AD101 — Signals

Use notes and chords to learn to read signals in time and in frequency, and to see what a filter does to them.

AD101 is the first course in the UofT ASIC Team's analog track, published at https://uoftasic.com/ad101/. It's for students who have finished IC101 and want to read the three plots analog engineers use every day: the waveform (voltage against time), the spectrum (how strong each frequency is) and the Bode plot (what a circuit does to each frequency).

The course uses music as its running example. A single signal plays the part of a note, a chord is several signals added together, timbre is the recipe of harmonics in a sound, and a filter works like a tone knob. You don't need any musical background to follow it.

Before you start

Prerequisite	IC101: Docker and the IIC-OSIC-TOOLS noVNC desktop working, with the shared `workspace` repo from IC101 cloned. The labs run inside that workspace.
Math	High-school level: sines, logarithms and basic algebra. You won't need calculus.
Tools	Python, numpy and matplotlib, which are already installed in IIC-OSIC-TOOLS
Time	About 10 hours 20 minutes: 2 hours 50 minutes of reading and 7.5 hours of labs, not counting the optional spectral-leakage part at the end of Lab 03

What you'll learn

1. Read a voltage against time the way you'd read an oscilloscope: amplitude, frequency, phase, DC offset
2. Build complicated waveforms from simple sines, and see their spectra
3. Use the frequency domain to find tones that time plots hide
4. Read a Bode plot and watch an RC filter reshape a square wave
5. Write your own signal-analysis script, and listen to what a filter does to a chord

Course path

The guide pages are grouped into four units, which the course calls movements, and each movement is followed by a lab. A capstone lab comes last. Work down this table in order. The Read rows are guide pages, with concepts, figures and worked examples but nothing for you to run; the Do rows are labs, which is where you run everything. The times are estimates, and they add up to the total above.

#		What	Time
1	Read	Getting started, then Movement I, a single note: What is a signal? · Pitch and loudness · A family of waveforms · Two voices in time	50 min
2	Do	Lab 01: Signal explorer. Load AD101, then predict and measure a sine's pe-	1.5 h

#		What	Time
		riod, peak-to-peak, RMS and phase delay.	
3	Read	Movement II, chords and timbre: Adding signals · Timbre and harmonics · Rhythm and duty cycle	30 min
4	Do	Lab 02: Harmonic builder. Build a square wave from sines, predict its harmonic amplitudes, and watch duty cycle change its spectrum.	1 h
5	Read	Movement III, the mixing board: The FFT as an equalizer · Finding a quiet note · Distortion and THD · Sampling fast enough	45 min
6	Do	Lab 03: Spectrum detective. Find a hidden tone and check your answer with a script, measure total harmonic distortion (THD), and make a tone alias.	1.5 h
7	Read	Movement IV, tone controls: Filters are tone knobs · Reading a Bode plot · Filtering a beat · More filter shapes	45 min
8	Do	Lab 04: RC filter and Bode. Predict an RC low-pass's cutoff and gain, check them on a Bode plot, and filter a square wave.	1.5 h
9	Do	Lab 05: Signal workshop. Write your own chord synthesizer, spectrum plot and filter, then listen to the result.	2 h

Three reference pages are worth keeping open while you work: Reading plots is a cheat sheet for the three plots, Music and signals translates each musical term and lists note frequencies, and Python in the workbench covers running the labs and what to do when a plot window won't open.

After AD101

- AD102: Linear Circuits & Fabrication
- AD103: Nonlinear Circuits (XSchem)
- AD104: Layout (Magic / Netgen)