EEE 51: Second Semester 2017 – 2018

Lecture 25

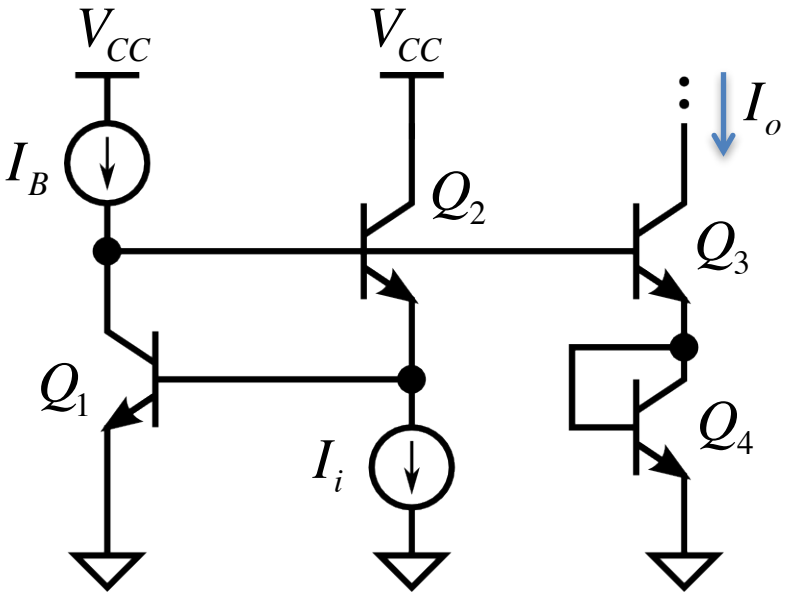
Analog Computation and Course Summary

Analog Computation Circuits

- Translinear Circuits
  - Nonlinear Function Synthesis

- Addition
- Subtraction

The Square-Root Circuit



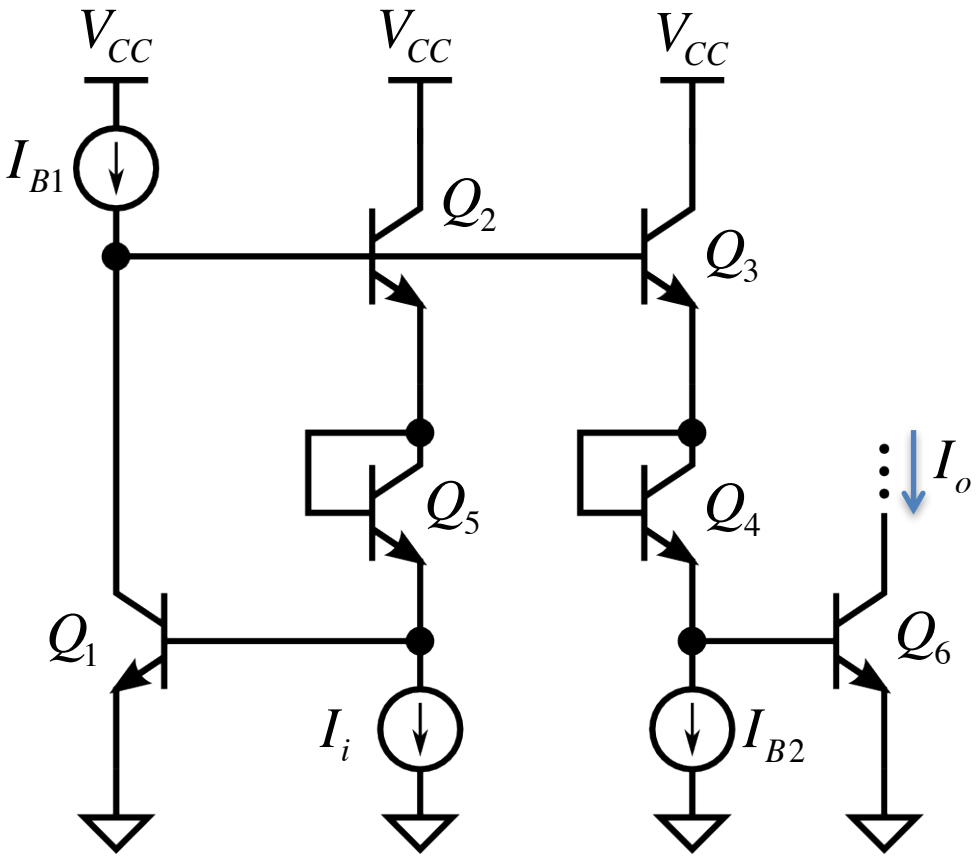
$$V_{BE1} + V_{BE2} - V_{BE3} - V_{BE4} = 0$$

$$V_T \ln\left(\frac{I_B}{I_{S1}}\right) + V_T \ln\left(\frac{I_i}{I_{S2}}\right) - V_T \ln\left(\frac{I_o}{I_{S3}}\right) - V_T \ln\left(\frac{I_o}{I_{S4}}\right) = 0$$

$$\ln\left(\frac{I_B}{I_{S1}}\frac{I_i}{I_{S2}}\right) = \ln\left(\frac{I_o}{I_{S3}}\frac{I_o}{I_{S4}}\right)$$

$$I_o = \sqrt{I_i}\sqrt{I_B}\sqrt{\frac{I_{S3}}{I_{S1}}\frac{I_{S4}}{I_{S2}}}$$

The Square-Law Circuit



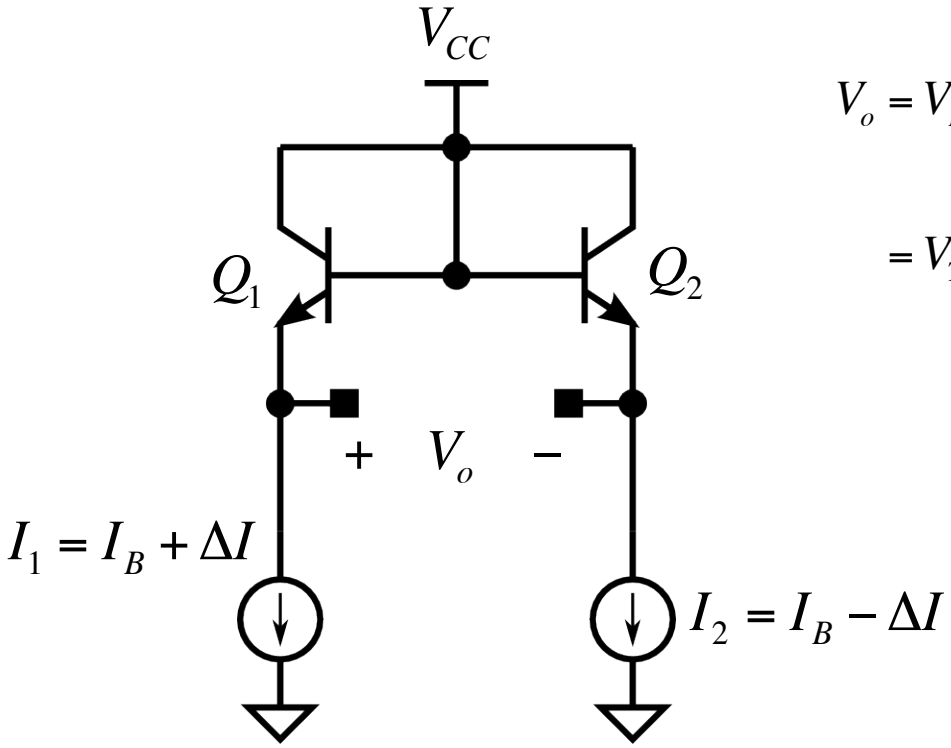
$$V_{BE1} + V_{BE5} + V_{BE2} = V_{BE3} + V_{BE4} + V_{BE6}$$

$$V_{BE} = V_T \ln\left(\frac{I_C}{I_{S1}}\right)$$

$$\ln\left(\frac{I_{B1}}{I_{S1}}\frac{I_i}{I_{S5}}\frac{I_i}{I_{S2}}\right) = \ln\left(\frac{I_{B2}}{I_{S3}}\frac{I_{B2}}{I_{S4}}\frac{I_o}{I_{S6}}\right)$$

$$I_o = I_i^2 \frac{I_{B1}}{I_{B2}^2}\frac{I_{S3}}{I_{S1}}\frac{I_{S4}}{I_{S5}}\frac{I_{S6}}{I_{S2}}$$

The $\tanh^{-1}$ Circuit



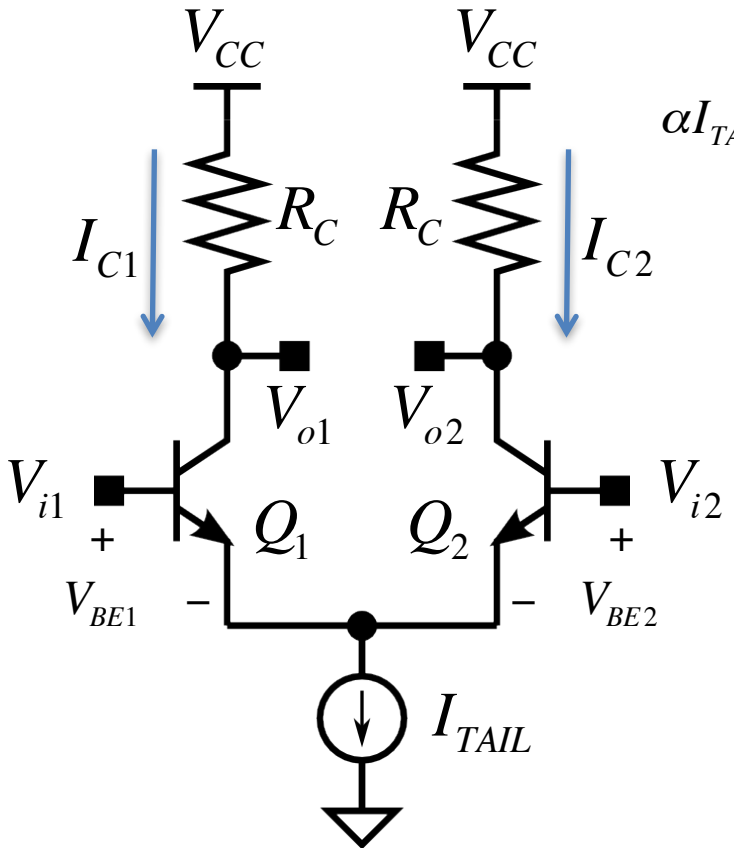
$$V_o = V_{BE1} - V_{BE2} = V_T \ln\left(\frac{I_B + \Delta I}{I_S}\right) - V_T \ln\left(\frac{I_B - \Delta I}{I_S}\right)$$

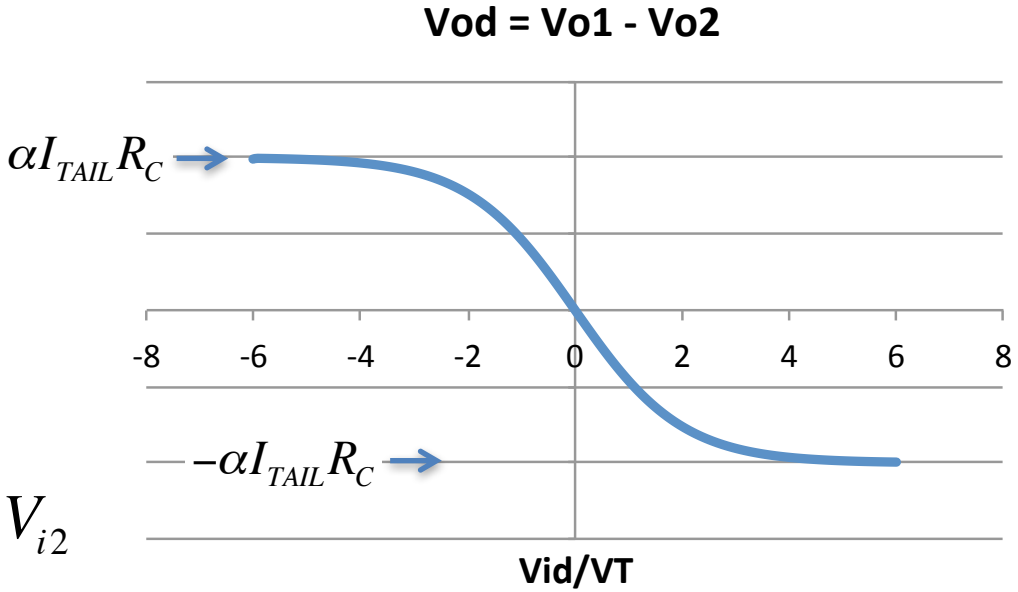
$$= V_T \ln\left(\frac{I_B + \Delta I}{I_B - \Delta I}\right)$$

Note: $\tanh^{-1} x = \frac{1}{2} \ln\left(\frac{1+x}{1-x}\right)$

$$V_o = 2V_T \tanh^{-1}\left(\frac{\Delta I}{I_B}\right)$$

Linearization

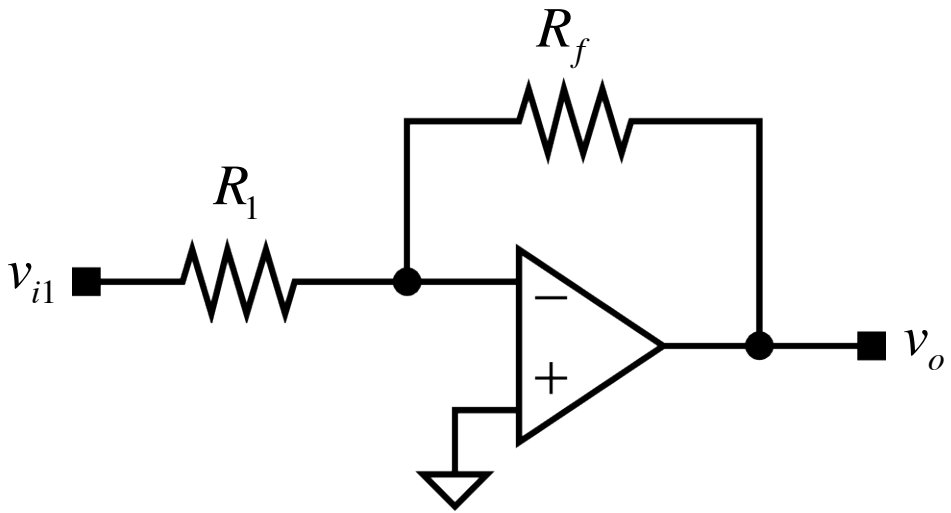




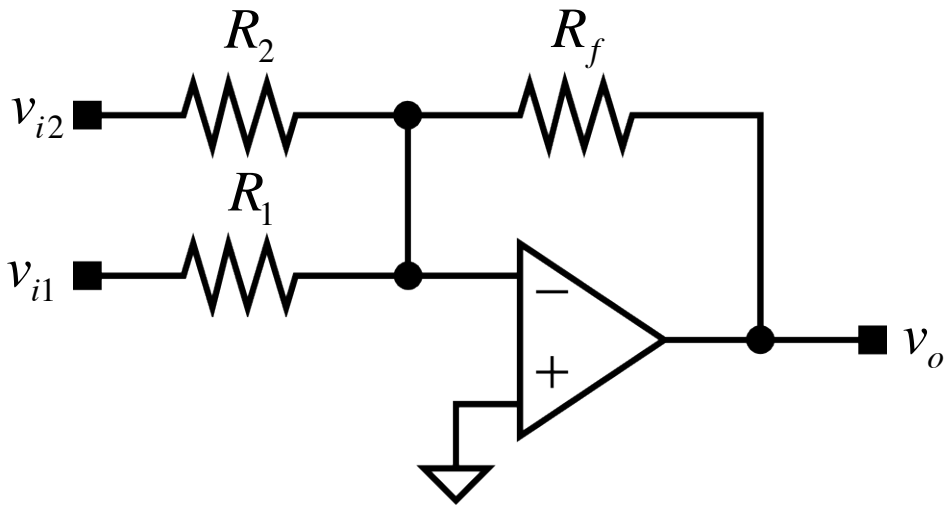
$$V_{od} = \alpha I_{TAIL} R_C \tanh\left(-\frac{V_{id}}{2V_T}\right)$$

Can this function be made linear?

Analog Addition



Analog Addition



Subtraction

COURSE SUMMARY

EEE 51 – Linear Transistor Amplifiers

- Transistor Models
  - Large signal → Biasing
  - Small signal → Linearization → 2-port equivalents
- Basic Amplifiers
  - Single-stage amplifiers
  - Current mirrors
  - Differential amplifiers
- Cascaded Amplifiers
  - Operational amplifiers

EEE 51 – Linear Transistor Amplifiers

- Frequency Response
  - Capacitances (and inductances)
  - Poles, zeros, Bode plots (magnitude/phase)
- Feedback
  - Basic topologies, loop gain, closed-loop gain
  - Advantages → input/output impedances, bandwidth, linearity
  - Cost → Stability

EEE 51 – Linear Transistor Amplifiers

- Stability
  - Positive feedback vs. negative feedback
  - Metrics → phase margin, gain margin
  - Effect of the loop gain
- Oscillators
  - Barkhausen's Criteria
  - Phase-shift model, generalized (LC) model, negative resistance
  - Crystal oscillators
- Translinear Circuits
  - Analog computation → examples: square-root, square-law, $\tanh^{-1}$
  - Addition, subtraction, etc.

Example: AM Receiver

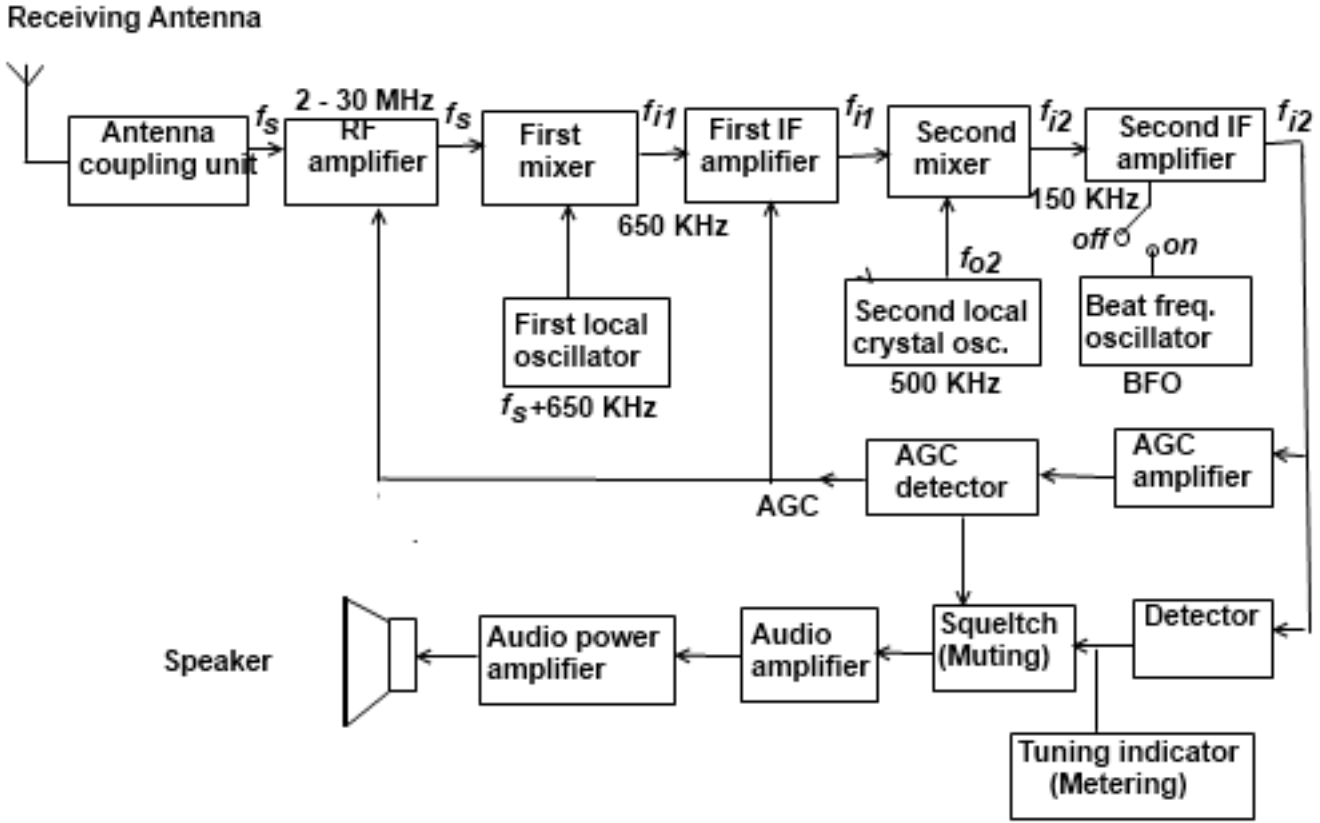
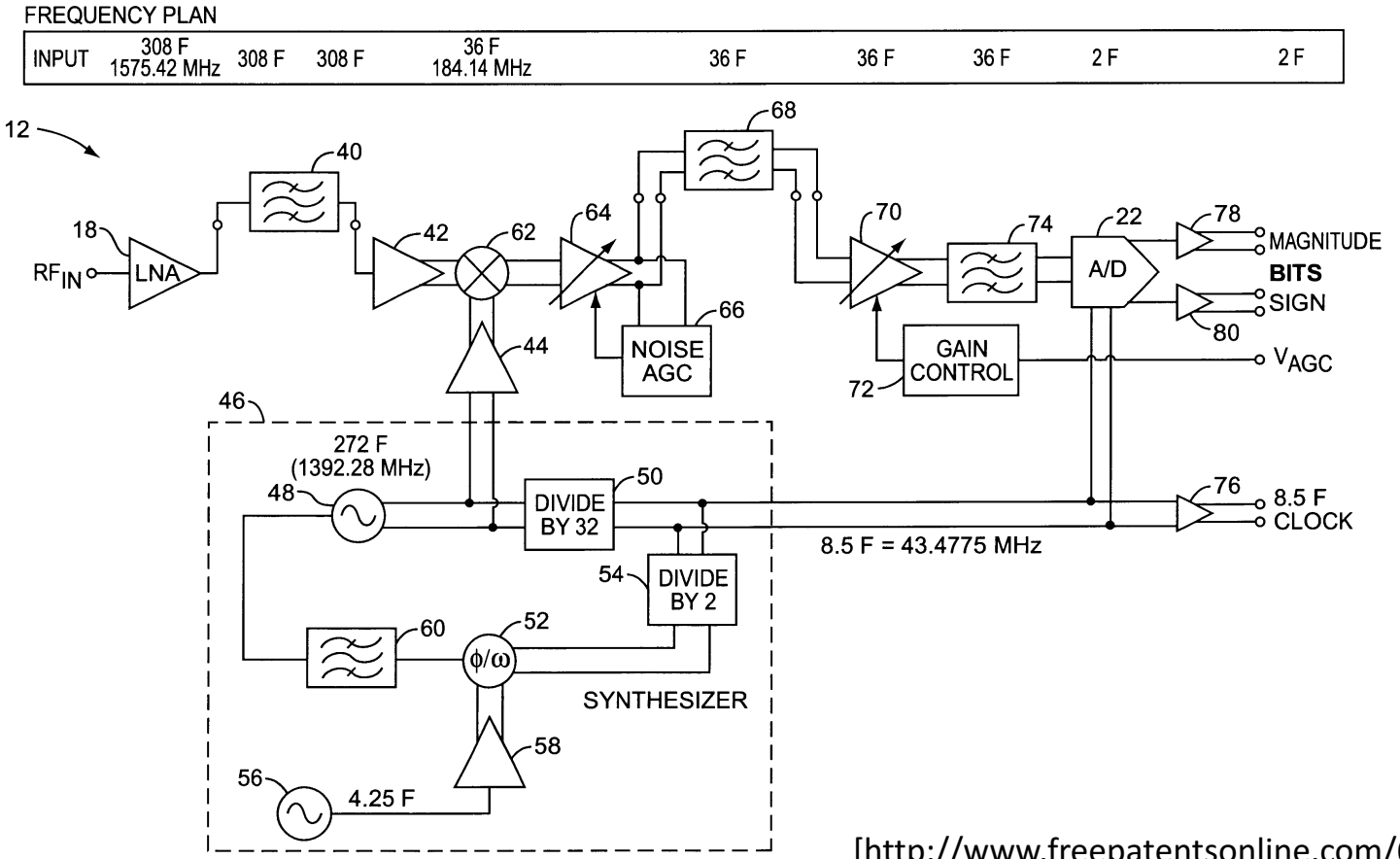


Figure (a): Block Diagram of a Typical AM Communication Receiver

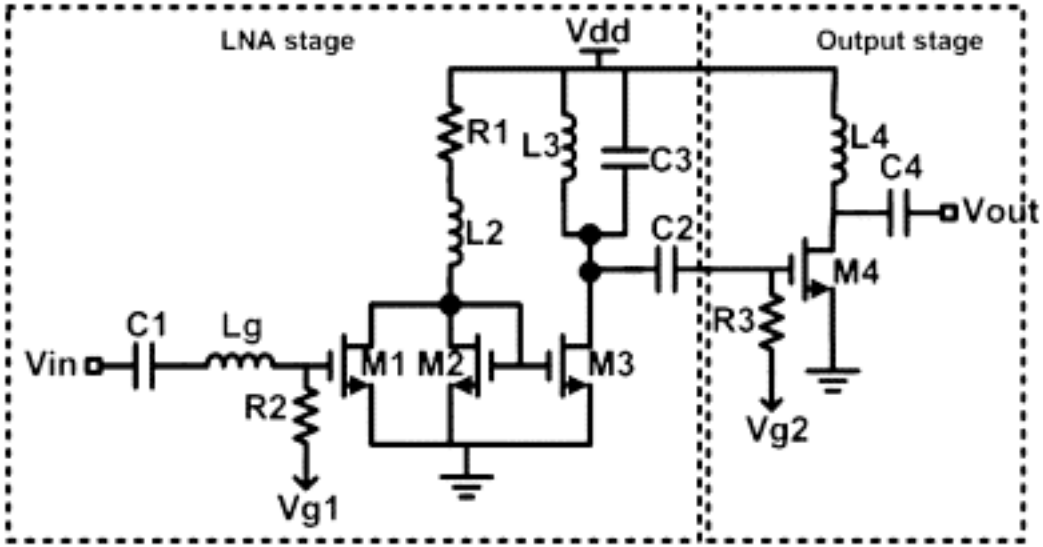
[www.daenotes.com]

Example: GPS Receiver



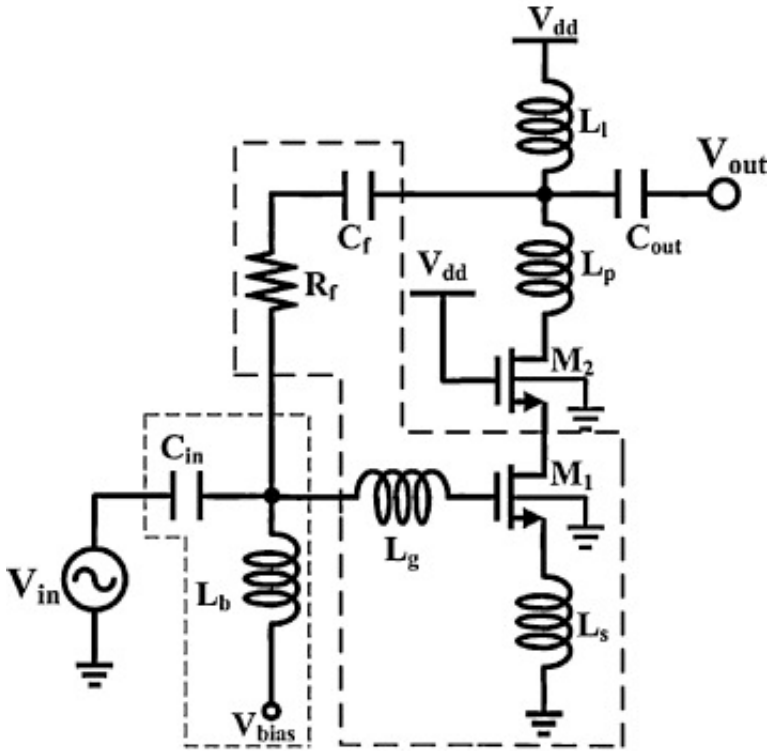
[http://www.freepatentsonline.com/6670914.html]

Example: 1V 12.8 GHz Low Noise Amplifier



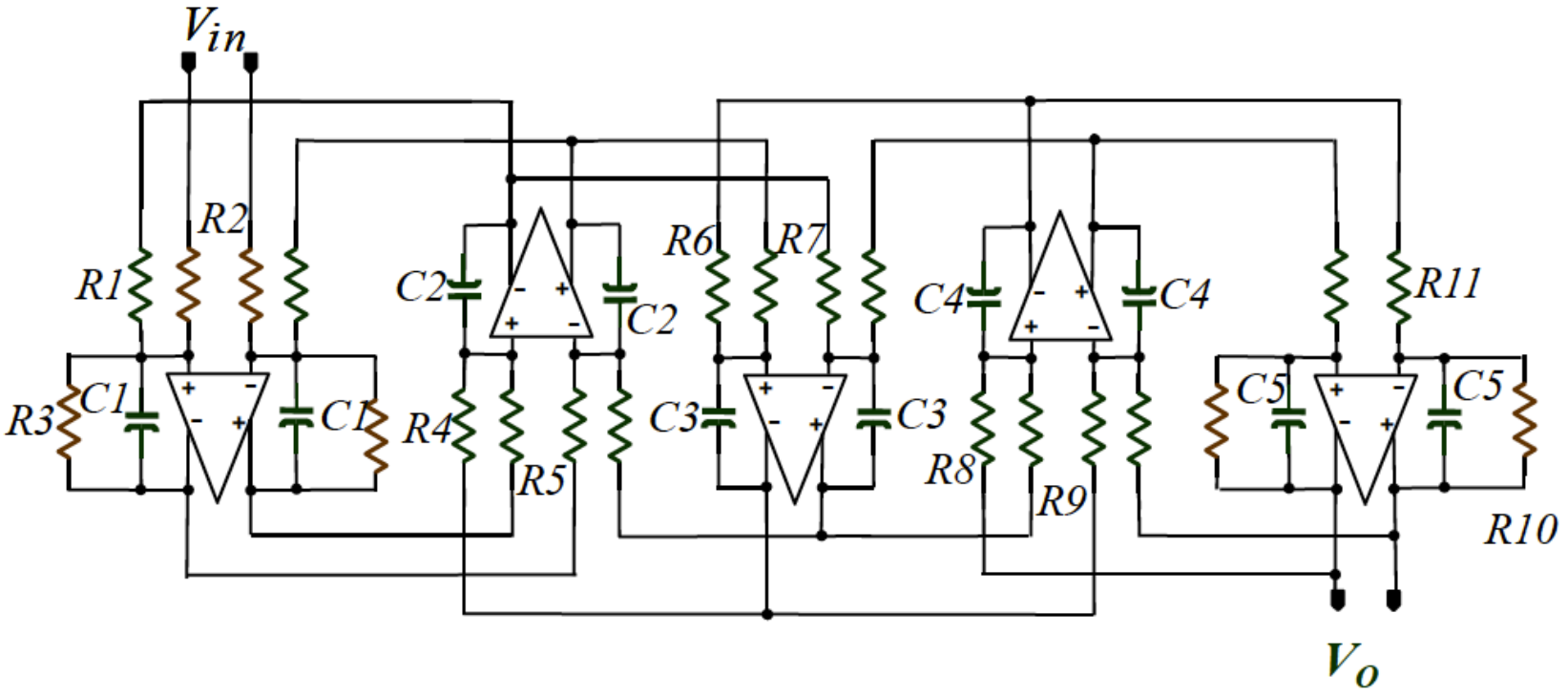
[www.sciencedirect.com]

Example: 1.8V 3.1 – 10.6 GHz LNA

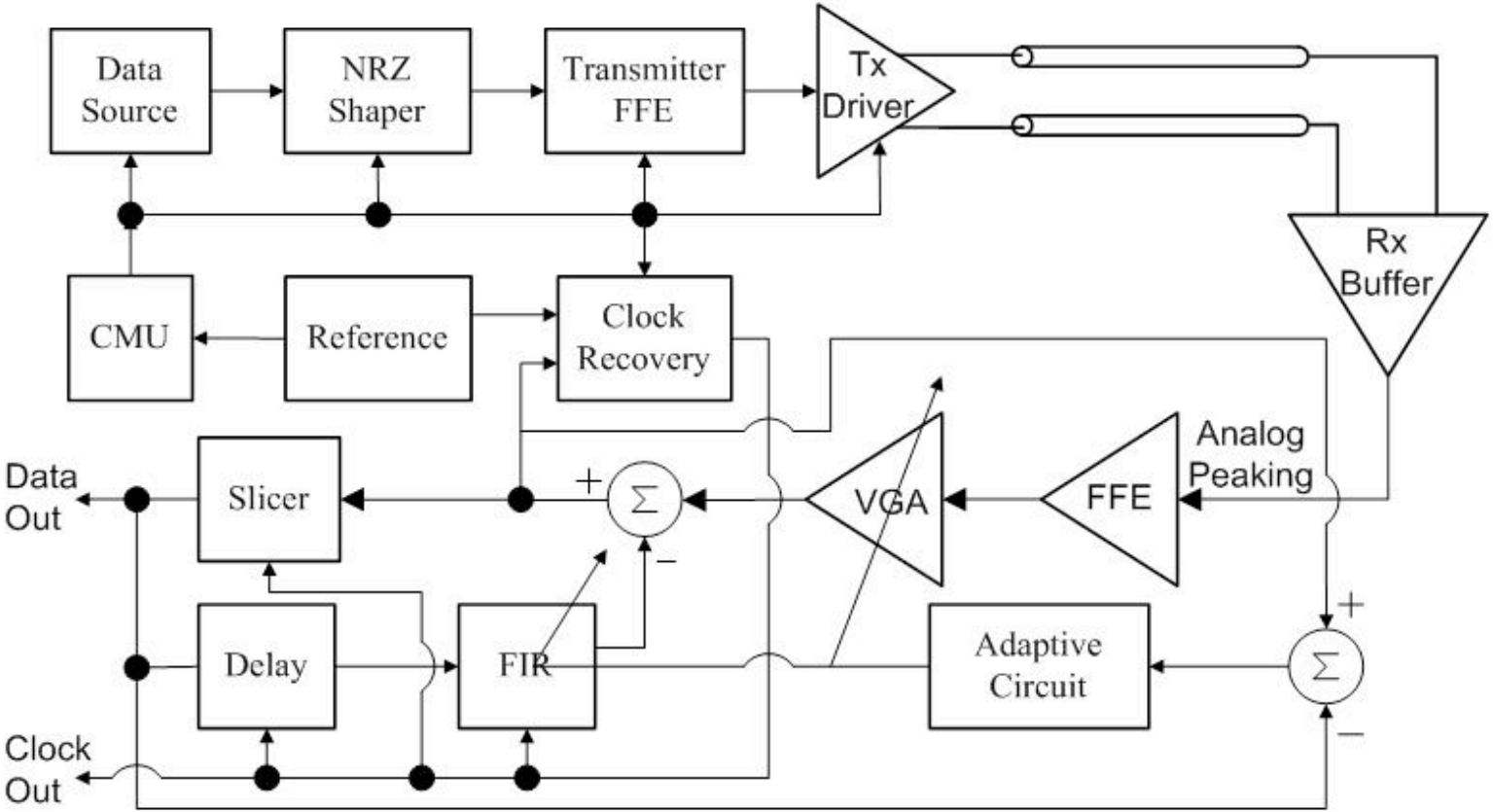


[www.sciencedirect.com]

Example: Integrator-Based Active Filter



Example: High-Speed Wired Communications



[www.doe.carleton.ca]

End of EEE 51!

- Final Exam:
  - Thursday May 24, 2018
  - 1 – 4 pm
  - Bring: pen, calculator