Welcome!

- You should have an Analog Discovery module, a USB drive and a USB connector
- You should have a laptop or netbook PC
- Get started by installing the software on your PC:
  - Plug in USB drive
  - Software is at the root directory
  - Double-click on the filename
- Connect the Analog Discovery to your PC
  - Use USB connectors
Engineering Design in K-12 Education

Tim Hanshaw
Washington State University

ASEE June 2012

www.digilentinc.com
We need K-12 help

Percentage of high school students entering university expressing interest in EE/CptE/CS

Low Interest

Declining Enrollment

Overall University Enrollment
EE, CptE/CS Enrollment
EE, CptE/CS Graduates
A problem that affects us all

2-3 engineers leave the workforce for every new grad that enters
Roots of the problem

- Lecture → homework → test → repeat approach has limited effectiveness
- Students must be more engaged and involved in their own learning
  - Students who perform hands-on activities are more successful and interested in academic studies
Makers Are Learners

Student with their own kits...

• Learn more, learn faster, retain more
• Score higher on tests
• Complete more assignments
• Use fewer resources
• Enjoy their experience

[Bar charts showing exam scores and student evaluations for Rose Hulman Institute of Technology and Washington State University, comparing Student Owned Tools and Non-Student Owned Tools.]
Getting students involved and motivated

Engineering provides an ideal framework for bridging math/physics and the “real world”:

• A reason to apply math skills
• Develop abstract thinking skills (models vs. reality)
• Creating projects in an “open” but well-defined environment builds confidence and knowledge

Bonus! Students develop skills with real/critical job applications!
Why Digilent?

• Strong partnerships with leaders in technology (Analog Devices, Xilinx, Microchip, etc.)

• World leader in educational kits
  – Products in more than 1500 universities worldwide, used by more than 100,000 students/semester
  – Used in 90% of top schools
  – Active in PTLW, First, and academic research
Powerful Design Kits Built For Students
Robust, low-cost, always current, use free tools*

**Digital**
- Basys2
  - Xilinx Spartan 3E
  - $49
- Nexys3
  - Xilinx Spartan 6
  - $119

**Micro-Controller**
- ChipKIT UNO32
  - Microchip PIC32
  - $26
- Cerebot MX7
  - Microchip PIC32
  - $99

**Analog**
- Analog Discovery
  - Analog Devices Converters
  - 50 MSPS oscilloscopes, waveform generators, and digital I/O
  - $99
- Parts Kits
  - Starting under $10

[www.digilentinc.com](http://www.digilentinc.com)
Free Support Materials

On-line textbooks
- Lecture notes
- Exercises & Lab Projects with solutions

Complete Video Lecture Series
- “Classroom” lectures
- Lab/project videos
- Special topics

Reference Designs
- FPGA, MPU, Analog
Help us help you

• We will help you build a program at your school
• All you need are low-cost PC’s, Digilent design kits, and a few electronic parts
• We will help customize materials
  – What would you like to do in your classroom?
  – What kind of instructional resources would you want?
  – Drop by Digilent’s booth and chat
Let’s start the hands-on workshop

• We will use the Analog Discovery in this workshop

• The Analog discovery provides all capabilities necessary for test and measurement of analog circuits
  – Just add analog parts kit and WaveForms software!

$99 Student Price
Workshop Outline

1. Overview of tools we will use
   - Analog Discovery physical interface (connections to the electrical circuit)
   - Software used to control the Analog Discovery

2. Briefly recap goals and specific objectives of the workshop

3. Do some exercises to illustrate the Analog Discovery’s capabilities
   - Feedback appreciated relative to your assessment of its utility in YOUR classroom
WaveForms main window

- Controls inputs/outputs
- Analog instruments
  - Control power applied to circuits (*Voltage*, *WaveGen*)
  - Measure voltages (*Scope*)
- Digital instruments
  - We will ignore these
Fixed Power Supplies

- Connectors
- Waveforms *Voltage* instrument

Fixed voltage supplies
Variable Power Supplies (Waveform Generator)

- Connectors
- WaveForms **WaveGen** instrument

Waveform generators
Voltage Measurement (Oscilloscope)

- Connectors
- WaveForms *Scope* Instrument

![Oscilloscope Channels](image)
Remember our goals?

• Get students excited about engineering and math
  – Show students the building blocks of electric circuits
  – Relate to familiar systems
  – Expose students to engineering design methods
  – Demonstrate basic physical laws using real devices and real tools

• Establish foundations and framework for later studies
  – Intuit/understand physics, math, models that benefit students in many ways in many subjects
Analog Discovery’s Role

• The Analog Discovery provides the ability to apply voltages (signals) to a circuit or device and measure the response
  – Allows us to test our designs!
• Designs are based on mathematical models
  – Are abstract, can lack physical significance
• Implementing and testing circuits allows us to:
  – visualize concepts
  – develop insight into mathematics
  – relate theoretical models to reality
Example: Home Heating System

- Need to be able to design and test the individual components separately
- Have to apply signals to the components and measure their response
How does this relate to a circuit?
Application to introductory courses

• The overall circuit can be intimidating
• **However,** the individual “bits” **are** within the capabilities of a novice to implement
• Suggestion: Introduce the overall system in order to motivate implementation of simple sub-circuits
  – Students learn within the context of the familiar
  – Gives students a reason to care about the “boring” parts
  – Can sometimes sneak up on having them implement the overall (too complicated) circuit
How we will implement some “bits”

- Need individual components
- Need a way to interconnect them
- Need to apply power and make measurements
- Resistors, LED, speaker, capacitors...
- Solderless breadboard
- Analog Discovery module, WaveForms software and personal computer
“Solderless” Breadboard

- Circuit connections are made by inserting leads into holes in breadboard
- Five holes in each row are electrically connected
- The channel isolates the rows on either side
Concept: Voltage Division

• Traditionally, we present models (equations) and assume that the link to the real world somehow happens...

• Voltage divider

• Formula:

\[ V_2 = 5V \cdot \left( \frac{R_2}{R_1 + R_2} \right) \]

• Boring...
Better! Let's build a useful/real circuit using this concept...

- Use a resistor $R_1$ whose resistance changes predictably with temperature
  - “Thermistor”
- Then the voltage $V_2$ changes with temperature!
- We can use this to turn on the heater
Back to our home heating system
Example 1a: Temperature Measurement

• Connect circuit as shown
  – Connect Vp (+5V) to thermistor
  – Connect ground (\(\downarrow\), black wire) to resistor
  – Turn on Vp (Open Waveforms, click Voltage, Vp→Rdy, Power On)
  – Warm thermistor (grasp between thumb and finger)
  – Voltage across resistor increases!
Example 1b: Measure the temperature change

- But how do we know that the temperature changed?
- Oscilloscope provides a visual representation of the voltage
  - Add scope measurements to your circuit as shown
  - Open Scope instrument
    - Time Base: 5 s/div
    - C1 Offset: -2V
    - C1 Range: 500 mV/div
    - Click Run
Concept: Energy Conservation

• “Green” (energy conserving) systems are a recognized important topic

• We’ll do an example using a Light Emitting Diode (LED)
  – LEDs are intrinsically energy efficient

• We can improve their efficiency by “pulsing” the power applied to them
  – We are essentially switching the LED on and off very rapidly
  – Aside: This approach can also allow us to dim lights
Square Wave

• We can switch the LED on and off by applying voltage in the form of a “square wave”
  – The wave has “amplitude” and “period”
Light Emitting Diodes (LEDs)

- LEDs emit light if sufficient voltage provided to them (e.g., more than 2V)
  - They burn out if too much current is applied (e.g., more than 100mA for simple LED).
Example 2a: Time varying voltage to LED

• Connect circuit as shown

• Apply square wave with “WaveGen” instrument
  – Min frequency $\rightarrow$ 1Hz, Max frequency $\rightarrow$ 200Hz
  – Set frequency = 1Hz, amplitude = 3V, offset = 0V
  – Increase frequency slowly, observe response
Example 2b: Measure LED voltage

• Visually, LED response may not indicate actual circuit behavior at higher frequencies
  – Flashes too fast to perceive

• Use oscilloscope to determine response
  – Connect leads as shown
  – Time Base: 50 ms/div
  – C1 Offset: 0 V
  – C1 Range: 1 V/div
  – Click “Run”

• Repeat previous exercise
Example 2c: Reduce energy applied to LED

- We saw that the LED appears to be “on” if the frequency of the square wave is high
  - We are saving energy!
- Our square wave was “on” 50% of the time
  - Let’s reduce this and save more energy
- In waveform generator, select Symmetry
  - Choose 20% and examine LED response
  - Repeat previous exercise
- Try even smaller “on” times; now you have a dimmer
Now let’s look at audio applications

- Students play instruments & listen to music
  - Sounds can give insight into the math
- Sinusoids (math stuff)
  - \[ f(t) = A\cos(2\pi ft + \theta) \]
Example 3a: Creating sounds using AWG

- Connect circuit as shown

![Circuit Diagram]

- Use “WaveGen” instrument to apply sinusoid to speaker
  - 2kHz, 2V amplitude, 0V offset
  - Set symmetry = 50%, change frequency ranges!
Concept: Modulation

• Amplitude and frequency modulation are often used in communications (e.g. AM, FM radio)
• We will get some insight into frequency modulation by generating sounds
Frequency Modulation

• The frequency of one signal is varied according to the amplitude of a second signal.
Example 3b: Modulated signals

- Same circuit as before
- Modulate with triangle wave:
  - choose “Advanced” tab
  - Set “Carrier” to sine wave (2kHz frequency, 2V amplitude, 50% symmetry)
  - Set “FM” to 2Hz triangle with Amplitude 50%
- Run AWG1
- Try modulating with a square wave.
  - Should “toggle” between two tones
Example 3c: Play “scales”

• Same circuit as before

• Play “scales”
  – Text file provided with discrete values
  – AWG: Advanced
    • FM → Custom → Open File
      – Select scales.txt file
      – Set frequency = 500mHz, Amplitude = 100%
    • Carrier → Standard → Sine
      – Set frequency = 500Hz, Amplitude = 2V
  – Run AWG
Concept: Select frequencies to see and hear

- **Filters** are electrical circuits which “pass” signals with selected frequencies
- Common examples:
  - Bass, treble adjustments on audio systems
  - Speakers with both woofers and tweeters contain a crossover circuit which sends low frequencies to the woofer and high frequencies to the tweeter
Example 4: Low-pass filter

- Add capacitor to circuit of Example 2
  - The capacitor stores and releases energy
  - Basically, performs an integration
- LED “sees” only slowly changing voltages
  - Low pass filter
Example 4: Low-pass filter

- Add capacitor to circuit of Example 2 as shown to the right
- Apply sine sweep
  - Type → Sine, Sweep → On, Damp → Off
  - 1Hz → 200Hz in 10 seconds
  - Amplitude = 4V
- Monitor LED response as frequency changes
Thank You!

Please come see us in our booth...