Mini Project 4

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ELEC 301

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# Part A – An Active Filter

Given transfer Function:

## Values of C and A­M

We have to find the poles of the transfer function; therefore it follows that.

Which defines the system behavior as,

To obtain a 2nd order Butterworth filter with given 3dB frequency of 10kHz,

Which yields.

And using the s-plane (Plot 1), we can find the 2nd order Butterworth filter poles.

Complex pole damping factor,

Chart, pie chart

Description automatically generated

Plot 1: Location of poles on s-plane

Therefore,

Thus,



Circuit 1: 2nd Order Butterworth filter model



Plot 2: Magnitude Bode Plot for 2nd order Butterworth filter.



Plot 3: Phase Bode Plot for 2nd order Butterworth filter.

## Oscillating Gain

The pole locations are found from the roots of the denominator of transfer function,

So, when and yields,



Circuit 2: Oscillating Circuit



Plot 4: Oscillating Transient Output of Circuit 2

Oscillation frequency at marginally stable gain,

As increases, the poles move along the root locus (the circle) from the pole location as shown in figure 4a to the right until it lands on the imaginary axis as shown in figure 4b. After that point, the response is an undamped oscillation. Increasing further will cause the filter to go unstable as the poles have now crossed to the right-hand plane.

Diagram

Description automatically generated with low confidenceDiagram

Description automatically generated with low confidence

Plot 5: Root Locus for AM=3

Plot 6: Root Locus for AM=1.585

# Part B – A Phase Shift Oscillator



Circuit 3: Phase Shift Oscillator Circuit

, which satisfy the gain condition for non-inverting amplifier. The transfer function of the oscillators contains a pair of complex poles situated on the imaginary axis with a denominator, which results in the generation of a finite signal even in the absence of an input signal. Initially, the feedback resistor had a resistance of 29R (29kΩ) but the signal produced eventually decayed. To prevent this, the resistance was increased to 29.1kΩ.

Chart, line chart

Description automatically generated

Plot 7: Oscillating Circuit Output

Using the above formula from class notes, Measured and Calculated frequencies for different values of R and C are written in table below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Original | Halved | Double |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

The frequencies listed in Table, which were both calculated and measured, are quite similar. However, because our SPICE program measures frequency graphically, the accuracy of these measurements is limited to the nearest hertz. The differences between the measured and calculated frequencies for the halved component values could potentially be attributed to non-idealities of the operational amplifier that were not considered when deriving the frequency formula.

# Part C – A Feedback Amplifier



Circuit 4: Feedback Amplifier

## Largest Open Gain

Using Parameter Sweep on RB2 on *CircuitMaker*,



Plot 8: Transient Analysis with increasing values of RB2

Thus, we obtain which can yield maximum Open Loop Gain.

## DC Bias Values

Measured DC Bias Values of each Transistor is given in Table Below:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| Q1 |  |  |  |  |  |  |
| Q2 |  |  |  |  |  |  |

Hybrid π models of transistor is calculated with,

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Q1 |  |  |  |
| Q2 |  |  |  |

## Open-Loop Frequency Response

With (infinite resistance), the open loop frequency response from the circuit,



Plot 9: Open-Loop Frequency Response

Measured Values from Plot 6 are,

Applying the test voltages,

## Prediction of Closed Loop Response

Chart

Description automatically generated

Circuit 5: Feedback Network

Since shunt-shunt topology is being utilized by the feedback network, the y-parameters to represent the feedback network can be written as,

Thus,

, as the feed-forward gain is very small.

### Voltage Gain

, but due to shunt-shunt topology, the unit of gain should be in terms of

Therefore, closed-loop gain calculated by,

Or,

### 3dB frequency Points

Due to Feedback, there exists a bandwidth extension with a factor of ,

### Impedance Values

## Measured Closed-Loop Frequency Response

## 

Plot 10: Bode Plot for Feedback Amplifier with Rf=100k

The values measured from the bode are compared to our calculated values in following table:

|  |  |  |
| --- | --- | --- |
|  | Measured | Calculated |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

\*Values of impedances were measured using the same methods described above.

Input impedance has a higher error.

## Closed-Loop frequency response with different values of

Closed frequency response is measured over the same range of frequencies (10mHz to 100MHz), for



Plot 11:Closed loop magnitude Bode plots for Rf = 1kΩ, 10kΩ, 100kΩ, 1MΩ, from lowest to highest midband gain respectively.

Feedback factor , can be calculated by solving,

The units of are whereas, the bode plot gives in unit of . But as solved earlier, we can just multiply to change units from to .

Moreover, calculated (from feedback network)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | Measured | Calculated |
| 1k | -14.07 | -0.198 | -0.990 | -1.001e-3 | -1e-3 |
| 10k | 5.892 | -1.971 | -9.853 | -1.015e-4 | -1e-4 |
| 100k | 24.72 | -17.21 | -86.09 | -1.002e-5 | -1e-5 |
| 1M | 37.82 | -77.80 | -389.01 | -9.993e-7 | -1e-6 |
| 10M | 41.60 | -120.2 | -601.13 | -9.069e-8 | -1e-7 |

As seen from the table,

### I/O Impedance with Varying

Using the methods described above, we calculate the I/O impedances of our amplifier for .

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Additionally, to “amount of feedback (1+Aβ)” can be estimated using the formula,

For predicted “amount of feedback”, we are using the measured from part 2 and the calculated values of from part 3 as described by instructor.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

From table 5, it appears that the amount of gain calculated from measured output impedance is consistently closer to predicted values as feedback resistance increases and amount of gain values decrease and become closer to predicted values.

### De-sensitivity Factor

Gain de-sensitivity can be found by,

Thus, de-sensitivity factor is given by



Circuit 6: Feedbavk Circuit with Rf = inf (top) and Rf = 100k (below)



Plot 12:Bode Plot for midband gain for Rf=inf (top) and Rf=100kΩ (below)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

‘

On Comparison with the Predicted value of from part 4 for the obtained values are very close.

Additionally, for the circuit is a open loop and therefore has , due to which