EET368 HOMEWORK #5 KEY

MILLER CHAPTER 3 PROBLEMS 1-9,11-17,20-31

28 POINTS TOTAL (1 PER QUESTION). ALL WORK MUST BE SHOWN.

1. The student should have drawn a block diagram of a TRF receiver:

```
        --------------      --------------      --------------
        |  RF AMP/    |     |  DETECTOR   |     |             |
ANT --->|             |--->|             |--->| AUDIO AMP   |----> TO
 IN     |  SELECTOR   |     |             |     |             |      SPKR
         --------------      --------------      --------------
```

2. **SENSITIVITY**: The ability of a receiver to deal with small input signals. It is controlled by gain, but dominated by receiver noise figure. Usually expressed in units of uV (Microvolts), or even better, dBf (Decibels with respect to 1 Femtowatt, 1 x 10e-15 watts.)

   SELECTIVITY: The ability of a receiver to separate signals (in other words, to "select" the desired signal from a group of undesired input signals.) Selectivity is a function of bandwidth and has units of frequency (Hz).

3. An **overly-selective** receiver has **TOO NARROW a bandwidth**, and thus destroys part of the information contained in the sidebands by band-limiting the radio signal.

(Key continued on next page)

4. Given: Need tuning range 550-1550 KHz in a TRF receiver. A 25 μH inductor is provided (ideal).
   Find: (a) The required capacitance range
   (b) Q needed if 10 KHz bandwidth is required @ 1000 KHz.
   (c) Resulting selectivity at 550 and 1550 KHz (assuming the Q from step B).

(a) The resonant frequency formula is manipulated to solve for C:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

So solving for C we get:

$$C = \frac{1}{4\pi^2 L f_r^2}$$

$$C_{\min} = \frac{1}{4\pi^2 L f_{\max}^2} = \frac{1}{4\pi^2 (25\mu H)(1550KHz)^2} = \underline{\underline{421.7\,pF}}$$

$$C_{\max} = \frac{1}{4\pi^2 L f_{\min}^2} = \frac{1}{4\pi^2 (25\mu H)(550KHz)^2} = \underline{\underline{3349.5\,pF}}$$

(b) The required Q is given by:

$$BW = \frac{f}{Q} \Rightarrow Q = \frac{f}{BW} = \frac{1000KHz}{10KHz} = \underline{\underline{100}}$$

(c) Because BW depends on both Q and center frequency, the following can be derived:

$$BW' = BW\left(\frac{f'}{f}\right)^2$$

Where f′ and f are the new and old frequencies, and BW is the original bandwidth.

Therefore, at 550 KHz, the bandwidth will be:

$$BW_{550} = 10KHz\left(\frac{550KHz}{1000KHz}\right)^2 = \underline{\underline{3.025KHz}}$$

and at 1550 KHz, the bandwidth will be:

$$BW_{1550} = 10KHz\left(\frac{1550KHz}{1000KHz}\right)^2 = \underline{\underline{24.025KHz}}$$

*Note: The answers here are **very different** than those given in the text. <u>The author of the text has assumed Q to be constant</u>, which is **false**! (See example 3-1 on page 104). **Q always changes when frequency is changed, unless something in the circuit is adjusted to compensate for the variance in Q!***

5. A **diode detector** is simply a RECTIFIER in the time domain. It removes the negative half of the modulated wave, leaving only positive pulses. Each pulse is a "sample" of the baseband information signal; a low-pass filter (RC network) smooths the pulses back into a continuous signal that approximates the original information.

6. Diode Detector advantages and disadvantages:

   ADVANTAGES: Can handle higher power levels than some active circuits; high efficiency; possible DC output (useful for AGC); distortion levels quite acceptable for AM broadcast reception.

   DISADVANTAGES: Provides no amplification; must be supplied with enough signal to overcome diode drop; significant distortion limits application.

7. DIAGONAL CLIPPING occurs in a diode detector during the discharge interval when the modulated envelope is falling. It is caused by the RC time-constant of the detector being longer than the fall-time of the envelope. This is a form of distortion, and the output information is altered.

8. Diagonal clipping is **directly related** to modulation index. The greater the percentage of modulation, the larger the peaks and valleys of the detected information signal, and farther the voltage “distance” the RC circuit in the AM detector must go to discharge if it is to accurately Follow the information signal. Thus, diagonal clipping becomes worse as percentage modulation increases.

9. Diagonal clipping occurs when the modulation envelope falls faster than the RC time-constant of the AM detector circuit. During this time, the detector’s output signal is no longer an accurate representation of the information signal; the detector output signal “lags” the information. This is perceived by a listener as distortion of the information signal.

11. The student should draw a block diagram of a superhet receiver. The following stages should be included and explained:

    a. RF AMP / PRESELECTOR: Narrows down range of input signals for mixer, (eliminates image). May provide gain.

    b. MIXER (1st mixer): Converts the RF signal down to the IF frequency.

    c. LOCAL OSCILLATOR: Provides the correct frequency to "beat" with the RF signal at the mixer, in order to produce the IF frequency.

    d. IF AMPLIFIER: Provides most of the receiver's gain and determines the bandwidth. Passes the difference signal from the MIXER and rejects other mixer products to provide "single signal" reception.

    e. DETECTOR: Extracts information from modulated IF carrier wave.

    f. AUDIO AMP: Processes recovered baseband information for driving a loudspeaker (voltage & current gain.)

12. SUPERHETERODYNE receivers contain IF transformers.

13. GIVEN: An AM signal with Fc=1100 KHz is modulated by a 2 KHz sine wave. It is mixed with a 1555 KHz local oscillator signal. Show the resulting output frequency components of the mixer.

    The mixer's output contains the original, sum and difference frequencies:

```
Fout = (1555 K + 1100 K) , (1555 K - 1100 K)     (CFC conversion)
       (1555 K + 1102 K) , (1555 K - 1102 K)     (USB conversion)
       (1555 K + 1098 K) , (1555 K - 1098 K)     (LSB conversion)

Fout = 2655 KHz, 455 KHz (CFC)
       2657 KHz, 453 KHz (USB)
       2653 KHz, 457 KHz (LSB)
```

    The FREQUENCIES ACCEPTED by the IF AMP are 453 KHz, 455 KHz (CFC), and 457 KHz. Note the transposition of USB and LSB.

14. The **FIRST DETECTOR is really the MIXER.** Its purpose is to convert the incoming RF signal to the IF frequency, with the help of the local oscillator.

15. The variable tuned circuits in a superhet are mechanically "ganged" together on a common shaft, thus causing them to change at the same time when the tuning control is operated.

16. The student's adjustment procedure may vary; tracking is typically adjusted in the following manner:

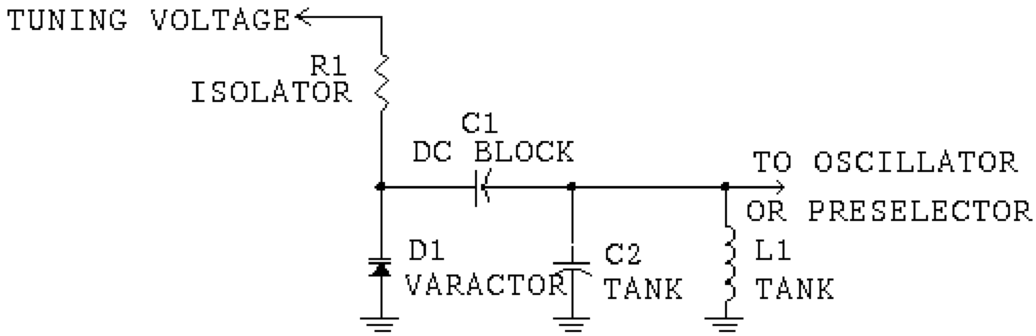
    a. Adjust IF amplifier for correct frequency and response shape using an IF sweep generator.

    b. Tune a station near 810 KHz, and adjust the LO TRIMMER for correct dial frequency indication.

    c. Tune a weak station near 1510 KHz, and adjust the ANT TRIMMER for maximum output.

    d. Tune a weak station near 550 KHz, and adjust the PRESELECTOR COIL for maximum output.

17. A circuit using a varactor diode for **electronic tuning** might look like this:



The **TUNING VOLTAGE** is applied through R1, which prevents tank currents from being short-circuited by the tuning voltage circuitry. The tuning voltage appears directly across D1, which adds its capacitance C_d to the "tank" circuit, thus varying its resonant frequency. This can be used to either vary the frequency of an oscillator, or to modify the center frequency of a bandpass filter.

20. GIVEN: Fc = 1000 KHz, Flo=1300 KHz. What is the image frequency?

Fimage = Fc + 2Fif (when using high-side injection: Flo>Fc).

Fif = Flo-Fc = 300 KHz,

Fimage = Fc + 2Fif = 1000 KHz + 2(300 KHz) = 1600 KHz.

21. **Assuming high-side injection,** the range of oscillator frequencies and image frequencies would be given by:

$$f_{LO} = f_c + f_{if}$$
$$f_{image} = f_c + 2f_{if}$$

At f=20 MHz:
$$f_{LO} = f_c + f_{if} = 20MHz + 10.7MHz = \underline{\underline{30.7MHz}}$$
$$f_{image} = f_c + 2f_{if} = 20MHz + (2)(10.7MHz) = \underline{\underline{41.4MHz}}$$

At f=30 MHz:
$$f_{LO} = f_c + f_{if} = 30MHz + 10.7MHz = \underline{\underline{40.7MHz}}$$
$$f_{image} = f_c + 2f_{if} = 30MHz + (2)(10.7MHz) = \underline{\underline{51.4MHz}}$$

22. Image frequency rejection is not a difficult problem for the AM broadcast band, because the range of carrier frequencies is approximately 3:1 (550 KHz-1620 Khz). For example, at 610 KHz, the image would be at 610KHz + (2)(455 KHz) = 1520 KHz –- more than an octave away, which is easy to reject, even for a 2^{nd} order preselector circuit.

23. The advantages of adding a **tuned RF frequency stage** ahead of the mixer are:

- Receiver **sensitivity** is improved, since weak signals at the preselector can now be pushed above the noise floor of the mixer.

- The possibility of **local oscillator radiation (reradiation)** is reduced. With some mixers, signal can flow backwards from the LO port (where a fairly strong, +3 dBm to +10 dBm signal exists) to the antenna circuit. The RF amplifier will have very low gain in the reverse direction, thus minimizing this problem.

24. A **temporary repair** might be made by using a small capacitor (0.01 – 0.1 μf) to "bridge" the input and output of the RF amplifier stage. This will send signals directly from the antenna to the mixer port. There will be a fairly large loss of receiver gain and sensitivity, but it should work. Using a capacitor instead of a shorting wire eliminates problems that might arise from conflicting DC levels at the input and output portions of the circuit.

25. The **dual-gate MOSFET** has several primary advantages:

- There is excellent isolation between the two gates, so that if one is used for local oscillator injection, and the other for RF injection, the oscillator signal can not easily travel back towards the antenna. It's very good as an unbalance mixer.

- The MOSFET is a **square-law** device. This means that spuriously-generated outputs from the stage are most likely to appear on the 2nd and higher harmonics, which are quite easy to filter out. BJTs also generate harmonic distortion in this fashion, but also produce a significant amount of 3rd and higher order term distortions – which can result in "close-in" spurs that are hard to filter out. An example of a 2nd order product is any frequency that is obtained by adding and/or subtracting **two** original frequencies. For example, f1 + f2 and f1+f1 (2f1) are both **2nd order products** and would fall well outside the bandpass of most normal filters tuned to f1. A 3rd order product is obtained by adding and/or subtracting **three** original frequencies. For example, f1+f1-f2 = 2f1-f2 which could fall close to the original frequency (try setting f1=710 KHz, f2=720 KHz and you'll get a 3rd order product of 700 KHz, which would be very difficult to filter out!)

- It's very convenient to use the "spare" gate input in a dual-gate MOSFET as an **AGC** input.

26. The **MIXER** in a superhet receiver is the stage that converts the incoming RF frequency into the IF frequency, with the help of the local oscillator. It is sometimes called the "1st Detector."

27. An **autodyne** mixer requires only one active amplifying device (usually a transistor). A standard converter scheme uses two devices, one as the oscillator, and the other as the mixer. With modern electronics, this isn't much of an advantage, as it costs nothing more to add one more transistor to an IC chip!

28. The bulk of a reciever's gain and selectivity is obtained in the IF amplifier for two reasons.

    First, the IF frequency is usually lower than the carrier frequency; this causes the IF bandwidth to be less than the preselector tuned-circuit bandwidth. The lower bandwidth always dominates the frequency response of the receiver. (Since the IF frequency is constant, the receiver bandwidth and selectivity are constants too, a good thing!)

    Second, it is good design to do most of the amplification at the low IF frequency, where low-noise amplifiers are most easily realized.

29. An AM receiver without AGC will not have a steady volume level, especially in a moving vehicle. Even in a fixed location, signal strengths are not a constant, as propogation is not fixed.

30. **AVC** (or **AGC**) is accomplished by sampling the signal strength at the detector (a DC or AVERAGE signal). This signal is fed back to control the bias of the RF and IF amplifiers, which "modulates" (varies) their gains accordingly.

31. DC bias controls the gain (or transconductance) of a BJT by varying its **dynamic emitter resistance**, ***r'e***. In a circuit designed for this purpose, changes in r'e ($1/g_m$) will directly affect signal gain.