UNIVERSITY OF CAPE TOWN

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University of Cape Town

Department of Electrical Engineering

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The AM Radio Receiver Project

“RADIO IN A LUNCHBOX”

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3RD YEAR BSc ELECTRICAL ENGINEERING

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INTRODUCTION

The project aimed to build a simple AM radio receiver circuit. The radio receiver was intended to listen to the Cape Talk AM radio station which transmits at the frequency of 567 kHz. The AM radio receiver should be able to drive the demodulated signal through a pair of earphones and a simple speaker.

DESIGN

The following diagram below shows the block diagram of an AM radio receiver.

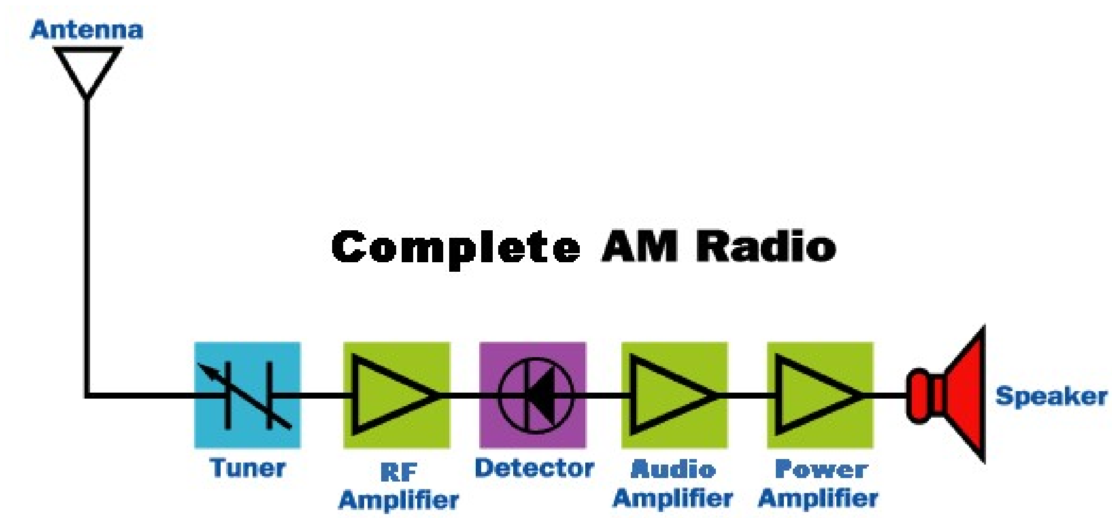

Figure 1: The block diagram of an AM radio receiver.

- **The Antenna**.

  An antenna type used in most radio receivers is mostly the monopole antenna.
  From antenna design theory (Electromagnetic Engineering), a monopole antenna operates efficiently when the antenna maximum dimension is a quarter of the wavelength of the received signal.

  The operating frequency is 567 kHz, therefore the wavelength $\lambda = \frac{c}{f} = \frac{3*10^8\ m/s}{567\ kHz} = 529.1\ m$.
  And the maximum length of the antenna should be $l_{max} = \frac{\lambda}{4} = \frac{529.1}{4} = 132.3\ m$.

  The antenna should be longer than the length of a soccer field!

- **The Tuner**.
  The following figure shows the tuning circuit.

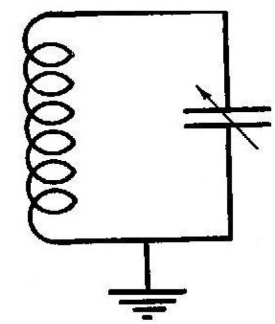

Figure 2: LC tank – tuner circuit

The circuit above in an LC tank with a resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$ which for the above parameters ranges from 371 kHz all the way up to 2.35 MHz. The desired frequency of 567 kHz is within the parameters range. The knob of the variable capacitor used to change the resonant frequency.

- **RF Amplifier**.
  As the signal frequency goes up, some general purpose electronic components deviate from their desired operating behaviours. The normal amplifier circuit, like the Opamp feedback circuit, fails at higher frequencies due to limited slew rates.
  An RF (radio frequency) amplifier is required for this project. RF amplifier would typically use MOSFETS which are considered fast transistors.

A MOSFET circuit was used to buffer the received signal and to provide some little gain. A NPN transistor circuit was used to amplify the signal to a useful level.

The following circuitry was designed and used for the RF amplification.

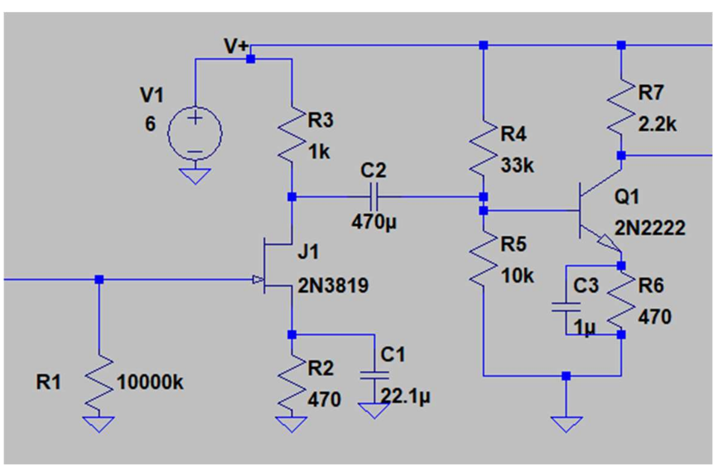

Figure 3: RF amplifier circuit.

From the N-type JFET datasheet V-I characteristic curve, a drain current of 2 mA and gate to source voltage of 1 V was chosen. A 500 Ω resistor is then required in the source leg, 470 Ω was used (E-12 resistor closest). An operating point of 4 V is chosen at the drain (No input-output value), hence 1 kΩ drain resistor.
The JFET has a g_m parameter of 4 mS and therefore the circuit has a gain of about 4. This circuit was mainly used as a buffer so that the circuit does not load the input signal, hence the 10 MΩ used from gate to ground.

The NPN is a normal class A amplifier. Voltage divider resistors are used to obtain base voltage of 1.4 V. A potentiometer of 500 Ω was used to vary the how much capacitance was connected from the emitter down to ground, hence varying the gain of the circuit. At 470 Ω of emitter resistance, 1.5 mA flow in the emitter (and approximately in the collector also), and a 2.2 kΩ was used to set the DC operating point of the collector to be 2.7 V. The little r_e becomes 17 Ω for 1.5 mA collector current and hence the gain becomes around 130 $\left(\frac{R_c}{r_e}\right)$.

- **The Envelope Detector**.

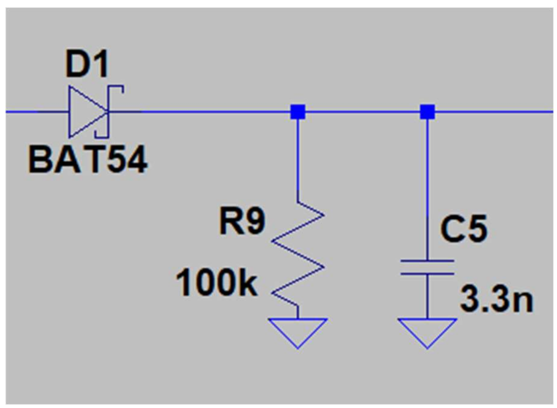

Figure 4: The envelope detector with LP and HP filters.

The time constant of the envelope detector $\tau = R_e C_e$ should meet the following requirement for a good envelope detection. [1]

$$\frac{1}{f_c} < \tau = R_e C_e < \frac{1}{\omega_m}\sqrt{\frac{1}{m^2} - 1} = \frac{2\pi}{f_m}\sqrt{\frac{1}{m^2} - 1}$$

Where f_c is the carrier frequency, f_m is the modulating frequency and m is the modulation index.

Therefore the $1.8\ \mu s < R_e C_e < 544\ \mu s$, given that an audio signal goes up to 20 kHz and $m = 0.5$.
If R_e is chosen to be $100\ k\Omega$ (for high input impedance), then $C_e = 3.3\ nF$ for $\tau = 330\ \mu s$.

A surprising behaviour unexpected from the envelope director: The signal into the envelope does not necessarily have to the zero centred for a good detection (rectification), the capacitor always charges to the **highest** value of the signal, and hence only the **top** envelope signal is produced in the output.

- **The Audio Buffer and earphones connection**.

The RF amplifier gain provided a gain enough so that the earphones circuit can be connected to the envelope detector without further amplification. The following circuit shows the earphones circuitry. The earphones are model by the 33 Ω load resistor, the resistance value of the earphones is measured with a multimeter.

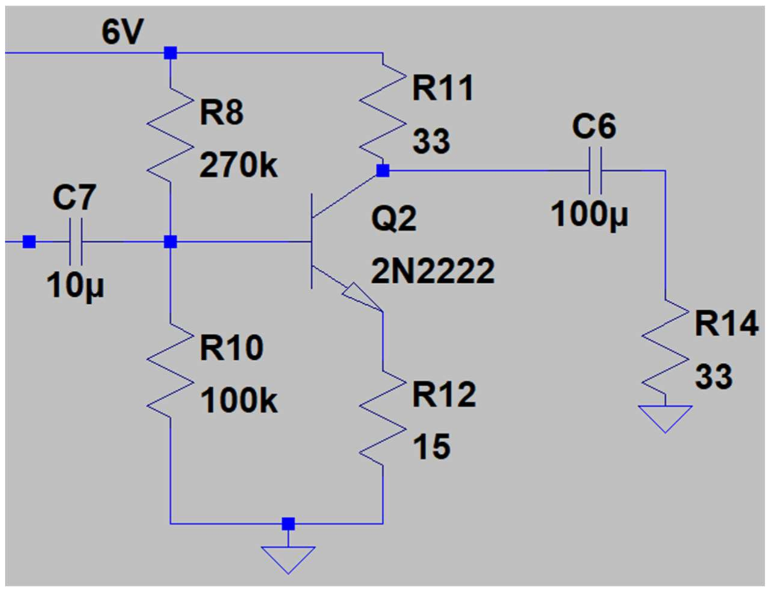

Figure 5: The amplifier buffer and earphones load matching transistor circuit.

A darlington transistor was used in the circuit above instead of a normal NPN transistor. The key design component in this circuit was the collector resistance. The collector resistance should match the load resistance for maximum power transfer. The voltage divider sets the base voltage at 1.6 V. The 15 Ω emitter resistor allows about 13 mA to flow through the transistor, and as a result, the DC operating voltage point of the collector is set to 5.6 V.

The earphones need above 100 mV peak to peak voltage to produce loud enough sounds audible to a listener, hence setting the Q collector voltage point of 5.6 V is not an unfavourable thing.

Earphones connection.

The earphones appear in parallel to the collector resistance and without an emitter capacitor, the gain of the circuit is only about 1. The circuit is mainly used as a load/source impedance matcher given the low impedance earphones and the need for a high input impedance circuit after the envelope detector.

The following figures show the earphone connectors.

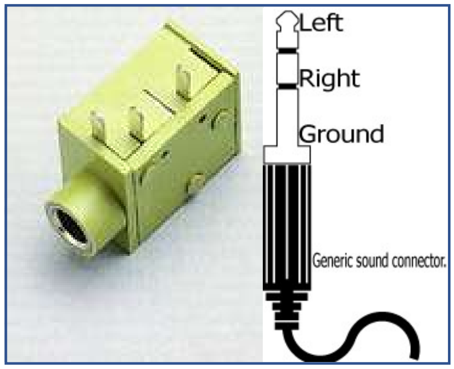

Figure 6: The earphones connectors.

The connectors above are used to connect the earphones to the circuit. The left and right points are connected.

- **THE SPEAKER.** [2]

The following circuit was used to connect an 8 Ω speaker to the circuit.

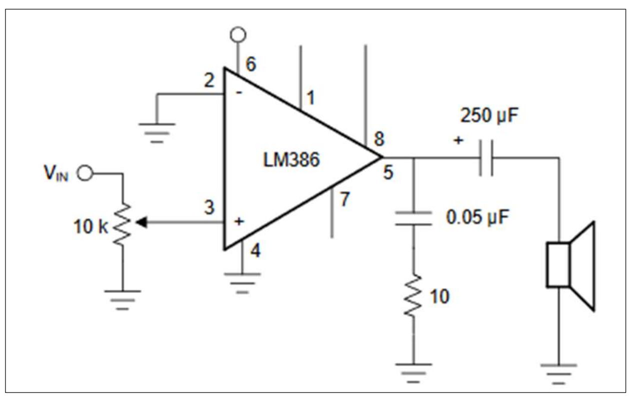

Figure 7: LM386 amplifier circuit.

The input into the above circuit could be the earphones pot or the output of the envelope detector.

RESULTS AND CONCLUSION

The [13.6 – 548 pF] variable capacitor was bigger in size and was therefore replaced with a smaller variable capacitor of between 5 – 60 pF and was placed in the coil to increase the relativity permeability of the coil, hence its inductance also. This was done to keep the resonance frequency close to the desired frequency, or the desired frequency within the tuneable range $\left(f_0 = \frac{1}{2\pi\sqrt{LC}}\right)$.

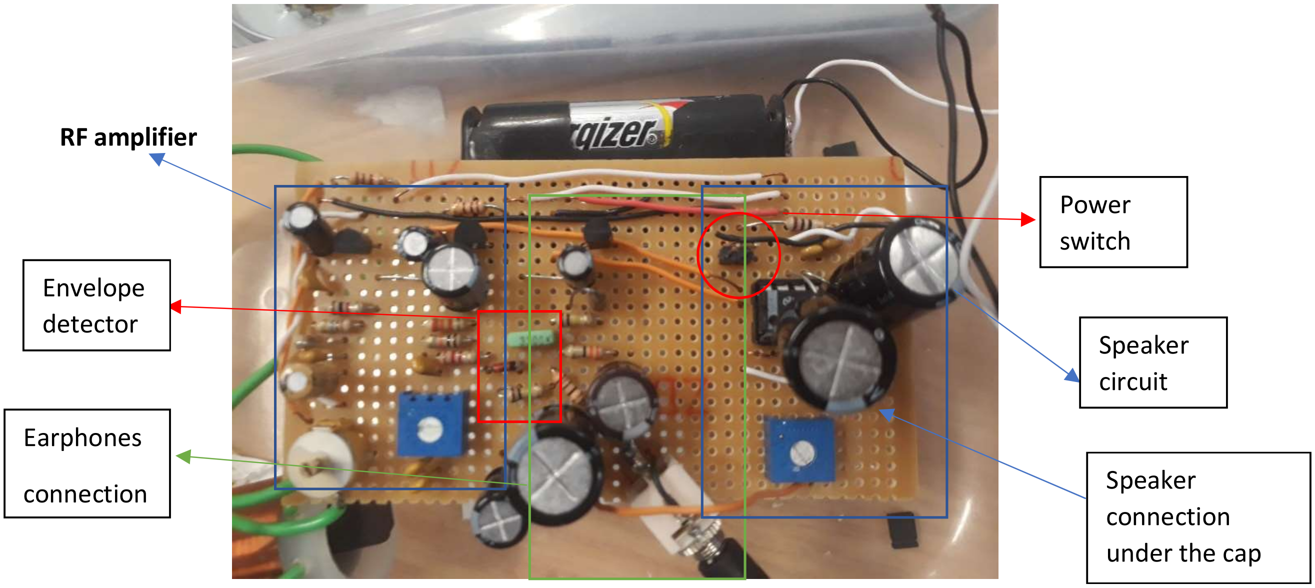

Figure 8: The Veroboard *circuit of the radio.*

The figure 9 below shows the full circuit as modelled in LTSpice. A few capacitors are connected in a few places on the power rails to removes fluctuations in the supply.

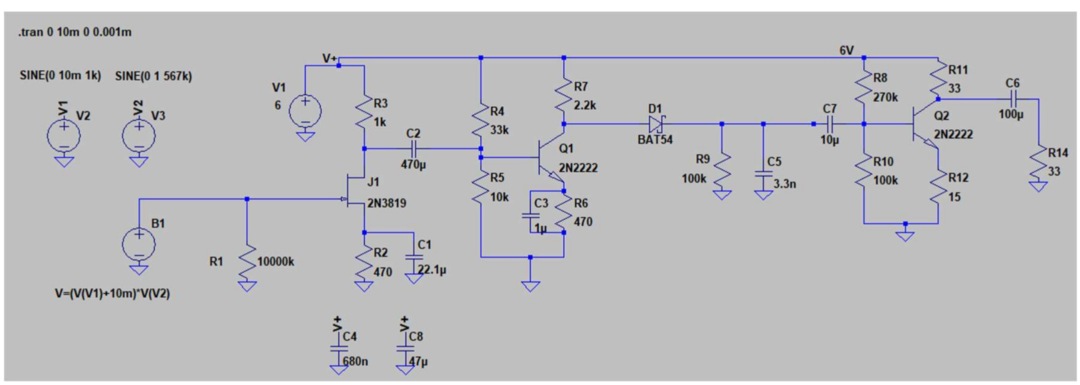

Figure 9: The radio completed circuit.

The following two figures show the simple packaging of the circuit.

Figure 10a: The opened package.

Figure 10b: The closed package.

In conclusion, the completed device works. The earphones are audiable enough, but the speaker is not that loud. The simple packaging is good enough and allows for opening and closing of the device. The tuning knob and the power switch are inside, hence the opening and closing.

AREAS FOR IMPROVEMENT

1. The audio signal can be amplified enough before the feeding into the speaker circuit.
2. Packaging could be done better by putting the tuning knob and power switch outside.

REFERENCES

[1] http://stanford.edu/class/ee133/handouts/lecturenotes/lecture2b_am_demod.pdf

[2] http://www.ti.com/lit/ds/symlink/lm386.pdf