FM Detector Notes

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1   High Level Design

There are a few different types of fm detectors that are commonly used:

- Foster-Seeley Discriminator

- Ratio Detector

- Quadrature Discriminator

Out of all of these, the Quadrature Discriminator seems to be the best for a few reasons:

- Has a simple design only requiring a few components.

- Does not require an RF transformer, which needs to be weakly coupled in the case of the Foster-Seeley Discriminator - cannot easily find one off of digikey/mouser.

- Works with low input levels and has good linearity.

2   Principle of Operation

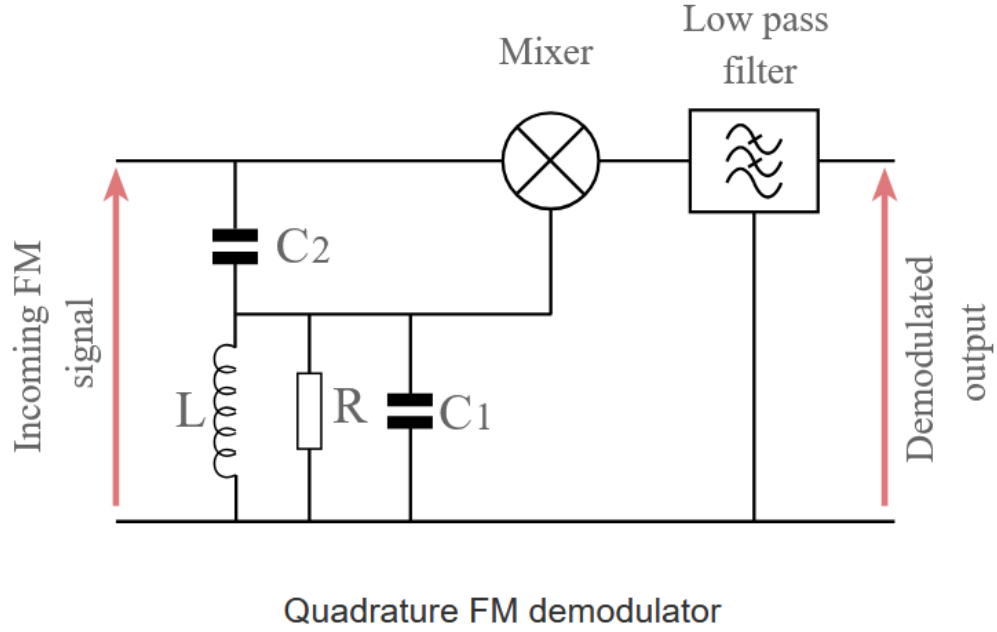The fm modulated signal is

$$Acos((w + bb(t))t)$$

where bb(t) is the baseband signal. The signal after C2 is shifted by 90 degrees due to the capacitor, and additionally shifted by ϕ due to the difference between the resonant frequency of the tank circuit and the incoming FM signal. Therefore the signal after C2 is

$$Acos((w + bb(t))t + \frac{\pi}{2} + \phi)$$

Multiplying these two together gives

$$Acos((w + bb(t))t) * Acos((w + bb(t))t + \frac{\pi}{2} + \phi)$$

By the identity $cos(a)cos(b) = \frac{1}{2}[cos(a - b) + cos(a + b)]$,

Quadrature FM demodulator

$$= \frac{A^2}{2} cos(-\pi/2 - \phi) + cos(2(w + bb(t))t + \frac{\pi}{2} + \phi)$$

Noting that $cos(-\pi/2 - \phi) = sin(\phi)$,

$$= \frac{A^2}{2} sin(\phi) + cos(2(w + bb(t))t + \frac{\pi}{2} + \phi)$$

The higher frequency cosine component can be filtered out, leaving a function whose amplitude is proportional to the phase, which in turn is proportional to $sin(\phi)$. For small values of ϕ, this is approximately equal to ϕ.

3 Detailed Design

- For the tank circuit, the self resonant frequency is given by $\frac{1}{2\pi\sqrt{LC}}$. If we choose L = 0.1 uH, then for a resonant frequency of 10.7 MHz, this gives us 2.21 nF.
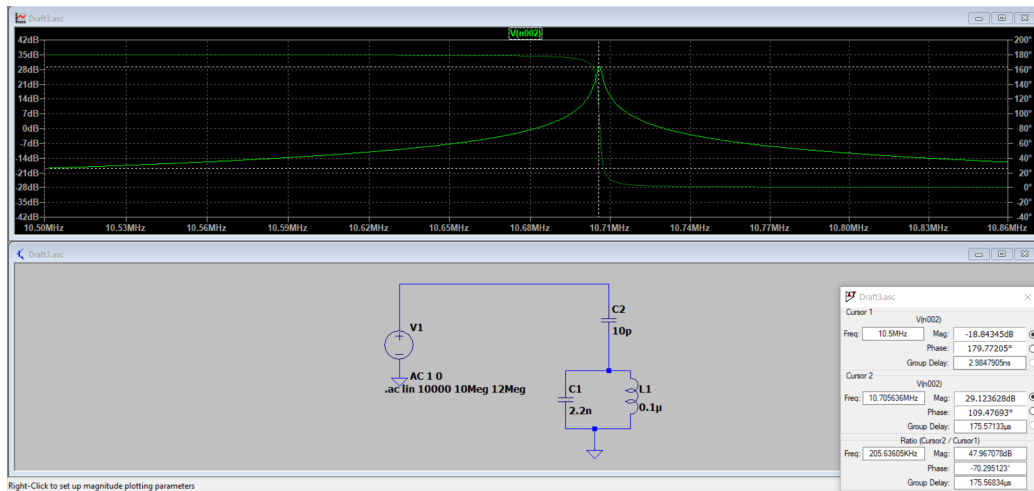
- For the 90 degree phase shift cap, we can use a small 10 pF cap.

- Since the inductor and capacitor values are not exact, the resonant frequency of the tank circuit will not be exactly 10.7 MHz. This will result in a phase error α. We can AC couple the output to solve this issue.

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$$out = \frac{A^2}{2}sin(\phi + \alpha)$$

- We need a mixer that can mix down to very low frequencies, since the mono baseband is typically 50 Hz to 15 kHz. Let's use the AD831, since the output can go down to DC.

4 Simulations

Here is a simulation of the tank circuit in the discriminator:

Here's a simulation of the fm detector working at low frequencies (at high frequencies LTSpice doesn't handle it very well)