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TECHNOLOGY

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# PulseRain Reindeer (FRV2001) RISC-V Soft CPU

Quick Start Guide

*--Validated with*

**Lattice MachXO3D  
Breakout Board**

Jul, 2020

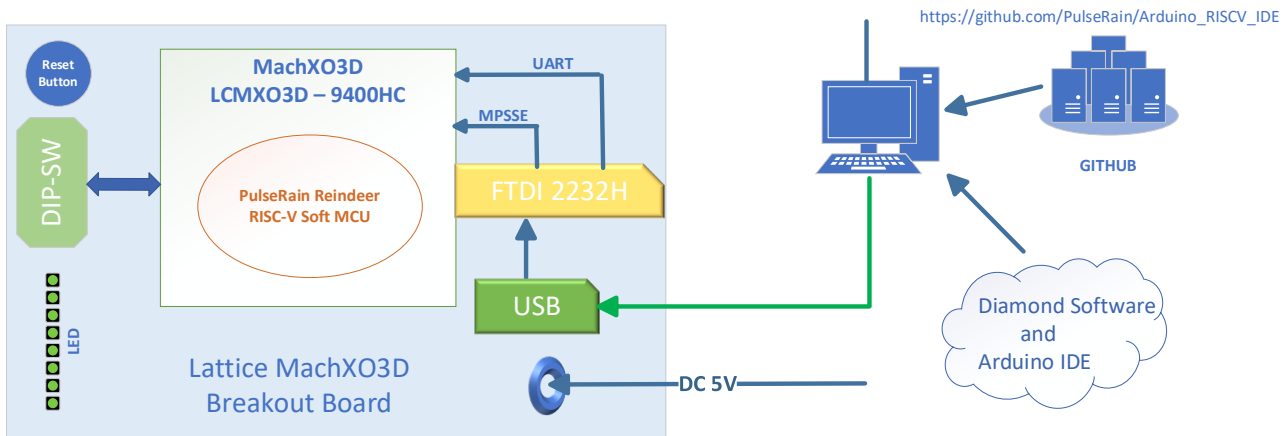
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# 1 Introduction

## 1.1 System Overview



**Figure 1-1 System Overview**

PulseRain Reindeer (FRV2100) is a soft CPU of Von Neumann architecture. It supports RISC-V RV32I[M] instruction set, and features a 2 x 2 pipeline. It strives to make a balance between speed and area, and offers a flexible choice for soft CPU across all FPGA platforms.

And at this point, it has also been successfully ported to the Lattice MachXO3D Breakout Board (“Breakout Board” for the rest of the document), with the following configurations:

- RV32I processor core, Von Neumann Architecture
- 32KB Block RAM for code and data
- 1 UART
- 32 bit GPIO for both input and output

As shown in Figure 1-1, to further facilitate the software development for RSIC-V, an Arduino board support package has been provided on GitHub for the Breakout Board, with which the software developers can write code for RISC-V directly in Arduino IDE.

And the following components can also be found on the Breakout Board, as illustrated in Figure 1-1.

- A Lattice LCMXO3D-9400HC FPGA
- 8 LEDs
- 1 Reset Button
- Connectors for FPGA IO ports
- FTDI 2232H for USB connection

## 1.2 Supply of Power

The Breakout Board can be powered a Mini-USB cable.

## 1.3 Programming Cable and USB /UART Cable

As indicated in Figure 1-1, the Mini-USB cable also serves as both a programming cable and a USB/UART cable.

## 1.4 Lattice Diamond Software

The Lattice Diamond software is needed to compile the RTL code and program the FPGA. The Lattice Diamond can be found at

<https://www.latticesemi.com/Products/DesignSoftwareAndIP/FPGAandLDS/LatticeDiamond>

And users can also request a free license for this software from Lattice website.

# 2 GitHub Repository

The complete code of PulseRain Reindeer (FRV2100) for MachXO3D Breakout Board can be found on GitHub at

[https://github.com/PulseRain/Reindeer\\_MachXO3D](https://github.com/PulseRain/Reindeer_MachXO3D)

To check out (clone) the repository, run the following commands under Cygwin on Windows:

```
$ git clone https://github.com/PulseRain/Reindeer\_MachXO3D.git
```

```
$ cd Reindeer_MachXO3D
```

```
$ git submodule update --init --recursive
```

# 3 Program the Breakout Board

The repository above has a pre-built FPGA image for PulseRain Reindeer(FRV2100) MCU. To program the Breakout Board with this image, do the following:

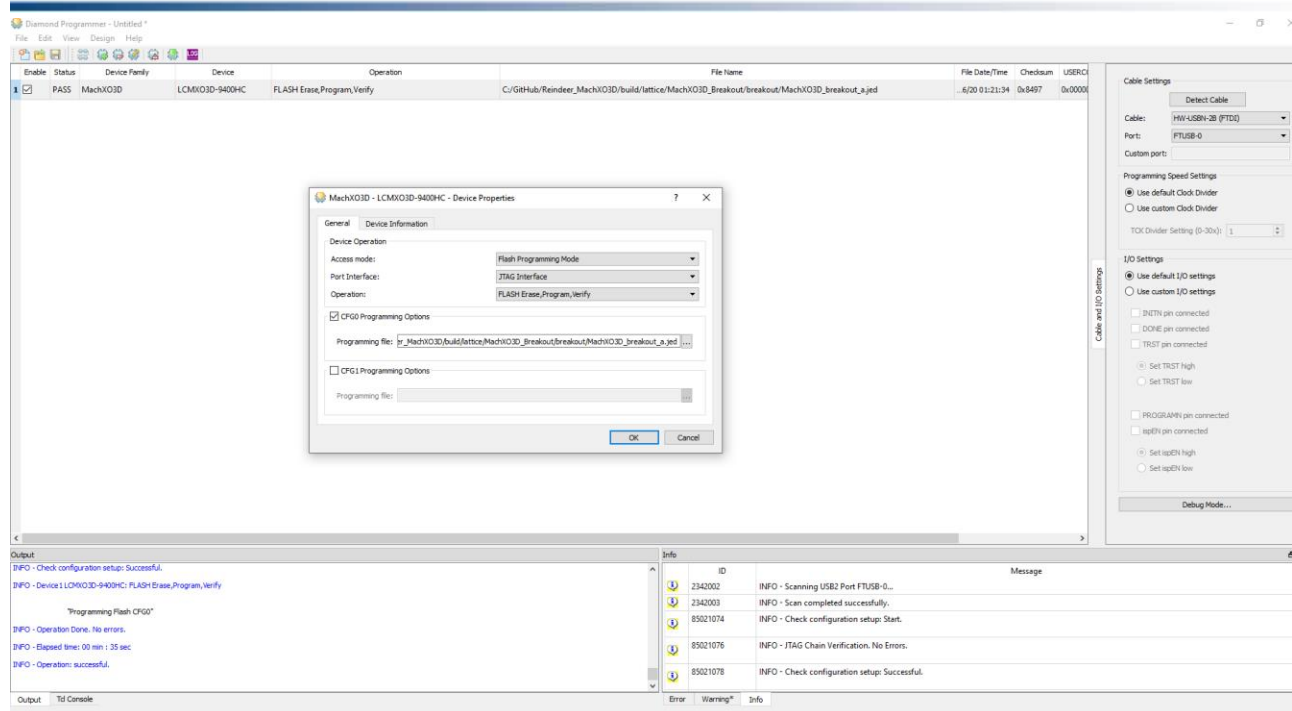
1. Connect the Breakout Board to PC through a Mini-USB Cable.
2. Launch Diamond Programmer,

Set the Device to be LCMXO3D-9400HC

Set Operation to be FLASH Erase, Program, Verify

As shown in Figure 3-1, point the File Name to

[Reindeer\\_MachXO3D\build\lattice\MachXO3D\\_Breakout\breakout\MachXO3D\\_breakout\\_a.jed](#),



**Figure 3-1 Diamond Programmer**

The FPGA image above contains PulseRain Reindeer(FRV2100) RISC-V core, and it will light up the led in a rotating fashion. Please set DIP-SW 1 and 2 for LED pattern, and set DIP-SW 3 and 4 for LED refreshing rate.

## 4 Prepare the Breakout Board for UART

The RISC-V core needs a UART for programming and communication. The MachXO3D Breakout board carries a FTDI FT2232H chip, with 2 channels. Channel A is used for FPGA programming. And Channel B can be used as a UART for RISC-V.

However, to enable the UART, some extra work has to be done:

1. For the Breakout Board (Rev A), the resistors R14 and R14 are DNI on the board. They should be installed (0 Ohm or simply connect with bard solder), as shown below in Figure 4-1:

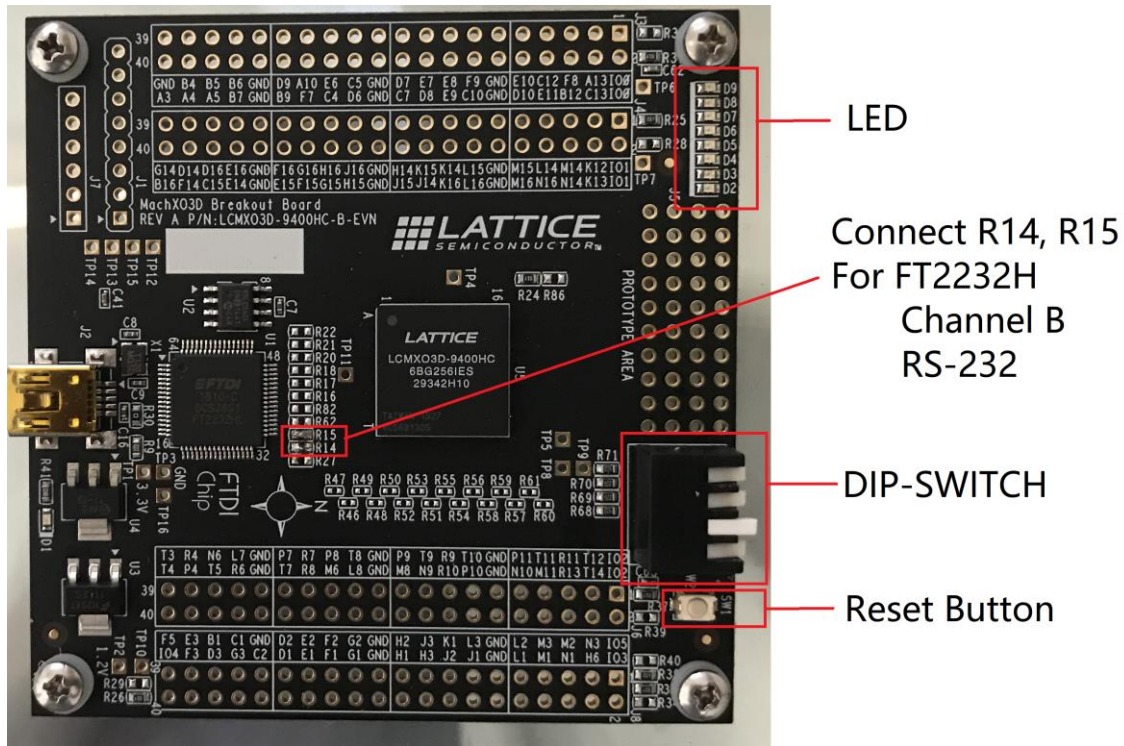


Figure 4-1 Lattice MachXO3D Breakout Board (Rev A)

- The EEPROM for the FT2232H needs to be reconfigured. To do that, please install the [FT\\_PROG utility](#) from [Future Technology Devices International Ltd.](#)
- Launch [FT\\_PROG utility](#), press F5 to scan the devices, set Hardware Specific/Port B/Hardware to be RS232 UART, as illustrated below in Figure 4-2:

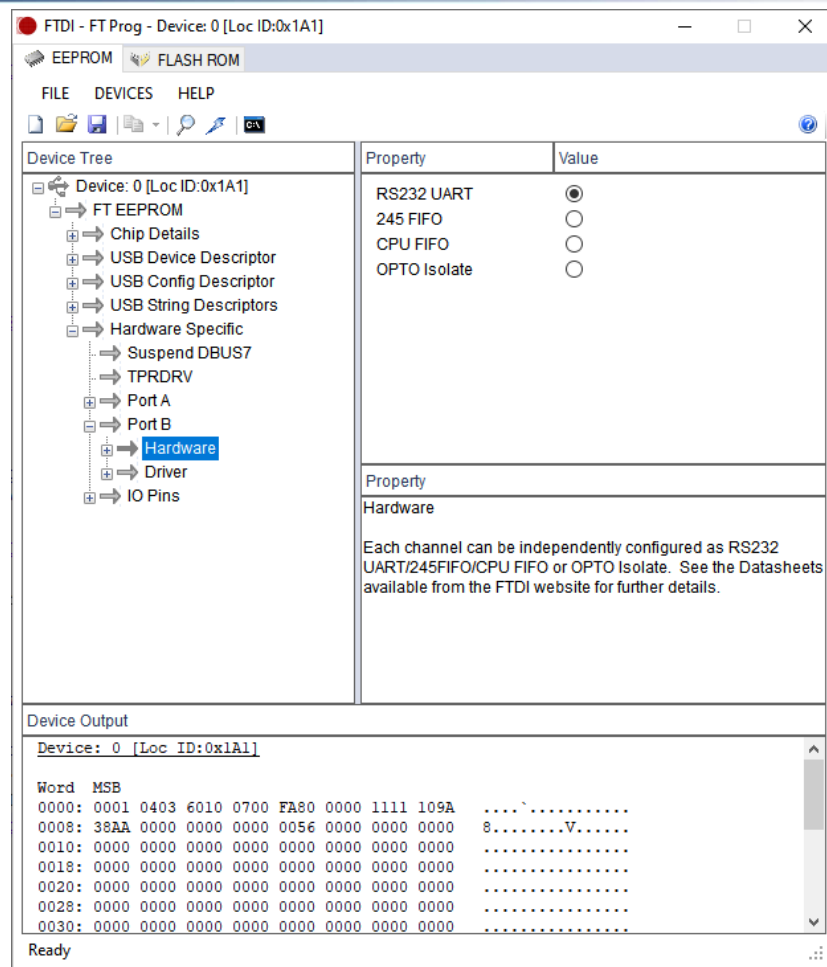
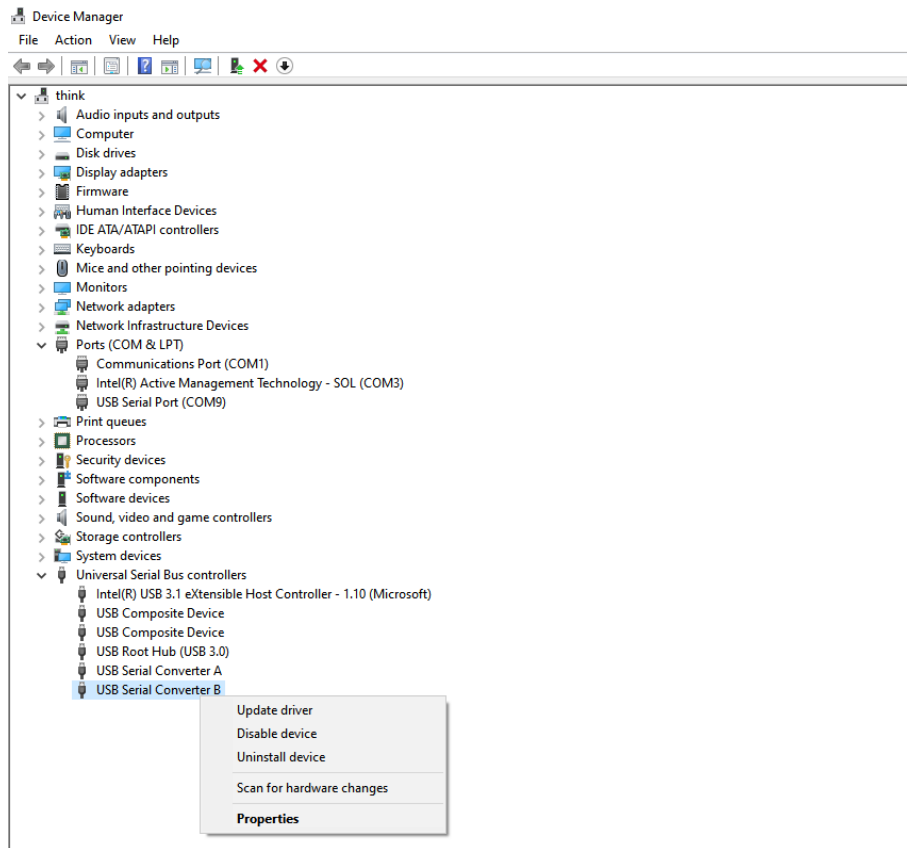


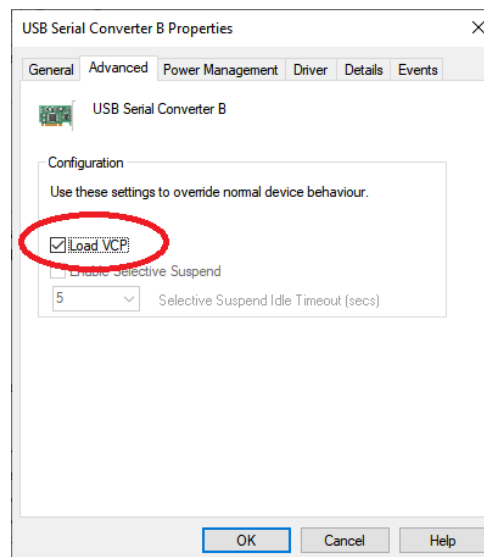
Figure 4-2 FTDI FT\_PROG Utility

4. Press Ctrl+P to program the FT2232H on the Breakout Board.
5. Open Windows Device Manager, right click "Universal Serial Bus controller / USB Serial Converter B", then choose Properties, as shown below in Figure 4-3.



**Figure 4-3 Device Manager**

6. In the Advanced Tab, make sure “Load VCP” is selected, as shown in Figure 4-4.



**Figure 4-4 USB Serial Converter B Properties**



7. Unplug and re-plug the Mini-USB Cable. If everything goes ok, you should be able to find a new COM port in Windows Device Manager, as shown in Figure 4-5.

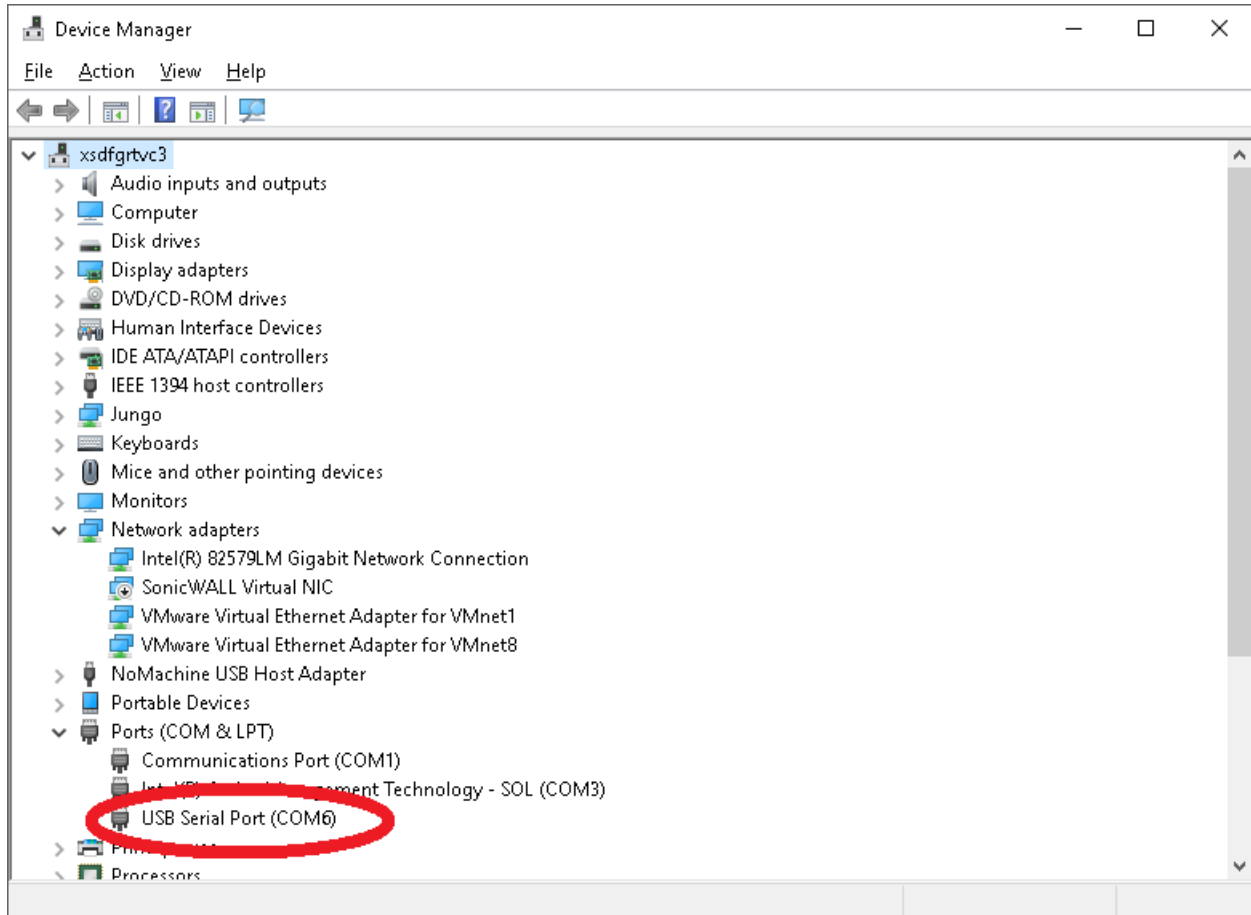


Figure 4-5 USB Serial Port in Windows Device Manager

## 5 Using Arduino IDE

### 5.1 Install Arduino IDE

PulseRain Reindeer(FRV2100) RISC-V MCU can be developed and programmed through Arduino IDE. On Windows 10, the Arduino IDE can be installed as an App directly from Windows App store. Otherwise, the Windows installer for Arduino IDE can be found at Arduino Website:

<https://www.arduino.cc/en/Main/Software>

## 5.2 Setup Arduino IDE

After the Arduino IDE is installed, launch it and click the menu File / Preferences, as shown in Figure 5-1:

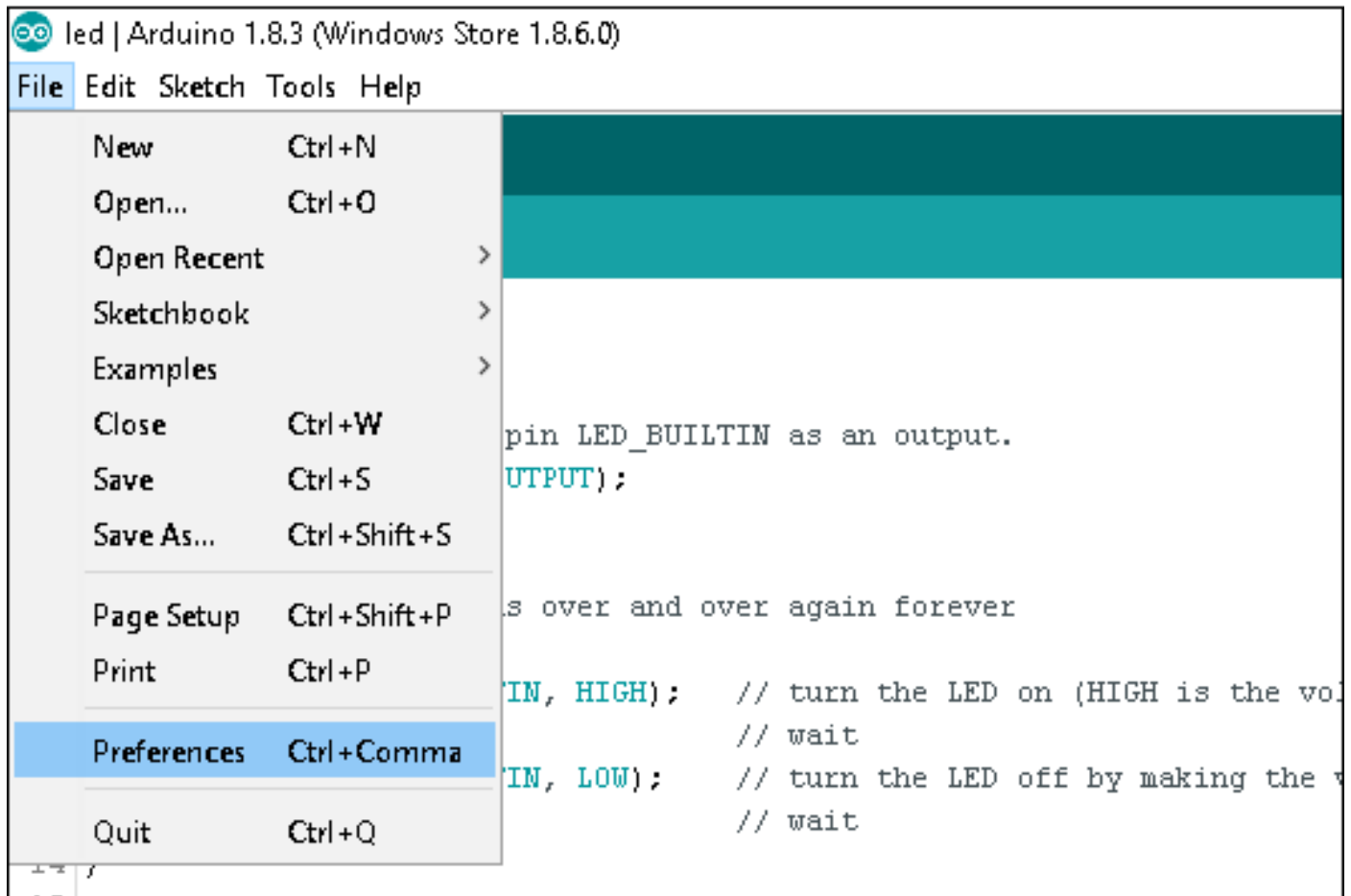


Figure 5-1 Arduino IDE, Preferences Menu

- 1) The File / Preferences menu will bring out a dialog like the one shown in Figure 5-2. Please set the "Additional Boards Managers URL" to [https://raw.githubusercontent.com/PulseRain/Arduino\\_RISCV\\_IDE/master/package\\_pulserain.com\\_index.json](https://raw.githubusercontent.com/PulseRain/Arduino_RISCV_IDE/master/package_pulserain.com_index.json)

(If this input box is not empty, use semicolon to separate multiple URLs.) And click OK to close the dialogue.

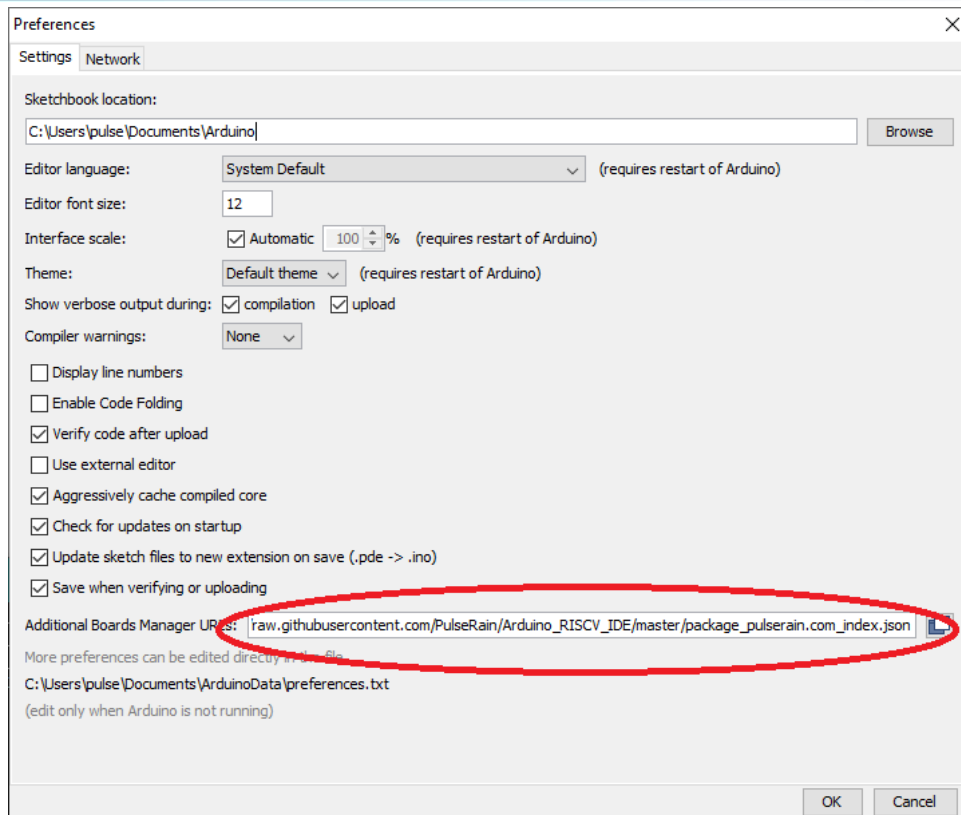


Figure 5-2 Arduino IDE, Preferences Dialogue

2) Now click the menu Tools / Boards / Boards Manager, as shown in Figure 5-3.

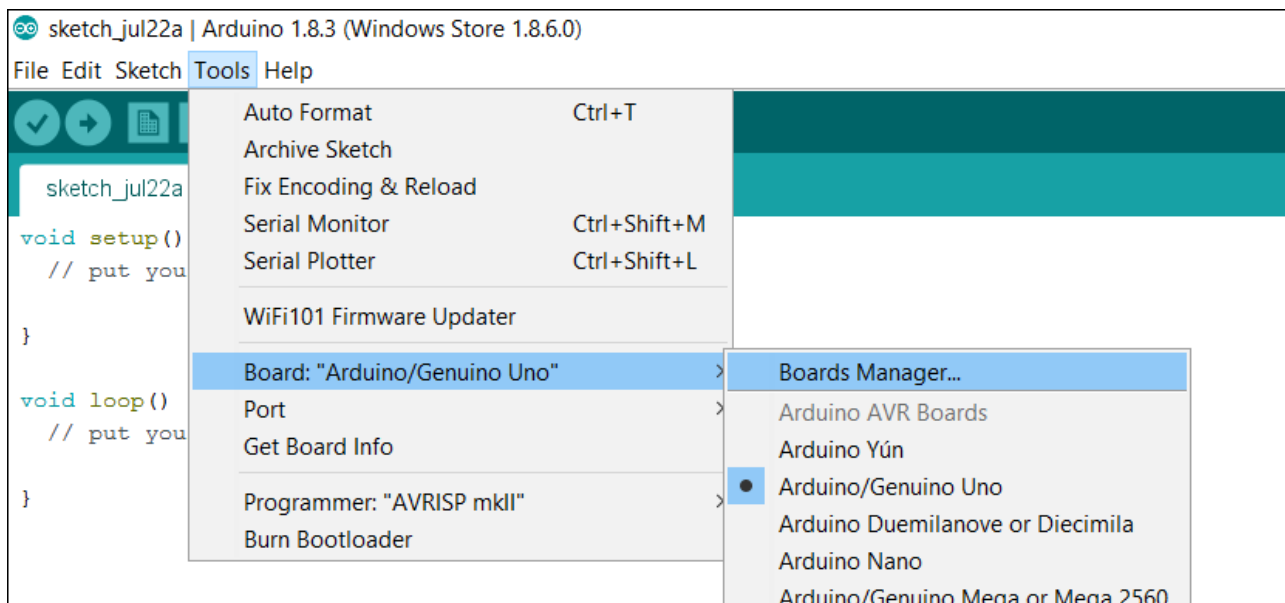
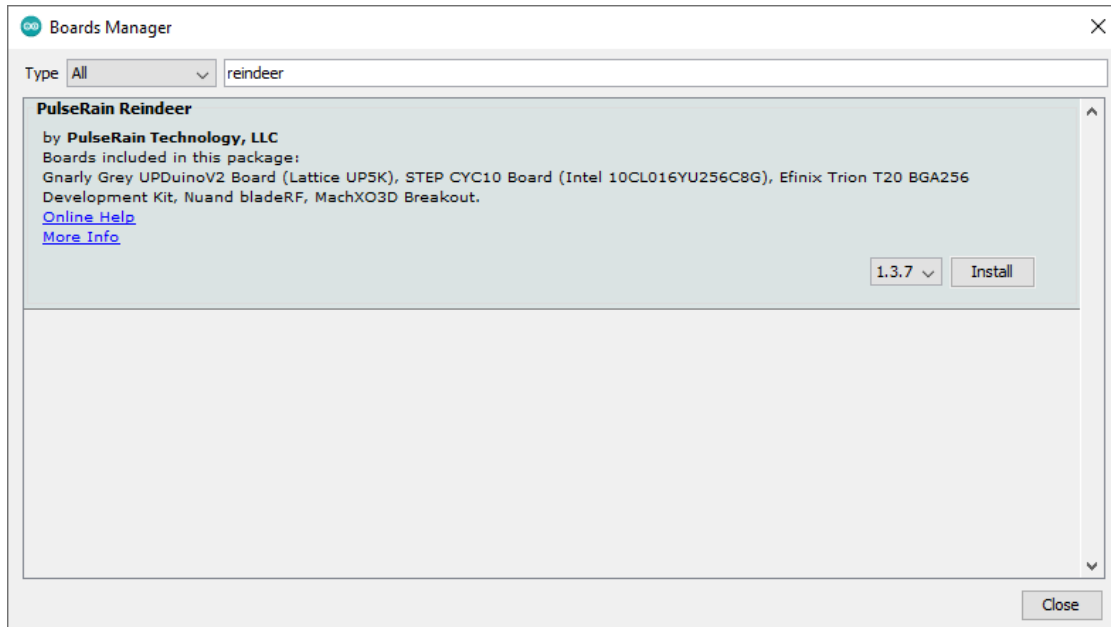


Figure 5-3 Arduino IDE, Boards Manager Menu

- 3) The "Boards Manager" will bring out a dialogue like the one shown in Figure 5-4. Type in "Reindeer" in the search box to find the board support package for the MachXO3D Breakout Board. Click "Install" to download and install the board support package.

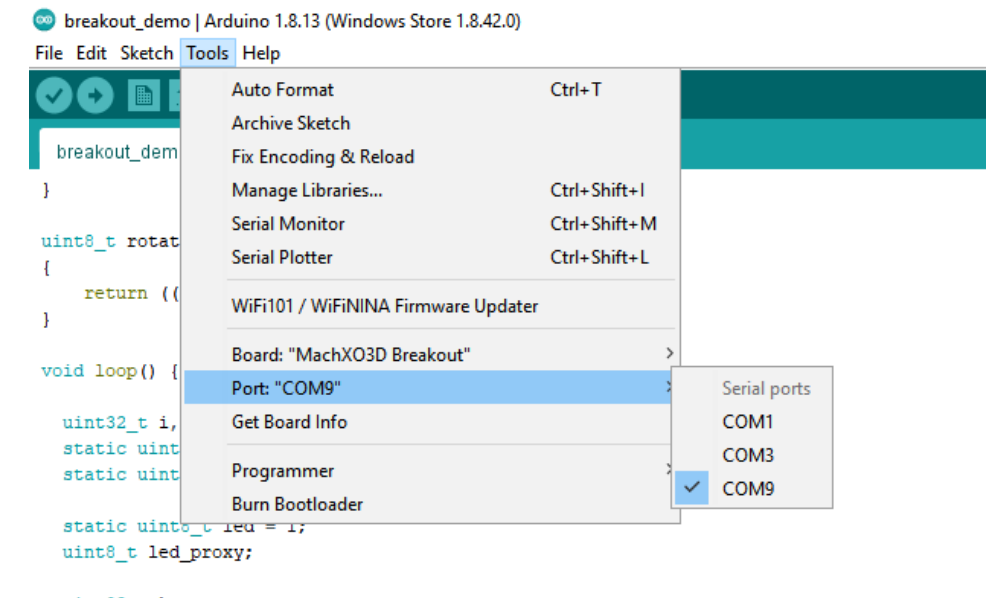


**Figure 5-4 Arduino IDE, Boards Support Package for Lattice MachXO3D Breakout Board**

## 5.3 Write Sketches

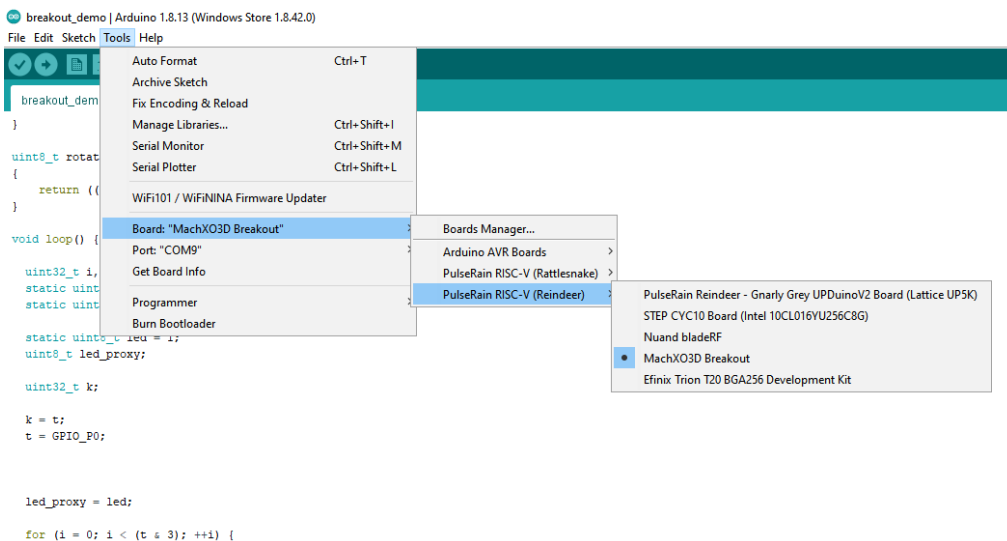
Just like Arduino, you need to select the correct COM port and Board Name before you can start writing sketches.

To select the COM port in Arduino IDE, click the menu Tool / Port, as shown in Figure 5-5. The COM port for the Breakout Board is usually the one that has the biggest index number, but not always. If you have trouble determining which COM port corresponds to the Breakout Board, you can always open the device manager to check, as illustrated in Figure 4-5.



**Figure 5-5 Arduino IDE, Select COM port**

To select the board name as "MachXO3D Breakout", click the menu Tool / Board. If the previous steps were done right, you should see the name "MachXO3D Breakout" in PulseRain RISC-V (Reindeer), as illustrated in Figure 5-6.



**Figure 5-6 Arduino IDE, Select MachXO3D Breakout**

Now you can start to write some sketches, you can open the demo Sketch provided in the GitHub repository [Reindeer MachXO3D/sketch/breakout\\_demo](https://github.com/PulseRain/Reindeer_MachXO3D/tree/main/sketch/breakout_demo).

After opening the demo Sketch in Arduino IDE, you can type in "ctrl-U" (or menu Sketch/Upload) to compile and upload the sketch to the Breakout Board. And it is also recommended to turn on the option of "Show Verbose Output" in Preferences Dialogue (Menu File / Preferences), as illustrated in Figure 5-7. In this way, the path of the .hex file can be located through the verbose output.

Also, you can type in "Ctrl-Shift-M" (or menu Tools / Serial Monitor), as illustrated in Figure 5-8, to see the output of the COM port (Please set baud rate to 115, 200)

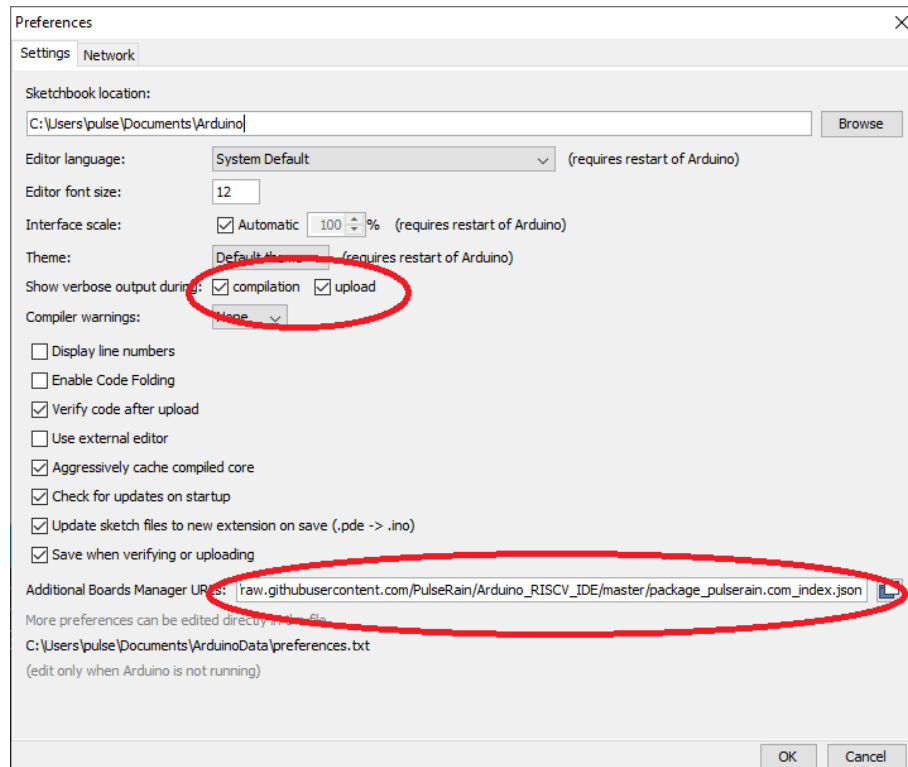


Figure 5-7 Turn on Verbose Option

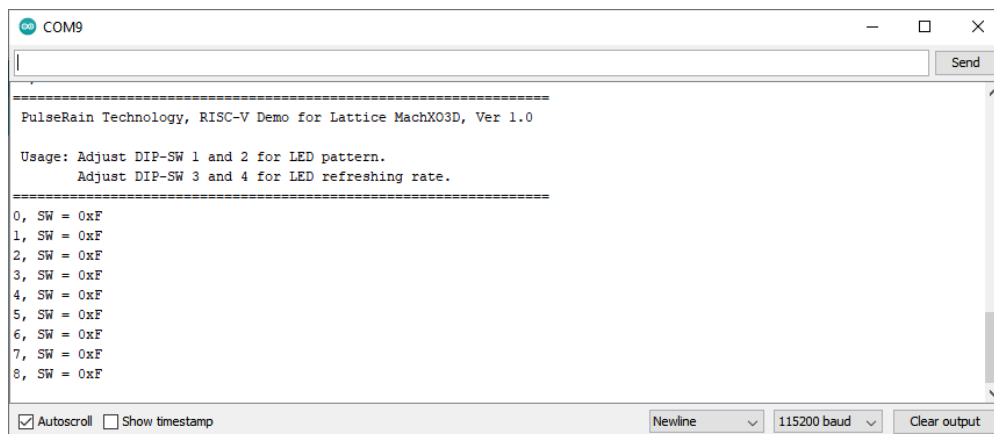


Figure 5-8 Arduino IDE, COM Port output

## 6 Build the FPGA Image from RTL Code

To build the FPGA image from RTL, launch Lattice Diamond software, and open the project under

[Reindeer\\_MachXO3D\build\lattice\MachXO3D\\_Breakout\MachXO3D.lfd](#)

If every goes ok, the screen should look like the one in Figure 6-1

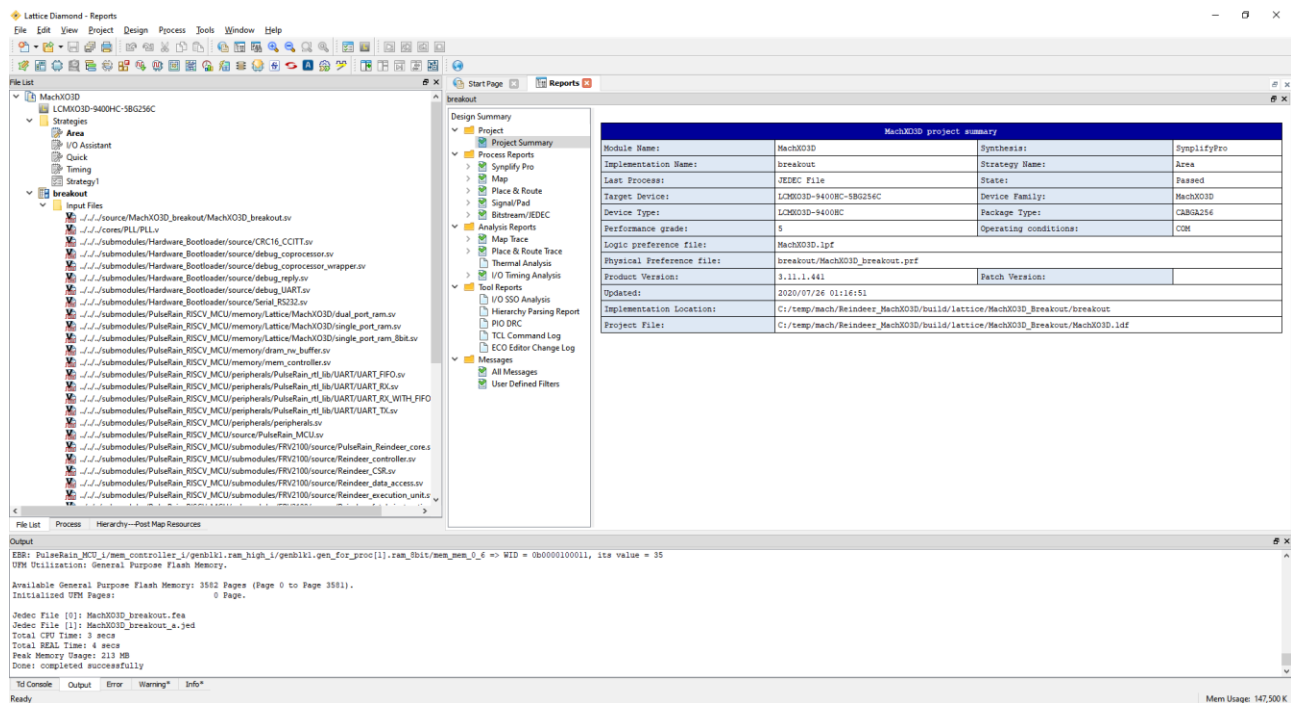
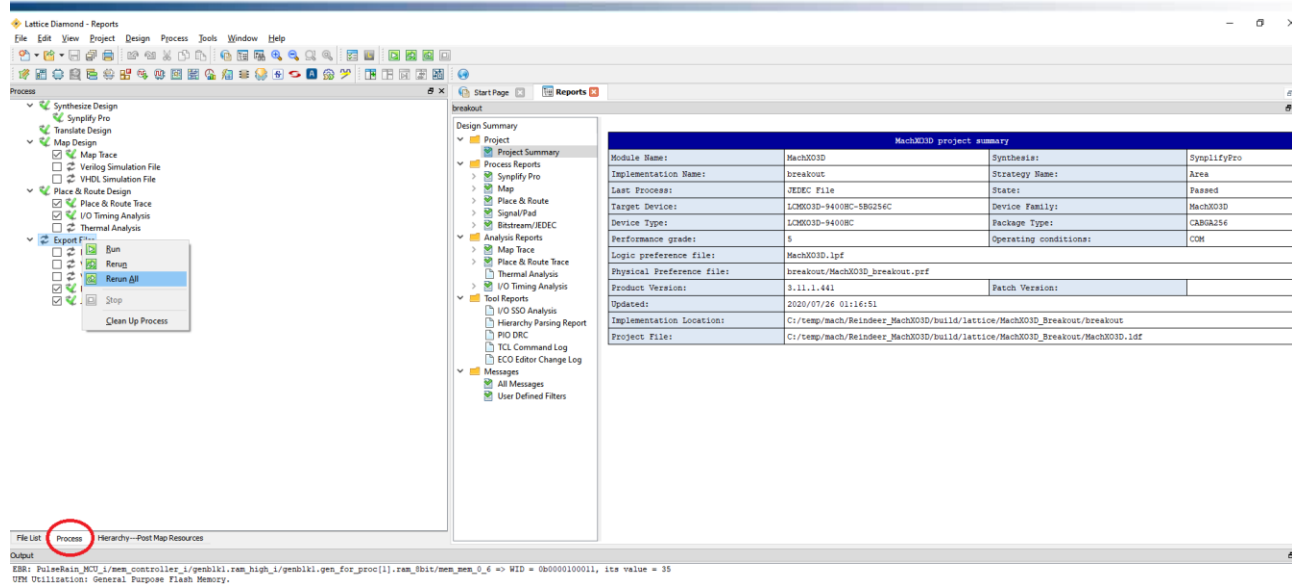


Figure 6-1 Lattice Diamond, Project

And please choose the process tab, right click the Export Files, and then click Rerun All, as show below in Figure 6-2.



**Figure 6-2 Lattice Diamond, Rerun All**

After the build is complete, the newly generated bit stream file and JEDEC file can be found in

Reindeer\_MachXO3D\build\lattice\MachXO3D\_Breakout\breakout

- MachXO3D\_breakout.bit
- MachXO3D\_breakout\_a.jed

## 7 Generate Memory Init File

There are 4 memory init files in Reindeer\_MachXO3D\build\lattice\MachXO3D\_Breakout\breakout

- mem\_init\_0.mem
- mem\_init\_1.mem
- mem\_init\_2.mem
- mem\_init\_3.mem

They contain the power-on software image for the MCU. To replace the default software image, users can use the script in Reindeer\_MachXO3D\build\scripts\gen\_mem.cmd

This script needs one parameter for the software's image in hex format. And for Arduino, the path to the hex file can be found in Arduino message window if verbose option is turned on (Figure 5-7).

To generate the new memory init files, open the command prompt, enter the script folder path, and run something like: (The path should be copied/pasted from Arduino message window.)

*gen\_mem.cmd C:\Users\pulse\AppData\Local\Temp\arduino\_build\_32247\sketch\_jul24a.ino.hex*