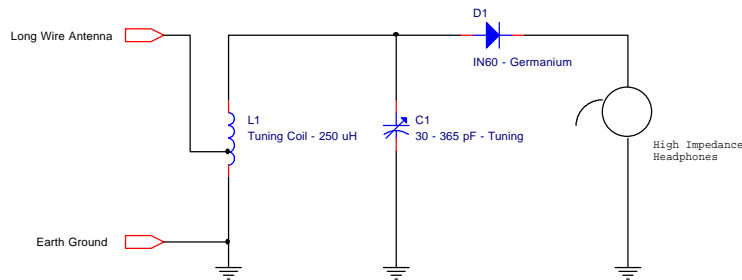


Homework #6 Solution Set

(32 points - 1 per problem)

- List the five steps in the process of receiving a radio signal.
 - Acquisition of the radio signal
 - Selection of the appropriate carrier
 - Amplification of the selected RF signal
 - Recovery of the information (Detection)
 - Processing the recovered information signal
- In the crystal radio receiver of figure 5-2, which of the five steps are being performed?



[Figure 5-2]

The following steps are being performed: *Acquisition* (Long-wire antenna), *Selection* (Tuned circuit with L1 and C1), *Detection* (D1), and *Processing* of the recovered information signal (Headphones).

- Why is RF amplification needed in a radio receiver?

RF amplification is needed because the input signals at the antenna are of extremely low voltage and power; much too low to be directly processed without amplification.
- How is a variable capacitor used in the tuning mechanism of a receiver?

A variable capacitor is used with an inductor to form a variable-frequency bandpass filter. This filter is tuned to the frequency of the desired carrier signal.
- A certain TRF radio receiver uses a variable capacitor with a range of 40 pF to 300 pF in combination with a fixed inductor of 200 mH. What is the tuning range of this receiver?

To solve this problem, the resonance formula is used twice:

$$f_{\min} = \frac{1}{2\pi\sqrt{LC_{\max}}} = \frac{1}{2\pi\sqrt{(200\text{mH})(300\text{pF})}} = \underline{\underline{649.75\text{KHz}}}$$

$$f_{\max} = \frac{1}{2\pi\sqrt{LC_{\min}}} = \frac{1}{2\pi\sqrt{(200\text{mH})(40\text{pF})}} = \underline{\underline{1779.41\text{KHz}}}$$

6. A receiver's bandpass filter can be tuned by changing the inductor instead of the capacitor. Such an arrangement is called permeability tuning. If the selector circuit of this receiver uses an inductor with a range of 20 mH to 200 mH in combination with a fixed capacitance of 270 pF, what will the tuning range be?

This technique was once very popular in high-end communications receivers. Again, the resonance formula is applied to find the operating frequencies:

$$f_{\min} = \frac{1}{2\pi\sqrt{L_{\max}C}} = \frac{1}{2\pi\sqrt{(200\text{mH})(270\text{pF})}} = \underline{\underline{684.89\text{KHz}}}$$

$$f_{\max} = \frac{1}{2\pi\sqrt{L_{\min}C}} = \frac{1}{2\pi\sqrt{(20\text{mH})(270\text{pF})}} = \underline{\underline{2165.82\text{KHz}}}$$

7. Compare and contrast an AM diode detector and a half-wave DC power supply.

The primary similarity between these stages is the use of a diode as a half-wave rectifier. The primary difference between them is the length of the RC time constant in the circuit. A DC power supply has a long RC time constant so that relatively smooth (ripple-free) DC is produced. An AM detector has a short RC time constant so that the information can pass (the information appears as "ripple" on the resulting DC voltage).

8. What are the three frequency components present in the output of a diode detector circuit?

The three frequency components are a DC level, the RF carrier frequency, and the AF information signal.

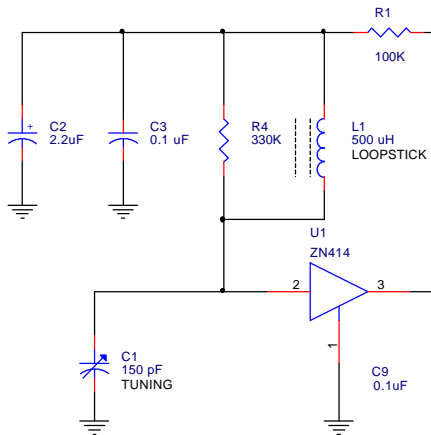
9. Why is a low-pass filter circuit used in a diode AM detector circuit?

A low-pass filter allows the AF information signal to pass, but blocks the RF carrier frequency component, which is no longer needed after detection.

10. What causes diagonal clipping distortion in an AM detector? What operating conditions are most likely to produce this form of distortion?

Diagonal clipping distortion is caused by having a falling envelope slope that is larger (faster) than the RC time constant used in the detector. The condition is mostly likely to show up under high percentages of modulation.

11. What is the function of inductor L1 in figure 5-7?



[Partial of Figure 5-7]

L1 performs two functions in this circuit. It acts as the receiving antenna as well as part of the selector band-pass filter circuit.

12. Explain the operation of a loopstick antenna. What portion of the radio wave is such an antenna sensitive to?

A loopstick antenna is a coil of fine wire wound on a rod of ferrite, which is a magnetic material. The antenna essentially acts like a transformer secondary, as it couples to the magnetic portion of the radio wave field.

13. Explain the difference between the sensitivity and selectivity of a radio receiver. What circuit characteristic controls selectivity?

Sensitivity is the ability to process weak signals, while selectivity is the ability to separate (select) signals that are closely-spaced in frequency. One parameter describes an amplitude characteristic, while the other describes a frequency characteristic. The bandwidth of the receiver controls its selectivity.

14. What are the two main problems with TRF receivers?

The two main problems with TRF receivers are (1) Bandwidth that varies with operating frequency, and (2) Unsuitability for operation above approximately 2 MHz.

15. A certain tuned circuit has a resonant frequency of 710 KHz and a Q of 100. What is its bandwidth?

$$BW = \frac{f}{Q} = \frac{710\text{KHz}}{100} = \underline{\underline{7.1\text{KHz}}}$$

16. What is the Q of an inductor having an inductive reactance X_L of 10 Ohms and an equivalent parallel resistance R_p of 100 Ohms?

For a parallel reactive circuit, Q is found by:

$$Q_p = \frac{R_p}{X_p} = \frac{100\Omega}{10\Omega} = \underline{\underline{10}}$$

17. A certain TRF tuning circuit consists of a 300 mH loopstick, in combination with a 30 to 300 pF variable capacitor for tuning. The equivalent tank parallel resistance is 100K Ohms. (See figure 5-9)
- What is the tuning range of the receiver?
 - What is the circuit bandwidth when tuned to 540 KHz?
 - What is the bandwidth at 1500 KHz?

a) To determine the tuning range, the resonant frequency formula is used:

$$f_{\min} = \frac{1}{2\pi\sqrt{LC_{\max}}} = \frac{1}{2\pi\sqrt{(300\text{mH})(300\text{pF})}} = \underline{\underline{530.52\text{KHz}}}$$

$$f_{\max} = \frac{1}{2\pi\sqrt{LC_{\min}}} = \frac{1}{2\pi\sqrt{(300\text{mH})(30\text{pF})}} = \underline{\underline{1677.64\text{KHz}}}$$

b) The bandwidth at 540 KHz is determined as follows:

$$X_p = X_L = 2\pi fL = 2\pi(540\text{KHz})(300\text{mH}) = 1018\Omega$$

$$Q_p = \frac{R_p}{X_p} = \frac{100\text{K}\Omega}{1018\Omega} = 98.24$$

$$BW = \frac{f}{Q} = \frac{540\text{KHz}}{98.24} = \underline{\underline{5.5\text{KHz}}}$$

c) At 1500 KHz, the bandwidth becomes:

$$X_p = X_L = 2\pi fL = 2\pi(1500\text{KHz})(300\text{mH}) = 2827\Omega$$

$$Q_p = \frac{R_p}{X_p} = \frac{100\text{K}\Omega}{2827\Omega} = 35.37$$

$$BW = \frac{f}{Q} = \frac{1500\text{KHz}}{35.37} = \underline{\underline{42.4\text{KHz}}}$$

18. *How does a superheterodyne receiver achieve a constant bandwidth?*

A superhet receiver has a constant bandwidth because the primary bandpass filtering occurs in the fixed frequency tuned circuits of the IF amplifier.

19. *What is the function of the converter section in a superhet receiver?*

The function of the converter is to convert the incoming RF carrier frequency up or down to the IF frequency.

20. *An ideal mixer is being supplied with the frequencies 600 KHz and 400 KHz. What output frequencies will be produced?*

The following frequencies will be produced: (a) Originals, 600 KHz and 400 KHz; (b) Sum, 1000 KHz; (c) Difference, 200 KHz.

NB: A *balanced mixer* does not allow the original frequencies to pass, ideally. Balanced mixers are used in high-grade communication transmitters and receivers.

21. *A certain mixer is producing the following output frequencies: 760 KHz, 1760 KHz, 1000 KHz, and 240 KHz. What are the two most likely input frequencies?*

The two most likely input frequencies are 760 KHz and 1000 KHz. These two frequencies appear at the output and also could be responsible for producing the other two frequencies by sum (1760 KHz) and difference (240 KHz).

22. *What is the standard IF frequency for AM broadcast receivers?*

The standard IF frequency for AM broadcast receivers is 455 KHz.

NB: Other IF frequencies have been used; for example, 262.5 KHz was once used in many early broadcast receivers. Modern DSP-based receivers may use a final IF frequency of only 10 KHz to 20 KHz.

23. *In order to convert a 870 KHz carrier down to a 455 KHz IF frequency using high-side injection, what local oscillator frequency is required?*

Because high side-injection is being used, equation (5-1) is used:

$$f_{lo} = f_c + f_{if} = 870\text{KHz} + 455\text{KHz} = \underline{\underline{1325\text{KHz}}}$$

24. *What local oscillator frequency would be needed in question 23 if low-side injection was used?*

For low-side injection, the local oscillator runs *below* the carrier frequency, and we get:

$$f_{lo} = f_c - f_{if} = 870\text{KHz} - 455\text{KHz} = \underline{\underline{415\text{KHz}}}$$

25. The superhet receiver of figure 5-15 is tuned to a carrier frequency of 1080 KHz.
- What frequency is the preselector tuned to?
 - What frequency is the local oscillator tuned to?
 - List all the frequencies produced by the mixer.
 - Which of the mixer output frequencies is amplified by the IF amplifier?
- The preselector is tuned to the carrier frequency f_c , or 1080 KHz.
 - $f_{lo} = f_c + f_{if} = 1080\text{KHz} + 455\text{KHz} = \underline{1535\text{KHz}}$
 - The mixer will output the following frequencies: 1080 KHz, 1535 KHz, 455 KHz, and 2615 KHz.
26. The superhet receiver of figure 5-15 is tuned to an unknown carrier frequency. The preselector tank consists of a 300 mH inductor and a 30 to 300 pF variable capacitor, which is set for a capacitance of 88 pF.
- What frequency is the receiver tuned to?
 - What frequency should the local oscillator be producing?
 - If the local oscillator has a 250 mH inductor, what capacitance will set the local oscillator to the correct frequency?

$$\text{a) } f_{pre} = \frac{1}{2\pi\sqrt{LC_{max}}} = \frac{1}{2\pi\sqrt{(300\text{mH})(88\text{pF})}} = \underline{979.53\text{KHz}}$$

$$\text{b) } f_{lo} = f_c + f_{if} = 979.53\text{KHz} + 455\text{KHz} = \underline{1434.53\text{KHz}}$$

- c) The resonant frequency formula must be solved for C to determine this answer:

$$C = \frac{1}{(2\pi)^2 f^2 L} = \frac{1}{(2\pi)^2 (1434.53\text{KHz})^2 (250\text{mH})} = \underline{49.24\text{pF}}$$

27. An AM superhet receiver is tuned to 1270 KHz and uses a 455 KHz IF. If high-side injection is being used, what is the image frequency?

$$f_{image} = f_c + 2f_{if} = 1270\text{KHz} + 2(455\text{KHz}) = \underline{2180\text{KHz}}$$

28. What section of a superhet receiver is responsible for eliminating the image frequency?

The preselector band-pass filter is responsible for eliminating (actually, attenuating) the image frequency.

29. Why is AGC needed in AM receivers?

AGC is needed to compensate for varying signal strength because AM receivers are greatly affected by signal strength.

30. *What stage of an AM receiver develops the AGC signal?*

The detector develops the AGC signal. The DC component of the detector's output is used to develop the AGC control voltage.

31. *What stages of an AM receiver are controlled by the AGC signal?*

The RF and IF stages are controlled by the AGC signal.

32. *Why are C1A and C1B mechanically ganged together in the receiver of figure 5-16?*

These two capacitors are ganged to provide tracking between the preselector and local oscillator circuits, so that a constant difference of f_{if} (455 KHz) is maintained as the receiver is tuned.