P524: Survey of Instrumentation and Laboratory Techniques

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

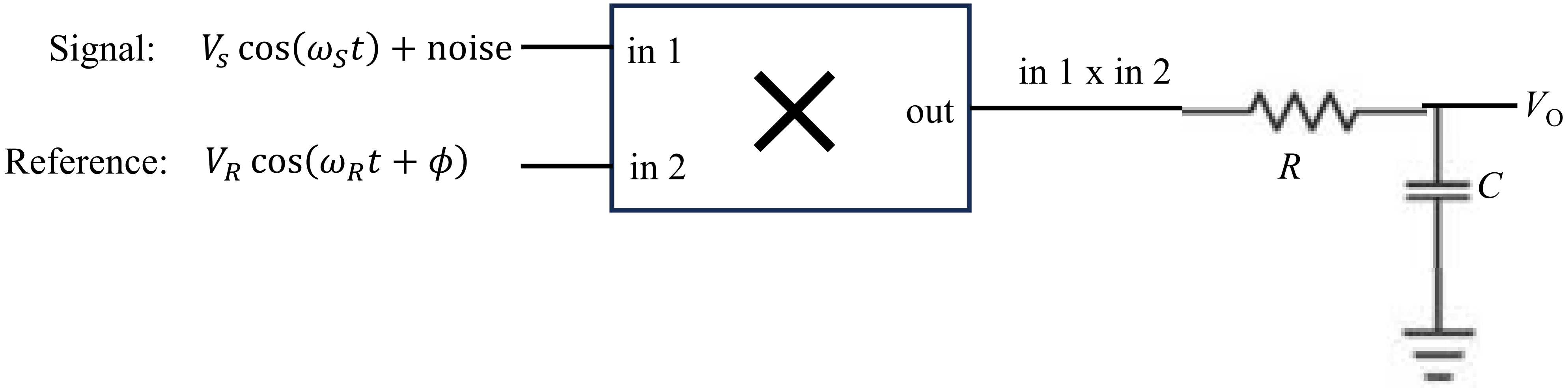
Printed Circuit Board (PCB) software: KiCAD

- 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:

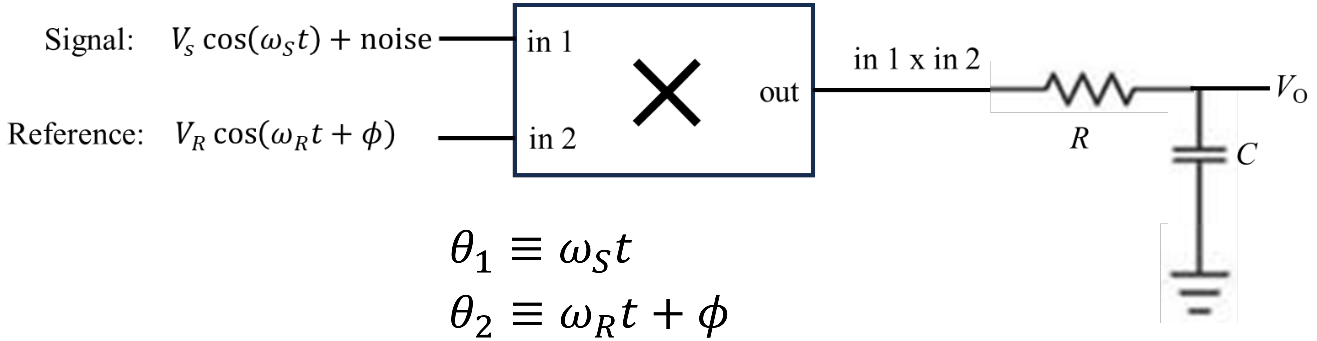
Simple model:



Lock-In Amplifier

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

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



$$\theta_1 \equiv \omega_S t$$
$$\theta_2 \equiv \omega_R t + \phi$$

$$V_S\cos(\omega_S t)\,V_R\cos(\omega_R t+\phi) = \tfrac{V_S V_R}{2}\cos(\omega_S t+\omega_R t+\phi) + \tfrac{V_S V_R}{2}\cos(\omega_S t-\omega_R t-\phi)$$
$$V_S\cos(\omega_S t)\,V_R\cos(\omega_R t+\phi) = \tfrac{V_S V_R}{2}\cos\big((\omega_S+\omega_R)t+\phi\big) + \tfrac{V_S V_R}{2}\cos\big((\omega_S-\omega_R)t-\phi\big)$$

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

$$V_O = \tfrac{V_S V_R}{2}\cos\big((\omega_S-\omega_R)t-\phi\big)$$

Choose $\omega_R = \omega_S$: $V_O = \tfrac{V_S V_R}{2}\cos\phi$

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

In-class assignment and Homework (due 9/18)

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