Design a filter for the temperature sensor circuit of Lab 2. Requirements:

- Pass DC unattenuated \( |H(f)| \approx 1 \) → low pass
- Attenuate 60 Hz noise by 40 dB
- Minimize component size and cost
- Any resistor values \( 100 \, \Omega < R < 100 \, \text{k}\Omega \)

Since \( |H(f=0)| \approx 1 \), low pass filter

Approach: Calculate \( f_B \) from transfer function

Given: \( |H(f=0)| \approx 1 \), \( |H(f=60 \, \text{Hz})| = 0.01 \) @ \( f = 60 \, \text{Hz} \)

\[
|H(f)| = \sqrt{1 + \left(\frac{f}{f_B}\right)^2}
\]

\[
0.01 = \sqrt{1 + \left(\frac{60}{0.6}\right)^2}
\]

\[
f_B = 0.6 \, \text{Hz}
\]

R-L or RC circuit?

\[
\gamma = \frac{L}{R} = 265 \, \text{ms} \quad \text{or} \quad \gamma = RC = 265 \, \text{ms}
\]

LARGE "R" → SMALL "C"

SMALL "R" → SMALL "L"

Choose \( R = 100 \, \text{k}\Omega \), \( L = 26.5 \, \text{H} \)

\( R = 100 \, \text{k}\Omega \) → \( C = 2.6 \, \mu\text{F} \)

Choose \( 100 \, \text{k}\Omega + 2.6 \, \mu\text{F} \)
Using the general step response for the specific times 10 and 90 and subtracting

\[ V_{\text{OUT}} = V(1 - e^{-t/\tau}) \]

\[ V_{\text{OUT}} = V(1 - e^{-t/\tau}) \]

From (2) and (3) bandwidth and time constant are related by

\[ \frac{\Delta f}{f} = \frac{\Delta t}{t} \]

where \( \Delta f \) is the bandwidth at 3-dB frequency and \( \Delta t \) is the time constant.

In practice, a measurement of the rise time, rise time, or time constant is usually easier to make than the bandwidth, which is often easier to work with.

First order Low Pass Filter which is often easier to work with and can be expressed as

\[ H(f) = \frac{\frac{bpf f}{f} + 1}{1} \]

maximum defines the bandwidth (3-dB frequency) of the frequency at which the \( H(f) \) magnitude is a factor of \( \frac{1}{\sqrt{2}} \) or \( 0.707 \) of its rated

For the transfer function in the frequency domain for sinusoidal input and output

\[ \frac{V_{\text{OUT}}}{V_{\text{IN}}} = \frac{\frac{Z_f R}{Z} + \frac{Z}{Z_z}}{\frac{Z_f R}{Z} + \frac{Z}{Z_z}} = \frac{\omega L}{\omega C} \]
Features

The LM741 Operational Amplifier is a general purpose operational amplifier with an excellent common mode rejection ratio (CMRR) and high open-loop gain. It is ideal for low-level signal amplification and filtering applications. The LM741 is available in both single and dual supply versions, allowing flexibility in power supply options.

Connection Diagrams

General Description

Operational Amplifier

LM741

August 2000