

Lab Manual:  
Communications Principles  
  
Using the EMONA Communications board for NI ELVIS III



Introduction

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## Introduction

The Communications Principles Lab Manual covers a broad range of introductory digital and analog telecommunications topics through a series of hands-on laboratory experiments. Each experiment is written to support the theoretical concepts introduced in the class work of a first course in modern telecommunications.

To make the student's learning experience more memorable, the student can view a variety of signals on the NI ELVIS III oscilloscope including their own voice undergoing the modulation or coding being investigated.

Each lab experiment presents an interesting, hands-on learning experience for the student. In each experiment the student is challenged to build, measure and consider: there are no “instant” or “cookbook-style” experiments. The EMONA Communications Board is actually a true engineering modeling system where students see that the block diagrams so common in their textbooks represent real functioning systems.

## Learning Objectives

After completing the labs in this manual, you should have the ability to complete the following actions.

1. Discuss the use of amplitude, frequency and phase in transmitting information in a signal.
2. Describe how the time and frequency domains expressions of a signal are related, and discuss how and why signals are shifted in frequency.
3. Describe the differences between continuous signals and discrete time (sampled) signals.
4. Explain the relationship between analog and digital signals in a communications context as well as describe the use of Fourier analysis.
5. Describe the concept of the transmission model of a communications system.
6. Construct various communications systems from their fundamental blocks.
7. Improvise solutions to be able to process signals using the available blocks.
8. Create new signals and systems using LabVIEW code both as a generator and receiver of signals.

## Prerequisites

Experiments in this volume have been prepared for students with only a basic knowledge of mathematics and a limited background in physics and electricity.

Students with a higher level of competence in mathematics will also gain a deeper understanding of telecommunications theory by using this system. Due to the engineering “modeling” nature of the board, they will be able to investigate more complex issues, carry out additional measurements and then contrast their findings to their theoretical understanding and mathematical analysis.

This lab manual was designed for students who have completed the following courses and have a working knowledge of the following hardware, software, and tools.

### Completed Courses

1. Basic mathematics
2. Introductory telecommunications lectures

### Hardware, Software, and Tool Knowledge

1. Basic test instruments e.g. Oscilloscope, Function Generator, Spectrum Analyzer
2. No software knowledge required

## Organization of the Lab Manual

Each experiment in this Lab Manual provides a basic introduction to the topic under investigation, followed by a series of carefully graded hands-on activities. After each sub section the student is asked to answer questions to confirm their understanding of the work before proceeding.

It should be noted that the included modules on the board can implement many more experiments than are documented in this Lab Manual and further experiments will be released in later manuals.

Finally, since the EMONA Communications board is a true modeling system, the instructor has the freedom to modify existing experiments or even create completely new experiments to convey new and course-specific concepts to students.

## Documented capabilities of the Emona Communications board

Lab 1: Introduction to the EMONA Communications Board

Lab 2: Modeling equations

Lab 3: FFT and Spectra

Lab 4: Amplitude Modulation

Lab 5: Amplitude Demodulation

Lab 6: DSBSC Modulation and Demodulation

Lab 7: SSB Modulation and Demodulation

Lab 8: FM Modulation

Lab 9: FM Demodulation

Lab 10: FSK

Lab 11: BPSK

Lab 12: QPSK

Lab 13: Introduction to DSSS

Lab 14: SNR and BER measurements

Lab 15: Principles of OFDM

Lab 16: Sampling, PAM and Nyquist

Lab 17: Carrier Acquisition with PLL

Lab 18: Carrier regeneration with Costas Loop

Lab 19: ASK Modulation and Demodulation

Lab 20: Principles of Superheterodyne

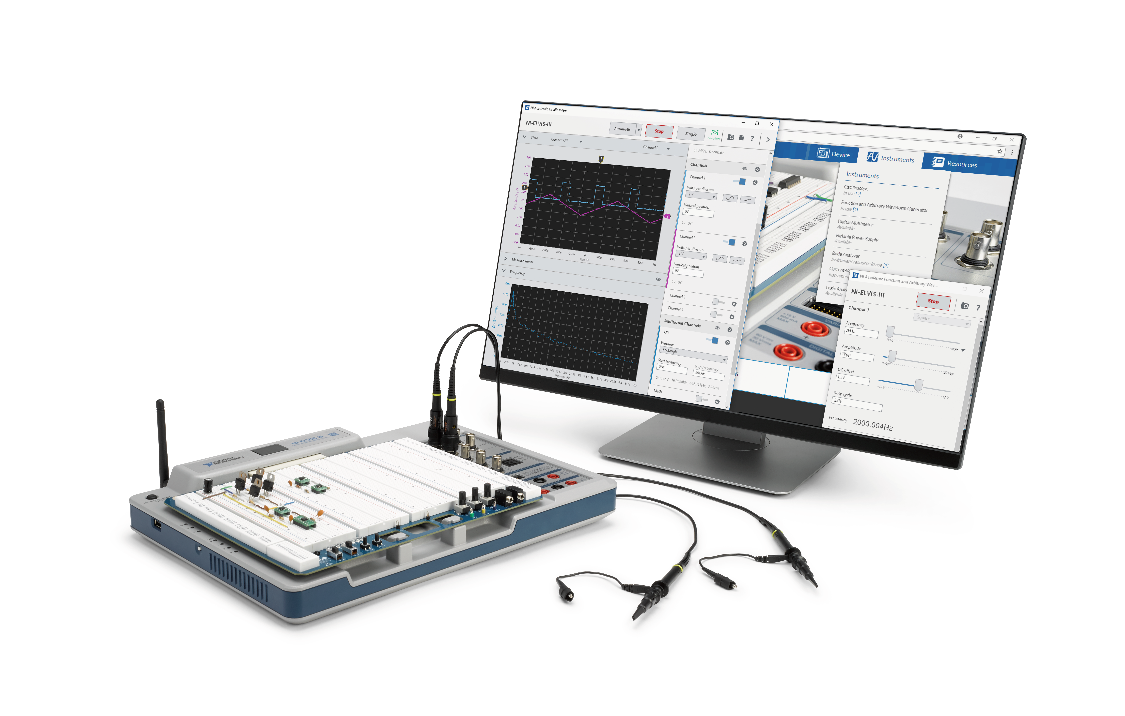
Lab 21: AM & FM via SDR using IQ signals

Lab 22: BPSK, DPSK & QPSK via SDR using IQ signals

Lab 23: OFDM via SDR using IQ signals

## Required Tools and Technology

### Platform: NI ELVIS III

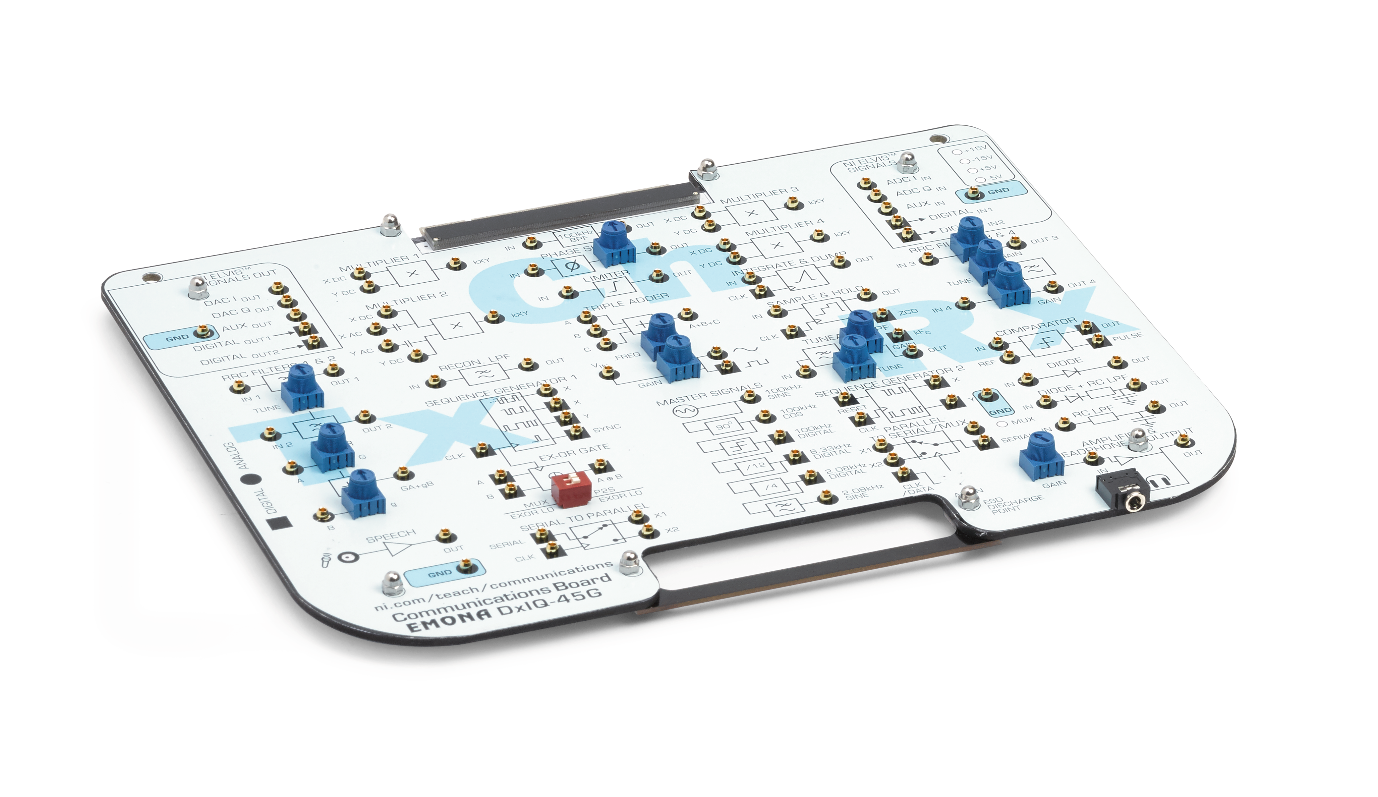


The NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) is an engineering laboratory solution for project-based learning that combines instrumentation and embedded design with a web-driven experience to create an active learning environment in the lab and studio and flipped classrooms, delivering a greater understanding of engineering fundamentals and system design. NI ELVIS addresses engineering curriculum by integrating project-based learning, teamwork, and design with course-specific application boards and labs developed by experts from education and industry. NI ELVIS, as a programmable platform, gives educators the ability to scale to future multidisciplinary applications driving student employability.

**

Learn more at [http://www.ni.com/en-us/support/model.ni-elvis-iii.html](http://www.ni.com/en-us/support/model.ni-elvis-iii.html%20)

### Hardware: Emona Communications Board



The Emona Communications Board is an application board for the NI ELVIS III developed to teach introductory digital and analog communications topics. The Emona Communications Board offers students the opportunity to build, measure, and experiment with communications systems commonly only theorized in textbooks which includes various modulation schemes, superheterodyne topology, restoring recovered data, and more communications architecture topics.



## Learn more at <http://www.ni.com/en-us/support/model.emona-communications-board-for-ni-elvis-iii.html>

## Background: Teaching methodology behind the “block diagram approach”

The Emona Communications board draws on a well-established experimental methodology that brings to life the “universal language” of telecommunications, the BLOCK DIAGRAM. Originally developed in the 1970’s by Tim Hooper, a senior lecturer in telecommunications at The University of New South Wales, Australia, and further developed by Emona Instruments, this modeling approach is used by thousands of students around the world, **to implement practically any form of modulation or coding**.

### Block Diagrams

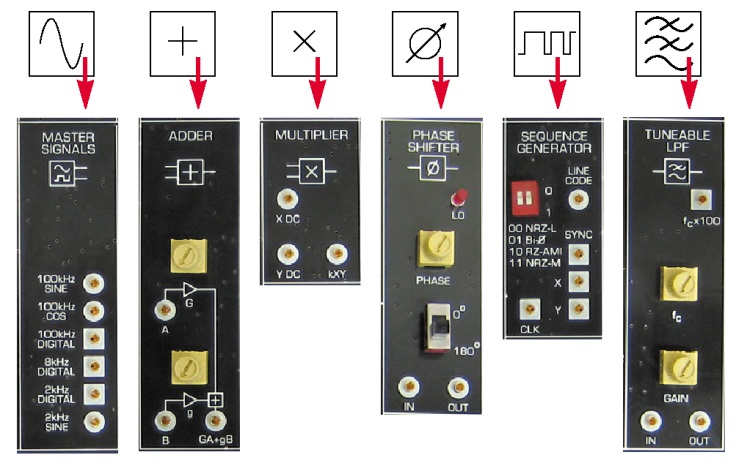
Block diagrams are used to explain the principle of operation of electronic systems (like a radio transmitter for example) without worrying about how the circuit works. Each block represents a part of the circuit that performs a separate task and is named according to what it does. Examples of common blocks in communications equipment include the *adder*, *multiplier, oscillator*, and so on.

Fig%202-P-1The board is a collection of blocks (called modules) that are patched together to implement dozens of telecommunications experiments. Experiments make use of the board together with the NI ELVIS III providing the instrumentation.

#### Figure 1: Example block diagram

This approach to implementing telecommunications experiments through realizing BLOCK DIAGRAMS has the following benefits in the educational environment:

* Students gain practical experience with true mathematical modeling hardware, designed specifically for implementing telecommunications theory.
* Students build each experiment stage-by-stage, in an engineering manner, by following the BLOCK DIAGRAM.
* Students are free to try “what-if” scenarios to validate their understanding of the theory being investigated, by viewing real, real-time electrical signals.
* The board is designed to allow students to make mistakes, hence students will learn from their hands-on experiences as they investigate their findings.



#### Figure 2: Example individual circuit blocks

### One-to-One Relationship

The figure above illustrates the one-to-one relationship between each block of the BLOCK DIAGRAM and the independent functional circuit blocks of the board.

The functional blocks of the board are used and re-used in experiments, just as blocks of the block diagram reappear in many different implementations, and just as LabVIEW blocks are interconnected to form program flows.

## Guidelines for Using the Lab Manual

This manual covers a broad range of telecommunications concepts, from fundamental topics familiar to all students, such as AM and FM broadcasting, through to the underlying technologies used in the latest mobile telephones and wireless systems. In each experiment, the core technology is revealed to the student, at its most fundamental level. The first chapters also provide a solid introduction to the NI ELVIS platform.

Chapters can be covered in any order; however, it is imperative that all students complete the first two chapters before proceeding to the subsequent chapters.

* Lab 1 introduces the EMONA Communications board
* Lab 2 introduces modeling equations with the board

### 

## Tips for Success

An important factor which makes the learning experience more valuable for the student is that the student can make wiring mistakes. Inputs and outputs can be connected in any combination, without causing damage. As the student builds the experiment, they need to make constant observations, adjustments and corrections. If signals are not as expected then the student needs to decide as to whether the correction required is an adjustment or an incorrectly placed patching wire.

Follow these tips to be more successful and avoid common pitfalls in this lab manual.

* Build and test each stage as you go. Be systematic.
* Confirm your expectations with measurements. Be precise.
* Confirm that measurements make sense as you go through each stage. Think about what you are doing and don’t rush ahead hoping that it will all work first time. Be realistic.

## Safety Precautions

**How to install and power up the DxIQ-45G with NI ELVIS III**

*Handling DxIQ-45G*

When holding the board, always hold the circuit board by the edges, as illustrated.

|  |  |
| --- | --- |
| C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_183048 (600 x 337).jpg | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162829.jpg |

|  |  |
| --- | --- |
| *Ensure NI ELVIS III Application Board* ***Power is OFF***  Before installing the board in the  NI ELVIS III Application PCI SLOT, always check the Application BOARD POWER switch is in the  OFF position. | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162521.jpg |
| *Installing board on  NI ELVIS III*  When installing the board in the NI ELVIS III PCI SLOT, always carefully check the alignment is correct before pushing | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_181337 (1032 x 580).jpg |
| C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162322.jpg  *The boards handle firmly engages with the holding brackets of the ELVIS III* | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162430.jpg  The board fully engages with the PCI connector on the back panel. |
| *Power up the ELVIS*  After board is correctly positioned, turn the NI ELVIS III Board Power switch ON by pressing the toggle switch on the back panel. | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162502.jpg |
| *Power up the board*  After board is correctly positioned, turn the NI ELVIS III Application Board Power switch ON by pressing the button in the back-left corner of the unit. | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162539.jpg |
| Before removing the board from the NI ELVIS III Application board SLOT, always **turn the Application board POWER switch OFF.** | C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\dxiq-board-on-elv3-pix\small\20180403_162521.jpg |

## ESD Warning – ESD Sensitive Product

**Caution** Although this product has been designed to be as robust as possible, ESD (Electrostatic Discharge) can damage or upset this product. This product must be protected at all times from ESD. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD precautions must be employed at all times.

The Emona DxIQ-45G board is designed and intended for use as an experimental platform for hardware or software in an educational/professional laboratory environment. To facilitate usage, the board is manufactured with its components and connecting traces openly exposed to the operator and the environment. As a result, ESD sensitive (ESDS) components on the board, such as the semiconductor integrated circuits, can be damaged when exposed to an ESD event. To indicate the ESD sensitivity of the Emona DxIQ-45G board, it carries the symbol shown at left.

**Unpacking, Transporting, and Storage**

When unpacking the Emona DxIQ-45G board from its shipping carton, do not remove the board from the antistatic packaging material until you are ready to complete the installation. Before unwrapping the antistatic packaging, discharge yourself by touching a grounded bare metal surface, touching an approved anti-static mat, or wearing an ESD strap. When transporting or storing the Emona DxIQ-45G board, first place it in an antistatic container or packaging.

**Handling and Setup**

Handling the Emona DxIQ-45G board can damage the board components if ESD prevention measures are not applied. Before handling or setup, equalize your potential with the board by touching one of the integrated ESD discharge pads. During all handling and setup, ESD prevention measures must be applied. In addition, the Emona DxIQ-45G board should be handled by the edges. Touching exposed circuits, components or connectors could result in an ESD event. When setting up Emona DxIQ-45G board, observe the following guidelines to minimize the potential impact of ESD:

• Patch the desired experiment blocks using 2mm patch cords.

• Set switches and other controls to initial settings.

• Ensure the NI ELVIS is powered correctly by plugging the NI ELVIS AC/DC power supply brick into an appropriate AC outlet.

• Move the board power switch ON.

**Operation**

When operating the Emona DxIQ-45G board, ESD can cause upset as well as damage to the board components. Therefore, apply ESD prevention measures whenever operating the Emona DxIQ-45G board. In addition, observe the following guidelines:

• Do not touch exposed traces or components on the board while the board is powered on.

• Exercise caution when manipulating switches, buttons, knobs, and other controls while the board is powered on.

**ESD Prevention Measures**

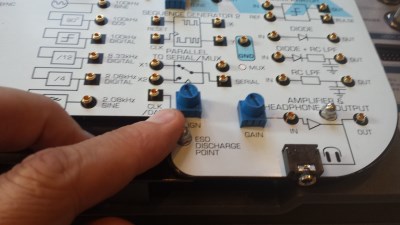
ESD prevention measures focus on reducing or eliminating the build-up of static charge that may result in an ESD event that could damage or upset sensitive electronics. To minimize the potential for an ESD event, implement the following measures:

• Perform all work at an approved work station.

• Use an approved antistatic mat to cover your work surface.

• Wear a conductive wrist strap attached to the antistatic mat and a good earth ground.

• Before handling or beginning work, equalize your potential with the board by touching one of the “ESD Discharge point” pads or a known ground point.



#### Figure 3:ESD discharge point; 1 of 8