Wireless Technologies for Medical Applications

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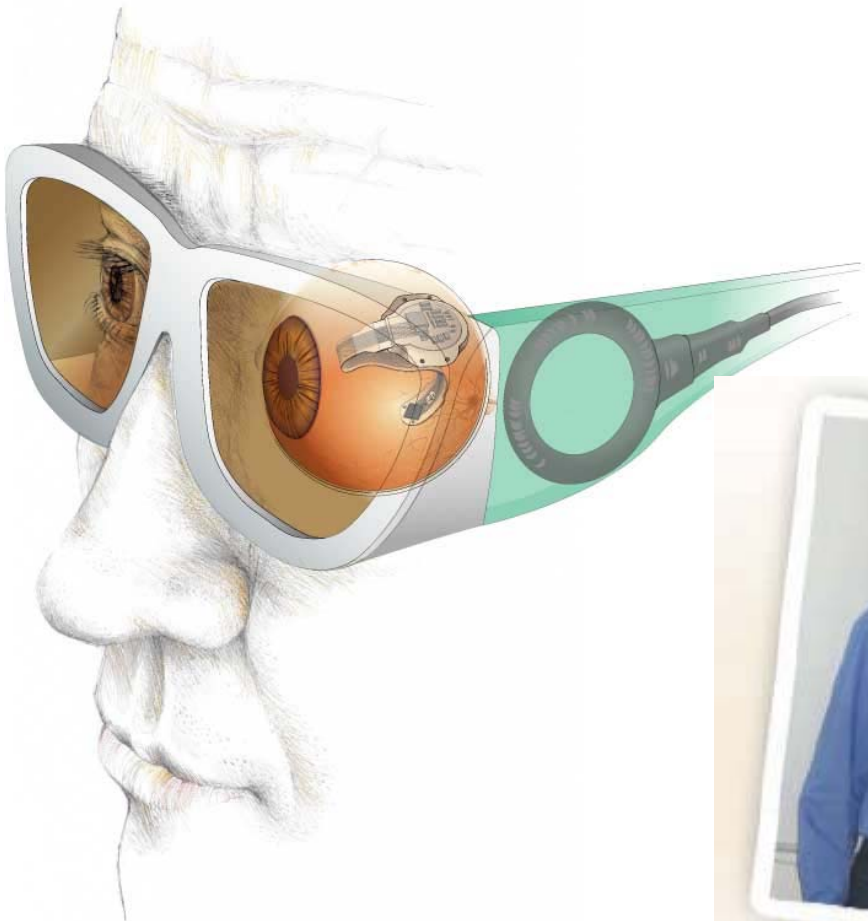
Outline

- Representative medical applications
- Spectrum regulations
- Radio building blocks
- A low-power radio architecture

Biomimetic Systems

- Mimic or augment biological functionalities
- Interface with living tissues
- Implantable or wearable
  - Pacemakers, cochlear and retinal implants
  - Hearing aids

Example: Retinal Implant



Intelligent Medical Implant (IMI) Group
Also see: Science, vol. 132, 26 May, 2006, pp. 1124-1125

Diagnostic

Example: Capsule endoscopy

Pill Cam (by Given Imaging Inc.)

Monitoring

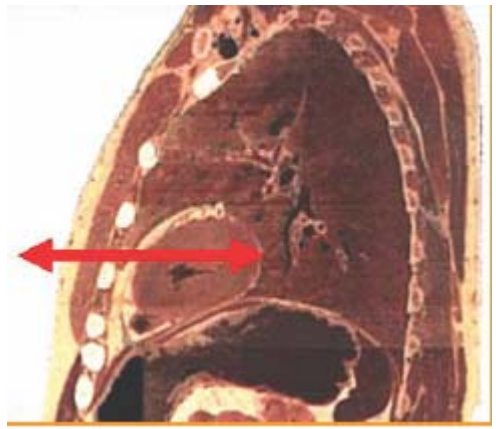
- Heart rate
- Respiration
- Temperature

Example: Temperature Monitoring

- CorTemp (by HQ Inc.)

Example: Heart and Respiration Rate Monitor

- Interesting use of UWB



Back to the Topic

- Wireless systems are enabling technology in many medical applications.
- Many require small size
- Miniature devices with (ultra) low power
- Power supply (one or a combination of): battery, inductive coupling, energy harvesting

Spectrum Regulations

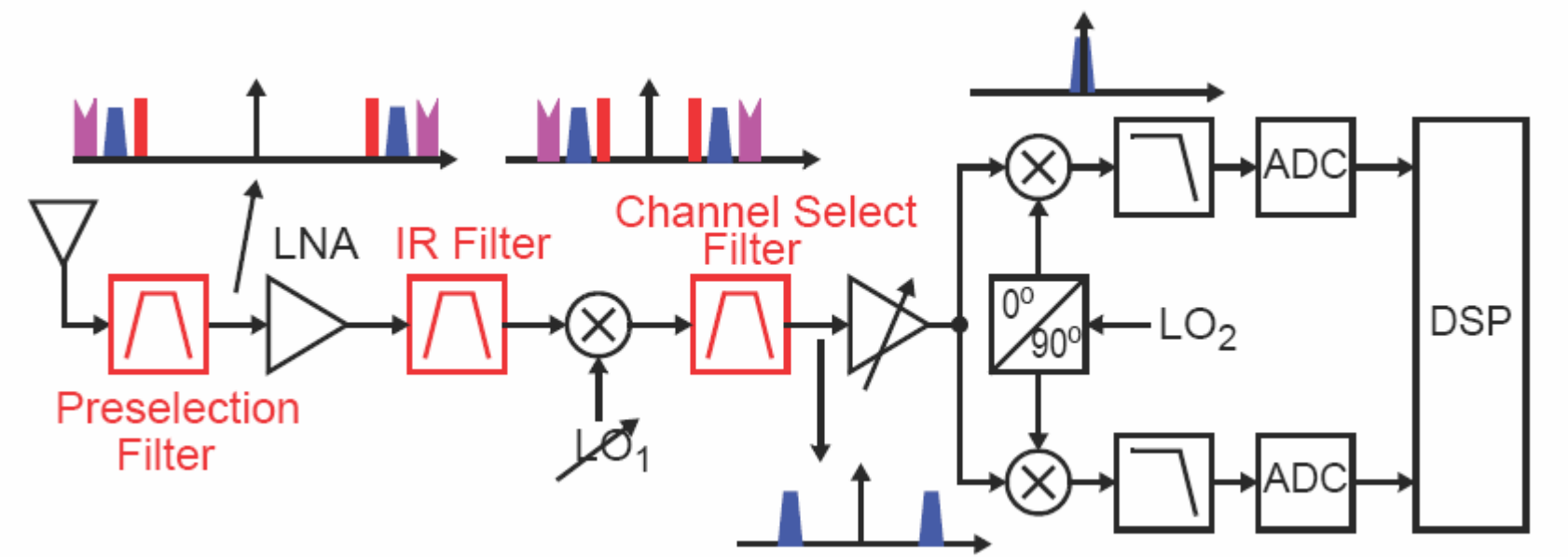
- FCC has opened up a few frequency bands for medical use:
  - Medical Implant Communications Service (MICS)
  - Wireless Medical Telemetry Service (WMTS)

- MICS: 402 to 405MHz (10×300kHz channels)

- WMTS: 608–614MHz, 1395–1400MHz, and 1427–1432MHz

Receiver Architecture

- Heterodyne

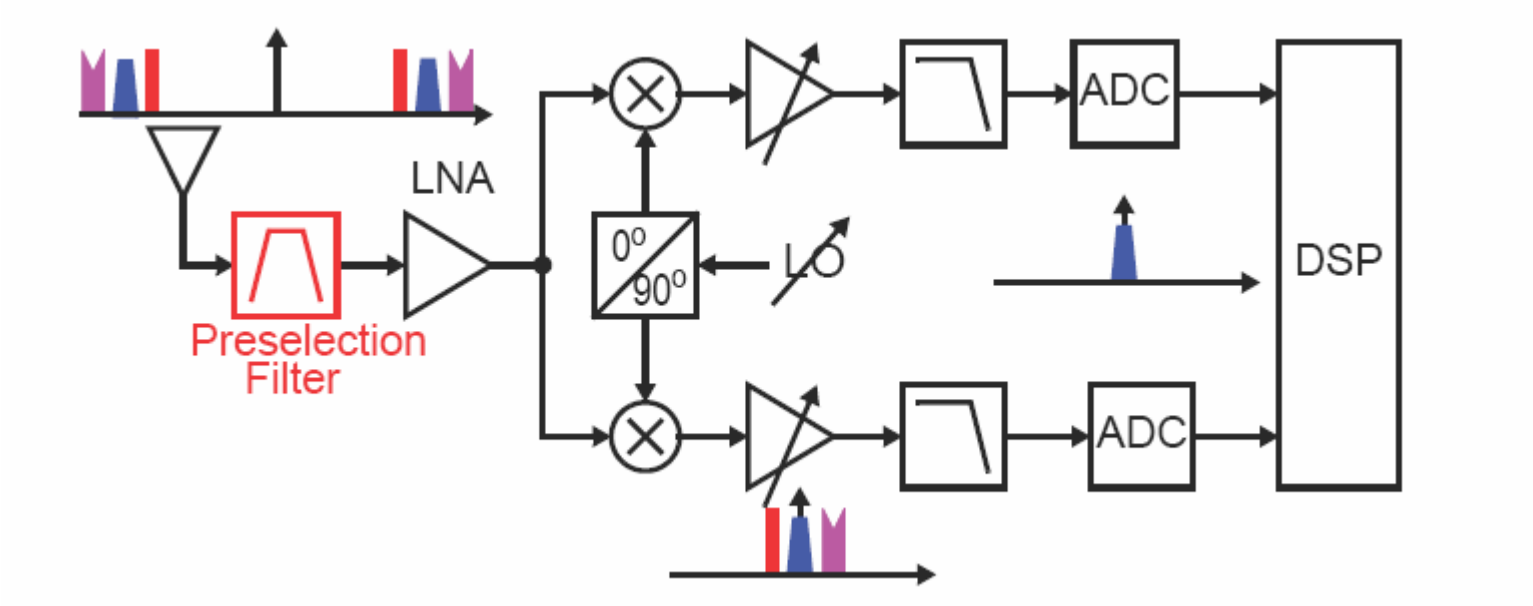


- Not a good choice:

  Power, size (integration), cost issues

Receiver Architecture

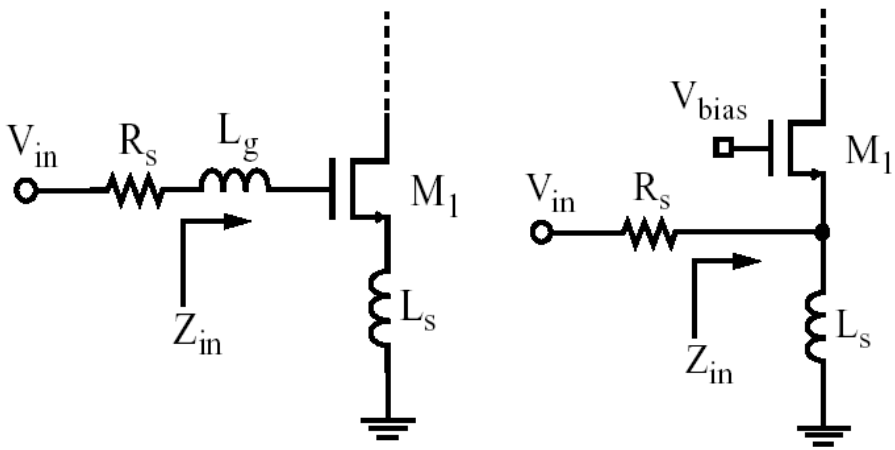
- Direct conversion and low IF



- Direct conversion: DC offset and 1/f noise
- Highly integrated solutions

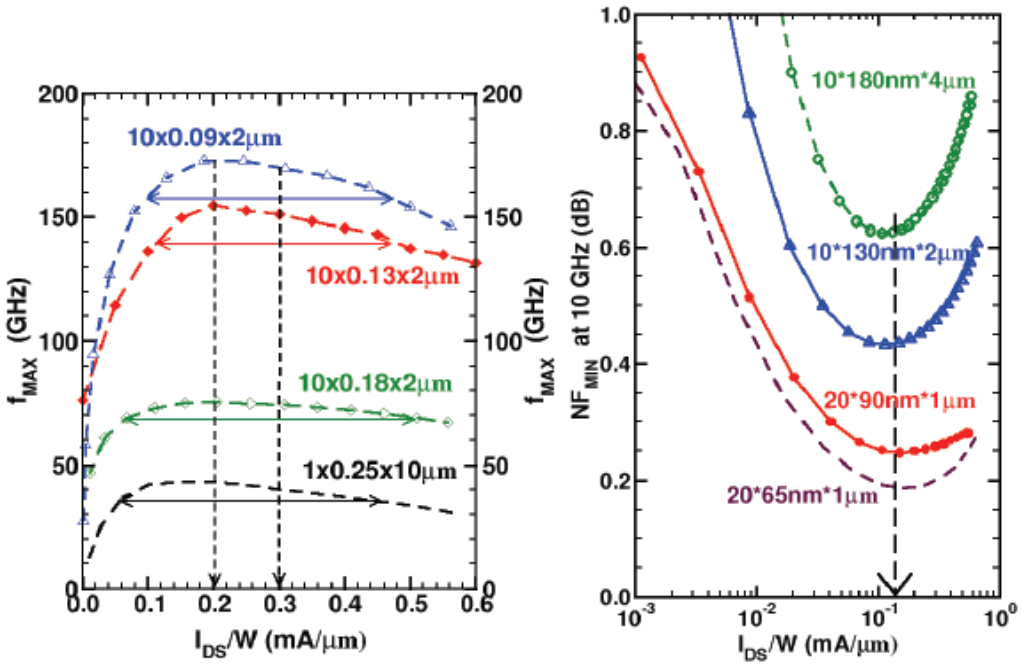
Receiver Building Blocks: LNA

- Dominant impact on overall receiver NF
- Various topologies exists
- Two good candidate topologies:



LNA

S.P. Voinigescu, T.O. Dickson, T. Chalvatzis, A. Hazneci, E. Laskin, R. Beerkens, and I. Khalid, “Algorithmic Design Methodologies and Design Porting of Wireline Transceiver IC Building Blocks Between Technology Nodes,” CICC, 2005



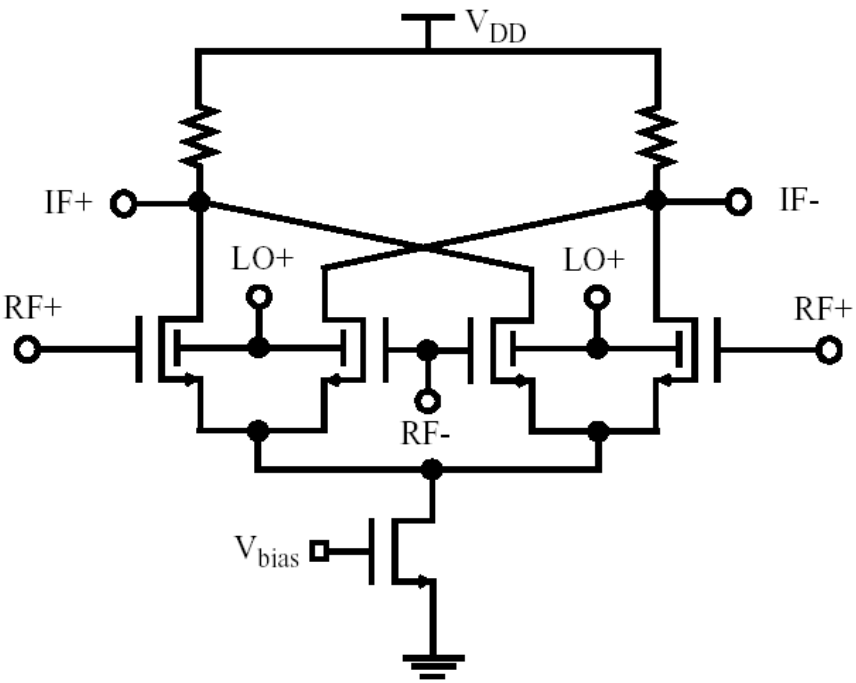
Peak f_{MAX} @ 0.2 mA/μm NF_{MIN} @ 0.15 mA/μm

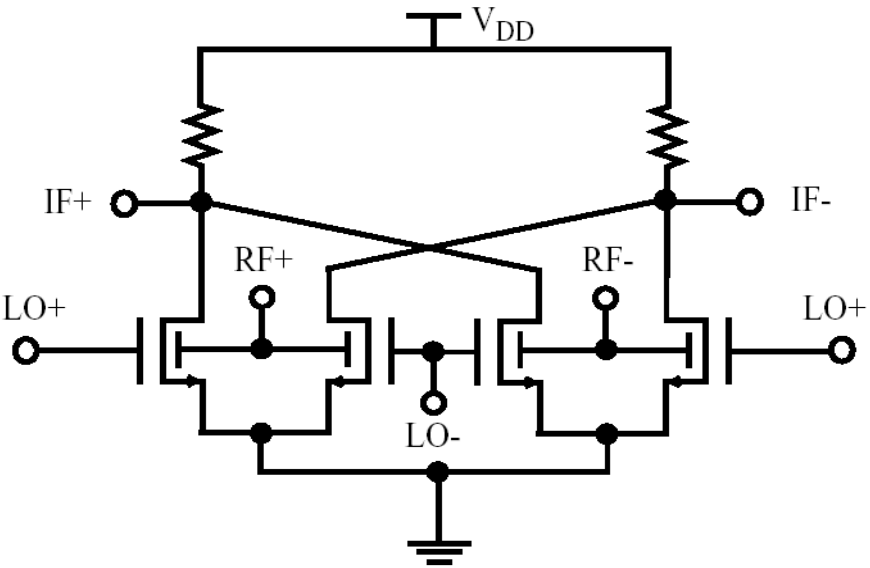
Receiver Building Blocks: Mixers

- Active
  - + Conversion gain
  - + Possibly better overall noise figure
  - + Less loading on LNA compared to passive
  - + Lower LO amplitude
  - – Power consumption
  - – Classical Gilbert mixer not suitable for low voltage

Mixers

- Two low-voltage friendly Gilbert-based mixers





Trade-Offs in Analog Circuit Design, Edited by C. Toumazou, G. Moschytz, and B. Gilbert

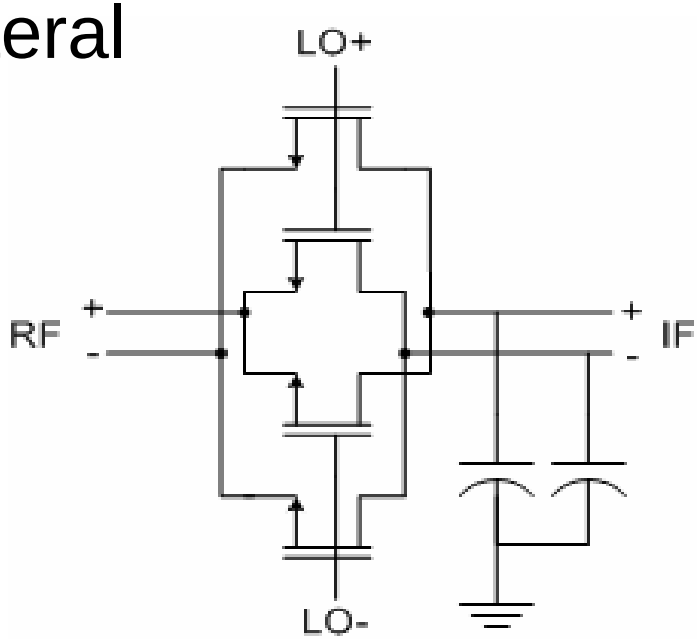
Mixers

- Passive mixer

  + No power consumption

  - Conversion loss (affecting noise budget)

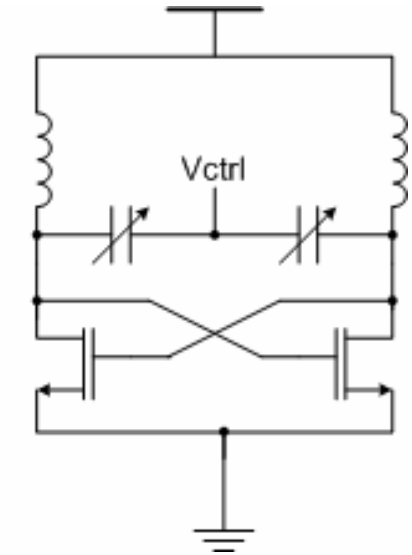
  - Non-unilateral



Local Oscillator

- Important block: VCO
- Typical choice for wireless systems: LC-VCO
  + lower phase noise

$$L(f_m) = 10 \cdot \log\left[\frac{FkT}{P} \cdot \frac{1}{2Q^2} \cdot \left(\frac{f_o}{f_m}\right)^2\right]$$



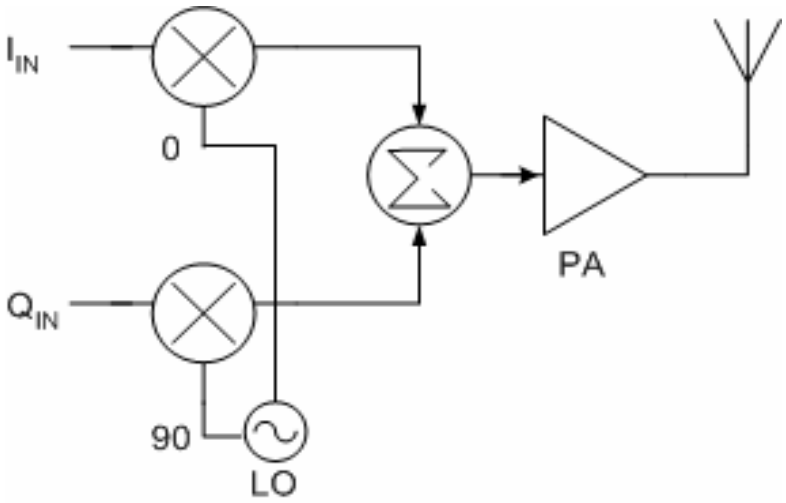
- Phase noise requirement depends on system specifications

LC VCO

- MICS band LC-VCO large inductor size
- Could design the LC-VCO for higher frequency (e.g., 1.6GHz), then divide
  - \+ Good phase noise
  - \+ smaller inductors
  - \- power consumption
- Use a ring oscillator
  - \+ very compact
  - \- higher phase noise

Integrated Transmitter Architecture

- Direct Conversion

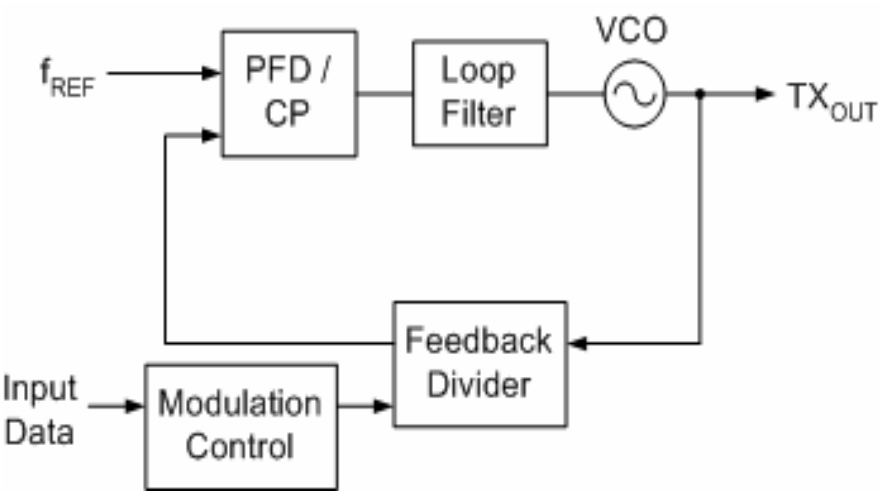


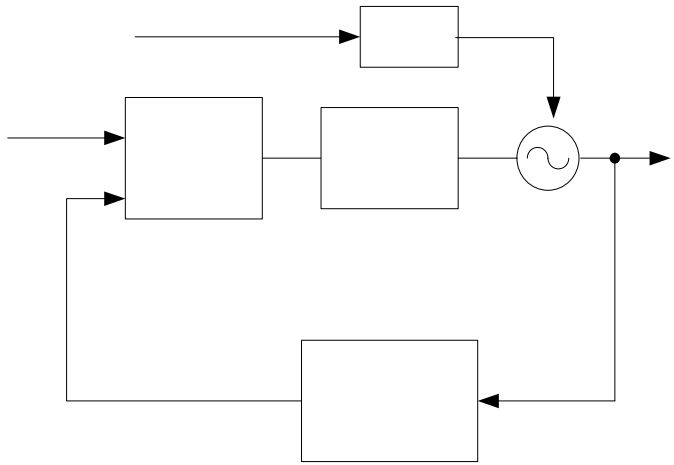
- Issue: Efficiency of PA especially for non-constant envelope

Transmitter

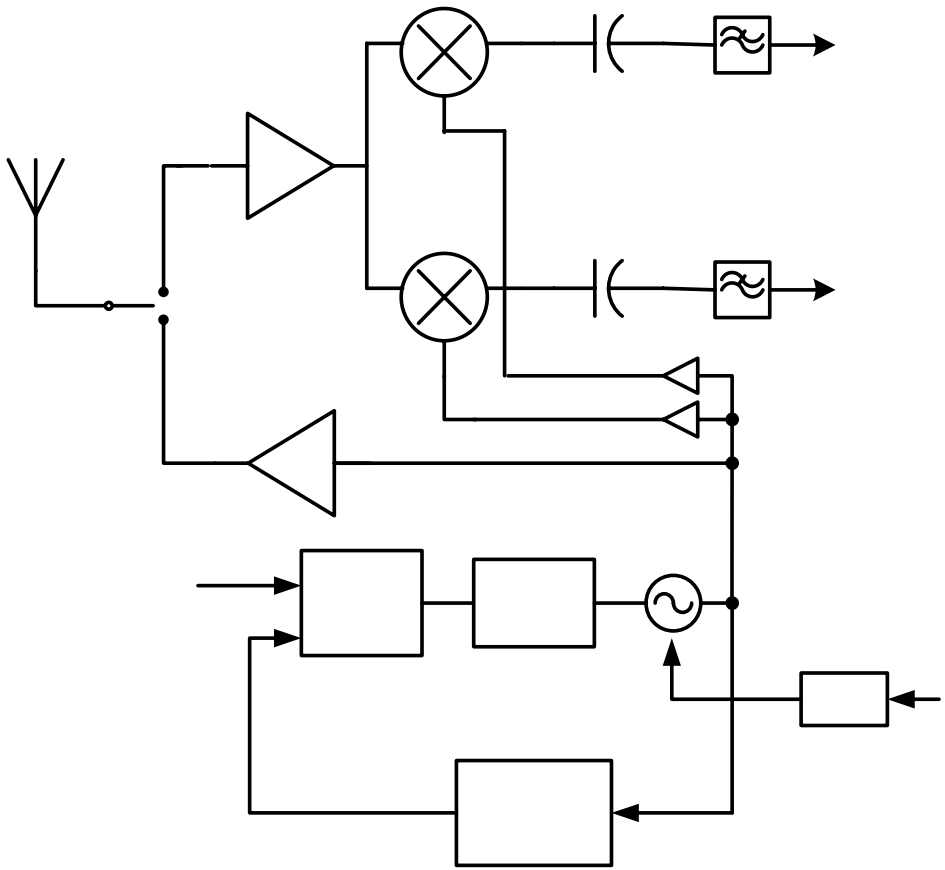
- With constant-envelope modulations such as FSK higher efficiency PAs can be used.

- FSK modulation can be embedded in the PLL





A Low-Power Transceiver Architecture



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Challenges

- Limited source of energy
- Reliable energy harvesting techniques
- (Ultra)-low power design
- (Ultra)-low voltage design

Acknowledgements

Technical contribution of Chris Siu and support from NSERC and CMC Microsystems are greatly acknowledged.