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HF Receivers, Part 3

Introduction to frequency synthesis;

ancillary receiver functions

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[View an excellent tutorial on receivers](#)

[Another link to receiver principles](#)

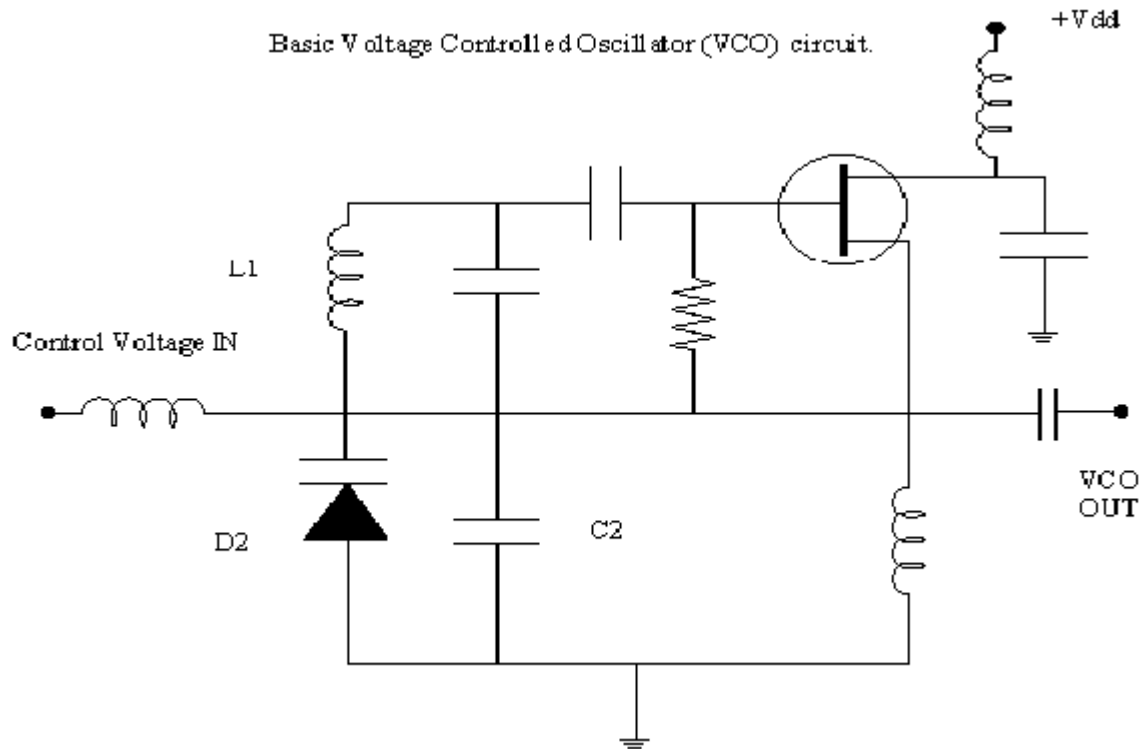
Basic Principles of Frequency Synthesis



■ Phase-locked loop (PLL):

- ◆ Output of a **voltage-controlled oscillator (VCO)** is divided down to a low frequency and compared to a fixed reference frequency in a **phase detector**.
- ◆ Phase-detector output voltage (**error signal**) is zero when divided-down VCO output and reference are in phase. Any VCO Δf causes + or – error signal, which pulls VCO back in phase with reference.
- ◆ Output frequency is set by varying division ratio of VCO divider.
- ◆ VCO and reference divider output freq. = tuning step (e.g. 100 Hz).
- ◆ [Further reading.](#)

Voltage-Controlled Oscillator (VCO)

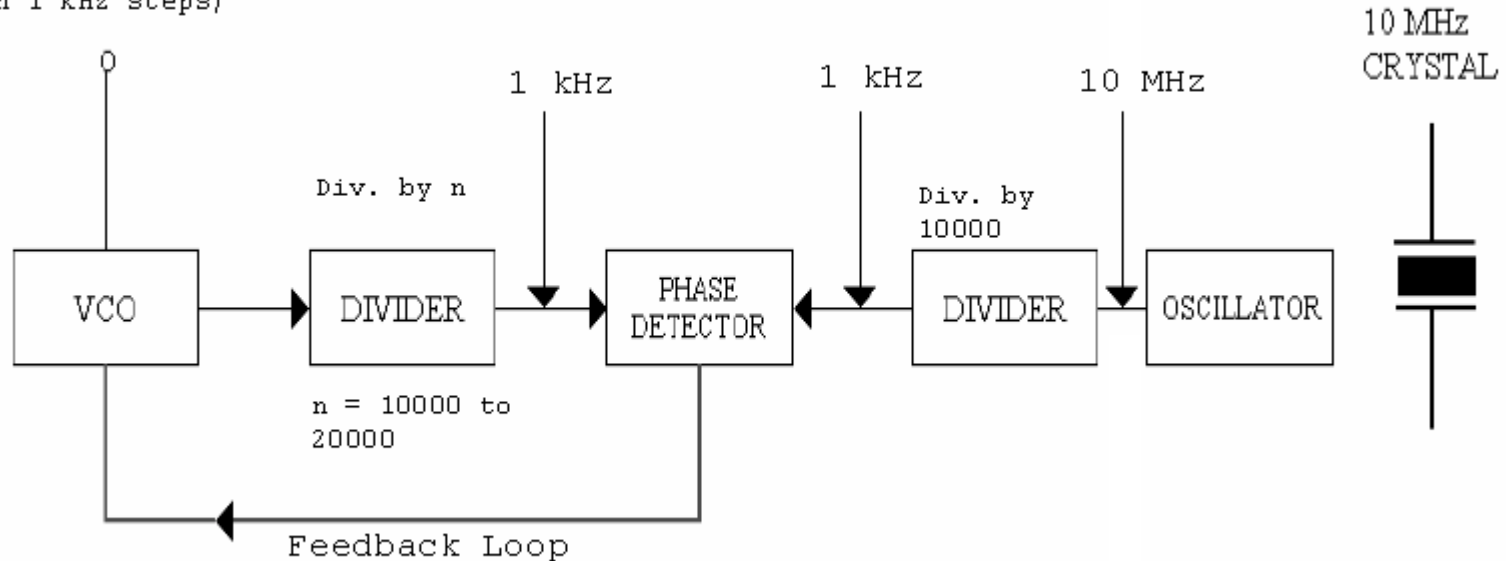


- L1, C2 and D2 determine frequency of oscillation.
- D2 is a varactor (varicap).
- Increasing control voltage (error signal) decreases D2 capacitance, increasing frequency.

A Simple PLL Synthesizer



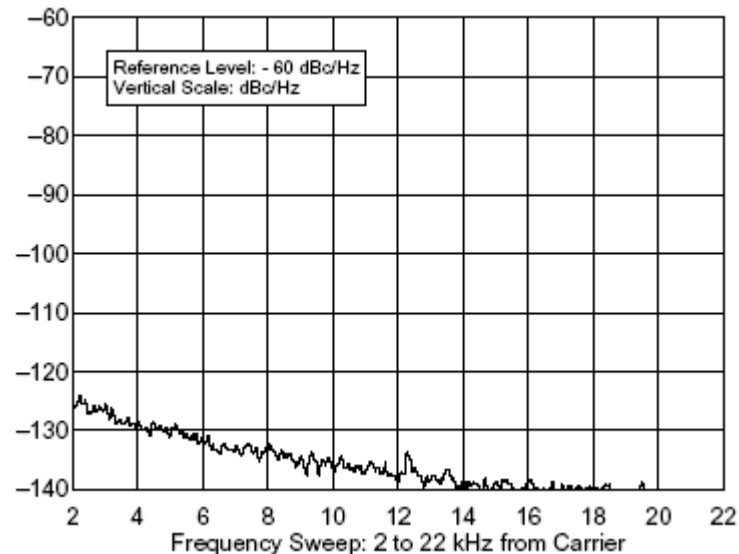
10 to 20 MHz
(in 1 kHz steps)



SIMPLIFIED PLL FREQUENCY SYNTHESIZER

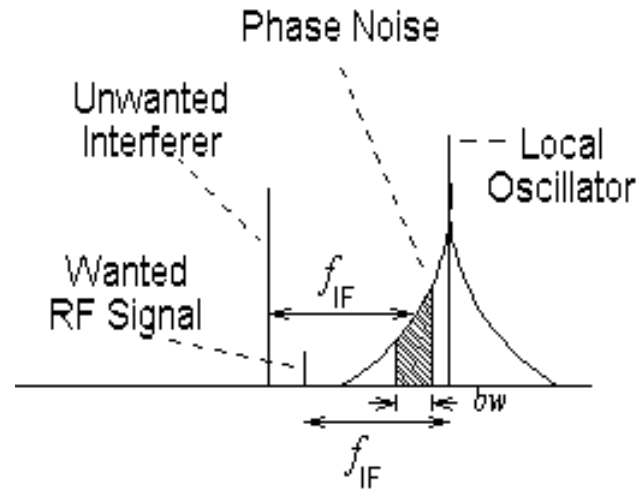
- VCO output and 10 MHz reference are both divided down to 1 kHz, then compared in phase detector. Any phase difference causes error voltage on feedback loop. This “pulls” VCO back into exact phase with reference.
- “Divide-by-n” divider ratio determines output frequency (variable in 1 kHz steps).

Synthesizer Design Criteria



- **Resolution (step size):** determined by VCO operating frequency and division ratio. 100 or 10 Hz in earlier designs, 1 Hz in current radios.
- **Trade-off:** in classical PLL designs, smaller step size increases *phase noise*.
- **Phase noise:** noise produced by short-term, random phase jitter (fluctuations) in the VCO.
- Noise power increases with decreasing offset from carrier.
- Excessive phase noise mixes with RF signal at mixer input, degrading S/N at mixer output (reciprocal-mixing noise). This degrades dynamic range and selectivity.

Reciprocal Mixing Noise

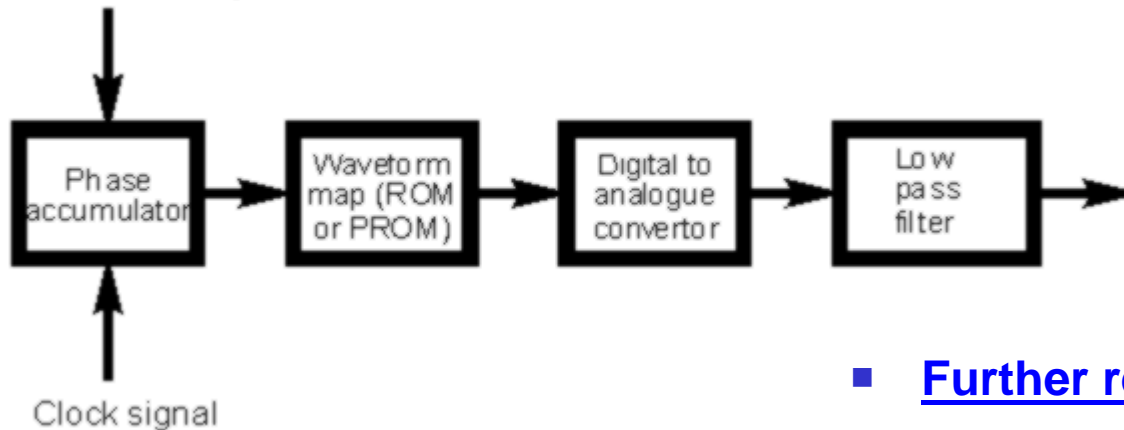


- Here the **phase noise** on the local oscillator is shown. To see the effect this can have on dynamic range and selectivity, imagine a strong interfering signal close to the wanted RF signal as shown. This unwanted signal can mix with the noise sidebands of the LO to also produce an output at the IF. This process is called reciprocal mixing. The noise sidebands involved are shown shaded in the figure.

Direct Digital Synthesizer (DDS)



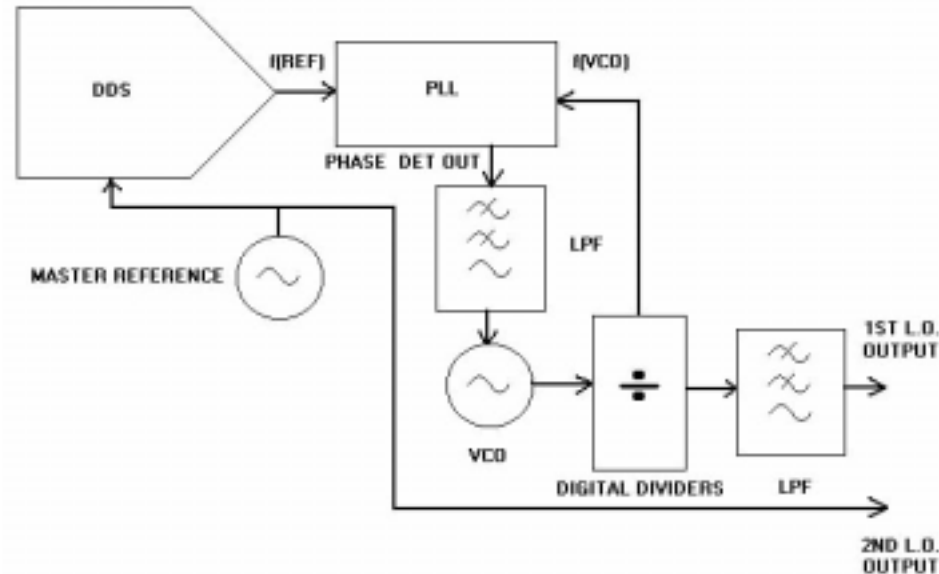
Frequency information
(phase increment)



■ [Further reading](#)

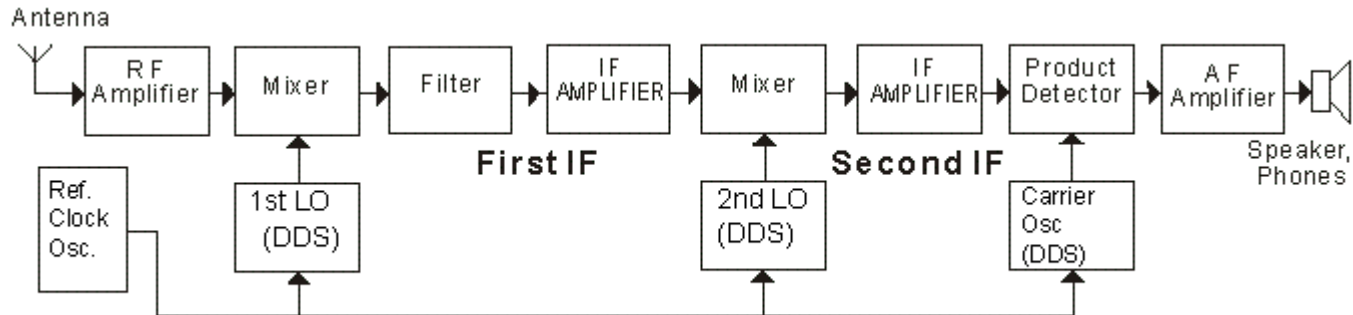
- **DDS** operates by storing the points of a waveform in digital format, then recalling them to generate the waveform.
- Phase increment size, controlled by radio's CPU, determines rate at which DDS completes one cycle. This sets output frequency.
- Waveform map stores instantaneous amplitude vs. phase (point on cycle).
- DAC converts digital waveform amplitude values to analogue waveform.
- Low-pass filter integrates sinusoidal DAC output & attenuates harmonics.

DDS/PLL Synthesizer Example



- DDS supplies variable reference frequency to phase detector for comparison with divided VCO output.
- CPU sets output frequency by varying DDS freq. setting and divider ratio.
- Divider is optional, depending on VCO freq. range.
- Subsystem furnishes all local oscillators and carrier insertion (“BFO”).
- Phase noise 10 to 30 dB lower than that achievable with classical PLL.

DDS HF Receiver



Double-Conversion HF Receiver with DDS Local and Carrier Insertion Oscillators

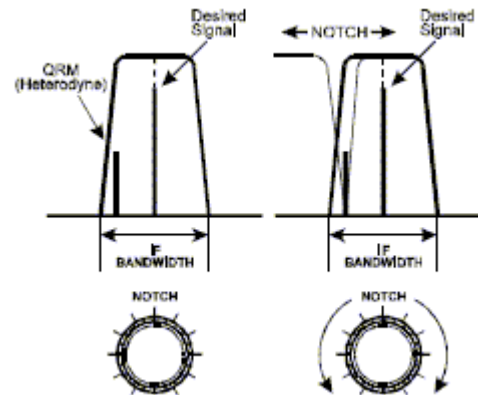
- All oscillators are DDS's clocked from common master reference source (OCXO or TCXO).
- CPU "tunes" receiver by setting 1st LO freq.
- Receiver incremental tuning (RIT): CPU applies Δf to 1st LO.
- Passband tuning or IF shift: CPU varies 2nd LO freq.
- CPU shifts carrier osc. freq. for sideband selection.

Ancillary Receiver Functions



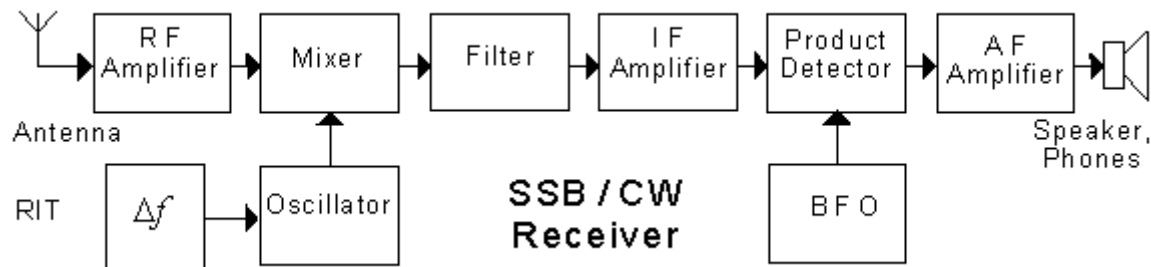
- **IF Shift** *(see HF Receivers 2, Slide 13)*
- **Passband Tuning** *(see HF Receivers 2, Slide 9)*
- **Tunable IF Notch Filter**
- **RIT & XIT Tuning**
- **RF Gain & Attenuator**
- **Split Operation in Transceiver**
- **Dual Watch**
- **Noise Blanker**

Tunable IF Notch Filter



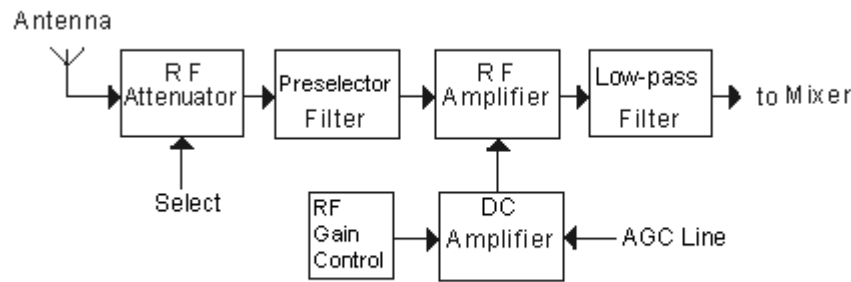
- **IF notch filter:** a narrow bandstop filter in the IF signal path.
- **NOTCH** control shifts notch-filter centre frequency within IF passband to notch out interfering carrier.
- As notch filter is inside AGC loop, interfering signal cannot swamp receiver.
- Notch filter attenuates interfering carrier by 50 dB (typical).

RIT & XIT Tuning



- **RIT** (Receiver Incremental Tuning) applies a small Δf (± 10 kHz or less) to the local oscillator.
- Allows operator to tune in SSB, CW and RTTY signals accurately.
- RIT is also termed **Clarifier**.
- Modern transceivers also have **XIT** (Transmitter Incremental Tuning) – similar function for transmitter.
- RIT and XIT Δf displayed separately from main freq. display.
- Pushbuttons allow addition of RIT/XIT offset to operating freq.

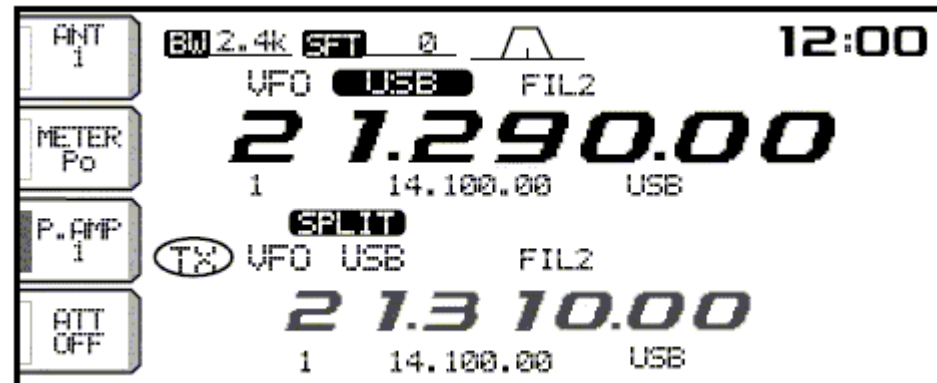
RF Gain & Attenuator



Gain-Controlled RF Amplifier with Front-End RF Attenuator

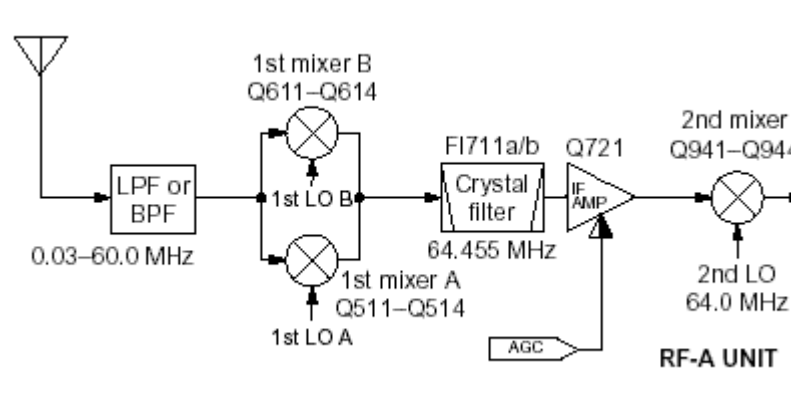
- **RF front-end attenuator** located between antenna input and preselector filter.
- 6, 12 or 18 dB attenuation (typical) selected by CPU.
- **RF Gain control** increases AGC bias on gain-controlled RF amplifier (or 1st IF amplifier in some designs); raises AGC threshold.
- Receiver dynamic range increases by amount of attenuation inserted.
- Usually, band noise is 10 to 12 dB above Rx noise floor; attenuation does not significantly degrade noise figure. Attenuator & RF Gain can be used together.

Split Operation in Transceiver



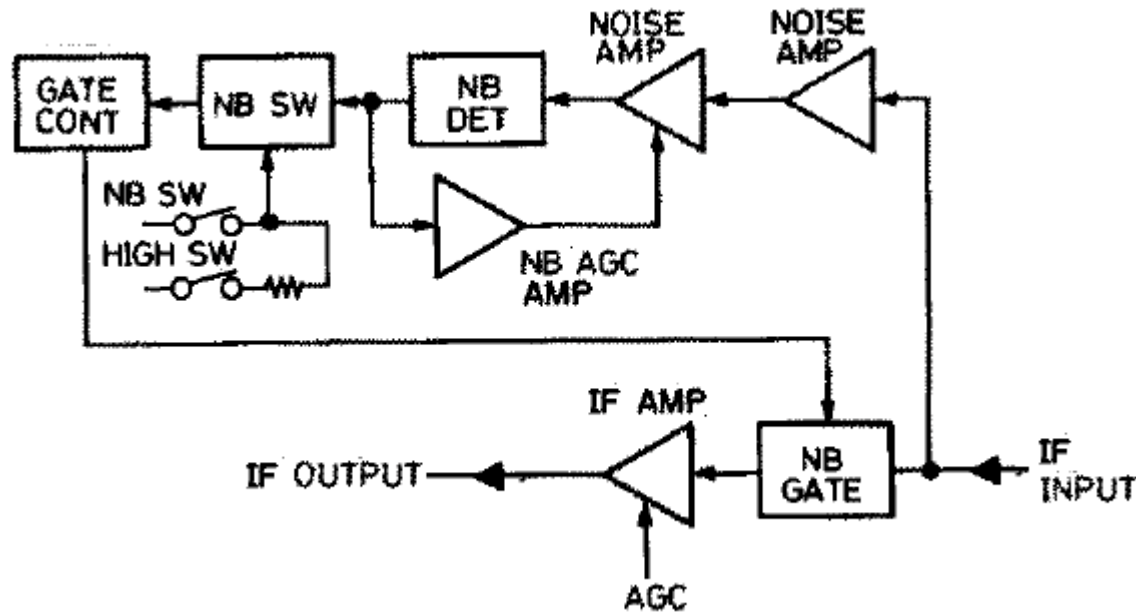
- **Split operation:** receive on freq. A, transmit on freq. B.
- Easily implemented in modern transceivers; CPU stores and displays A and B frequencies separately as “VFO A” and “VFO B”. Can select different modes and/or bands for A and B.
- Split enabled by pressing front-panel **SPLIT** key.
- In above example: Rx on 21.290 MHz; Tx on 21.310 MHz.

Dual Watch



- Simplified dual-receive scheme developed by **Icom Inc.**
- Separate A & B 1st mixers and 1st LO's allow simultaneous reception of 2 signals.
- A & B 1st LO's are physically separate synthesizers.
- As RF and IF signal paths are shared, both signals must be in same mode and same (or adjacent) bands. Both signals are heard in audio output.
- Balance control adjusts relative gain of A & B channels.
- **Dual watch** can be combined with **Split**.

Noise Blanker *(pulse-gate type)*



- **IF** is typically 455 kHz. A portion of IF signal is amplified by **NOISE AMP**, detected by **NB DET** and applied to **NB SW**. **HIGH SW** switch increases **NB SW** threshold.
- When detected noise voltage exceeds **NB SW** threshold, **NB SW** sends transition to **GATE CONT** to close **NB GATE** & break IF signal path for duration of noise pulse.
- **NB AGC** loop time constant holds average signal level at **NB DET** constant, but is too long to respond to impulse noise.