

P524: Survey of Instrumentation and Laboratory Techniques

Week 3 (1c): PCB layout and
circuit simulation

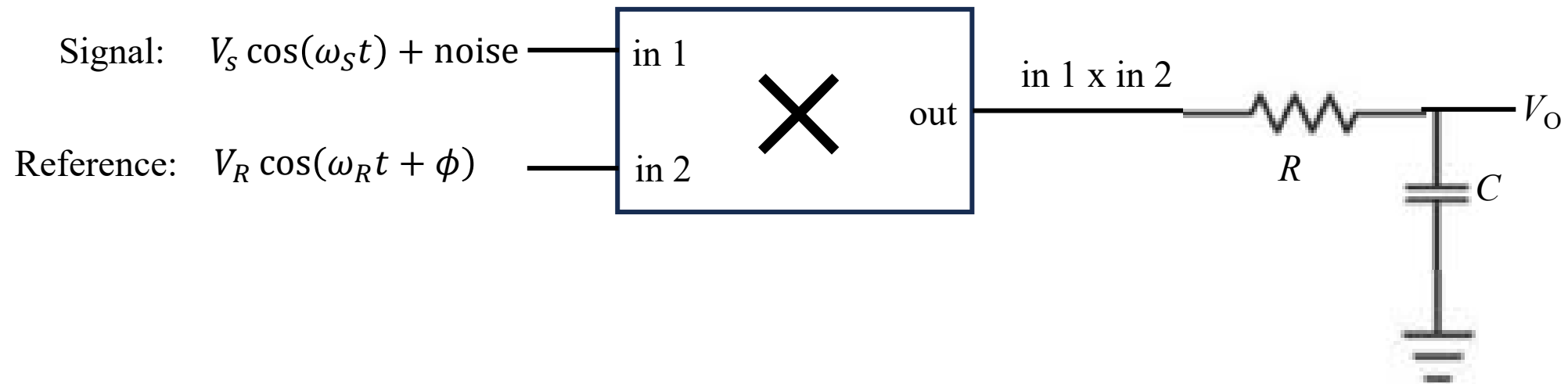
Printed Circuit Board (PCB) software: KiCAD

- Schematics, PCB layout, 3D visualization, SPICE (circuit simulation) interface
- Previous: EAGLE (from Autodesk)
 - No longer supported by Autodesk (June 2026)
 - Cumbersome installation

Example from Physics P404 (Electronics): Lock-In Amplifier

Suppose we have some (usually) small signal with unknown amplitude V_S and known frequency ω_S :

Simple model:



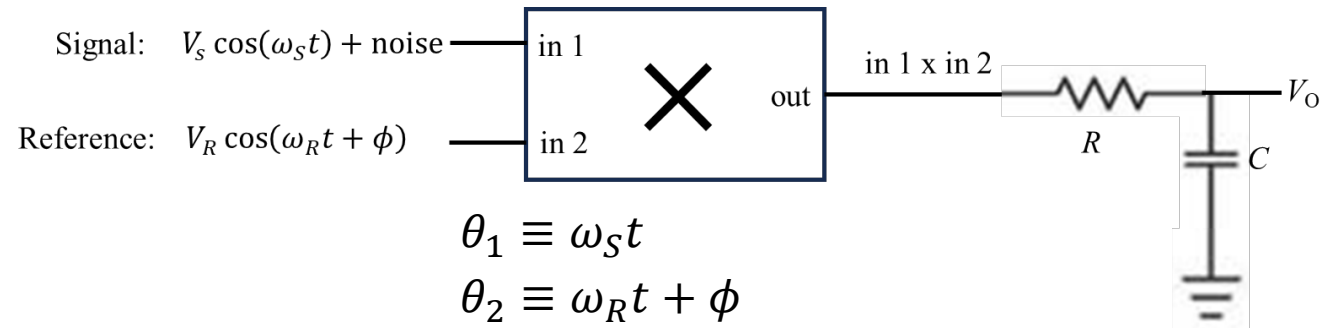
Lock-In Amplifier

$$\cos(\theta_1 + \theta_2) = \cos \theta_1 \cos \theta_2 - \sin \theta_1 \sin \theta_2$$

$$\cos(\theta_1 - \theta_2) = \cos \theta_1 \cos \theta_2 + \sin \theta_1 \sin \theta_2$$

$$\cos(\theta_1 + \theta_2) + \cos(\theta_1 - \theta_2) = 2\cos \theta_1 \cos \theta_2$$

$$\cos \theta_1 \cos \theta_2 = \frac{1}{2}\cos(\theta_1 + \theta_2) + \frac{1}{2}\cos(\theta_1 - \theta_2)$$



$$\theta_1 \equiv \omega_s t$$

$$\theta_2 \equiv \omega_R t + \phi$$

$$V_s \cos(\omega_s t) V_R \cos(\omega_R t + \phi) = \frac{V_s V_R}{2} \cos(\omega_s t + \omega_R t + \phi) + \frac{V_s V_R}{2} \cos(\omega_s t - \omega_R t - \phi)$$

$$V_s \cos(\omega_s t) V_R \cos(\omega_R t + \phi) = \frac{V_s V_R}{2} \cos((\omega_s + \omega_R)t + \phi) + \frac{V_s V_R}{2} \cos((\omega_s - \omega_R)t - \phi)$$

Low-pass filter with cutoff frequency $(\omega_s - \omega_R) < \omega \ll (\omega_s + \omega_R)$:

$$V_O = \frac{V_s V_R}{2} \cos((\omega_s - \omega_R)t - \phi)$$

Choose $\omega_R = \omega_s$: $V_O = \frac{V_s V_R}{2} \cos \phi$

Choose ϕ to maximize V_O : $V_s = \frac{2V_O}{V_R}$

In-class assignment and Homework (due 9/17)

- Download and install KiCAD (<https://www.kicad.org/download/>)
- Finish the lock-in amplifier PCB
- email finished KiCAD project to jcl11@illinois.edu