Lab 1

Multi-Stage Amplifier: High Critical Frequency and Peaking

1.1 Objectives

Objective A: Calculate and measure the Critical Frequency High of an Amplifier.

- **Frequency Critical High:** Re-Draw that AC equivalent circuit at Frequency Critical High. Draw and Calculate parallel capacitance $Ctotal_{In}$, $Ctotal_{Mid}$, and $Ctotal_{Out}$. Calculate the Thevenin Equivalent Resistances and Frequency Critical High.

Objective B: Improve the Critical Frequency High of an Amplifier Circuit Using Emitter, Shunt, & Series Peaking.

- **Emitter, Shunt, & Series Peaking:** Understand and apply techniques such as emitter peaking, shunt peaking, and series peaking to enhance the high-frequency response of an amplifier circuit. These techniques involve the use of additional components to mitigate the roll-off in gain at high frequencies.

Objective C: Discuss and Show Calculations for Each Circuit Modification, including the predicted Improvement Factor (K).

- **Calculations:** Discuss and demonstrate the mathematical calculations involved in implementing each circuit modification. This includes determining component values and their impact on the amplifier's high-frequency response.

Objective D: Measure, Calibrate, and Document the Results of Each Circuit Modification.

- **Measurement:** Use measurement instruments like an oscilloscope, audio function generator, and a DMM to measure and document the actual performance of the amplifier after each circuit modification.
- **Calibrate:** Calibrate each modification to optimize the pass-band, document the calibration procedure.

- **Record Data** Record calculated, measured, and calibrated data related to gain, frequency response, and other relevant parameters.

Objective E: Identify and Reconcile Any Discrepancies Between a Calculated and Measured Result.

- **Discrepancies:** Analyze the differences between calculated and measured results for each circuit modification. Identify potential sources of error and work to reconcile any disparities between theoretical predictions and experimental observations.

Objective F: Demonstrate the Proper Use of the Oscilloscope, DMM, and Audio Function Generator to Obtain Accurate Measurements.

- **Oscilloscope, DMM, and Sweep Audio Generator:** Continuously emphasize the correct setup and operation of measurement instruments such as oscilloscopes, DMMs, and sweep audio generators. Ensure that students can use these tools effectively to obtain precise measurements and validate circuit modifications.

1.2 Reference Documents:

- Theory Notes
- First Year Text Books
- First Year Laboratory Books
- Multi-Stage Amplifiers Section **??**.

1.3 Checkoff Sheet:

See Table 1.2 *Multi-Stage Amplifier Part 1 Check-Off Sheet* on Page 9.

1.4 Lab Instructions

1.4.1 Frequency Critical High Calculations

1. Note circuit considerations and formulas for calculating FC_{HIGH}.
2. Calculate the following. Show all formulas and steps for calculations:
   (a) $C_{TotalIN}$, $C_{TotalMID}$, $C_{TotalOUT}$
   (b) $RTH_{CTotalIN}$, $RTH_{CTotalMID}$, $RTH_{CTotalOUT}$
   (c) $FC_{TotalIN}$, $FC_{TotalMID}$, $FC_{TotalOUT}$
   (d) FC_{HIGH}

1.4.2 Frequency Critical High Measurements

1. Measure the FC_{HIGH} frequency response using Sine-wave method.
2. Measure the FC_{HIGH} frequency response using Square-wave method.
3. Compare the calculated and measured values noting any discrepancies.
4. Collect the calculated and measured data in a table.

1.4.3 Frequency Critical High adjusted to 2Mhz

1. Modify the circuit by adding parallel capacitance at the load to achieve a new frequency critical high equal to 2Mhz, $Fc_{High} = 2Mhz$.
2. Document procedure, calculations, and measurements.

1.4.4 Above the Pass-band Output Calculations

1. Show all formulas and steps for calculating the output at frequencies beyond FC_{HIGH}:
   (a) V_{OUT}
   (b) Phase ϕ
   (c) Loss in dB
2. Show all calculations for the output at the following points, including Voltage, Phase, and dB (Use your measured FC_{HIGH} value from the previous sub-section):
   (a) FC_{HIGH}
   (b) The first *Octave*
   (c) The first *Decade*

1.4.5 Above the Pass-band Output Measurements

1. Measure Voltage, Phase, and dB for the following:
   (a) FC_{HIGH}
   (b) The first *Octave*
   (c) The first *Decade*
2. Compare the calculated and measured values noting any discrepancies.
3. Collect calculated and measured data in a Table.
4. Section Check-Off:

(a) Prior to Instructor check-off, make sure all of the section steps are completed and your lab book is up to date.

(b) Be prepared to answer questions and demonstrate measurements made in this section.

1.4.6 Emitter Peaking Calculations:

1. Explain what Emitter Peaking is and how it works.

    (a) Begin by providing a theoretical explanation of Emitter Peaking in terms of the voltage gain formula: $\Delta v = \frac{Vout}{Vin}$

2. Step through the calculation process to determine the value of the capacitor required for emitter peaking for the Multi-Stage Amplifier.

    (a) Calculate the Emitter Peaking Capacitor (C_{EP}) using the previously adjusted and measured FC_{High}.

    (b) Calculate the new Frequency Critical High (FCH_{EP}).

    (c) Calculate the Emitter Peaking Improvement Factor (K_{EP}).

    (d) Create predicted Emitter Peaking Bode Plot in reference to the original Bode Plot.

1.4.7 Emitter Peaking Measurements

1. Measure/verify FC_{High}.

2. Install the calculated Emitter Peaking Capacitor into the circuit.

3. Using the function generator, sweep the frequency and observe the bode plot response on the oscilloscope.

    - If pre-peaking is observed, adjust C_{EP} capacitance to flatten or calibrate the pass-band. Verify that the pass-band is flat.

4. Measure the new FCH_{EP} and note any changes to C_{EP}.

5. Calculate the measured Emitter Peaking Improvement Factor.

    - If the pass-band is flat but the improvement factor is below expectations, adjust C_{EP} to achieve the proper improvement factor without adding any pre-peaking to the pass-band.

6. Capture the frequency sweep image of the Bode Plot on the Oscilloscope with Cursor 1 set to the pass-band voltage and Cursor 2 set to the -3dB point.

7. Analyze the data and identify any differences between your calculated and measured results. Think critically about potential sources of error in your practical setup and provide explanations for these discrepancies.

8. Collect calculated and measured data in a table.

9. Section Check-Off:

   (a) Prior to Instructor check-off, make sure all of the section steps are completed and your lab book is up to date.

   (b) Be prepared to answer questions and demonstrate measurements made in this section.

1.4.8 Shunt Peaking Calculations:

1. Explain what Shunt Peaking is and how it works.

   (a) Begin by providing a theoretical explanation of Shunt Peaking in terms of the voltage gain formula: $\Delta v = \frac{Vout}{Vin}$

2. Step through the calculation process to determine the value of the inductor required for shunt peaking for the Multi-Stage Amplifier circuit.

   (a) Calculate the Shunt Peaking Inductor (L_{ShuntP}) using the previously adjusted and measured FC_{High}.

   (b) Note the Shunt Peaking Optimal Improvement Factor (K_{ShuntP}).

   (c) Calculate the new Frequency Critical High (FC_{HIGH_ShuntP}).

   (d) Create predicted Shunt Peaking Bode Plot in reference to the original Bode Plot.

1.4.9 Shunt Peaking Measurements

1. Measure/verify FC_{High}.

2. Install the calculated Shunt Peaking Inductor into the circuit.

3. Using the function generator, sweep the frequency and observe the bode plot response on the oscilloscope.

   - If pre-peaking is observed, adjust L_{ShuntP} inductance to flatten or calibrate the pass-band. Verify that the pass-band is flat.

4. Measure the new FCH_{ShuntP} and note any changes to L_{ShuntP}.

5. Calculate the measured Shunt Peaking Improvement Factor.

   - If the pass-band is flat but the improvement factor is below expectations, adjust L_{ShuntP} to achieve the proper improvement factor without adding any pre-peaking.

6. Capture the frequency sweep image of the Bode Plot on the Oscilloscope with Cursor 1 set to the pass-band voltage and Cursor 2 set to the -3dB point.
7. Analyze the data and identify any differences between your calculated and measured results. Think critically about potential sources of error in your practical setup and provide explanations for these discrepancies.
8. Collect calculated and measured data in a table.
9. Section Check-Off:
   (a) Prior to Instructor check-off, make sure all of the section steps are completed and your lab book is up to date.
   (b) Be prepared to answer questions and demonstrate measurements made in this section.

1.4.10 Series Peaking Calculations:

1. Explain what Series Peaking is and how it works.
   - Begin by providing a theoretical explanation of Series Peaking in terms of "Voltage Magnification".
2. Step through the calculation process to determine the value of the inductor required for series peaking for the Multi-Stage Amplifier circuit.
   (a) Calculate the Series Peaking Inductor (L_{ShuntP}) using the previously adjusted and measured FC_{High}.
   (b) Note the Series Peaking Optimal Improvement Factor ($K_{SeriesP}$).
   (c) Calculate the new Frequency Critical High ($FCH_{SeriesP}$).
   (d) Create predicted Series Peaking Bode Plot in reference to the original Bode Plot.

1.4.11 Series Peaking Measurements

1. Measure/verify FC_{High}.
2. Install the calculated Series Peaking Inductor into the circuit.
3. Using the function generator, sweep the frequency and observe the bode plot response on the oscilloscope.
   - If pre-peaking is observed, adjust $L_{SeriesP}$ inductance to flatten or calibrate the pass-band. Verify that the pass-band is flat.
4. Measure the new $FCH_{SeriesP}$ and note any changes to $L_{SeriesP}$.
5. Calculate the measured Series Peaking Improvement Factor.

- If the pass-band is flat but the improvement factor is below expectations, adjust $L_{SeriesP}$ to achieve the proper improvement factor without adding any pre-peaking.

6. Capture the sweep image of the Bode Plot on the Oscilloscope with Cursor 1 set to the pass-band and Cursor 2 set to the -3dB point.

7. Analyze the data and identify any differences between your calculated and measured results. Think critically about potential sources of error in your practical setup and provide explanations for these discrepancies.

8. Collect calculated and measured data in a table.

9. Section Check-Off:

   (a) Prior to Instructor check-off, make sure all of the section steps are completed and your lab book is up to date.

   (b) Be prepared to answer questions and demonstrate measurements made in this section.

1.5 Collected Data

- See *Table Formatting and Data Sets Examples* on page 8.
- Include all the data sets referenced in the lab.

1.6 Key Terms

Define The Following:

- Frequency Critical High
- Peaking
- Pre-Peaking
- Emitter Peaking
- Shunt Peaking
- Series Peaking
- Improvement Factor

1.7 Key Formulas

- List and define each of the key formulas used in this lab.

1.8 Conclusion Instructions

1. Verify that your Check-Off Sheet is completed.
2. Review *Conclusion Guidelines* page **??**.
3. Complete your Conclusion.
4. Create an electronic PDF copy of your lab report, making the Check-Off sheet the first page of the PDF.
5. Submit your lab report PDF via Moodle.

1.9 Table Formatting and Data Sets

Table 1.1: Multi-Stage Peaking Frequency Response Data.

Sec.1.4.6	FC_{HIGH}	C_{EP}	FCH_{EP}	*Imp.(K)*
Calculated				
Measured				
Sec.1.4.8	FC_{HIGH}	L_{ShuntP}	FCH_{ShuntP}	*Imp.(K)*
Calculated				
Measured				
Sec.1.4.10	FC_{HIGH}	$L_{SeriesP}$	$FCH_{SeriesP}$	*Imp.(K)*
Calculated				
Measured				

Table 1.2: Multi-Stage Amplifiers Part 2 Check-Off Sheet

RCET 2252 Clinical Assistant Professor Timothy Leishman *Multi-Stage Amplifier Part 2* Check-Off Sheet			
Student Name:		Lab Start Date:	
Check-Off	Section	Date	Instructor Int.
FC_{High} *Calculations and Measurement*	1.4.1		
FC_{High} *Calibrated*	1.4.3		
Emitter Peaking Calculations	1.4.6		
Emitter Peaking Measurements	1.4.7		
Shunt Peaking Calculations	1.4.8		
Shunt Peaking Measurements	1.4.9		
Series Peaking Calculations	1.4.10		
Series Peaking Measurements	1.4.11		
Instructor Notes:			