Located on the ground floor at Galbraith Building

Background

[3]

Key advancements in radio technology include the development of vacuum tubes in the early 1900s for amplification and detection,

[4]

In the 1960s, the creation of radio frequency (RF) integrated circuits allowed for the integration of multiple radio components onto a single chip.

[2]

Today, software-defined radio (SDR) technology is at the forefront of radio innovation, allowing for greater flexibility and adaptability to changing communication needs.

Subsystem A: Circuit, Theory, Operation

Design Development Update

David Li
Irving Wang

Team 010

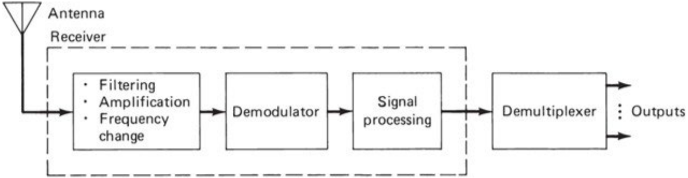
March 3, 2023

Content Overview

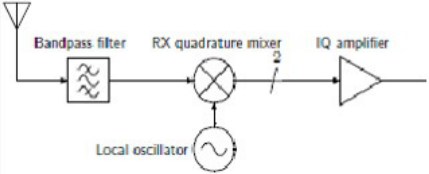
- Communication Receiver
- Subsystem input & Output
- RF Circuit
  - Bandpass filter design
  - Mixer Design
- BaseBand Circuit
  - Low-Pass filter design
  - Amplifier design
- Next Steps & Challanges

Electrical Interface Requirements [1]
Clip the input signal such that it does not exceed $\pm 0.7\ V_{pp}$
66% fractional 3dB bandwidth centered at 12 MHz, maximally flat response (approx. 8-16Mhz)
30dB gain applied post-mixing
At least first order filtering applied with an upper cutoff frequency at 96kHz.

Communication Receiver

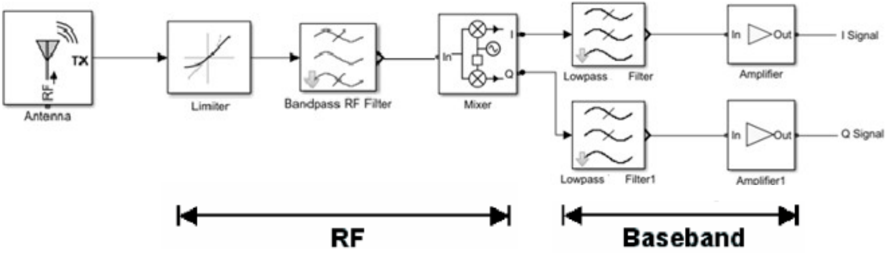


Subsystem A:



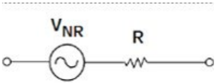
Subsystem A's role: Signal Filtration and Down-Conversion

Subsystem A Input/output



- Subsystem A receives input signals from the antenna and the local oscillator and outputs a filtered and converted signal.
- Subsystem design split into two parts: RF frequency and Baseband frequency.

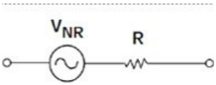
Filter Architecture



RC, RL Filter: At high frequencies, thermal noise in resistors becomes increasingly significant due to the increased energy of the thermal fluctuations.

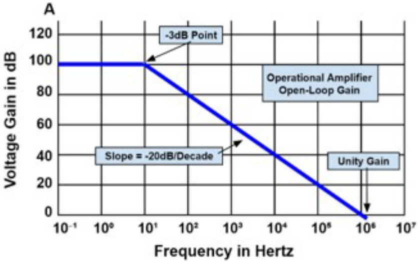
ALL resistors have a voltage noise of $V_{NR} = \sqrt{(4kTBR)}$

Filter Architecture

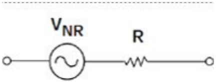


RC, RL Filter: At high frequencies, thermal noise in resistors becomes increasingly significant due to the increased energy of the thermal fluctuations.

Active Filter: The bandwidth of the active components themselves can become a limiting factor at high frequencies.



Filter Architecture



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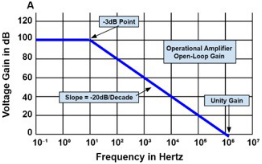
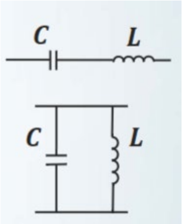
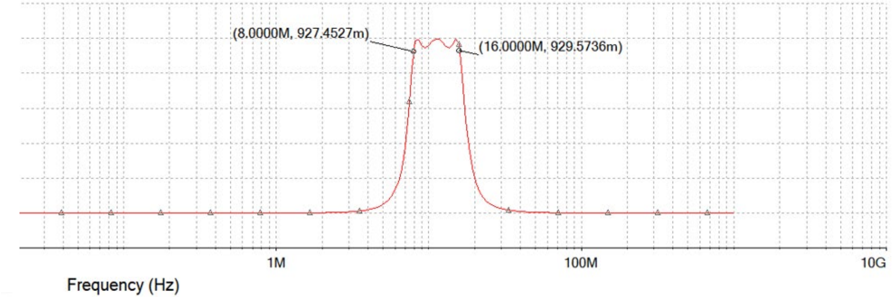


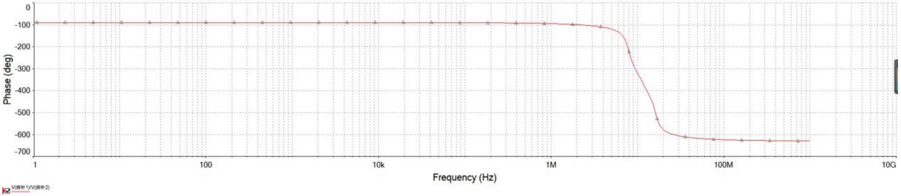


Passive LC Filter: Commonly used at radio frequencies (RF) due to their ability to provide high levels of attenuation for frequencies outside of the passband, while minimizing losses within the passband.

BandPass LC Filter Response

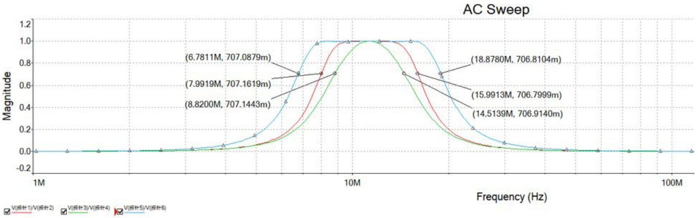
Chebyshev filter: passband ripple





BandPass LC Filter Response

Butterworth Filter :maximally flat passband and stopband (with no ripples).



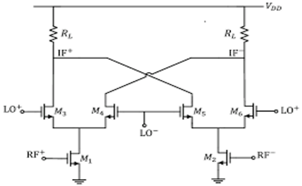
Summary of Filter Type Trade-Offs

Filter Type	Advantages	Disadvantages
Butterworth	Maximum pass-band flatness	Slight overshoot in response to pulse input and moderate rate of attenuation above f_c
Chebyshev	Fast rate of attenuation above f_c	Pass-band ripple
Bessel	Constant group delay – no overshoot with pulse input	Slow rate of attenuation above fc

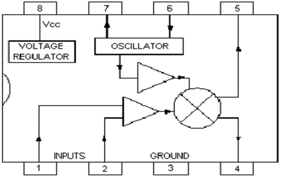
Mixer Design

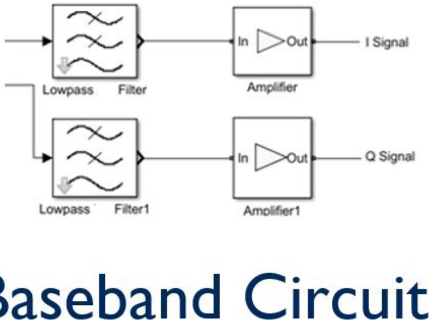
Balanced Mixing:
The balanced mixer help to cancel out unwanted mixing products that arise from the LO signal, resulting in a cleaner output signal with less distortion.

Gilbert Cell Topology high gain, and low noise.

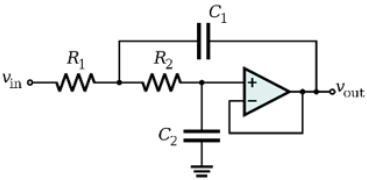


Use of IC Chip: NE602




Lowpass Filter
Amplifier
In
Out
I Signal
Lowpass Filter1
Amplifier1
In
Out
Q Signal
Baseband Circuit

Low-pass filter

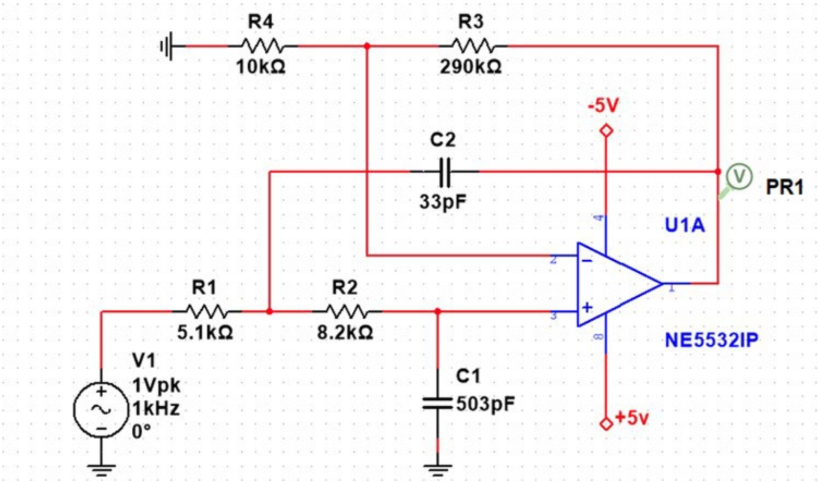


$$f_c = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

Sallen-Key topology
Choose values for resistors and capacitors to achieve a 96kHz cutoff frequency

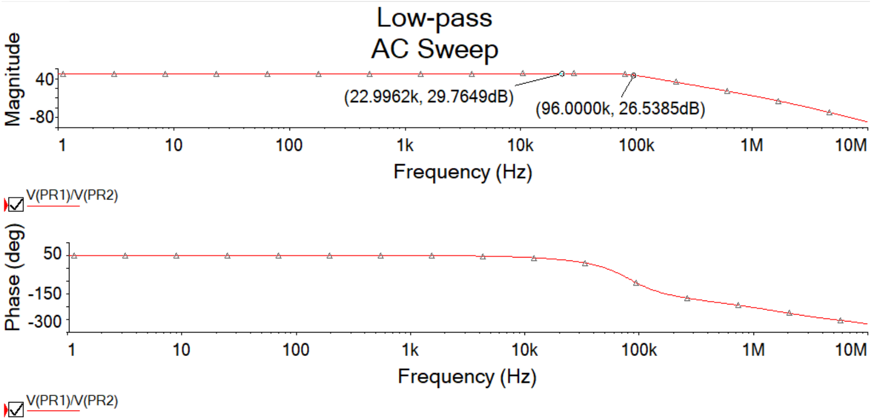
Run simulation on Multisim to see the cutoff curve

Low-pass filter



Multisim circuit design for low-pass filter

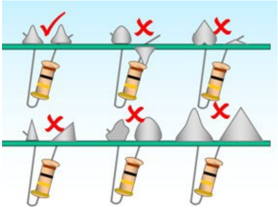
Low-pass filter



Multisim simulation result

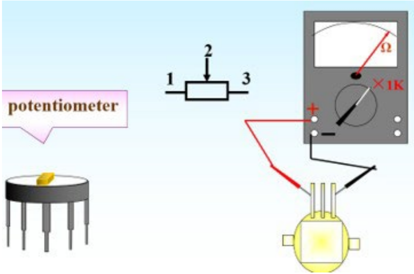
Future Plans

- Adjust current design based on Milestone 1 review
- Fix bugs and do more precise calculations
- Run simulations
- PCB layout design (Mechanical Requirements)
- Soldering



Challenges

- Filter should be built in a shielded enclosure
- Magnetic coupling between inductors should be avoided by physical separation
- Op-Amp biasing



Content Overview

Subsystem Design Satisfying all requirements in ICD

Electrical Interface Requirements [1]

Clip the input signal such that it does not exceed $\pm 0.7\ V_{pp}$
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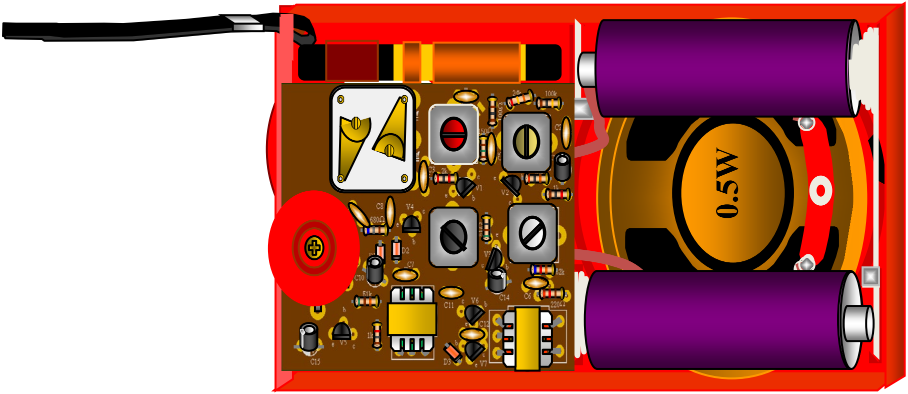
Thank you!



Reference

1 Flexible Radio Transceiver Interface Control Document

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4 J. J. DeLisle, “What Is RF Integrated Circuit Design? - Technical Articles,” Dec. 2020 [Online]. Available: https://www.allaboutcircuits.com/technical-articles/what-is-rf-integrated-circuit-design/. [Accessed: Feb. 26, 2023]

5 K. James, “Application Note, Low Pass Filter Design.” [Accessed: Mar. 0 3 , 2023]