Op-Amp Integrators and Oscillators

Op-Amp Integrator

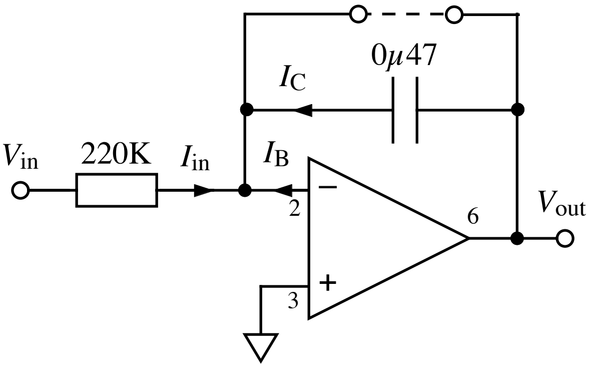
Milestone 0

Circuit 4.1 is a naive design for an integrator. Initially, the input voltage $V_{\mathrm{in}} = -12\,\mathrm{mV}$ and the capacitor is short-circuited. At time $t = 0$ the short-circuit is removed. Describe what would happen to the output voltage if all the components were ideal. Construct the circuit using a 741 op-amp and measure how it behaves in practice. Use a potential divider to generate the 12 mV DC input.

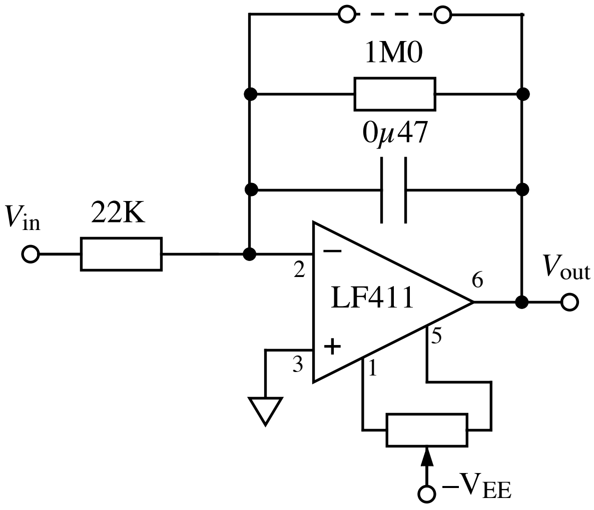
Milestone 1

Circuit 4.2 is an improved integrator design – build it using an LF411 type op-amp. The power supply will need to be decoupled with a capacitor of approximately $0.1\,\mu\mathrm{F}$ between ground and each supply rail. Adjust the input voltage offset ('balance' on the data sheet) with the feedback capacitor short-circuited. Remove the short-circuit and measure the rate (*i.e.* in volts per second) at which the output drifts over a period of a minute. Test the circuit using a 100 Hz square-wave of zero mean and peak-to-peak amplitude 1 V. Note that it is the different **input-bias current** I_{B} specifications of the two types of op-amps is responsible for the different performance.

Milestone 2



Circuit 4.1 Naive Integrator



Circuit 4.2 Practical Integrator

Calculate the frequency response of circuit 4.2 assuming that the op-amp is ideal and plot the results as a **Bode plot** using the graph-paper supplied. What is the purpose of the 1 MΩ resistor, and over what frequency range does circuit 4.2 behave as an integrator? Measure the frequency response (1 Hz to 10 kHz) of your circuit (using an oscilloscope and sine-wave generator) at no more than 16 representative points which should also be plotted on your Bode plot.

Milestone 3

Oscillators

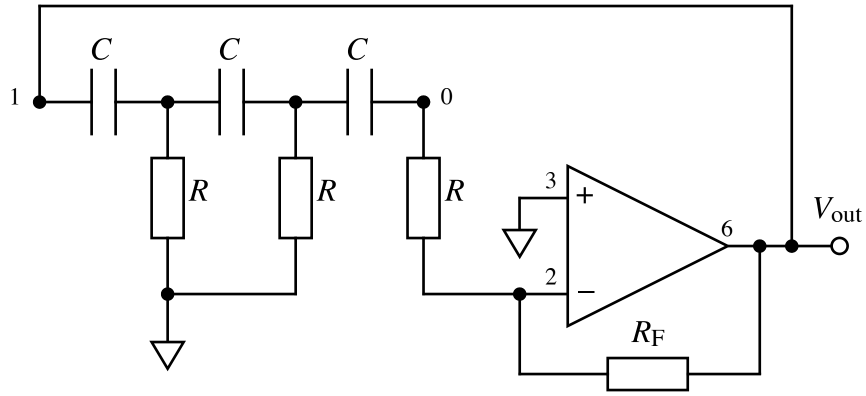
Circuit 4.3 is a loop comprising an amplifier of gain $\mathbf{G} = \mathbf{V}_1/\mathbf{V}_0$ and a feedback network coupling fraction **B** of the voltage at node 1 back to node 0. **B** is given by

$$\frac{1}{\mathbf{B}} = \frac{\mathbf{V}_1}{\mathbf{V}_0} = \left(1 - \frac{6j}{\omega CR} - \frac{5}{(\omega CR)^2} + \frac{j}{(\omega CR)^3}\right). \qquad (4.1)$$

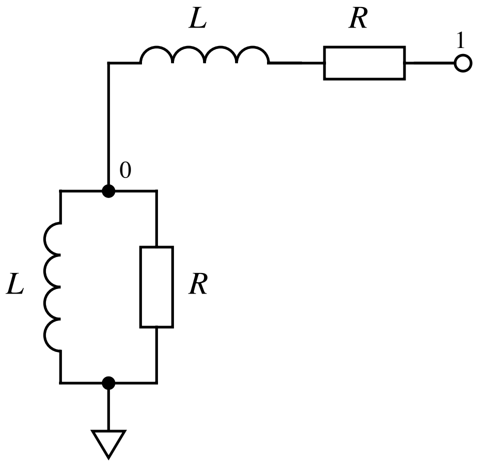
The **Barkhausen Criterion** applied to this circuit indicates that it will oscillate at frequency ω when $\mathbf{G}(\omega)\mathbf{B}(\omega) = 1$. Find the value of ωCR for which $\mathrm{Im}(\mathbf{B}) = 0$, and the corresponding value of **G** that satisfies the Barkhausen criterion. Hence calculate the frequency at which oscillation occurs when $C = 10$ nF and $R = 1.8$ kΩ, and the required value of R_F.

Milestone 4

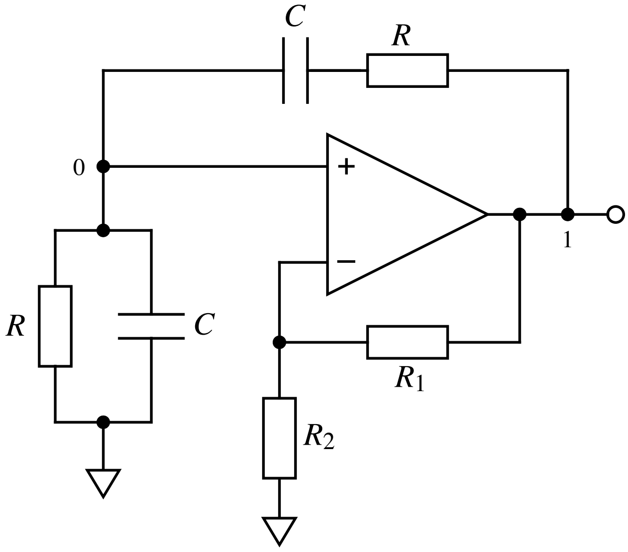
Construct the circuit using these values and a 741 op-amp. [Hint: Try a 47 kΩ resistor in series with a 10 kΩ variable resistor for R_F.] Investigate qualitatively how the signal shape depends on the value of A set by the variable resistor. Measure the oscillation frequency and the phase difference (use a Lissajous figure) between nodes 0 and 1. If these do not agree with your predictions above, explain why.



Circuit 4.3 Phase-Shift Oscillator



Circuit 4.4 Divider Circuit



Circuit 4.5 Wien Bridge Oscillator

Milestone 5

Calculate the complex ratio of voltages at nodes 0 and 1 of circuit 4.4.

Circuit 4.5 is known as a **Wien bridge oscillator** (see Storey, page 148). Select component values to give an oscillation frequency of approximately 1 kHz and build and test the circuit. You will need to include a potentiometer to allow fine adjustment of the ratio R_1/R_2.

End of Bonus Mile