SSCS Chipathon 2025 - Project Proposal
Time Transcenders

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Mixer design in GF180MCU

Targeting an active double-balanced mixer at WiFi freq 2.4GHz

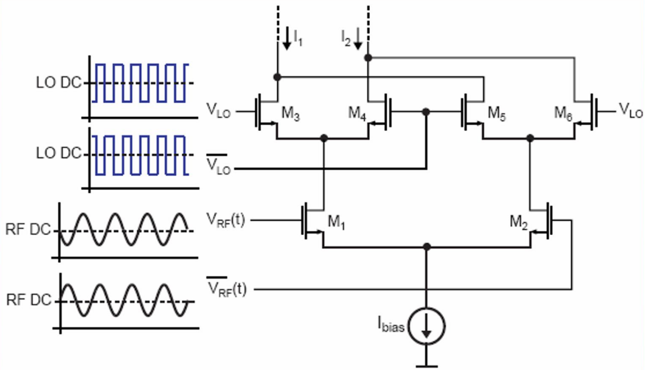
Advantages of double-balanced mixers over other mixer types:

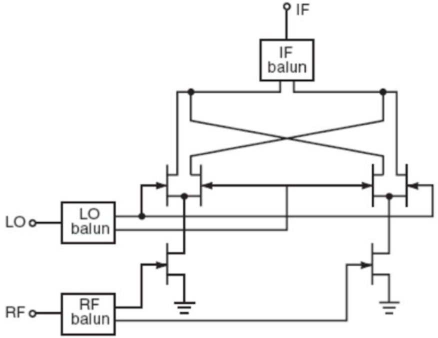
- Increased linearity
- Improved suppression of spurious products
- Good isolation between ports
- interchangeable ports, thus easy filtering

Disadvantages:

- Relatively high LO drive strength
- Require transformer Baluns (if time permits these will be integrated on-chip)

Decided on Gilbert cell topology (other possibilities are ring diode, star diode, or FET as switches)





https://www.qsl.net/va3iul/RF%20Mixers/RF_Mixers.pdf

Specs

- Target f_{RF} 2.4GHz
- f_{LO} 2.41GHz
- RF BW of 20MHz, with max 3dB droop over the baseband
- Vdd=3.3V
- Mixer conversion gain >15dB
- SSB NF<9dB (baseband integrated from 1kHz to 100MHz)
- IIP2 > 40dBm
- IIP3 > 8dBm (using 2 tones at 2400MHz and 2401MHz)

https://link.springer.com/article/10.1007/s11277-021-09115-6

https://ieeexplore.ieee.org/document/7280025

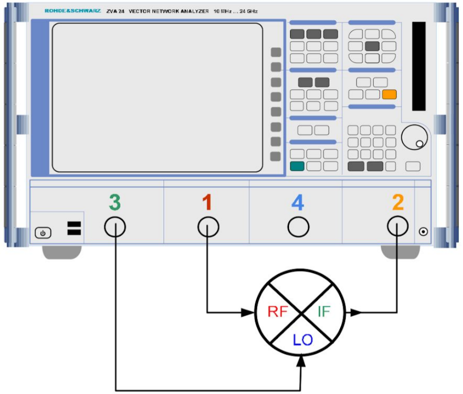
Sushmitha, D & Munivenkatappa, Nagabushanam. (2018). A 2.4GHz CMOS Double Balanced Down Conversion Gilbert Cell Mixer Design Using 180nm Technology. 1767-1770. 10.1109/RTEICT42901.2018.9012334.

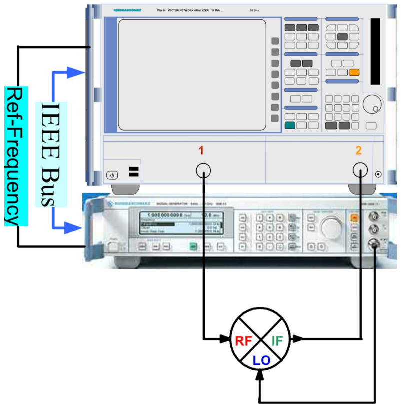
Testing equipment

Using either a 2 port Vector Network Analyzer (VNA) + signal generator

Or using a 4-port VNA

- Conversion Loss
- Intermodulation measurement
- Port isolation measurement





https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_application/application_notes/1ez58/1EZ58_0E_Mixer-Measurements_ZVA-K4.pdf?utm_source=chatgpt.com

Appendix

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Conversion gain

Mixer conversion gain >15dB

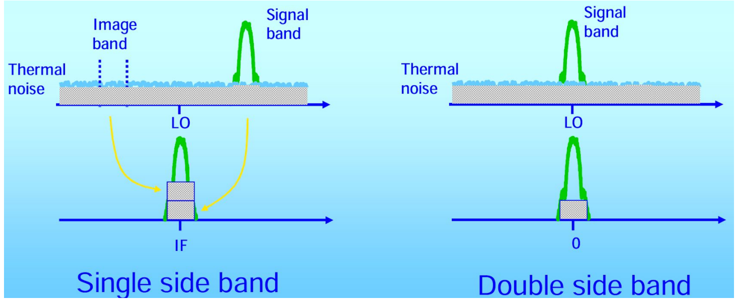
- ratio of desired IF signal (V or W) to RF signal
- Voltage gain = rms(IF)/rms(RF) - we will use this def in our specs
- Power gain = IF power delivered to load / Available power from souce

Note: if load and input Z are matched, Power gain = Voltage gain

Noise figures: SSB

SSB Noise Figure < 9dB (baseband integrated from 1kHz to 10MHz)

- signal from one sideband, noise from both bands
- (SNR at IF) / (SNR of RF), both measured in a single sideband



- **Noise Figure (NF)** is a measure of how much a device (such an amplifier) degrades the Signal to Noise ratio (SNR).

  SNR_input$_{[linear]}$ = Input_Signal$_{[Watt]}$ / Input_Noise$_{[Watt]}$
  SNR_input$_{[dB]}$ = Input_Signal$_{[dB]}$ - Input_Noise$_{[dB]}$

  SNR_output$_{[linear]}$ = Output_Signal$_{[Watt]}$ / Output_Noise$_{[Watt]}$
  SNR_output$_{[dB]}$ = Output_Signal$_{[dB]}$ - Output_Noise$_{[dB]}$

- **Noise Factor (linear not dB)** of a receiver is the ratio of the SNR at its input to the ratio of the SNR at its output.

  NoiseFactor_F$_{(linear)}$ = SNR_input$_{[linear]}$ / SNR_output$_{[linear]}$
  NoiseFactor_F$_{[dB]}$ = SNR_input$_{[dB]}$ - SNR_output$_{[dB]}$
  NoiseFigure_NF$_{[dB]}$ = 10*LOG (NoiseFactor_F$_{(linear)}$)

$$V_n = \sqrt{4kTRB}$$

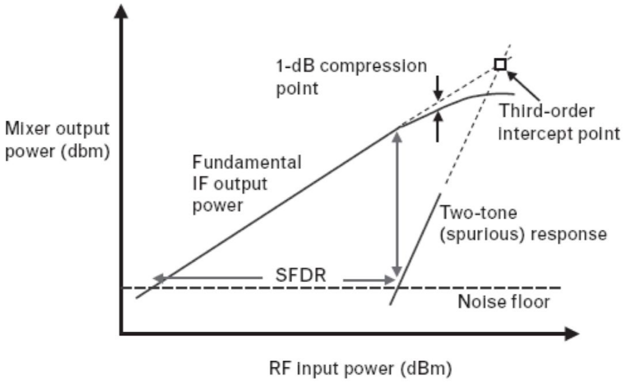
where:
k = Boltzmann constant (1.38 x 10^{-23} Joules/Kelvin)
T = Temperature in Kelvin (K= 273+°Celsius) (Kelvin is not referred to or typeset as a degree)
R = Resistance in Ohms
B = Bandwidth in Hz in which the noise is observed (RMS voltage measured across the resistor is also function of the bandwidth in which the measurement is made).

https://markimicrowave.com/technical-resources/application-notes/a-practical-guide-to-noise-in-frequency-conversions/

Intermodulation Intercept Point (IIP)

IIP3 and IIP2 referrer to the third and second order harmonics generated from the main signal. IIP3 and IIP2 are the intercept points, at which the power of these harmonics equals the linear term (IF).

- **IIP2 > 40dBm**
- **IIP3 > 8dBm** (using 2 tones at 2400MHz and 2401MHz)



https://www.rfwireless-world.com/terminology/ip2-ip3-formulas-calculations-significance

https://www.test-and-measurement-world.com/measurements/rf/rf-mixer-testing?utm_source=chatgpt.com

References

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- https://www.test-and-measurement-world.com/measurements/rf/rf-mixer-testing?utm_source=chatgpt.com