Design and construction of a 1.045 MHz FM receiver

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Abstract

Karto's general rule: one sent. for each sect. Give numbers (e.g., transmission line speed)

1 Introduction

Modulation of radio frequency (RF) electromagnetic waves is a simple and effective method for long distance information transmission, as exemplified by amplitude/frequency modulated radio. The generation, transmission, and reception of modulated signals are interesting engineering problems which are also accessible to interested amateurs and beginning students of electronics. Simple modulators and demodulators may be built with a minimum of passive and active components (i.e., enough to fit on a small breadboard). RF circuits hold great educational potential for undergraduate students.

Here we present the design and construction of an FM receiver (1.045 MHz with bandwidth 200 kHz). The only non-linear components necessary are a diode and a transistor. The primary purpose of this circuit is for self-edification, but the layout may also serve as a starting point for further exploration of RF circuit design.

Additional paragraphs on results

2 FM receiver design

The receiver is comprised of a passive RLC bandpass filter, diode envelope detector, and a common-emitter amplifier chained between antenna input and speaker output. Blocking capacitors are placed between different functional sections to enable voltage biasing.

2.1 Bandpass RLC filter

The input signal is first passed through an RLC filter centered at approximately $1.045MHz$ with the -3 dB point at ± 200 kHz on each side. For component values R, L, C (resistor, inductor, capacitor) and input signal component with angular frequency ω, the gain of this filter is given by the equation:

$$\left|\frac{V_{\text{out}}}{V_{\text{in}}}\right| = \left(1 + (RC)^2 \left(\frac{\omega_0^2 - \omega^2}{\omega}\right)^2\right)^{-1/2}$$

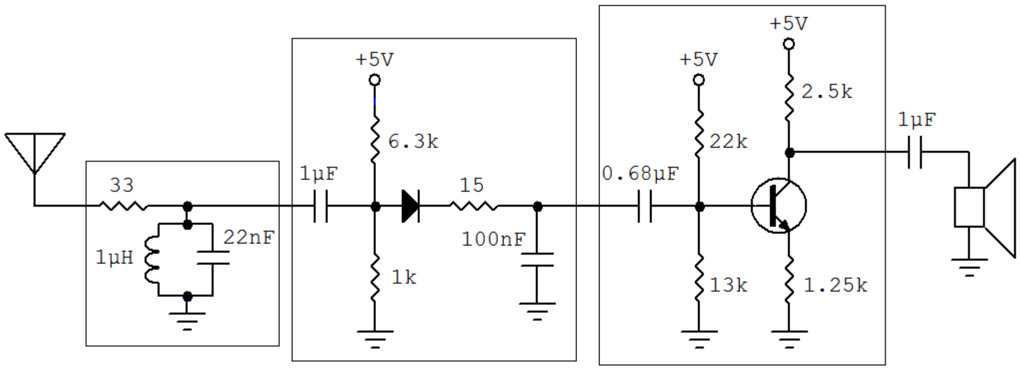

Figure 1. FM receiver circuit diagram with component values. Boxes demarcate functional components (see corresponding sections in text).

Here $\omega_0 \equiv 1/\sqrt{LC}$, emphasizing that this filter has unity gain at $\omega = \omega_0$. The -3 dB roll-off frequency occurs when the gain is equal to $1/\sqrt{2}$,or when:

$$(RC)\frac{\omega_0^2 - \omega^2}{\omega} = 1$$

Let the bandwidth be denoted by Δf, with corresponding cut-offs at $f = f_0 \pm \Delta f/2$, where $f_0 = w_0/(2\pi)$. This gives:

$$2\pi f_0 RC \approx \frac{f_0}{\Delta f}$$

as a prescription for our cut-off. Our component values $R = 33\ \Omega, L = 1\ \mu\text{H}, C = 22$ nF (Figure 1) give $f_0 = 1.073$ MHz, with bandwidth $\Delta f = 220$ kHz. Figure 2 plots the frequency-dependent gain along with the transmission band of interest at 1.045 MHz.

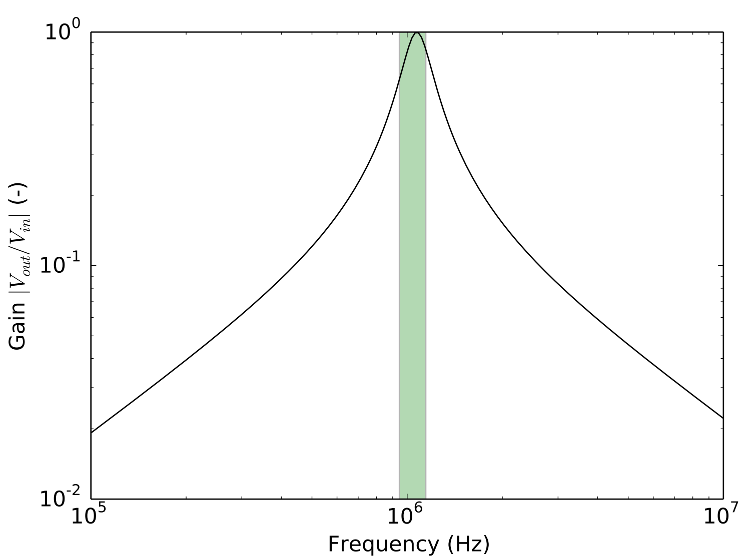

Figure 2. RLC filter gain as a function of input frequency f (Hz).

2.2 Diode envelope detector

* Describe overall design of receiver, with subsections for each functional plot. List salient features for each (-3dB point, bias voltages @ various locations, etc.). Present as if you invented it, and are writing a seminal paper (hahahaha)

* Plot expected output of LC filter in receiver as function of f. Mark transmission band on plot and explain rationale behind its placement on response curve.

* Plot bandpass of final filter that defines band of output audio signal. Describe (maybe plot) rationale for selecting said filter.

2.3 Common-emitter amplifier

* Describe speaker amplifier (circuit diagram), describe how it works, parts, bias voltages. Define operating band - what frequency range, and what sets the bounds?

* Suppose speaker amplifier connects to speaker at end of long wire. Given the circuit we built, what impedance cable do you recommend, how to terminate it (with 8-ohm speaker) to avoid reflections? Don't worry about maximizing current through speaker.

* Specify input/output impedance of circuit at audio frequencies

3 Results

* Discuss transmission line results.

3.1 Demodulator debugging

To test the RLC bandpass filter, we input a sine wave of varying frequencies and measured the output across the LC tank circuit. We obtained a maximum gain of 0.83 at input frequency 1.05 MHz (caveat: we may have used incorrect termination procedure for this measurement, but this only impacts our measurement of gain). The circuit qualitatively showed the correct roll-off behavior. When we input an FM signal at 1.045 MHz and observed the filter output on an oscilloscope, the signal was correctly converted into an AM signal with envelope code matching output audio.

* Explain our odd troubles with the diode detector. Whether the circuit helped was very equivocal...

3.2 Amplifier tests

* Discuss frequency / clipping issues here?

3.3 Noise characterization

* Noise measurement

4 Discussion

* Amplifier test - explain Allan variance test, but give reasonable physical numbers

5 Conclusion

What you're gonna do with this next. Don't rewrite your intro/abstract.

Use plain english. Don't worry about being technical, or too concise...

6 Acknowledgments

Circuit diagrams were generated using Fritzing.

7 References