DSPLab Introduction

August 2021

Second Edition

DSPgig.com

Contents

1 DSPLAB FEATURES 3

2 DSPLAB HARDWARE SPECIFICATIONS 4

3 DSPLAB 6

1) Introduction 6
2) Main parts 6
3) The lab structure 9
3.1) Part one: 30 hours 9
3.2) Part two 10
4) What should be expected from students after using DSPLab? 12
5) The DSP family 12
6) Prerequisites: 12
6.1) Is the team working possible? 12

1 DSPLAB FEATURES

- ✓ 'DSPLab student's manual' book for 6 laboratory sessions
  - It covers the first 30 hours of the Lab
  - Lab1: How to work with Code Composer Studio, gel file, and command file
  - Lab2: Get familiar with DSPLab hardware, including keys, LEDs, ADC, DAC, Image
  - Lab3: Memory management, entry-point, sections, symbols, SDRAM, ROM, optimization, DATA_SECTION
  - Lab4: TI DSP libraries, MATLAB simulation, FIR filter implementation in DSP, cycle count
  - Lab5: Fixed point FFT, fixed-point vs floating point
  - Lab6: Image processing, Memory models, DSP Image library
  - Appendix A: DSPLab hardware register description
  - Appendix B: C language
  - Appendix C: Code initialization
  - Appendix D: Flash programming

- ✓ 'DSPLab teacher's manual' book for the laboratory instructor.
  - Similar to 'DSPLab students' manual' with more descriptions for some of the topics.
  - Includes suggestions for extra explanation during the lab sessions.

- ✓ 'TI DSP step-by-step, C2000, C5000, and C6000' book (400 pages)
  - Can be used as a reference by the students or the instructor
  - More in-depth exercises for each topic

- ✓ 'DSPLab hardware manual' book covers DSP hardware and peripheral design
  - Can be used as the reference for the second part of the Lab (up to 50 hours)
  - Includes both software code examples and hardware design consideration for each peripheral
  - Chapter 1: How to design a DSP hardware
  - Chapter 2: Design the JTAG connection
  - Chapter 3: PLL/clock design
  - Chapter 4: How to add digital Input/Output to a DSP hardware
  - Chapter 5: Adding an FPGA to a DSP hardware
  - Chapter 6: Audio Codec design and connection for TI DSPs
  - Chapter 7: MMC design and communication protocol
  - Chapter 8: External memory design
  - Chapter 9: USB design and software consideration

- ✓ 'Real-time digital signal processing, implementation and application' book.
  - Can be used as the reference for the second part of the Lab (up to 50 hours)
  - Chapter 7: Adaptive filtering
  - Chapter 8: Signal generator
  - Chapter 9: Dual-tone multifrequency Detection
  - Chapter 10: Adaptive echo cancelation
  - Chapter 11: Speech-coding

- ✓ DVD for the code examples

- ✓ Power cable, USB cable, analog cable, UART cable, JTAG USB cable.

2 DSPLab hardware specifications

- ✓ LCD interface with a Graphical User Interface (GUI)
  - Configures ADC format, and the FIFO interface between DSP and ADC
  - Configures DAC format, and the FIFO interface between DSP and DAC
  - Configures the URAT baud rate
  - Set image display format
  - Monitors DSP frequencies
  - Displays the ADC or DAC signals (embedded oscilloscope)

- ✓ The processor is based on well-known TMS320VC5509A with a maximum frequency of 200MHz
  - ❖ Important note: Even though DSPLab uses the 55xx DSP family, it is designed to prepare the student for all three leading DSP families (2000, 5000, and 6000)
  - Very suitable to teach signal processors to beginners
  - While has many complexities of modern signal processors, it can help students to learn the basics in a short time
  - A famous DSP with many free resources
  - One/Two Instruction(s) Executed per Cycle
  - 128K x 16-Bit On-Chip DARAM/SARAM
  - Dual Multipliers (Up to 400 Million Multiply-Accumulates per Second)
  - External memory interface (EMIF)
  - Six Direct Memory Accesses (DMA)
  - USB, MMC, I2C, MCBSP interface

- ✓ Easy image display interface
  - 9.2KB of image memory mapped to DSP external memory
  - RGB (3-bit per color) or grayscale (8-bit)

- ✓ External 4MB SDRAM
- ✓ External 512KB parallel flash
- ✓ 8-bit digital output
  - The digital outputs are connected to 8 LEDs
  - Are used to teach how to access external device

- ✓ 8-bit digital input
  - The digital inputs are connected to 8 push buttons
  - Are used to teach how to access external device

- ✓ UART interface
  - RS232 Tx/Rx
  - Accessible through a 256 bytes TX FIFO and 256 bytes Rx FIFO

- ✓ Easy configurable ADC
  - 8-bit ADC with a frequency range of 1Hz to 1.5MHz
  - Can be configured by the GUI or the software
  - Integrated 256 bytes FIFO

- ✓ Easy configurable DAC
  - 12-bit DAC with a frequency range of 1Hz to 1.5MHz
  - Can be configured by the GUI or the software
  - Integrated 256 bytes FIFO

- ✓ Integrated JTAG interface
  - Integrated XDS100v2 JTAG interface
  - Communicate to PC with USB
  - Isolated USB interface to reduce the ground noise from the PC
- ✓ MMC/SD card interface
- ✓ Audio codec interface
  - Based on TLC320AIC12
  - 16-bit 26-KSPS Mono codec
  - Embedded amplifier with double speakers for testing the codec signals
  - Direct microphone input
- ✓ Internal RTC
  - 32768KHz crystal oscillator

3 DSPLab

1) Introduction

This document describes DSPLab documents structure and how to benefit from all documents and hardware available appropriately. The DSPLab is designed for students who are not familiar with Texas Instrument DSP. There are multiple documents and hardware provided as part of the DSPLab platform. DSPLab has one main goal: 'Teach students as much as possible in the shortest amount of time'. To achieve this goal, it is important to use the available documents and hardware properly.

2) Main parts

DSPLab has six main parts:

1- DSPLab hardware: The hardware is used by the students to learn Digital Signal Processors from Texas Instruments. The hardware is connected to a PC or Laptop with a standard USB cable. The hardware is a standalone device, and there is no need for any other particular device such as a power supply or oscilloscope.

Figure 1: DSPLab hardware

2- ‘DSPLab student’s manual’: This book has six lab sessions (30 hours) and is based on DSPLab hardware. After reading this book, the students learn the basics of DSP programming (download the table of contents from here).

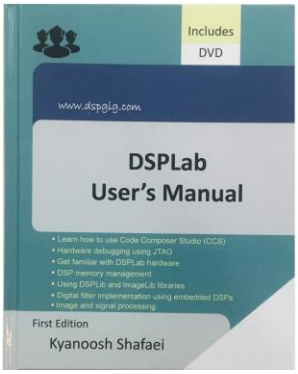

Figure 2: 'DSPLan user's manual' book

3- ‘DSPLab teacher’s manual’: This book is similar to ‘DSPLab student’s manual’, but has more information needed by the lab instructor for explaining to the student. Also, it has some tips and tricks for debugging students’ problems while using the DSPLab hardware (download the table of contents from here).

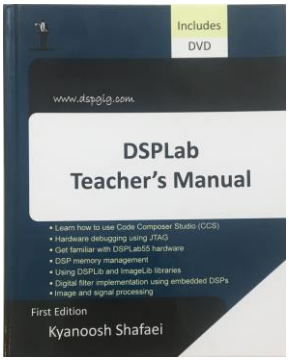

Figure 3: 'DSPLab teacher's manual' book

4- ‘DSPLab hardware manual’: After the first 30 hours of the lab, students are familiar with the TI DSP structure and coding. To practice more, there are two paths: One is writing more signal processing codes such as DCT, LMS, AEC, or … . The other path is to work on hardware design and peripheral programming. The hardware book explains how to design hardware for DSP and how to program each peripheral (download the table of contents from here).

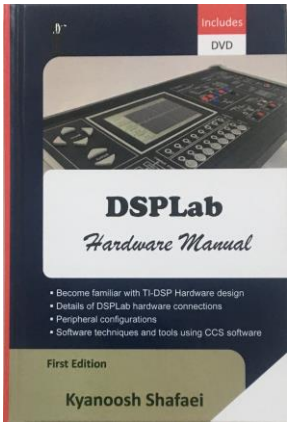

Figure 4: 'DSPLab hardware manual'

5- ‘Real-Time Digital Signal Processing’: This book is for those who are interested in more mathematical signal processing and can be used for the second part of the lab. It is recommended to work on chapters 7 to 11.

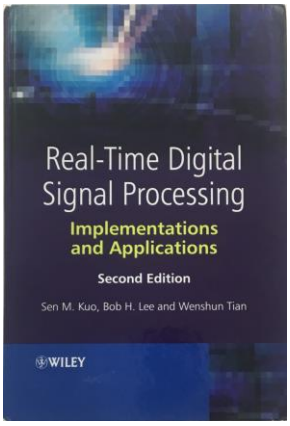

Figure 5: 'Real-Time digital signal processing'

6- ‘TI DSP step-by-step, C2000, C5000, and C6000’: This book can be used as a reference by students or instructor. The book covers some of the topics already explained in the lab with more details (download the table of contents and first chapter from here).

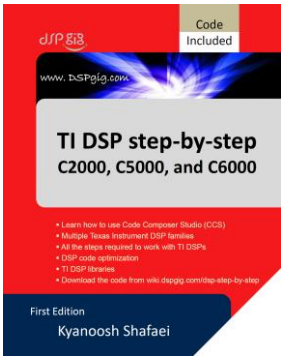

Figure 6: 'TI DSP step-by-step' book

3) The lab structure

We recommend dividing the signal processing lab into two parts:

3.1) Part one: 30 hours

The first 30 hours of the Lab are mainly focused on the basics. The following picture shows the steps the instructor needs to take before the lab starts. Here the ‘DSPLab hardware manual is recommended as the second document to read. One may read only the first four chapters of this book.

Although DSPLab can be used without an instructor, it is highly recommended to assign an instructor for the Lab. The documentation provided should be enough for any instructor to get familiar with DSP. First, the instructor should be prepared for the lab. The ‘TI DSP step-by-step’ book is a very good start for the instructor. This book helps the instructor have a deeper knowledge of DSP and better answer the students' questions. This step can be skipped if the instructor does not have enough time. Then, the ‘ DSPLab teacher’s manual’ should be studied. The answer to the exercises is provided in the accompanied DVD.

The answer for the exercises can not be downloaded from the website and only provided on the DVD.

Before starting the lab, at least the first five chapters of the ‘DSPLab hardware manual’ must be studied, and the code examples should be tested on the actual hardware. Running some test codes helps to gain more confidence. The source code for the ‘DSPLab hardware manual’ is provided in the accompanying DVD and can also be downloaded from the ‘wiki.dspgig.com/dsplab’.

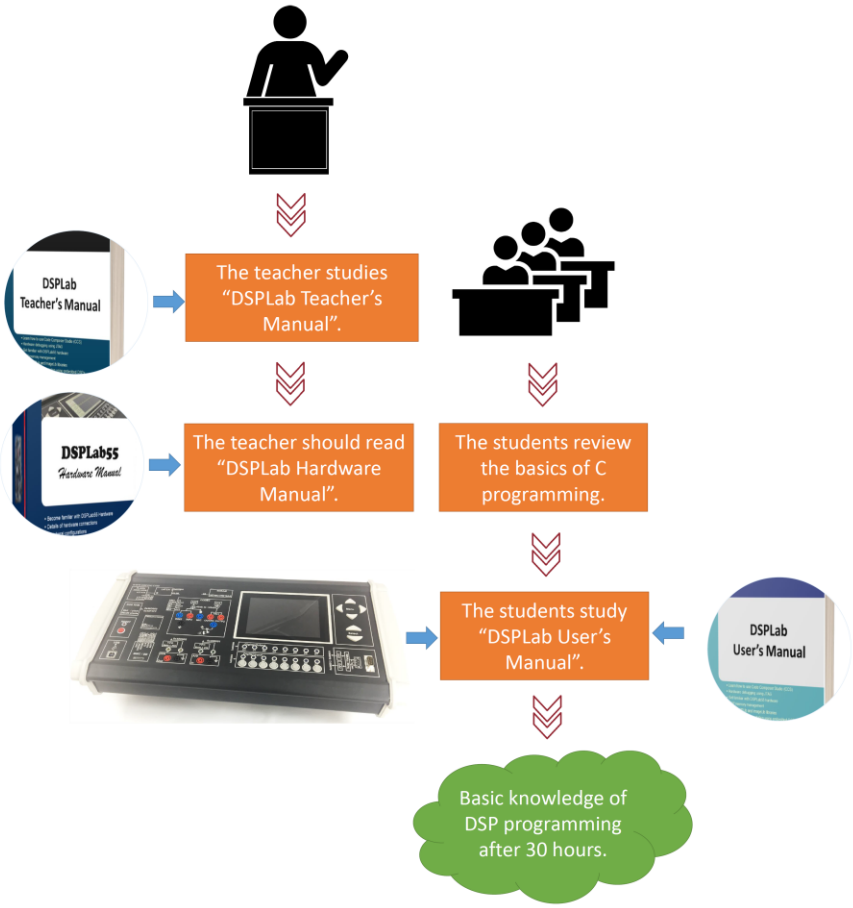

Figure 7: The first 30 hours of the DSP laboratory

The students can start from the 'DSPLab user's manual'. As the lab progresses, those interested in DSP programming can read the 'TI DSP step-by-step' book. It is important not to overwhelm students with too much information and documentation at the beginning of the lab. One of the problems of DSP Labs around the world is that they are famous for being a hard and tough lab. The DSPLab tries to make this process easy by slowly teaching the required skills and creating interest.

3.2) Part two

The next steps can be based on an individual student's goals and interests. For those who are more interested in mathematical signal processing, 'Real-Time Digital Signal Processing, Implementation, and Application' has many good examples. One or two chapters from this book can be assigned to each student as final Lab projects.

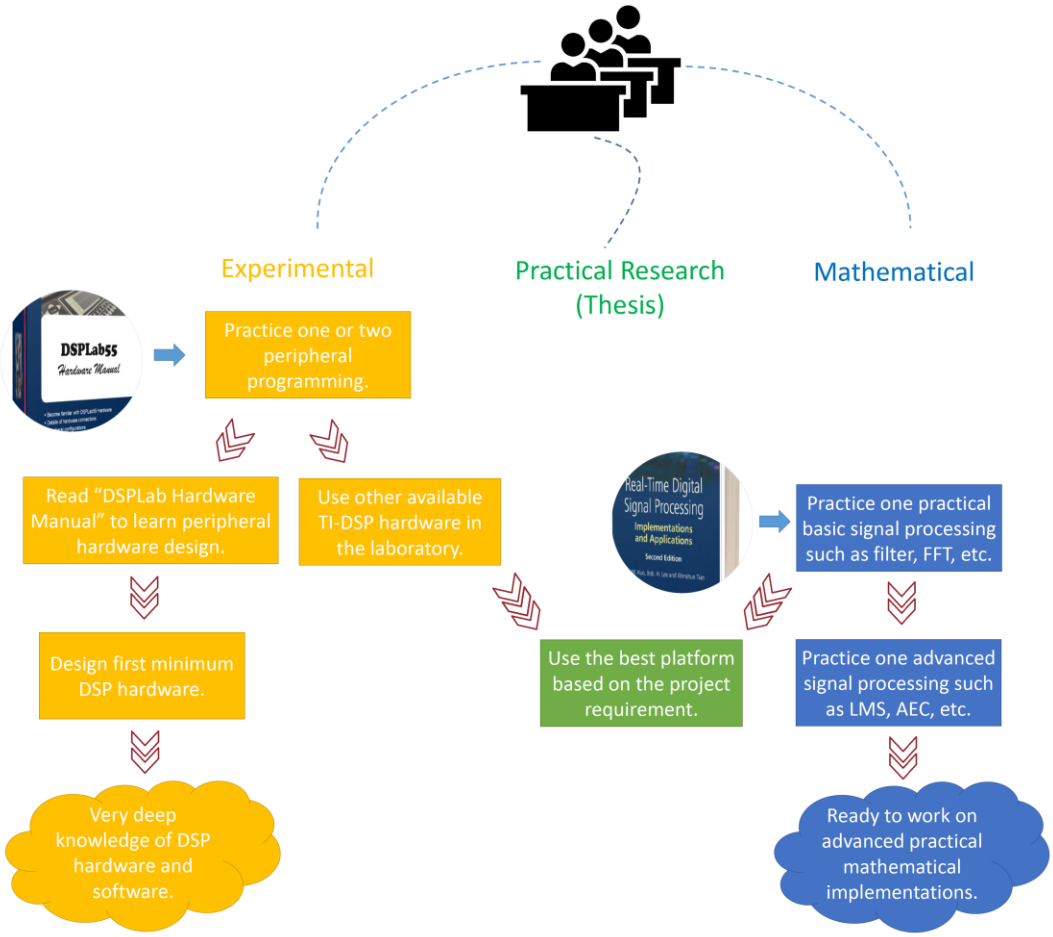

Figure 8: Possible roadmap after the first 30 hours of training

Those interested in practical DSP programming can choose a few chapters from "DSPLab Hardware Manual" and practice peripheral programming. It is recommended that all students start with the '*PLL*' chapter of the "DSPLab Hardware Manual." Each chapter of this book has a specific goal and focuses on a particular skill or knowledge.

As shown in Figure 8, some students who want to use DSP in their thesis (or any practical applications) should spend extra time in the laboratory. It is essential for them to gain sufficient experience before starting their applications. It may sometimes be tempting to skip some parts of training, but spending an extra 30 to 40 hours in the laboratory can give students valuable knowledge and confidence. Or, to save time, students may decide to work on chapters that will be used later in their thesis, but it is better to learn as much as possible before starting the thesis. Students may spend weeks later on a bug, which would be easy for an experienced designer to identify.

4) What should be expected from students after using DSPLab?

The goal is to learn TI signal processors in the shortest possible time. Learning DSP is not easy. But after 70 hours in the lab, the student should be able to do a small to medium size DSP software project. The TI documents and application notes are more suitable for those who are already familiar with TI DSPs. After attending the lab, the student should be able to work with other TI DSPs and SDKs.

Designing the DSP hardware is recommended mainly for students who have already designed other hardware and also read the 'DSPLab hardware manual'. It is highly recommended to start with a minimum system and then add new devices in the second revision.

5) The DSP family

Although DSPLab is based on the 55xx family, when using DSPLab, it is important to not focus only on the 55xx family. If other TI DSPs are available in the laboratory, students should work with other DSPs and at least run a few basic projects on each DSP. This creates confidence, and as the lab sessions progress, the student can apply their learning on other TI DSP platforms.

DSPgig has two other products with comprehensive documentation which can be used to learn about other families: F28M35H52C1 (C2000+ARM) and TMS320C6678 (C6600). When using in the DSP laboratory, only the first chapter of the documentation should be read by the instructor to teach advanced topics better.

It is highly recommended that the students spend enough time with DSPLab hardware before switching to any other project. DSP bugs are complicated and sometimes may take weeks to resolve only one bug. So learning DSP before engaging in an actual project is highly encouraged.

6) Prerequisites:

Students should be familiar with C/C++ language programming. It is not necessary to know C++, but it is helpful. Specifically, the students need to know the following C syntax:

1. Global and local variables.
2. 'int', 'char', 'long', 'float', structures, and unions.
3. 'for', 'while', 'if', 'else', 'extern'.
4. '#include', '#if', '#ifdef', '#else', '#endif', '#pragma'.

7) Is the team working possible?

Team working in the DSP laboratory is highly dependent on the equipment available in the laboratory. It is highly recommended that each student works alone. If that's not possible, the student should work alone at least for the first two lab sessions.

If there is not enough DSPLab hardware, students can share one DSPLab between multiple computers by connecting and disconnecting the JTAG USB cable.

8) What else is needed in the lab?

The only extra item needed besides DSPLab is a computer or a laptop with Code Composer Studio. The student may choose to use their own laptop.

DSPLab has an integrated oscilloscope that can show the input and output signals. The students can use the output signal as a signal generator and feed it to the input signal. So DSPLab includes all the equipment needed for the lab.

9) Can DSPLab be used for other projects?

Although DSPlab can be used for other projects, we highly recommend using other hardware for any project and only limiting DSPlab for training purposes. This ensures the hardware is safe and can serve the lab for years to come.

10) Why is DSPLab inside an aluminum box?

The DSP hardware is usually complicated. When students face DSP hardware for the first time, it creates fear and a mental push back. Even if they can do all the exercises with that hardware, some parts are still unknown. For example, inside DSPLab, there are two FPGAs, two DSP boards, and many more chips (in 5 different PCBs). It is essential to create confidence inside students and focus on what is important. By putting the hardware inside an aluminum box, we hide all the complexity.

11) What is inside the aluminum box?

In the current version, there are five boards (with an average size of 18cm x 12cm). The aluminum box is specially designed and cut for DSPLab. There are more than 50 plastic parts that are 3D printed for DSPLab. All parts, including PCB assembly, aluminum box CNC and bending, and 3D printing and painting, are currently done in the USA.