PURPOSE:

To design, build and test DC-coupled Inverting and Difference Amplifier circuits using off-the-shelf IC operational amplifiers (LM741/LM747)*.

For the design part of this work to be considered "complete" the amplifiers should amplify sinusoidal test signals within the specifications listed below.

PRELIMINARY WORK:


Design 1 : Inverting Amplifier:

Design an inverting amplifier by using an LM741* (or one of the two 741’s supplied in a dual package named LM747*). Inverting Amplifier specifications are:

\[ R_{in} \geq 10 \text{ Kohms} \quad |A_v| = (80 + GN \times 20) \pm 5\% \]

Design 2 : Difference Amplifier:

Design a difference amplifier by using an LM741* (or one of the two 741’s supplied in a dual package named LM747*). Difference Amplifier specifications are:

\[ A_{vcm} = 0 \text{ (trimmed)} \quad R_{id} \geq 10 \text{ Kohms} \quad |A_{vd}| = (80 + GN \times 20) \pm 5\% \]

All design calculations are required to be done with Mathematica (or MathCad), and both hard copies and input files should be attached to the final report.
EXPERIMENT:

Design 1 : Inverting Amplifier:

Set up your inverting amplifier circuit.

a. Measure its DC output offset by shorting its input to ground. Calculate the input DC offset voltage, VOS of your operational amplifier. Compare it with the specs of LM 741 (or LM 747) and make sure your operational amplifier and your circuit is healthy.

b. At 100 Hz, verify that your design is delivering the required inverting(!) gain and input impedance. Make a hard copy of oscilloscope screen to put in your report as a testimony to your verification. Also, measure its output impedance.

c. Employ “BODE-3” to measure and plot its gain-frequency characteristics from DC to 2 MHz. Determine the bandwidth of your amplifier from your plots and calculate the Gain x Bandwidth product of your amplifier and compare it with GBW of your LM 741.

Caution: Make sure the operational amplifier is not overdriven to create distorted output swings. An overdriven operational amplifier will invalidate most of the measurements done above and below.

Design 2 : Difference Amplifier:

Set up your difference amplifier circuit. Use a trimpot to make the ratios of resistances exactly balanced so that you may get the ultimate common-mode signal rejection possible from the operational amplifier you are employing.

Common-Mode Measurements:

a. Apply a low-frequency (10-15 Hz) common-mode signal and adjust your trimpot until you get the minimum possible signal amplification from the output. Now you have balanced your difference amplifier. Do not change this setting for the rest of the experiments.

b. Measure $A_{cm}$ and $|Z_{out}|$. Also, determine the maximum peak common-mode signal the amplifier can reject. You can do this by increasing the input amplitude gradually until the output starts responding to the peaks with significantly increased gain.

c. With an input signal with a swing smaller than the rejection limits vary its frequency, and determine and plot $|A_{cm} (j\omega)|_{dB}$ versus frequency. Employ BODE3.EXE for this purpose. You may have to increase the amplitude of the signal to several volts peak in order to bring the amplitude of the rejected output up to a measurable value.

Differential Mode Measurements:

d. Measure $A_{vd}(0)$ with a small DC voltage and also verify it with a sinusoidal small signal at a low frequency (10-15 Hz). Vary the frequency the sinusoidal signal, and determine and plot $|A_{vd} (j\omega)|_{dB}$ versus frequency.

e. Can you measure true $|Z_{id}|$ with a single non-differential signal source? How about measuring $|Z_{in}|$ at the two inputs separately? Compare the two $|Z_{in}|$ values and explain the difference.
CONCLUSIONS and REPORT:

1. Note that a real operational amplifier has finite output impedance, \( r_{out} \) and finite open loop gain, \( A_{vo} \). Derive formulae that give the output impedance for the two amplifiers you have designed and tested above. A symbolic solution with Mathematica is acceptable as well as hand calculations. For calculations the “\( I_{TEST} - V_{TEST} \)” method is suggested.

2. Use the formulae you have derived above and the LM 741 specs to calculate the output impedances of your circuits and compare them with your measured values.

3. Assuming the operational amplifier's transfer function can be approximated by,

\[
A_{vo}(j\omega) = \frac{A_{vo}(0)}{1 + j(f/f_{3db})}
\]

where \( A_{vo}(0) \equiv 100,000 \); and the unity gain bandwidth \( \equiv 1.5 \text{ MHz} \), calculate and plot the theoretical frequency response of your Design # 1. How is the bandwidth of your amplifier related to the gain it delivers?

3. In the light of your calculations above, give an assessment of your experimental findings.

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