ALPhA Advanced Laboratories

ALPhA's Laboratory Immersions

Noise Fundamentals

Buffalo State College, July 9–12, 2017.

One or two set-ups available

Host and Mentor

George Herold (B.S. 1983, Ph.D. 1993, Univ. of Buffalo) is Senior Scientist at Teachspin, Inc. For over ten years he has been designing and building physics teaching apparatus for TeachSpin. The Noise Fundamental apparatus is mostly his design, and he'll be happy to share circuit details. There is much untapped potential in this apparatus; he will be glad to talk about other noise experiments possible with this apparatus or showing up in current research.

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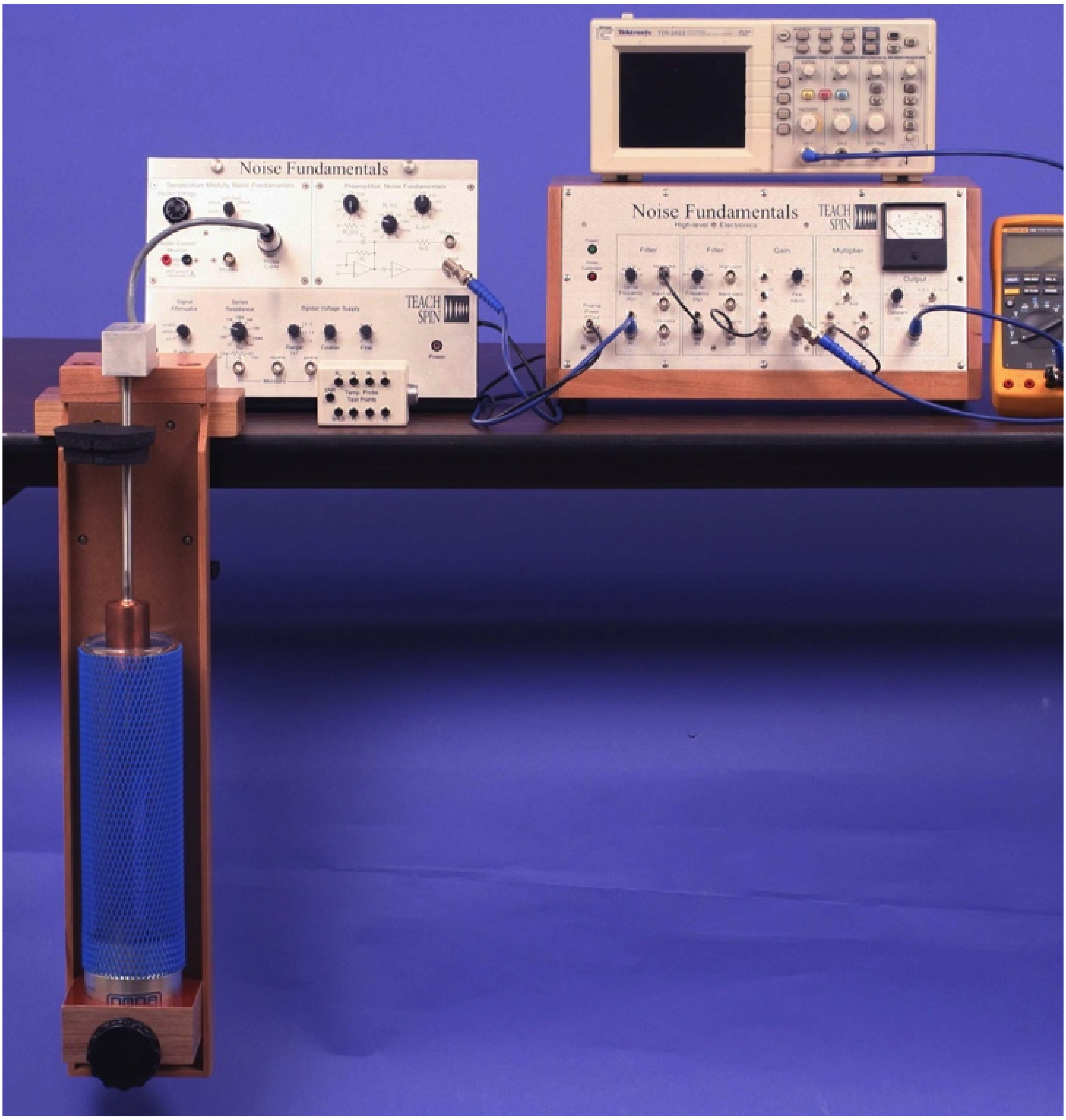
This Immersion will enable participants to investigate electronic noise. We may touch lightly on electro-static and magneto-static interference, but the focus will be on the fundamental sources of noise: the thermal or Johnson noise in resistors ($v_n^2 = 4Rk_BT\Delta f$) and the shot noise that is present in some currents ($i_n^2 = 2eI_{DC}\Delta f$). These investigations have two main motivations. First, many experiments in physics involve electrical signals, and where we are interested in making the signal to noise ratio as large as possible, these fundamental noise sources set a limit on such capabilities. An understanding of these fundamental sources can guide us when designing an experiment, and allows us to know when the limit has been reached. Second, an accurate measure of noise can lead to a determination of some physical constants. Johnson noise can be used to determine Boltzmann's constant (k_B) or the absolute temperature (T). And shot noise can be used to measure the charge on the electron (e).



The immersion will use the Noise Fundamentals apparatus developed by Teachspin. Additional equipment—a digital oscilloscope, a good voltmeter, and a signal generator—will all be provided. Participants need only bring a calculator, pencil and notebook. We will start by discussing the signal chain, and do some straightforward electronic measurements of gain and bandwidth (Δf). Then we will measure the Johnson noise as a function of bandwidth. This motivates the "units of noise", V^2/Hz and V/√Hz. Then we will look at the dependence of Johnson noise on resistance (R) and (time permitting) the temperature.

On the second day we'll reconfigure the pre-amp electronics to be a trans-impedance amplifier (much less scary than it sounds), learn a bit on how to capacitively compensate the gain, and then investigate shot noise from a light bulb shining on a photodiode to make a measurement of the electron charge. Time permitting; we might also look at currents that do not display full shot noise.

Please note that the Jonathan F. Reichert Foundation has established a grant program (ALPhA webpage; Foundation website) to help purchase apparatus used in Laboratory Immersions. Limitations and exclusions apply, but generally speaking the foundation may support up to 40% of the cost of the required equipment.