBWREN	duligen_dul(0)bram_lop_inst/bram_inst/mem_reg_0_1_ENDWREN_cooorigate_en_sig_12	
User Gated BRAMs	mem_reg_0_2 (RAMB36E1)	ENARDEN	dutigen_dut(0) bram_top_inst/bram_inst/mem_reg_0_2_ENARDEN_cooolgate_en_sig_4	
Tool Gated BRAMs	mem_reg_0_2 (RANE36E1)	ENBWREN	dubgen_dut0] bram_top_inst/bram_inst/mem_reg_0_2_ENBWREN_coopligate_en_sig_13	
BRAM WRITE_MODE 0	mem_reg_0_3 (RAME36E1)	ENARDEN	dutigen_dut[0].bram_top_inst/bram_inst/mem_reg_0_3_ENARDEN_cooolgate_en_sig_5	
SRLs	mem_reg_0_3 (RANE36E1)	ENBWREN	dutigen_dut[0] bram_top_inst/bram_inst/mem_reg_0_3_ENEWREN_coooligate_en_sig_14	
<ul> <li>Slice Registers</li> </ul>	mem_reg_0_4 (RANE36E1)	ENARDEN	dullgen_dull0[.bram_lop_inst/bram_inst/mem_reg_0_4_ENARDEN_cooolgste_en_sig_6	
User Gated Slice Regis	mem_reg_0_4 (RANE36E1)	ENEWREN	dutigen_dut[0] bram_top_inst/bram_inst/mem_reg_0_4_ENBWREN_coopligate_en_sig_15	
Tool Gated Slice Regist	mem_reg_0_5 (RANE36E1)	ENARDEN	dubgen_dut(0) bram_top_inst/bram_inst/mem_reg_0_5_ENARDEN_cooolgale_en_sig_7	
XPM URAMS	mem_reg_0_5 (RAMB36E1)	ENEWREN	dutigen_dut(0).bram_top_inst/bram_inst/mem_reg_0_5_ENBWREN_coopligate_en_sig_16	
	mem_reg_0_6 (RAMB36E1)	ENARDEN	dutigen dut(0) bram top instituram institurem reg 0 6 ENARDEN cooolgale en sig 8	
	mem reg 0 6 (RAME36E1)	ENEWREN	dulloen dull01.bram top instituram institurem reg 0 6 ENEWREN coopligate en sig 17	

Note that this block RAM is no longer in the list of Tool Gated BRAMs:  ${\tt dut}\,/$ 

gen_dut[0].bram_top_inst/bram_inst/mem_reg_0_0

### Step 6: Saving Power using UltraScale Block RAM in Cascaded Mode

UltraScale architecture-based devices provide the capability to cascade the data out from one block RAM to the next block RAM serially. This will enable the devices to create a deeper block RAM in a bottom-up fashion. When used in cascaded mode, the power consumption is considerably low compared to the block RAM used in non-cascaded mode.

- 1. Run the steps mentioned in Step 1 shown in Lab 1.
  - a. In the Add Source Files dialog box, add the source files in the <Extract_Dir>/ UltraScale/src for UltraScale devices.
  - b. In the Add Constraints (optional) page, click Add Files and select dut_fpga_kcu105.xdc in the file browser. In the directory structure, you will find the dut_fpga_kcu105.xdc file below the /src folder.
  - c. Select the Kintex UltraScale KCU105 Evaluation Platform (xcku040-ffva156-2-e FPGA), click **Next**.
- 2. Review the New Project Summary page. Verify that the data appears as expected and click **Finish**.
- 3. In the Vivado Settings dialog box (**Tools** → **Options** → **General**), enter the tutorial project directory in the Specify project directory box, so that all reports are saved in the tutorial project directory. Then click **OK**.
- 4. Click Run Synthesis in the Flow Navigator.

The Synthesis Completed dialog box appears after synthesis has completed on the design.

5. Select Run Implementation in the Synthesis Completed dialog box and click OK.



- 6. After the Implementation completes, click **Open Implemented Design**.
- 7. You can see the automatically generated power report impl_1 in the Power window, which shows as a saved report. This is an autogenerated vectorless power report.
- 8. Note the total power (Total On-Chip Power) in the power report Summary view.

Q X \$ C	Summary
Settings Summary (2, 349 W) Power Supply V Utilization Details Hierarchical (1, 85 W) Clocks (0, 385 W) Data (0, 385 W) Dota (0, 385 W) Clock Enable (0, W) SetReset (0, W) Logic (0, 089 W) ERAM (1, 132 W) Clock Manager (0, 125 W W0 (0, 004 W)	Power analysis from implemented netics: Activity derived from constraints files, simulation files or vectoriess analysis.       On-Chip Power         Total On Chip Power:       2.349 W         Junction Temperature:       20.3 °C         Thermal Margin:       71.7 °C (49.1 W)         Effective BJA       1.4 °C.W         Power supplied to off-chip devices:       0.W         Confidence levet       Medium         Launch Power Constraint Advisor to find and fix invalid switching activity       21%

9. Select **Hierarchical** view under **Utilization Details** on the left panel and observe the cascaded and non-cascaded block RAM power.

Power								? _ D ? X
Q X O C	Q 🔮 Hierarchical							
Settings	Utilization	Name	Clocks (W)	Signals (W)	Data (W)	Logic (W)	ERAM (W)	Clock Manager (
Summary (2.352 W)	<ul> <li>International 1.853 W (79% of total)</li> </ul>	🗿 dut_toga						
Power Supply	<ul> <li>Internet in the second s</li></ul>	😰 dul (dut)	0.105	0.393	0.393	0.089	1.132	≺0.0
<ul> <li>Utilization Details</li> </ul>	1.152 W (49% of total)	Roncascade_bram (Noncascade	0.052	0.173	0.173	0.051	0.875	<0.0
Hierarchical (1 853 W)	0.557 W (24% of total)	Cascaded_bram (Cascaded_bram)	0.052	0.22	0.22	0.038	0.257	<0.0
Clocks (0.11 W)	0.131 W (6% of total)	🖾 Leaf Cells (12)						
Signals (0.393 W)	> 10.003 W (<1% of total)	😺 in_diff_bulg (IBUFDS)	<0.001	<0.001	-0.001	<0.001	<0.001	<0.0
Data (0.393 W) Clock Enable (0 W) SetReset (0 W) Logic (0.089 W) BRAM (1.132 W) Clock Manager (0.125 W)								

- 10. You can see 50% to 60% saving in cascaded block RAM compared to non-cascaded block RAM.
- 11. Use the same steps as specified in Step 1, Step 2, and Step 3 to perform SAIF based power analysis using Vivado Simulator.

### Conclusion

In this tutorial, we have accomplished the following:

• Used the Report Power dialog box to verify and set device, thermal, and environmental conditions that contribute to power estimation.



- Synthesized the design and estimated the power after synthesis.
- Set switching activities on an I/O port and reran Report Power.
- Ran functional simulation using the Vivado simulator and generated a SAIF file that is input to Report Power for a more accurate power analysis.
- Implemented the design, ran post-implementation timing simulation using the Vivado simulator, and generated a SAIF file that is input to report power for a more accurate power analysis.
- Ran Questa Advanced Simulator post-implementation timing simulation and generated a SAIF file that is input to report power for a more accurate power analysis.
- Performed power measurement on the design implemented in a KC705 and KCU105 Evaluation Boards. Compared the hardware power numbers with the numbers generated by Vivado Report Power.
- Learned how to achieve power optimization as part of an implementation run.
- Examined the power optimization report and selectively turned off power optimizations on a cell in the design.
- Examined the power saving of UltraScale block RAMs in cascaded mode when compared to block RAMs in Non-cascaded mode.





### Appendix A

### Additional Resources and Legal Notices

#### **Xilinx Resources**

For support resources such as Answers, Documentation, Downloads, and Forums, see Xilinx Support.

### **Documentation Navigator and Design Hubs**

Xilinx[®] Documentation Navigator (DocNav) provides access to Xilinx documents, videos, and support resources, which you can filter and search to find information. To open DocNav:

- From the Vivado[®] IDE, select Help → Documentation and Tutorials.
- On Windows, select Start → All Programs → Xilinx Design Tools → DocNav.
- At the Linux command prompt, enter docnav.

Xilinx Design Hubs provide links to documentation organized by design tasks and other topics, which you can use to learn key concepts and address frequently asked questions. To access the Design Hubs:

- In DocNav, click the **Design Hubs View** tab.
- On the Xilinx website, see the Design Hubs page.

*Note*: For more information on DocNav, see the Documentation Navigator page on the Xilinx website.

### References

These documents provide supplemental material useful with this guide:





- 1. Vivado Design Suite User Guide: Power Analysis and Optimization (UG907)
- 2. Vivado Design Suite User Guide: Programming and Debugging (UG908)
- 3. Vivado Design Suite User Guide: Release Notes, Installation, and Licensing (UG973)
- 4. Xilinx Power Estimator User Guide (UG440)

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