

Physics 193POM/Physics 406POM
Acoustical Physics of Music/Physics of Musical Instruments
Lab Setups/Lab Equipment

1. Portable Sound Pressure Level Meter:

- Extech 407768 hand-held/portable sound pressure level meter, has PC RS-232 interface & software. Use for measuring/mapping out ambient sound level(s) in room as function of position, *etc.* Absolute calibration is of SPL meter is done using Extech 407766 94/114 dB calibrator unit.

2. Harmonic Analysis of Arbitrary Periodic Waveforms:

- Use choice of mics with Marantz PMD671 stereo 24-bit recorder (or e.g. Alesis ADAT HD24XR 24-channel, 24-bit recorder) to record sounds (short duration, steady tones) from *e.g.* musical instruments, arbitrary sound sources, *etc.* Transfer *.wav format sound files to PC for harmonic analysis using MatLab-based Wav_Analysis program, or manipulation with *e.g.* Sound Forge 10.0.
- Real-time FFT/harmonic analysis using Hewlett-Packard HP-3562A Dynamic Signal Analyzer, read out to PC via GPIB using National Instruments LabVIEW HP3562A.vi.
- Measure/capture/record waveforms on Tektronix digital scope, transfer waveform data to PC for inclusion with harmonic analysis info.
- Tektronix scopes can also carry out real-time FFT. Transfer FFT data to PC for offline use.

3. Measurement of Complex Impedance and Sound Intensity of Acoustic / Brass / Wind Instruments

- Use computer-controlled sine-wave function generator to excite piezoelectric transducer
- Use tiny omni-directional pressure mic and a differential pressure mic to measure complex pressure, p and complex particle velocity, u – referenced to phase of sine wave from function generator, using lock-in amplifiers.
- PC DAQ system records complex p and complex u at each frequency, calculates complex impedance $Z = p/u$ and complex sound intensity $I = pu^*$.
- Sine-wave function generator can be stepped over the entire audio range (and higher, if needed) e.g. in 1 Hz steps (fine) or 10 Hz steps (coarse) resolution.
- DAQ program displays ~ 25 online plots, writes out data file for off-line analysis.

4. Acoustic Holography

- A similar DAQ setup to that of # 3 above can be used to scan the modal vibrations of vibrating objects – *e.g.* drum heads, vibrating plates, acoustic guitar tops, violins, *etc.*

5. Measure Propagation Speed Of Sound In Free Air

- Use dedicated setup – very short pulse from function generator, piezo-transducer, UIUC pressure nano-mic on optical bench + oscilloscope to measure propagation delay time *vs.* propagation distance.

6. Measurement of Electric Guitar Pickup Properties/Pickup Performance:

- DMM for measuring pickup DC resistance, R_{dc} .
- Ordinary compass for measuring magnet polarity/mapping B-fields.
- Hall Probe for measuring magnetic pole strengths/mapping B-fields.
- HP 4262A LCR meter for measuring pickup inductance, L & dissipation, D at 3 frequencies – 120 Hz, 1 KHz and 10 KHz (low signal/low power level).
- PC-based DAQ system for measuring pickup complex impedance, $Z(f)$ vs. frequency using current injection technique (Pickup2.prj) over audio frequency range – *i.e.* 5 Hz to 20 KHz in 10 Hz frequency steps.
- PC-based DAQ system for measuring pickup impedance, $Z(f)$ vs. frequency using high-speed air drill (60,000 rpm = 1 KHz max) *i.e.* mechanical pickup excitation method (Drill1.prj).
- PC-based DAQ system for measuring pickup complex impedance, $Z(f)$ vs. frequency using magnetic coupling technique – direct excitation of strings of guitar using a sine wave/function generator (???.prj).
- HP 3563A Dynamic Signal Analyzer-based system for measuring impedance of electric guitar pickups as a function of frequency (HP3562A.prj) – uses Fourier Transform/cross correlation method.

7. Measurement of Loudspeaker Properties/Loudspeaker Performance:

- DMM for measuring loudspeaker voice coil DC resistance, R_{dc} .
- Compass for measuring magnet polarity/mapping B-fields.
- Hall Probe for measuring magnetic field strengths/mapping B-fields.
- HP 4262A LCR meter for measuring loudspeaker inductance, L and dissipation, D at 3 frequencies – 120 Hz, 1 KHz and 10 KHz (low signal/low power level).
- PC-based DAQ system for measuring loudspeaker impedance vs. frequency using current injection technique (Speaker2.prj). Offline analysis – determine some of the Thiele-Small parameters associated with loudspeakers.
- Agilent Function Generator, HP-3562A Dynamic Signal Analyzer (interfaced to PC via GPIB), DMM and Tektronix digital oscilloscope for measuring/mapping out harmonic content vs. driving amplitude of sine wave – different for different kinds of speakers, and good vs. bad sounding speakers.
- Software for loudspeaker enclosure design and cross-over network design.

8. Measurement of Tube Amp Output Transformer Properties/Performance:

- DMM for measuring output transformer winding DC resistances, R_{dc} .
- HP 4262A LCR meter for measuring output transformer winding open-circuit and short-circuit inductances, L at 3 frequencies – 120 Hz, 1 KHz, 10 KHz (low signal/low power level). Calculate turns ratio and primary load impedance for chosen secondary load impedance, calculate % leakage of primary & secondary windings of output transformer.
- Function generator, DMM and oscilloscope for measuring transformer turns ratio *e.g.* at fixed/reference frequency (1 KHz) or as a function of frequency. Calculate primary load impedance for chosen secondary load impedance.

- Variac, DMM and oscilloscope for measuring transformer turns ratio at 60 Hz line frequency. Calculate primary load impedance for chosen secondary load impedance.
- PC-based DAQ system for measuring transformer response as a function of frequency (Xfrmr1.prj).

9. Measurement of Mechanical Vibrational Resonances of Musical Instruments:

- HP 3563A Dynamic Signal Analyzer-based system for measuring mechanical vibrational response (mechanical impedance/admittance) *e.g.* of an acoustic or electric guitar as a function of frequency (HP3562A.prj) – uses Fourier Transform/cross correlation method.
- PC-based DAQ system for measuring complex mechanical vibrational response (mechanical impedance/admittance) *e.g.* of an acoustic or electric guitar and/or other stringed instruments as a function of frequency (Sonic1.prj).
- PC-based DAQ system for measuring/mapping out complex spatial dependence of mechanical vibrational modes *e.g.* of an acoustic or electric guitar and/or other stringed instruments at specific resonance frequenc(ies) (Resonant1.prj).
- PC-based DAQ system for measuring complex spatial modes of vibration *e.g.* of percussion instruments – drums, cymbals, *etc.* (Modal_Vibes.prj).

10. Measurement of Non-Linear Current-Voltage (I-V) Relations:

- PC-based DAQ system for measuring current-voltage relation of diodes and other non-linear 2-lead devices (such as varistors) (IV2.prj) used *e.g.* in distortion boxes for electric guitars.

11. Measurement of Capacitor Properties:

- Electronics setup for measuring capacitor properties – capacitance, frequency and voltage-dependent non-linearities, dissipation, *etc.*
- PC-based DAQ system for measuring complex impedance of real capacitors, *i.e.* including ESR vs. frequency (Capacitance.prj).

12. Measurement of Vacuum Tube Properties:

- Hickock Vacuum Tube Testing Machine.
- PC-based DAQ system for measuring tube rectifier properties (RectPar1.prj)
- PC-based DAQ system for measuring triode tube properties (TrioPar5.prj)
- PC-based DAQ system for measuring power tube properties (PowerPar1.prj)
- PC-based DAQ system for measuring properties of dual-triode vacuum tube voltage amplifier(s) (TrioAmp1.prj).

13. Measurement of Harmonic Signal Decay Associated with Musical Instruments:

- PC-based DAQ program that measures harmonic (*i.e.* Fourier) content of musical signal as a function of time, thereby enabling *e.g.* studies of frequency-dependent harmonic decay (TimeFreqAnalysis.vi).

14. Investigation of Consonance/Dissonance:

- Electronics setup (4 DMMs, 4-channel analog mixer, oscilloscope) for investigating consonance & dissonance.
- Electronic Keyboard and oscilloscope.

15. Psycho-Acoustics Facility:

- Electronics setup (2 DMMs, headphones) for investigating physics of human hearing – e.g. frequency response, phase sensitivity, perfect pitch, etc.

16. Measurement of Percussion Instrument Properties:

- PC-based DAQ setup for measuring frequency response of percussion instruments (Strike once with sound analysis options.vi).

17. Computer Simulation(s) of Complex Waveforms, Guitar String Vibrations:

- PC-based program that simulates plucking of guitar string, shows/displays the harmonic (*i.e.* Fourier) content and plays the actual sound (guitar.prj).
- PC-based program that enables user to investigate harmonic (*i.e.* Fourier) content of ~ 25 different waveforms – sine waves, triangle waves, saw-tooth waves, square waves, gaussian waves and various other waves (Fourisim.prj)

18. Force-Hammer Experiments: Measure the complex mechanical modal vibrations & mechanical admittance of vibrating objects – *e.g.* bars, guitars, guitar bridges, ... using force hammer technique(s).

19. Ultra-Sound Experiments:

- Investigate the phenomenon of sonoluminescence/ultra-sound waves in water.