6.101 Project Proposal
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1. General Outline

The invention and mass application of radio broadcast was triggered in the first decade of the nineteenth century by Lee De Forest with his Audion triode vacuum tube. By the first world war, radio transmission was in common use by many national entities, aided by the development of the superheterodyne receiver by Edwin Armstrong. This concept allowed engineers to filter, process, and work with signals at lower frequencies while still maintaining long distance transmission at higher carrier frequencies. While modern radio communication has predominantly moved away from amplitude modulation transmission in the lower frequency bands, the concept of the superheterodyne receiver has persisted in virtually every method of wireless communication since.

Because of our strong interest in radio transmission and the superheterodyne concept, we will build a superheterodyne AM Radio Receiver circuit that will have a bandwidth of the entire AM spectrum, and whose output will be a speaker. In addition, we will build what is essentially a spectrum analyzer for the AM band. We will sweep the full band and display the spectrum density on a visual device, such as a galvanometer or CRT screen. These two circuits will be calibrated, such that the currently tuned channel of the AM radio will be shown as a vertical line across the output spectrum plot. Figure 1 shows a full block diagram of our circuit, including all major circuit subsystems.

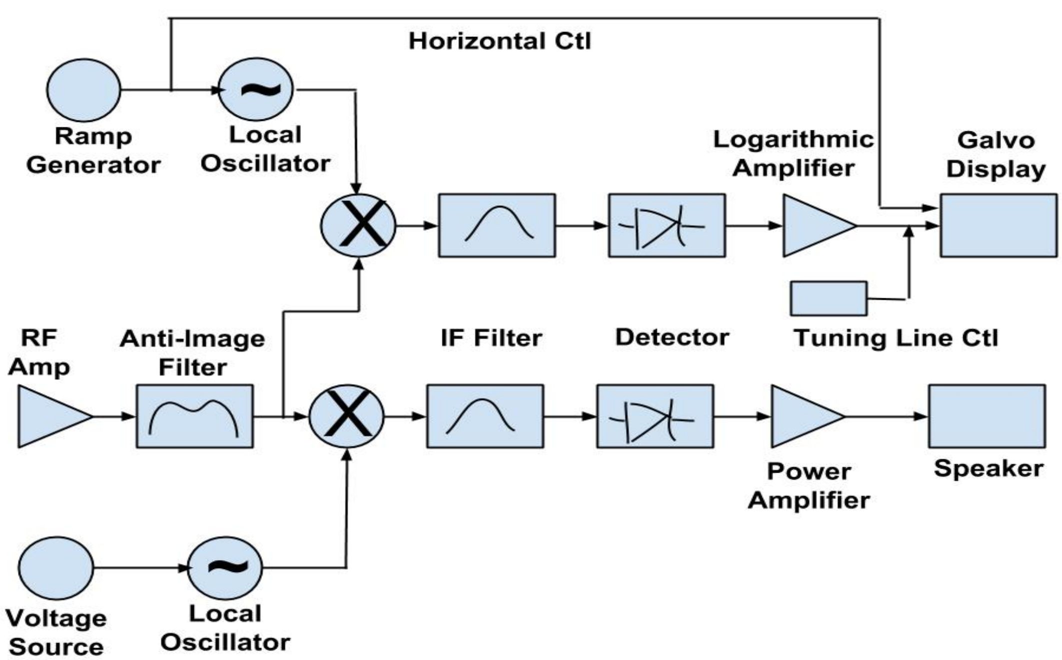

Figure 1. *High level system block diagram detailing major sub-blocks and interconnects between them.*

2. Sub-system Overview

2a. Low Noise Amplifier (LNA) - Kayla

Summary -

The LNA is a high-bandwidth transistor amplifier that will add gain to the signal before it is filtered and put through the mixer. This amp will likely be a single transistor, with a gain of about 10dB.

Inputs -

The RF signal from antenna

~ microV to mV Level

~ [Wide Bandwidth]

Output -

The gained RF signal

~mV Level

~[530KHz - 1710KHz]

Testing -

The module will be tested using a signal generator as the input and an oscilloscope or multimeter to measure the output magnitude and gain.

2b. Anti-Imaging Filter - Jason

Summary -

The Anti-Imaging Filter is a band pass filter and exists to band limit the signal picked up by the annanne to just the AM specturm. This filter will essentially consist of two band pass filters where the combination of the passbands encompases the entire AM spectrum. Such a design will allow us to create a large band pass filter with a pass band that spans the decade of AM, yet have a high rolloff without significant attenuation of the signals at the corners of the AM spectrum. This component is passive and requires no external power.

Inputs -

The gained RF signal from the RF amp

~ mV Level

~ [Wide Bandwidth]

Output -

The gained and bandwidth limited RF signal

~mV Level

~[530KHz - 1710KHz]

Testing -

The module will be tested by connecting it to a spectrum analyzer to verify that the passband encompasses the entire AM spectrum. We will also be passing test signals though this filter to verify that no noise is being injected into the system.

2c. Mixer - Kayla

Summary -

The mixer is a block multiplies the two input signals, and whose output is two copies of the RF signal whose frequencies equal the addition and subtraction of the frequency of the RF and the local oscillator. This reduction of frequency is what makes this AM receiver what is known as a superheterodyne receiver. This block will likely be designed simply using a diode at low voltage levels.

Inputs -

The amplified and bandwidth limited RF signal and the LO signal

~ mV Level; mV level

~ [530KHz - 1710KHz] ; [985KHz - 2165kHZ]

Output -

IF -> two signals identical to the RF input at $f_{RF} + f_{LO}$; $f_{LO} - f_{RF}$

~mV Level

~[455KHz with 10kHz BW]

Testing -

This subsystem can be tested using two different signal generators as the input, and by examining the output using either an oscilloscope or spectrum analyzer.

2d. Ramp Generator - Jason

Summary -

The Ramp Generator exists to provide a ramping voltage to not only allow the LO to sweep the entire AM band but also sweep the galvonometer display. The design will be not unlike the sawtooth oscillator constructed in lab 6 and will contain a current source with a 555 timer.

Inputs -

Power

~5 - 15V

~DC (no Bandwidth)

Outputs-

A sawtooth waveform

~5-10V

~[30Hz - 100Hz]

Testing -

The module will be tested by verifying that the output does indeed create a ramping signal on an oscilloscope.

2e. Voltage Controlled Local Oscillator (LO) - Jason

Summary -

The Local Oscillator (LO) exists to allow us to ‘tune into’ a radio station by mixing the frequency of interest with the LO in order to move it into the passband of the IF Filter (discussed elsewhere) The design at its core contains a Varactor which will allow us to adjust the resonant frequency of an RC circuit to generate our Local Oscillator.

Inputs -

Some voltage to tune the LO and power

~ V level

~ DC (no Bandwidth)

Outputs -

A periodic (sinusoidal) signal to mix with the RF signal

~mV level

~[530KHz - 1710KHz]

Testing -

The module will be tested by verifying that the local oscillator covers the entire AM band on an oscilloscope. The oscillator will not exhibit any significant harmonics around the fundamental frequency

2f. IF Filter - Kayla

Summary -

The IF filter is necessary to limit the frequency response to 455kHz, with a bandwidth of about 10kHz. This is necessary because the mixer has an output of two frequencies, the sum and difference of the LO frequency and RF frequency. The IF filter will be composed of several alternating high-Q filters (using the 455kHz transformers from lab 1) and transistor amplifier stages.

Inputs -

Two signals identical to the RF input

~ mV level

~$f_{RF} + f_{LO}$; $f_{LO} - f_{RF}$; each with 10kHz BW

Outputs -

A periodic (sinusoidal) signal to mix with the RF signal

~mV to V level

~[455kHz with 10kHz BW]

Testing -

The module will be tested using a sweeping signal generator and an oscilloscope in X-Y mode. We can use the the signal generator to sweep the range around the calculated frequency range and view the frequency response by viewing the output on one scope channel and the sweep using another scope channel. Alternatively, we can use the spectrum analyzer to view the output response to an input sweep.

2g. Detector - Jason

Summary -

The detector exists to rectify the signal of interest from the carrier frequency as some sort of envelope detector. This circuit is essentially a half wave rectifier with a low pass filter and is completely passively powered

Inputs -

The signal signal of interest coming from the IF filter

~mV level

~455KHz

Outputs -

The signal at the selected band

~mV level

~[20Hz - 20KHz] (audio)

Testing -

The module will be tested by applying an AM modulated signal to the input of the detector. The detector should be able to recreate the signal with minimal distortion

2h. Logarithmic Amplifier - Kayla

Summary -

The logarithmic amplifier boosts the output of the detector to the appropriate voltage level required by the galvanometer. The log amp will be composed of a series of amplifiers with varied gain, with control circuitry to chose which amplifier to use based upon a given input voltage level. This is necessary because the detector output will vary by several decades, depending on power of a specific station. The galvanometer output will thus be much easier to read if the input signal is amplified logarithmically

Inputs -

The demodulated output of the detector

~mV to V level

~455KHz

Outputs -

The spectrum power at a specific tuned channel

~V level

~[20Hz - 20KHz] (audio)

Testing -

The module will be tested by applying an input using a signal generator and measuring the output gain using an oscilloscope or multimeter.

2i. **Galvanometer Display - Both**

Summary -

The Galvanometer exists to provide a display to the AM power spectrum. It consists of two mirrors to steer a laser in an X and Y direction to draw the spectrum on a wall. The control circuitry is all provided and self contained. The X input will be provided by a ramp generator allowing us to sweep up the spectrum then rapidly reset. The Y input will be connected to the output of the logarithmic amplifier on the power detecting radio

Inputs -

Ramp Voltage from Ramp Generator to control the X sweep

~5-10V

~[30Hz - 100Hz]

Spectrum power to control the Y sweep

~V level
~[20Hz - 20KHz] (audio)

Outputs -

Laser

~No electrical specs (self contained)

Testing -

The module will be tested by applying test signals to the X and Y sweep inputs and verifying that the figure drawn matches that of an oscilloscope in XY mode.

3. External Components

The components listed below are the components that we believe we may potentially need to complete our project. Part numbers are given below. After confirming these parts with our mentor, we will begin purchasing the parts.

- x1 TL441 Logarithmic Amplifier
- x4 1N34A Diode
- x2 MA2C840 Varactor diode
- x4 NTE2401 RF BJT

4. Timeline

Week of April 14th	Project design finalized; parts ordered
Week of April 21st	Breadboarding, integration
Week of April 28th	Debugging, fine tuning and adjustments
Week of May 5th	Checkoff and Final Report

5. Conclusion

This project presents a very interesting spin on a very old topic. Though AM radio has been around for decades, the concept is still widely used today. Our implementation does not only address the challenges in designing a proper AM superheterodyne receiver but also presents a novel solution to being able to visualize the stations broadcasting on the spectrum of interest. The main challenges that will need to be overcome for this project include creating two oscillators that track each other as well as logarithmic amplifier. Our fallback options for these subsections include purchasing an IC to mitigate these risks. Overall, this project covers most topics presented to us in 6.101 and combines them into a very novel design.