HW – (5.1 – 1,2,3) – instantaneous freq.

5.2 – 1,2,3, – – bandwidth

Also find full spectrum of $\varphi_{FM}(t)$

Find BW by Carson's rule

and by Bessel functions,

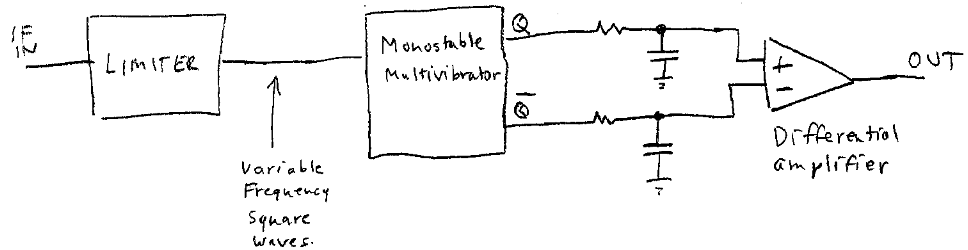
with all components over 1% of the max component.

5.3 – 1,2 – Also design (block diagram) the same specs using direct FM using a VCO that adjusts over the range of 10 – 14 MHz.

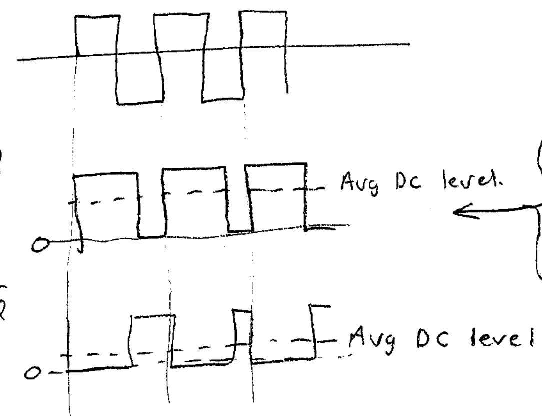
5.4 – 1,2



"Pulse count" or "zero-crossing" detector




LIMITER OUT




Q: Pulse width is constant, frequency varies – so lower freq ⇒ higher DC, higher freq ⇒ lower DC

$\bar{Q}$: Same except lower freq ⇒ lower DC, higher freq ⇒ higher DC

Advantages:

Good linearity, even when $\Delta f$ is high with respect to $f_c$. (high modulation)

Disadvantages:

Until recently, difficult to build at high frequencies.

Low output when $\Delta f$ is small with respect to $f_c$.

## Phase-locked loop (most common method today)

Recall, how we synchronized the BFO (6A-3-6) (see notes)

For FM detection, use the "error out" ($e_o(t)$)

It is the FM signal.

$$e_o(t) = \frac{AB}{2}\sin(\underbrace{\theta_i - \theta_o}_{=\theta_e})$$ ← No loop filter.

Instantaneous frequency of VCO..

$$\omega_{vco} = \omega_c + c\,e_o(t)$$

↑ some constant.

if VCO output is $B\cos(\omega_c + \theta_o(t))$

then instantaneous freq is $\omega_c + \dot{\theta}_o(t)$

so .. $\dot{\theta}_o(t) = c\,e_o(t)$

---

With a general loop filter---

$$e_o(t) = h(t) * \tfrac{1}{2}AB\sin(\theta_e)$$

↑ convolution

↑ The loop filter has a big effect on FM demodulation

Applying some math (p 237)

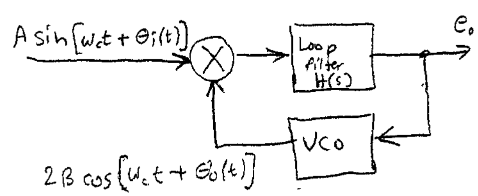
$$e_o(t) = \frac{1}{c}\dot{\theta}_o(t) \approx \frac{k_f}{c} m(t)$$

↑ shows that $e_o$ tracks $m(t)$ so this demodulates FM.

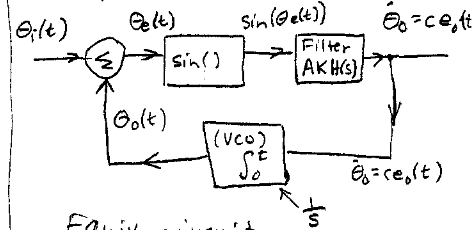


## PLL - Loop filter comments

PLL Diagram:




Equiv. circuit




Equiv circuit, thinking of it as a general feedback circuit.

The VCO is like an integrator because---

"output" is frequency

"input" represents phase.

frequency = $\int$ phase.

$\theta_i(t)$ is the "input" --- contained in the phase of the signal

$\theta_o(t)$ is the feedback --- contained in the phase of the VCO

$\dot{\theta}_o(t)$ is the frequency offset of the VCO.

$\theta_e(t)$ is the phase error

---

Book says "first order loop" -- means loop response = $\frac{1}{s}$

filter response = 1 (no filter).

This can't track a signal.

"Second order loop" means filter response = $\frac{1}{s+a}$

loop response = $\frac{\theta_o(t)}{\theta_i(t)} = \frac{FB}{1 + FB}$

like a non-inverting op-amp.

$FB = AKH(s)\cdot\frac{1}{s} = \frac{AKH(s)}{s}$ (subst.)

$$= \frac{\frac{AKH(s)}{s}}{1 + \frac{AKH(s)}{s}} = \frac{s}{s + AKH(s)} = \frac{s}{s + \frac{1}{s+A}} =$$