Carrier Acquisition

How do we synchronize the receiver's "BFO" to the suppressed carrier?

① Transmit something:

Ⓐ FM stereo: pilot tone —
19 kHz pilot — multiply by 2 to get 38 kHz, for L−R on 38 kHz DSB-SC.

Ⓑ Color TV: color "burst"
At the beginning of every scan line, transmit a short "burst" of the carrier. Use this to synchronize an oscillator, for QAM-SC.

② Guess, from the signal:

Ⓐ Signal squaring method — DSB-SC only
Apply the signal to a squaring circuit.
The output is $2\omega_c$.
Filter with high-Q filter
Limit it to remove amplitude variations.
Divide by 2 to get ω_c.

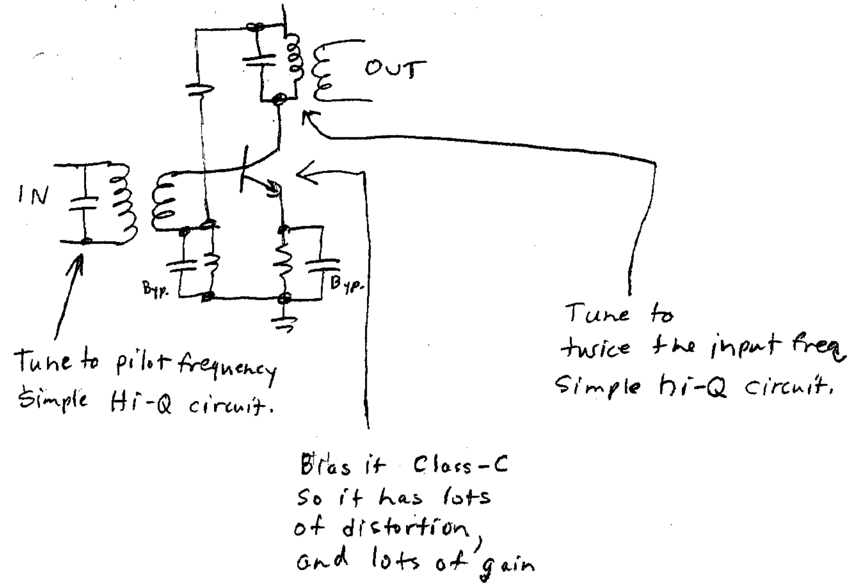
Ⓑ Costas loop — DSB-SC only
A fancy phase locked loop.

Ⓒ SSB or QAM — neither of these works —
Need either ① or guess.

Brute-force methods

ⒶA FM stereo (no longer used)

Simple frequency multiplier.



How to synchronize an oscillator?

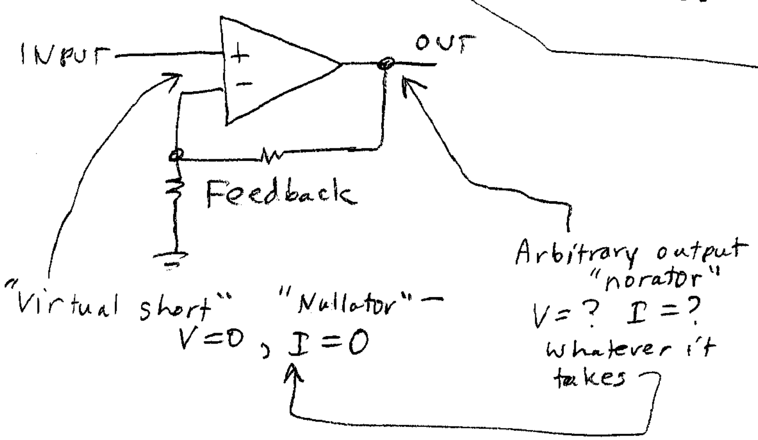
"Phase-Locked Loop"

We need: ① A controllable oscillator
"VCO" - voltage controlled oscillator.

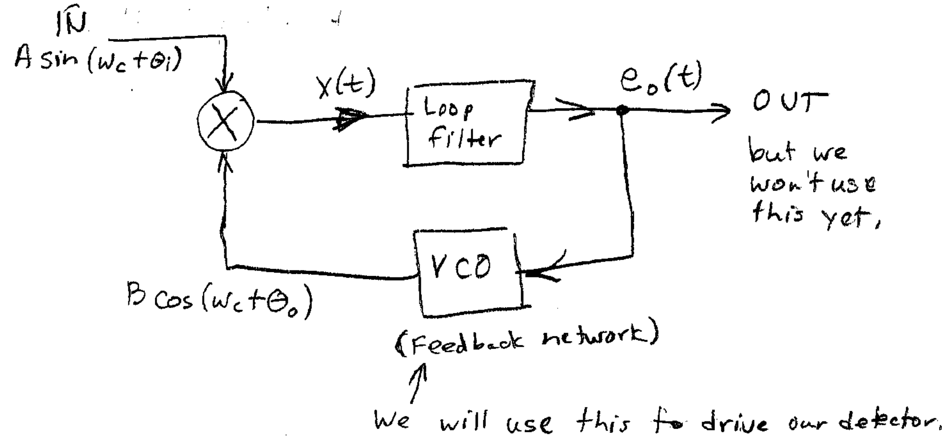
② A phase detector — so we know when the VCO is in phase with the incoming signal.

③ A low pass filter. to filter out noise, and make the oscillator hold its frequency when the input is lost.
It also filters out the detector's output at $2\,\omega_c$.

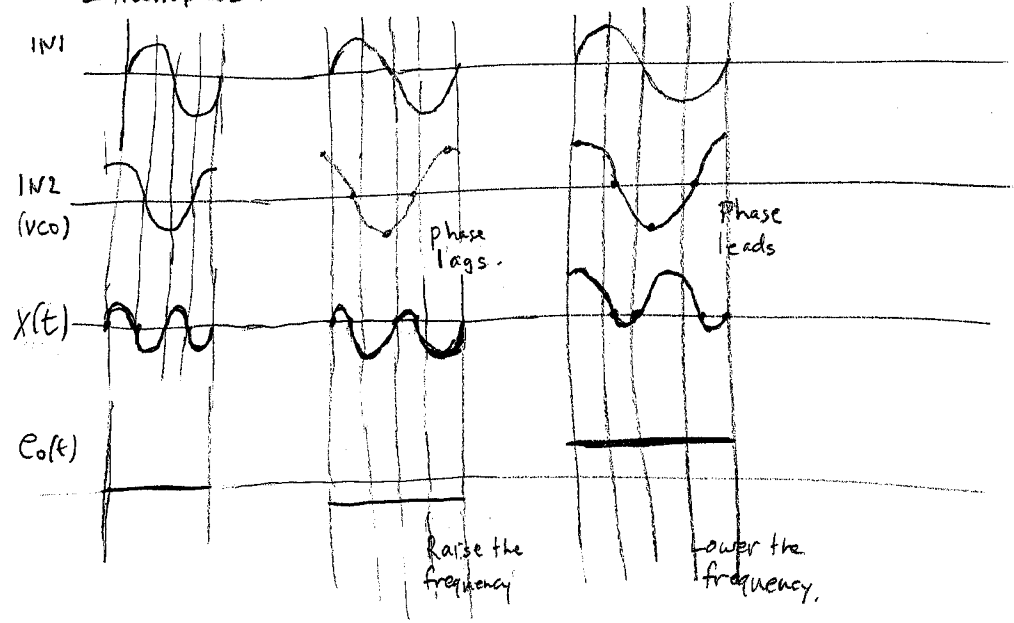
Think of an op-amp



Can we make the "input" a pair of oscillators?
Amplify the difference in phase?



The multiplier is used as a phase detector,
Examples:



The math:

$$X(t) = A\sin(\omega_c t + \theta_i)\ B\cos(\omega_c t + \theta_o)$$

by identity: $\sin x \cos y = \frac{1}{2}[\sin(x-y) + \sin(x+y)]$

$$X(t) = \frac{AB}{2}[\sin(\omega_c t + \theta_i - \omega_c t - \theta_o) + \sin(\omega_c t + \theta_i + \omega_c t + \theta_o)]$$

$$= \frac{AB}{2}[\sin(\theta_i - \theta_o) + \sin(2\omega_c t + \theta_i + \theta_o)]$$

Low frequency component – (DC?) proportional to phase difference.

$2\omega_c t$ component at $x(t)$. Loop filter suppresses this.

so.. $e_o(t) = \frac{AB}{2}\sin(\theta_i - \theta_o)$

$\theta_i - \theta_o = \theta_e$ ← phase error.

When loop is <u>locked</u> – the input and VCO have the same frequency, with a possible phase error.

Use the error signal to adjust the frequency of the oscillator.

It will seek a steady state, over a range of frequencies. the "pull-in" or "capture" range.

Once locked, it will hold over a wider range -- the "hold-in" or "lock" range.

When the loop is <u>not locked</u>, but the input is in the capture range, the error output swings randomly at first, slowly due to the loop filter.

It swings through the lock range, and stays there when the VCO meets the incoming frequency.

FM-Stereo – Use a PLL –
The VCO operates at 38 KHz.
Divide by 2 to get 19 KHz for phase detector.

Color TV. Use a PLL.
Even <u>old</u> TV's used a PLL,
The loop filter has a cut-off low enough so the VCO holds its phase + frequency for a full scan line, after the "burst" ended.
Actually --- the loop is broken – as in sample + hold.

Other uses:
(next week) – Can be used as an FM detector – The error signal is the detector output.