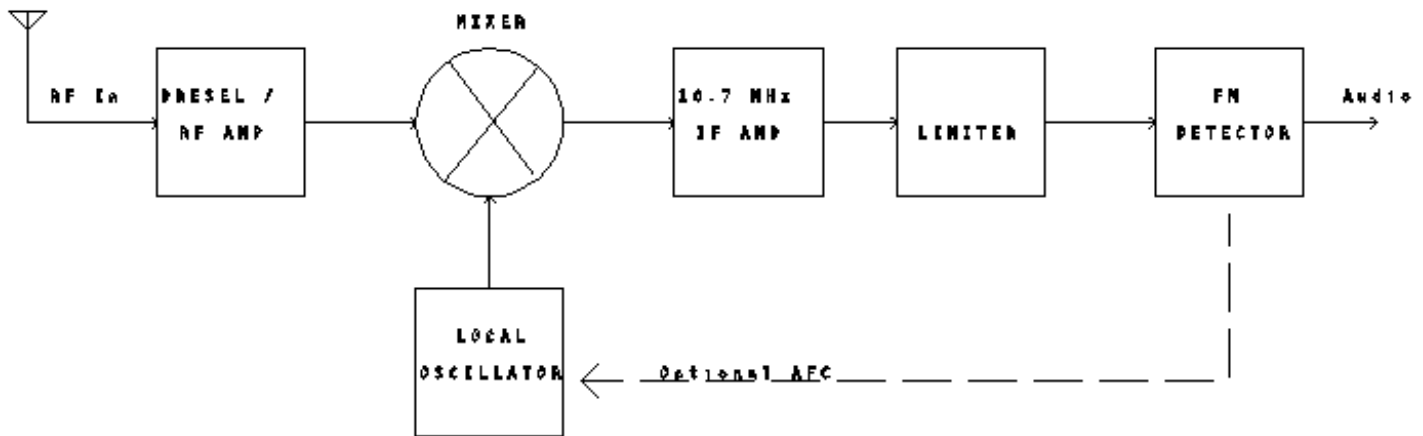


EET368 HOMEWORK #7 KEY

MILLER CHAPTER 6 problems 1-17,22,23-25

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

1. A **discriminator** is a circuit whose job is to "discriminate" among different input frequencies. It is better understood as a **frequency-to-voltage** converter. Input *frequency* changes to a discriminator are converted into output *voltage* changes. This circuit is useful as an FM detector.
2. **AFC** or **automatic frequency control** is not necessary with most modern FM receivers, because of **synthesized local oscillators**. The PLL is the most commonly-used technique to achieve this; it virtually eliminates receiver drift.
3. A superhet FM receiver has the following configuration:



4. Given $F_c=96.5$ MHz, $F_{if}=10.7$ MHz. Find F_{lo} and F_{im} .

$$F_{lo} = F_c + F_{if} = 96.5\text{MHz} + 10.7\text{MHz} = \underline{\underline{107.2\text{MHz}}}$$

$$F_{im} = F_c + 2F_{if} = 96.5\text{MHz} + (2)(10.7\text{MHz}) = \underline{\underline{117.9\text{MHz}}}$$

5. An **RF AMPLIFIER** is desirable at VHF for two reasons:

- At VHF and UHF, signals will be weaker due to increased free-space path loss between transmitter and receiver. Signals need to be boosted at a receiver to overcome the mixer's **noise floor**.
- At VHF and UHF, relatively small antennas can become effective radiators. Even a receiver's antenna could function this way. Because every receiver has a local oscillator, every receiver is a potential transmitter. The RF amplifier helps to prevent local oscillator signals from going backwards toward the antenna, reducing the potential for interference.

6. **Local oscillator reradiation** is a fancy term describing accidental radiation of RF from a receiver's local oscillator stage. The RF amplifier stage prevents most of it, since signals can pass easily in only one direction through the RF amplifier.
7. **Square-law** devices, such as FETs, are preferred because they will tend to produce better **cross-modulation** performance. This is because the accidental mixing products produced in a FET will generally be at a harmonic of the carrier frequency, instead of adjacent to it; it is much easier to filter out undesired mixing products far from the carrier frequency than near it!
8. **FETs** are used for two reasons. First, they are square-law devices, which tends to improve cross-modulation rejection. Second, they are relatively low-noise producers, especially at VHF and UHF. **GaSFETs** are a type of FET that are dominant in high-performance VHF / UHF RF amplifiers.
9. 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, $f_1 + f_2$ and $f_1 - f_2$ are both **2nd order products** and would fall well outside the bandpass of most normal filters tuned to f_1 . A 3rd order product is obtained by adding and/or subtracting **three** original frequencies. For example, $f_1 + f_1 - f_2 = 2f_1 - f_2$ which could fall close to the original frequency (try setting $f_1 = 710$ KHz, $f_2 = 720$ 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.
10. In figure 6-2, the **RF Choke** prevents undesired RF signal from going back into the power supply line, which could result in undesired feedback and oscillation.
11. The purpose of a **LIMITER** stage in an FM receiver is to reduce noise by eliminating any amplitude variations on the signal prior to detection.
12. A limiter stage is typically a small-signal RF amplifier that has been designed to easily cut-off and saturate. The circuit diagram is therefore the same as a standard RF amplifier. Limiter stages need to be well-shielded from the front-end of the receiver, since they may produce harmonics of the IF frequency due to the clipping action (which produces flattened sine waves in the collector circuit.)
13. The **limiter** stage of Figure 6-3 operates on several important principles:

- The **emitter** resistor is bypassed with a capacitor, causing the stage to have a high voltage gain.
- The **collector** includes a "damper" resistor, **R_c**. This resistor causes the stage to saturate easily.

The inclusion of these design principles produces a stage that essentially "squares off" the input signal, thus removing amplitude variations. The output tank circuit restores the impulse train resulting at the collector back into a sine wave.

14. The relationship among **limiting, sensitivity, and quieting** for an FM receiver is as follows:

- **Quieting** refers to the ability of the receiver to reject noise. For FM quieting to occur, the **limiter** must have enough signal to operate.
- In order for **limiter** to get enough signal, there must be sufficient **gain** in the stages preceding the limiter. In general, more gain produces more **sensitivity** (until noise effects take over, at which increasing gain no longer increases sensitivity).
- FM receiver **sensitivity** is generally expressed in terms of the *input signal level needed to attain a 10 dB or better input S/N (actually SINAD) ratio*. This test is generally performed with an FM signal generator set at 50% to 100% modulation, with a 1 KHz test tone. In general, given this input level, going above it results in a rapid "quieting" of the FM receiver as the limiter stage takes over and eliminates most of the amplitude noise.

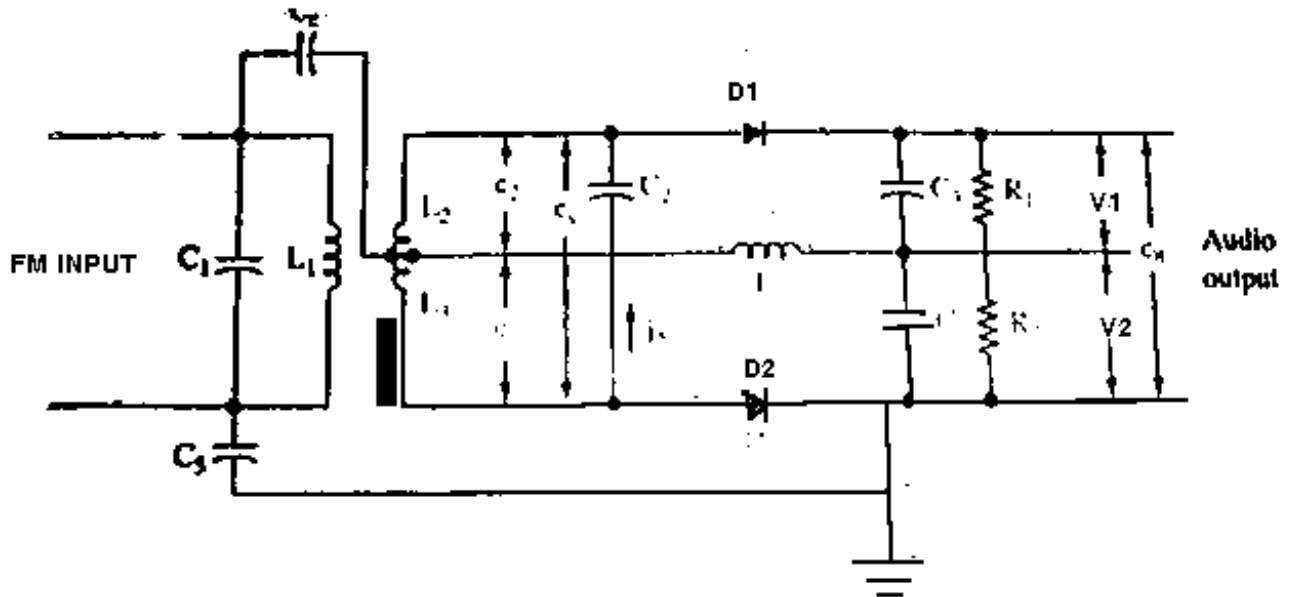
15. Given: An FM receiver has 100 dB of *voltage gain* prior to the limiter. The limiter requires 300 mV to operate. Find the receiver's sensitivity. Note: This calculation actually calculates *FM Limiter Threshold*; actual receiver sensitivity will probably be better than this calculation reflects.

By definition:
$$dB = 20 \log \left(\frac{V_{lim}}{V_{ant}} \right)$$

By rearranging this equation, we get:
$$V_{ant} = \frac{V_{lim}}{10^{(dB/20)}} = \frac{300mV}{10^{(100/20)}} = \underline{\underline{3\mu V}}$$

16. An FM **SLOPE DETECTOR** looks just like a classic AM detector. The tuned circuit is tuned to either side (but not the center) of the IF passband. They're not commonly used due to the "dual" response, as well as total lack of AM rejection.

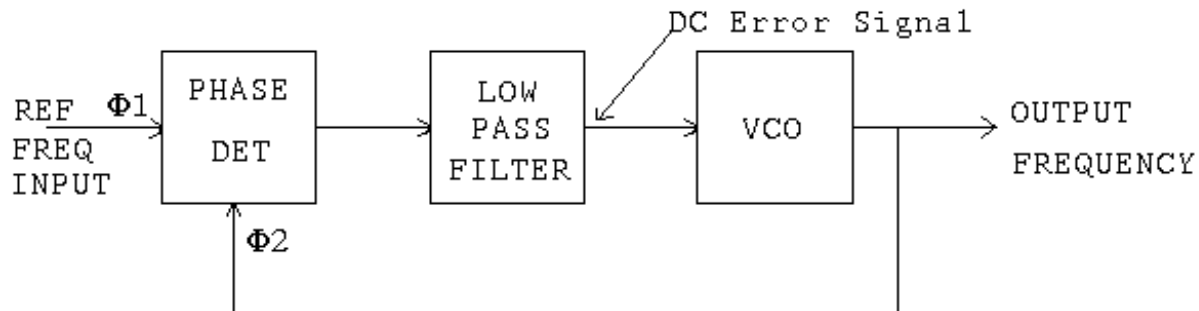
17. A **FOSTER-SEELEY** FM detector works by a frequency-sensitive balancing mechanism. When $F_{in} = F_c$ (F_{if}), V_1 and V_2 are equal and no output voltage results. When $F_{in} > F_{if}$, $V_1 > V_2$ and a positive output results. The opposite happens when $F_{in} < F_{if}$, producing a negative output. Thus, FM detection occurs.



22. A **QUADRATURE** detector works by comparing the phase of a reference tuned-circuit to that of the incoming carrier wave. The reference tuned-circuit actually gets its signal from the incoming carrier. Typically, an XOR (exclusive-OR) gate is used as the phase detecting element. Frequency deviation at the input of this detector causes a change in the phase difference at the two XOR inputs, causing the XOR gate's output duty cycle to change. When the gate's output signal is averaged using a low-pass filter, a copy of the information results.

23. A **PHASE LOCKED LOOP** contains several basic parts:

- A **PHASE DETECTOR**, whose job it is to convert the phase difference between the **reference oscillator** and **VCO** into an average DC voltage. Most phase detectors obey "Finley's Law," that is: If the two inputs are not exactly the same frequency, then the output will be in saturation.
- A **LOW PASS FILTER**, which smoothens the pulsating DC output from the **phase detector** prior to passing it to the **VCO**.
- A **voltage controlled oscillator** or **VCO**, which converts the DC input back into an output frequency.



The phase detector can be considered the decision maker in the loop. If the VCO and reference oscillators aren't on the exactly the same frequency, it will adjust its output voltage in the correct direction to make the VCO frequency exactly equal to that of the reference. Even if the reference frequency changes, the VCO will follow as the phase detector continually compares the VCO and reference frequency. This behavior is typical when the loop is in the "locked" state.

24. A **PLL FM DEMODULATOR** works because a PLL, when in lock, attempts to follow any frequency changes (modulation) at its input. Thus, as the VCO follows the modulation, the VCO control voltage is also following the information. The VCO control voltage is therefore a copy of the information, and can be used as the circuit output.

25. List the **states** of a PLL:

- **Free-Running**: No input signal has been applied.
- **Capture**: An input signal has just been applied, but the loop has not locked onto it. It is in the process of attempting to acquire lock.
- **Locked**: The PLL has fully locked onto the input signal; $F_{vco} = F_{reference}$.