1. Overview

The Digilent Analog Discovery 2™, developed in conjunction with Analog Devices®, is a multi-function instrument that allows users to measure, visualize, generate, record, and control mixed signal circuits of all kinds. The low-cost Analog Discovery 2 is small enough to fit in your pocket, but powerful enough to replace a stack of lab equipment, providing engineering students, hobbyists, and electronics enthusiasts the freedom to work with analog and digital circuits in virtually any environment, in or out of the lab. The analog and digital inputs and outputs can be connected to a circuit using simple wire probes; alternatively, the Analog Discovery BNC Adapter and BNC probes can be used to connect and utilize the inputs and outputs. Driven by the free WaveForms software, the Analog Discovery 2 can be configured to work as any one of several traditional instruments, which include:

Figure 1. The Analog Discovery 2.

- Two-channel oscilloscope (1MΩ, ±25V, differential, 14-bit, 100Msample/sec, 30MHz+ bandwidth - with the Analog Discovery BNC Adapter Board)
- Two-channel arbitrary function generator (±5V, 14-bit, 100Msample/sec, 12MHz+ bandwidth - with the Analog Discovery BNC Adapter Board)
- Stereo audio amplifier to drive external headphones or speakers with replicated AWG signals
- 16-channel digital logic analyzer (3.3V CMOS, 100Msample/sec)[1] [2]
- 16-channel pattern generator (3.3V CMOS, 100Msample/sec)[3] [4]
- 16-channel virtual digital I/O including buttons, switches, and LEDs – perfect for logic training applications [5] [6]
- Two input/output digital trigger signals for linking multiple instruments (3.3V CMOS)[7]
- Two programmable power supplies (0…+5V , 0…-5V). The maximum available output current and power depend on the Analog Discovery 2 powering choice:
  - 250mW max for each supply or 500mW total when powered through USB

    - 700mA max or 2.1W max for each supply when using an external wall power supply
- Single channel voltmeter (AC, DC, ±25V)
- Network analyzer – Bode, Nyquist, Nichols transfer diagrams of a circuit. Range: 1Hz to 10MHz
- Spectrum Analyzer – power spectrum and spectral measurements (noise floor, SFDR, SNR, THD, etc.)
- Digital Bus Analyzers (SPI, I²C, UART, Parallel)

The Analog Discovery 2 was designed for students in typical university-based circuits and electronics classes. Its features and specifications, as well as the additional requirements of operating from USB or external power, maintaining the small and portable form factor, the robustness to withstand student use in a variety of environments, and low-cost are based directly on feedback that was obtained from numerous professors from several universities. Meeting all of these requirements proved challenging; however, the task ultimately generated some new and innovative circuits. This document describes the Analog Discovery 2's circuits, with the intent of providing a better understanding of its electrical functions, operations, and a more detailed description of the hardware's features and limitations. It is not intended to provide enough information to enable complete duplication of the Analog Discovery 2, or to allow users to design custom configurations for programmable parts in the design.

Analog Discovery 2 is the next generation of the very popular Analog Discovery. The main improvements are:

- Ability to use an external power supply and consequently deliver more power to user supplies. When USB-powered, the Analog Discovery 2 delivers the same power as the Analog Discovery.
- New enclosure with enhanced design and improved connector reliability.
- Improved signal/noise and crosstalk performances for both the scope and waveform generator.
- Better defined bandwidth for both the scope and waveform generator.

1.1 Architectural Overview and Block Diagram

Analog Discovery 2's high-level block diagram is presented in Fig. 2 below. The core of the Analog Discovery 2 is the Xilinx® Spartan®-6FPGA (specifically, the XC6SLX16-1L device). The WaveForms application automatically programs the Discovery's FPGA at start-up with a configuration file designed to implement a multi-function test and measurement instrument. Once programmed, the FPGA inside the Discovery communicates with the PC-based WaveForms application via a USB 2.0 connection. The WaveForms software works with the FPGA to control all the functional blocks of the Analog Discovery 2, including setting parameters, acquiring data, and transferring and storing data.

Signals in the **Analog Input** block, also called the **Scope**, use “SC” indexes to indicate they are related to the scope block. Signals in the**Analog Output** block, also called **AWG**, use “AWG” indexes, and signals in the **Digital** block use a **D** index – all of the instruments offered by the Discovery 2 and WaveForms use the circuits in these three blocks. Signal and equations also use certain naming conventions. Analog voltages are prefixed with a “V” (for voltage), and suffixes and indexes are used in various ways: to specify the location in the signal path (IN, MUX, BUF, ADC, etc.); to indicate the related instrument (SC, AWG, etc.); to indicate the channel (1 or 2); and to indicate the type of signal (P, N, or diff). Referring to the block diagram in Fig. 2 below:

- The **Analog Inputs/Scope** instrument block includes:
  - **Input Divider and Gain Control**: high bandwidth input adapter/divider. High or low-gain can be selected by the FPGA
  - **Buffer**: high impedance buffer
  - **Driver**: provides appropriate signal levels and protection to the ADC. Offset voltage is added for vertical position setting
  - **Scope Reference and Offset**: generates and buffers reference and offset voltages for the scope stages
  - **ADC**: the analog-to-digital converter for both scope channels.
- The **Arbitrary Outputs/AWG** instrument block includes:
  - **DAC**: the digital-to-analog converter for both AWG channels
  - **I/V**: current to bipolar voltage converters
  - **Out**: output stages
  - **Audio**: audio amplifiers for headphone
- A precision **Oscillator** and a **Clock Generator** provide a high quality clock signal for the AD and DA converters.
- The **Digital I/O** block exposes protected access to the FPGA pins assigned for the Digital Pattern Generator and Logic Analyzer.
- The **Power Supplies and Control** block generates all internal supply voltages as well as user supply programmable voltages. The control block also monitors the device power consumption for USB compliance when power is supplied via the USB connection. When external power supply is used, the control block allows more power for the user supplies. Under the FPGA control, power for unused functional blocks can be turned off.
- The **USB Controller** interfaces with the PC for programming the volatile FPGA memory after power on or when a new configuration is requested. After that, it performs the data transfer between the PC and FPGA.
- The **Calibration Memory** stores all calibration parameters. Except for the “Probe Calibration” trimmers in the scope Input divider, the Analog Discovery 2 includes no analog calibration circuitry. Instead, a calibration operation is performed at manufacturing (or by the user), and parameters are stored in memory. The WaveForms software uses these parameters to correct the acquired data and the generated signals

In the sections that follow, schematics are not shown separately for identical blocks. For example, the Scope Input Divider and Gain Selection schematic is only shown for channel 1

since the schematic for channel 2 is identical. Indexes are omitted where not relevant. As examples, in equation 44 below, V_{indiff}Vindiff does not contain the instrument index (which by context is understood to be the Scope), nor the channel index (because the equation applies to both channels 1 and 2). In equation 33, the type index is also missing because V_{mux}Vmux and V_{in}Vin refer to any of *P*(positive), *N* (negative) or *diff* (differential) values.