Requirements:

Each lab partner group is to:

a) Design, construct and demonstrate an AM radio capable of modulating, transmitting, and demodulating a single tone AM-modulated signal $s(t)$ for all single tone frequencies between 300 Hz and 4000 Hz. The connection between transmitter and receiver will be via BNC cable. The received and demodulated single tone sine wave “message” signal $m(t)$ should be displayed without distortion on the digital oscilloscopes on your lab bench, and should be clearly audible when played on the speaker available in your parts kits. As an option, you may design your system to transmit voice input from the microphone in your parts kit.

b) Analyze the AM transmitter and receiver, test the overall deployed system, and compare analytical results with measured test data.

Each individual is to report on the design, simulations, construction, and testing according to the reporting guidelines attached.

Figure 1: Block diagram of a suggested design for the AM transmitter.

Figure 2: Block diagram of a suggested design for the AM receiver.
**Equipment and Specifications:**

1. Components: Student analog parts kit; any additional items must be instructor approved.
3. Input: Single sine wave m(t) from your bench signal generator.
4. Output: Single tone sine wave m(t) displayed on oscilloscope and played over the speaker. Please note that both your report and your project demonstration must demonstrate successful sine wave output at both 300Hz and 4000Hz, as well as any frequencies in between.
5. Special: The carrier frequency $f_c$ of the carrier wave $c(t)$ must be between 30000 and 80000 Hz. Please note that your design is expected to work with only one carrier frequency $f_c$, which you choose as part of your design process.
6. Transmitter bandpass filter frequency response $|H(f)|$ specifications:
   a. Lower stop band: $20\log_{10}(|H(f)|) \leq -20$ dB for $0 \leq f \leq 4000$ Hz.
   b. Upper stop band: $20\log_{10}(|H(f)|) \leq -10$ dB for $f \geq 2f_c$.
   c. Pass band: $-1$ dB $\leq 20\log_{10}(|H(f)|) \leq 1$ dB for $f_c-4000 \leq f \leq f_c+4000$ Hz.

**Discussion:**

The single tone message signal $m(t) = A_m \cos(2\pi f_m t)$ will be supplied by your bench signal generator. The carrier wave $c(t) = A_c \cos(2\pi f_c t)$ will be supplied by an oscillator that you will design. Your receiver should be able to handle any message signal frequency $f_m$ between 300 and 4000 Hz. The transmitted AM signal $s(t)$ is given by $s(t) = (1 + k_a m(t))c(t)$, where the value of $k_a$ is chosen so that $|k_a m(t)| < 1$ at all times.

The carrier frequency $f_c$ must be between 30000 and 80000 Hz. For both the interim and final reports, you will be expected to model and verify your AM transmitter design using PSPICE, and verify that the transmitter produces a single-tone AM signal.

Starting with the first lecture on the project delivered on Tuesday October 9, a detailed set of project notes will be posted and periodically updated online on our course website during the course of the project; these will be under the “Class Project” link on our website. These will include AM radio theory, examples of useful circuits for the project, and also hints and notes on PSPICE simulation. There will also be some background reading material on AM and on oscillator design posted under the Class Project link.

**Objectives:**

An important objective of this design project is generating a well thought-out design and supporting analyses. Concise and coherent documentation of results is crucial. Simply “getting it to work” is not adequate. In support of these objectives, it is suggested that you perform at least the following steps and document them in your final report:

- Generate a high-level block diagram providing primary components of the system and indicating the signals (voltages and/or currents) which are to be controlled or measured.
• Describe the operation of the individual blocks in your block diagram. This should include details of components and subsystems designed by the student.

• A description of the AM radio design process, and documentation of the final radio design including: (1) a summary of the theory behind the transmitter and receiver; (2) selected component values for the transmitter and receiver sub-circuits to achieve the desired system performance; (3) PSPICE plot of the transmitter and receiver output signals s(t) and m(t) showing amplitude and frequency.

• For the transmitter bandpass filter, you should include: (1) filter transfer function H(s); (2) list of filter poles and zeros; (3) Bode plots of filter’s amplitude and phase response.

• A PSPICE simulation of as much of the system as is practical. At a minimum, your PSPICE simulation for the interim report should consist of all of the components shown in Fig. 1, except for the buffer amplifier and BNC. The simulation should show the input and output signals, and selected intermediate signals. PSPICE frequency amplitude response plots for the bandpass filter should be included. For the final report, the PSPICE frequency response plots for the bandpass filter should be compared to the Bode plots generated with MATLAB. For the final report, you will also need to simulate (in PSPICE) the AM receiver, including the receiver power amplifier, which should drive an 8 ohm load to simulate the speaker. The PSPICE simulation in the final report should also show an end-to-end simulation of transmitter through receiver, verifying that the transmitted message m(t) is correctly demodulated by the receiver.

• Implementation of the system you designed. In particular, a neatly drawn schematic diagram of all circuits you designed should be included in the final report; the final values of all components should be listed on the schematic. If necessary, you may split the schematic up into parts, but the connections between the parts must be clearly indicated.

• Experimental data from the system you designed, in the form of stored analog waveforms from the transmitter and receiver. Your experimental data should be used to verify that your implemented radio can successfully transmit and receive signal tone AM waves according to the specifications listed above.

• Comparison and discussion of the analytical and experimental results.

Demonstrations:

Each group must demonstrate operation of their AM radio during regular laboratory sessions during the demonstration times listed at the top of this document. **Each member of the group is expected to be able to answer pertinent questions about their system’s design and operation.** Demonstrations are expected to take approximately 15 minutes.

Design Freedom and Innovation:
Innovation makes engineering fun, and sometimes lucrative. Although your instructor will provide suggested circuits for the sub-blocks shown in Figs. 1 and 2, in general you
are free to design and implement your AM radio using any techniques you wish, subject to meeting the design specs and using the parts in your kits. In particular, the major sub-blocks where you have the most freedom to innovate are:

- The oscillator in the transmitter. The reading assignment (from Sedra and Smith) and project notes cover the Wien-Bridge op-amp oscillator, but there are several other op-amp and transistor-based oscillator designs covered in Sedra and Smith and elsewhere.
- The bandpass filters in the transmitter and receiver. You can build these with op-amps or with passive components. Designs for BPFs are covered in your EE321 textbook and elsewhere.
- The buffer amplifier in the transmitter. It must to be able to drive the 50 ohm input impedance of the BNC. Thus, it does not need to be as heavy-duty as the power amplifier in the receiver, which must be able to drive an 8-ohm load. You might be able to get away with an op-amp voltage-follower. Or there are several other designs for buffer amplifiers that you could use, some of which (see for example Lab 7) we have already studied.

**Interim Design Report:**

An interim report will be submitted in order to provide the instructor with preliminary information relative to your design. It is expected that your interim design report follow, at least approximately, the format provided in Appendix A of this assignment. This report will, therefore, allow the instructor to provide students with feedback relative to their project implementation and reporting style, prior to submission of the final design report. The preliminary design report should provide the following information:

- A preliminary design of the AM transmitter, including all sub-circuits shown in Fig. 1 except for the buffer amplifier and BNC. This should include a summary of the theory behind the AM transmitter design, selected component values for the sub-circuits to achieve the desired AM modulation, and detailed schematics for the oscillator, switching modulator, and bandpass filter.
- A PSPICE simulation of the AM transmitter, including all sub-circuits shown in Fig. 1 except for the buffer amplifier and BNC. The **PSPICE simulation results included in the interim report should include plots of selected outputs at key points of your circuit simulation that demonstrate that your transmitter circuit is working, as well as PSPICE frequency response curves for the bandpass filter.** Note that for the interim report, the MATLAB Bode plots for the bandpass filter mentioned in the Objectives section above are not required.
- The format of the interim design report should follow the format for the final design report described in Appendix A below, except that the interim design report should contain only the following sections: Cover Sheet, Abstract, Introduction, Theory (including circuit description and schematics of the circuits you simulated in PSPICE, and the results of your PSPICE simulation), References, and Appendices containing your PSPICE code.
Final Design Report:

Your final design report should contain all items outlined in the Objectives section of this assignment. This should include all items contained in the Interim Design Report, along with your final AM transmitter and receiver designs, a circuit implementing your AM radio, analysis of your final implemented design, and a discussion of the experimental vs. analytical results for your circuit. Your final design report should follow, at least approximately, the format provided in Appendix A of this assignment.

Appendix A – Report Guidelines:

This report is a major component (30%, including 10% for the interim report and 20% for the final report) of your EE 352 grade. It should be prepared using a word processor. Hand-drawn circuit diagrams are OK, but ideally they should be scanned into the document in electronic form. Equations should be created with the word processor. When writing the report, use a format similar to that found in technical journals. An example formal report (which is actually a technical journal article) can be found on our course website. Assume that the audience for your report is an electrical engineer, who understands the EE jargon, but has no prior knowledge of the experiment and has not read the project handout. The report should include the sections described below. Write each section of the report in your own words; however, you may share circuit diagrams and equations between partners. The reports will be graded primarily for technical content, but grammar, clarity, spelling, and graphical presentation quality will also count towards your project grade, since this is a writing-in-the-major course.

Cover Sheet: Include your name and the name of your lab partner(s) along with the date and title of the experiment.

Abstract: A one paragraph summary of your report that summarizes and highlights the major points. The abstract should include the key system specifications, and a brief summary of the report’s content, including a summary of the performance of your design. Did your design meet the specifications? Include the conclusions and any recommendations made.

Introduction: Provide readers with any general information they must have to understand the detailed information in the report. System specifications should be included in the introduction. A system block diagram, along with a brief discussion of the key components of the diagram, should be included. Include the subject and purpose of your report.

Theory: Give the theoretical background for the experiment, including simulation results. Provide mathematical models of circuit as well as MATLAB and PSPICE simulation results.

Methodology: Describe, in general, how the design, fabrication, and/or measurement process was performed. Include circuit schematics and diagrams of your setup.
Results and Analysis: Compare your results to your predictions and interpret the outcome for your reader. A lab report analysis describes significant observations. Label and explain all figures and graphs.

Conclusions: Draw from the analysis of the data. The conclusions should not be a recapitulation of the results.

Recommendations: The author makes recommendations that follow logically from the data and conclusions in the report.

References: In writing your report, you must document all information and ideas obtained from others.

Appendices: Includes supporting data, derivations, figures, calculations, PSPICE or MATLAB code.