Additional RF system issues: Amplifier linearization Reference Phase distribution Master Clock

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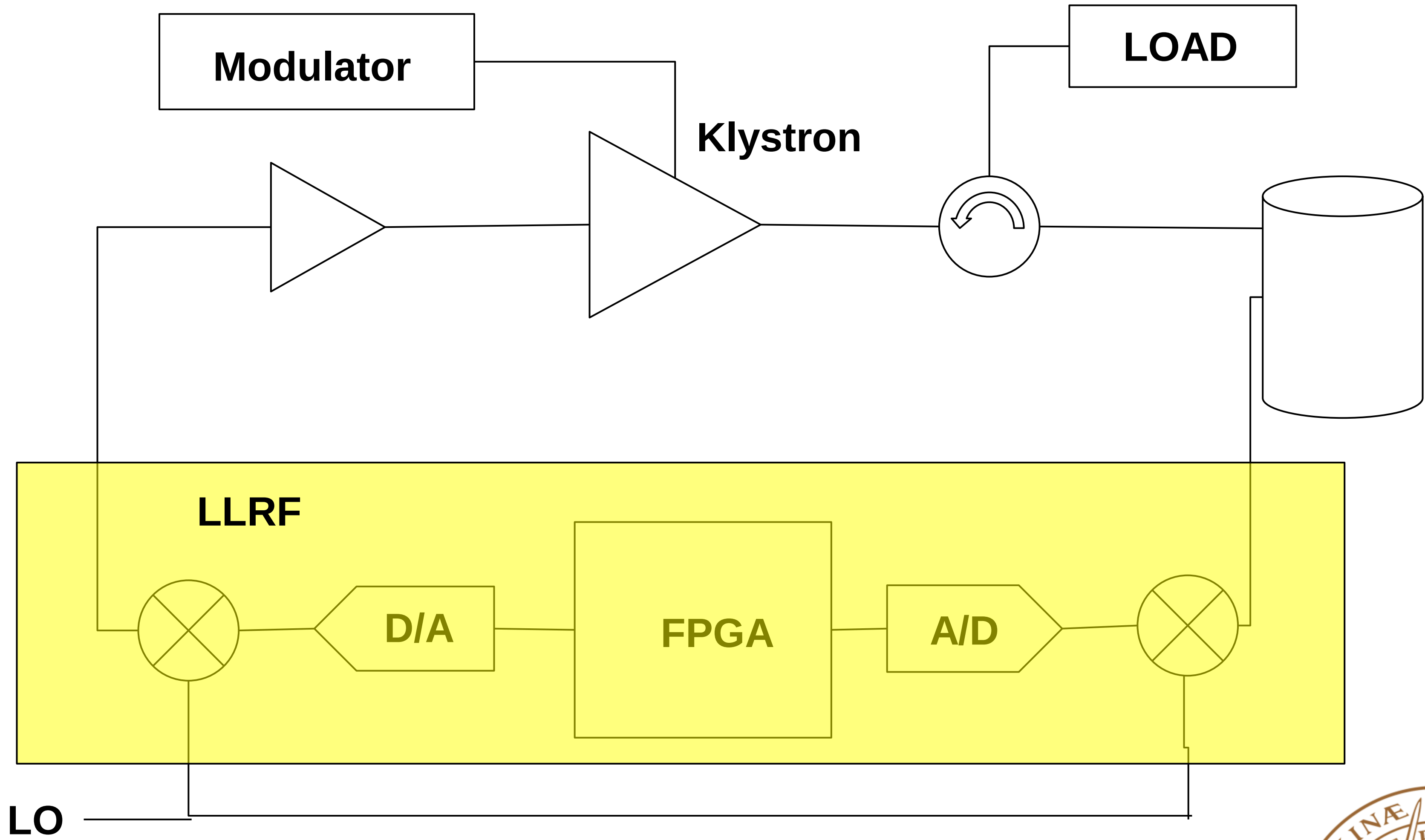
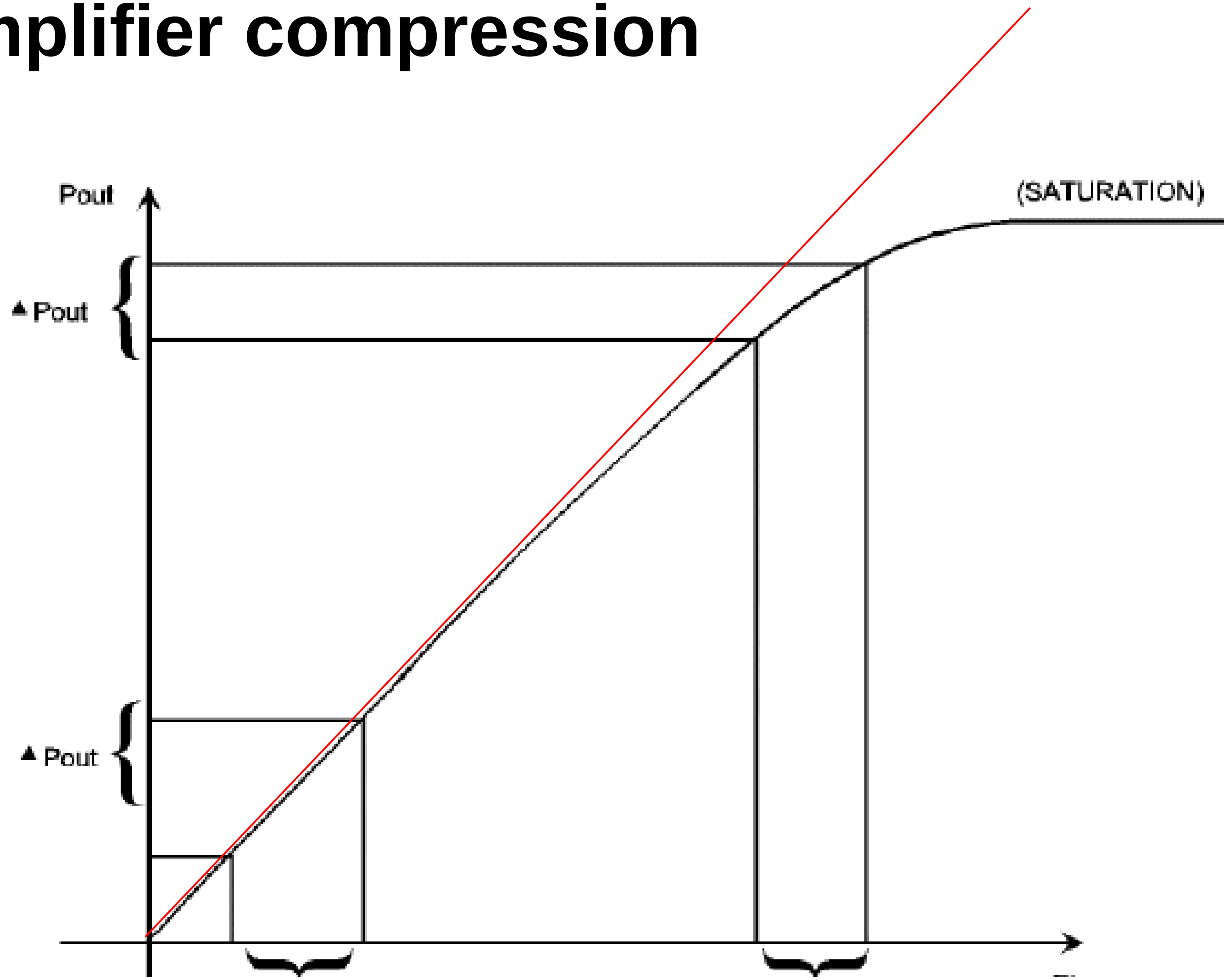
Low Level RF (LLRF)



Linearization of power amplifiers

- Linearization of PA common in mobile communications
- Makes it possible to use efficient amplifiers and still fulfill transmitt spectrum masks.

Amplifier compression



Power Amplifier Linearization Techniques, an Overview, Joel L. Dawson

Why linearization in mobile communications

- Increased demands due to:
  - Complex modulation schemes
  - Muliple channels per amplifier

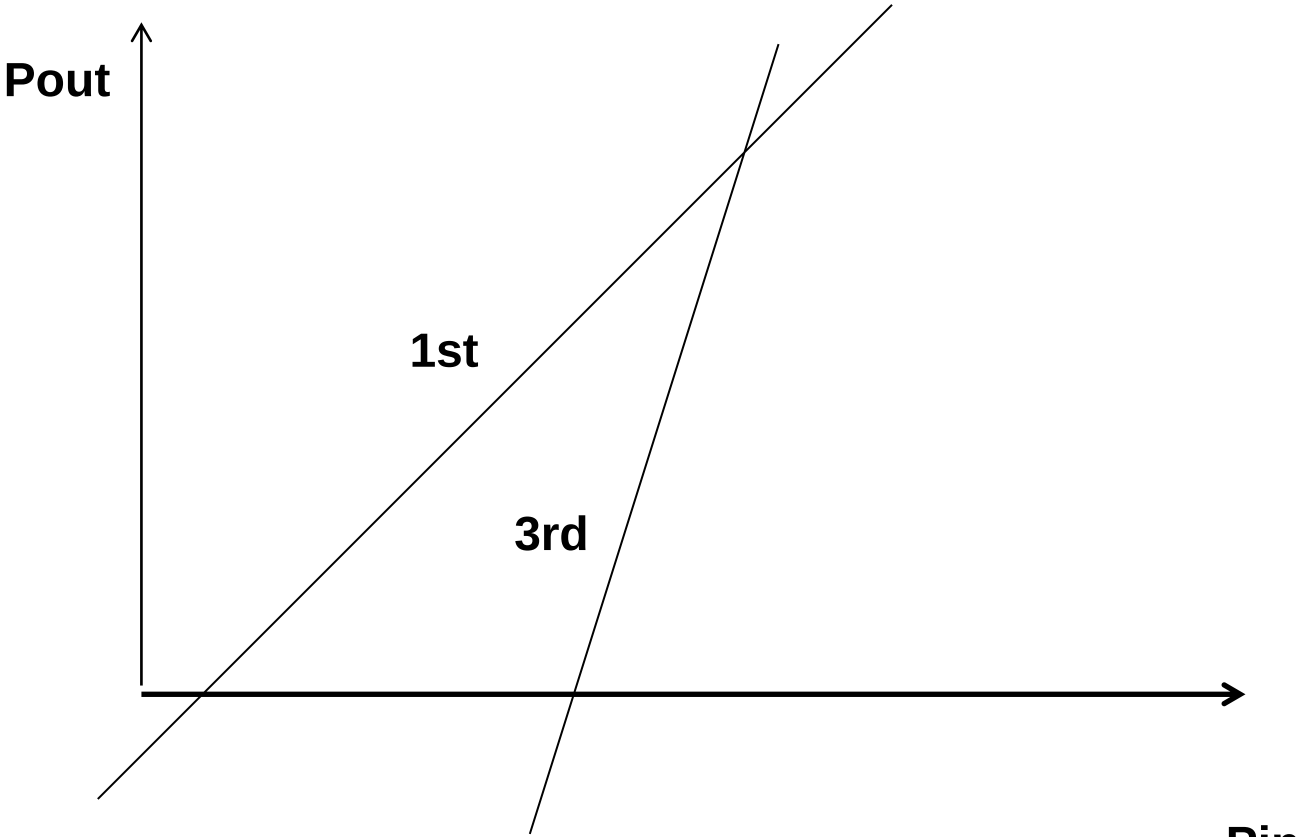
  - Running at compression/class C for efficiency

List of linearization techniques

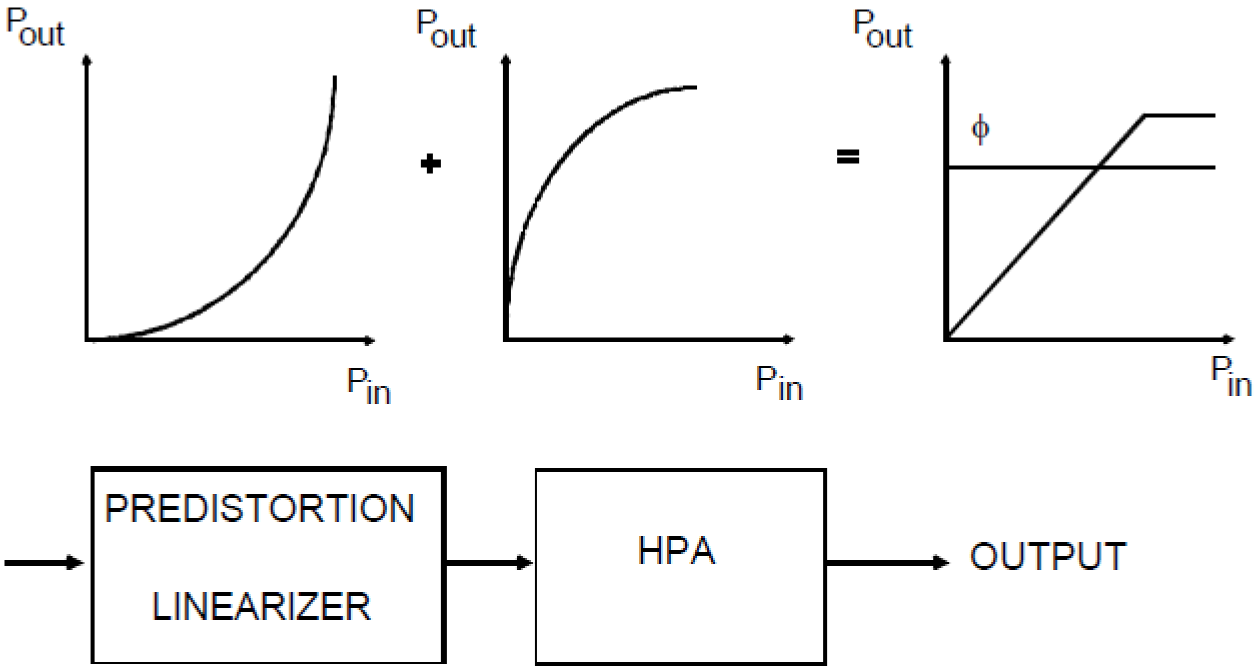
- Power backoff
- Predistortion
- Adaptive predistortion
- Feedforward Linearization
- Envelope elimination and restoration (EER)
- LINC (***LI**near amplification with **N**onlinear **C**omponents)*
- Cartesian feedback

List by Joel L. Dawson

Power backoff

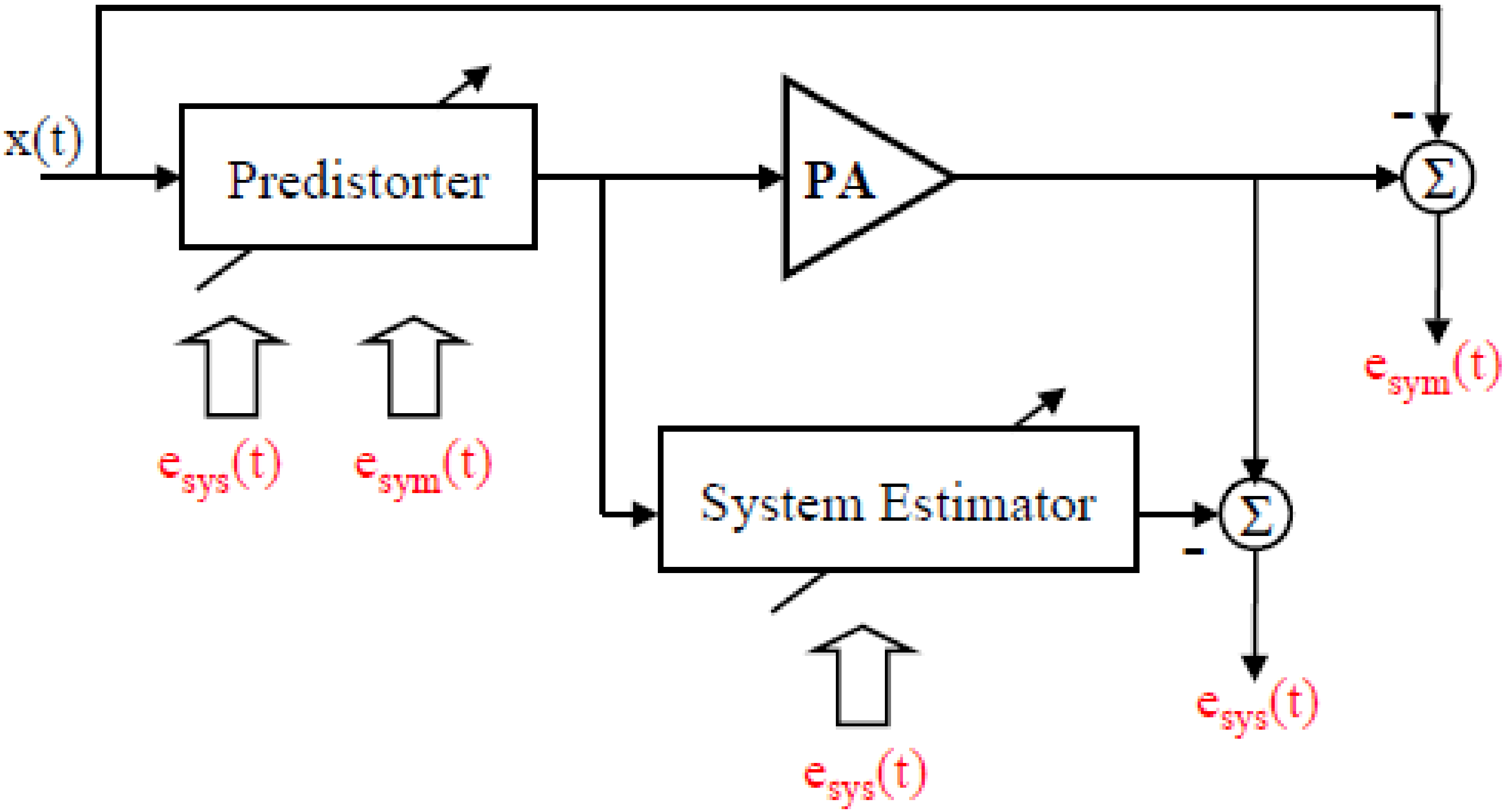


Predistortion



Linearization High Power Amplifiers, Allen Katz, Linearizing Technologies

Adaptive predistortion



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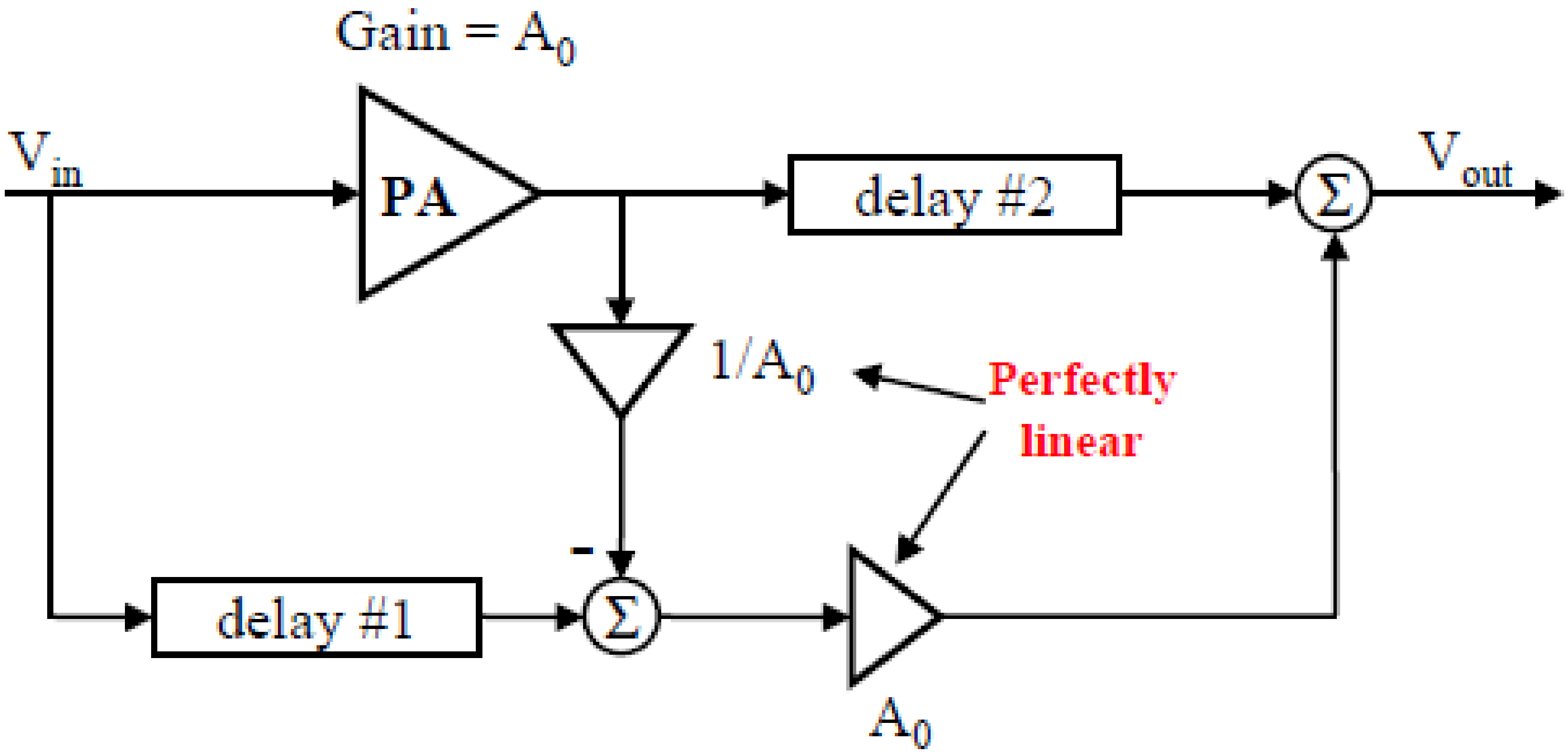
Feedforward Linearization



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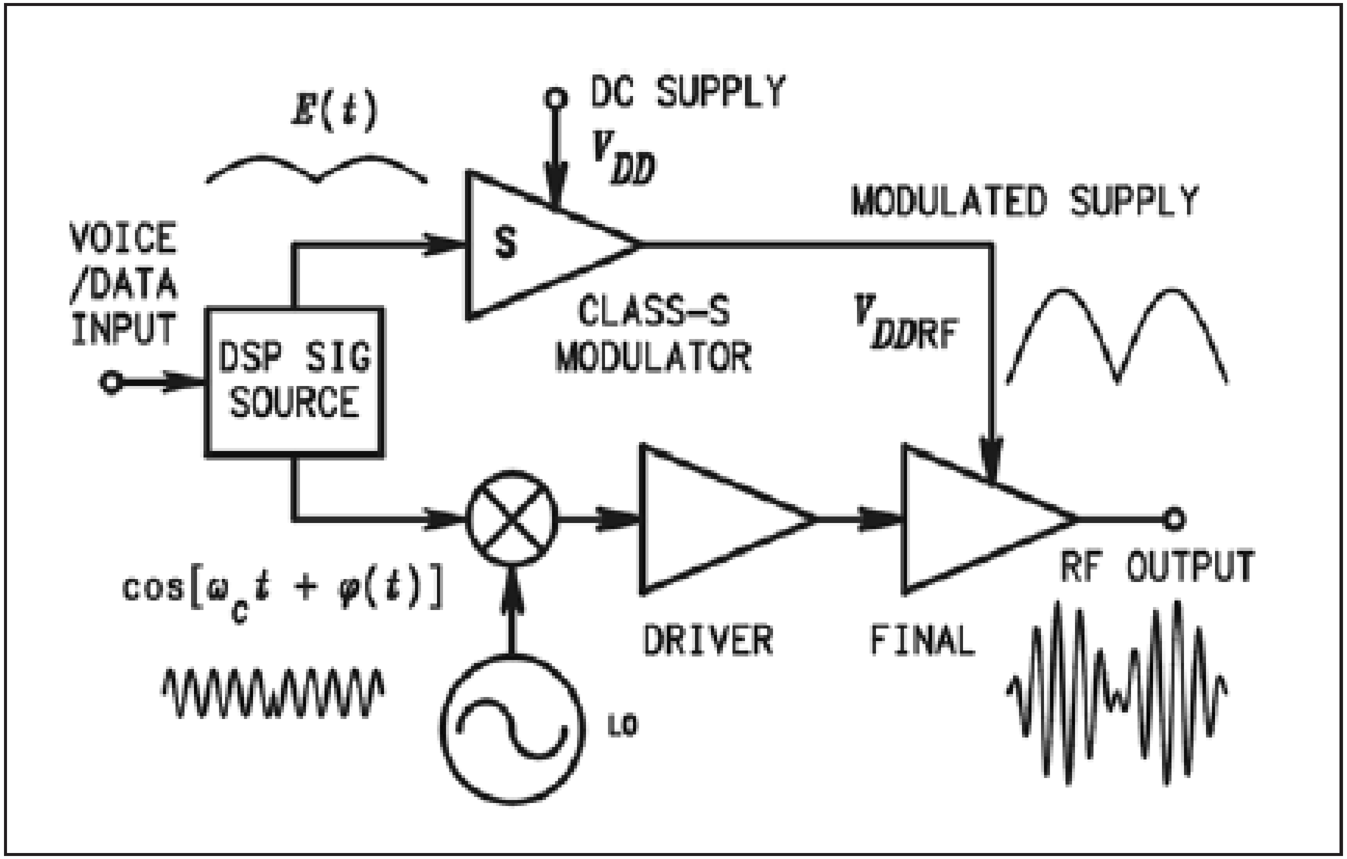
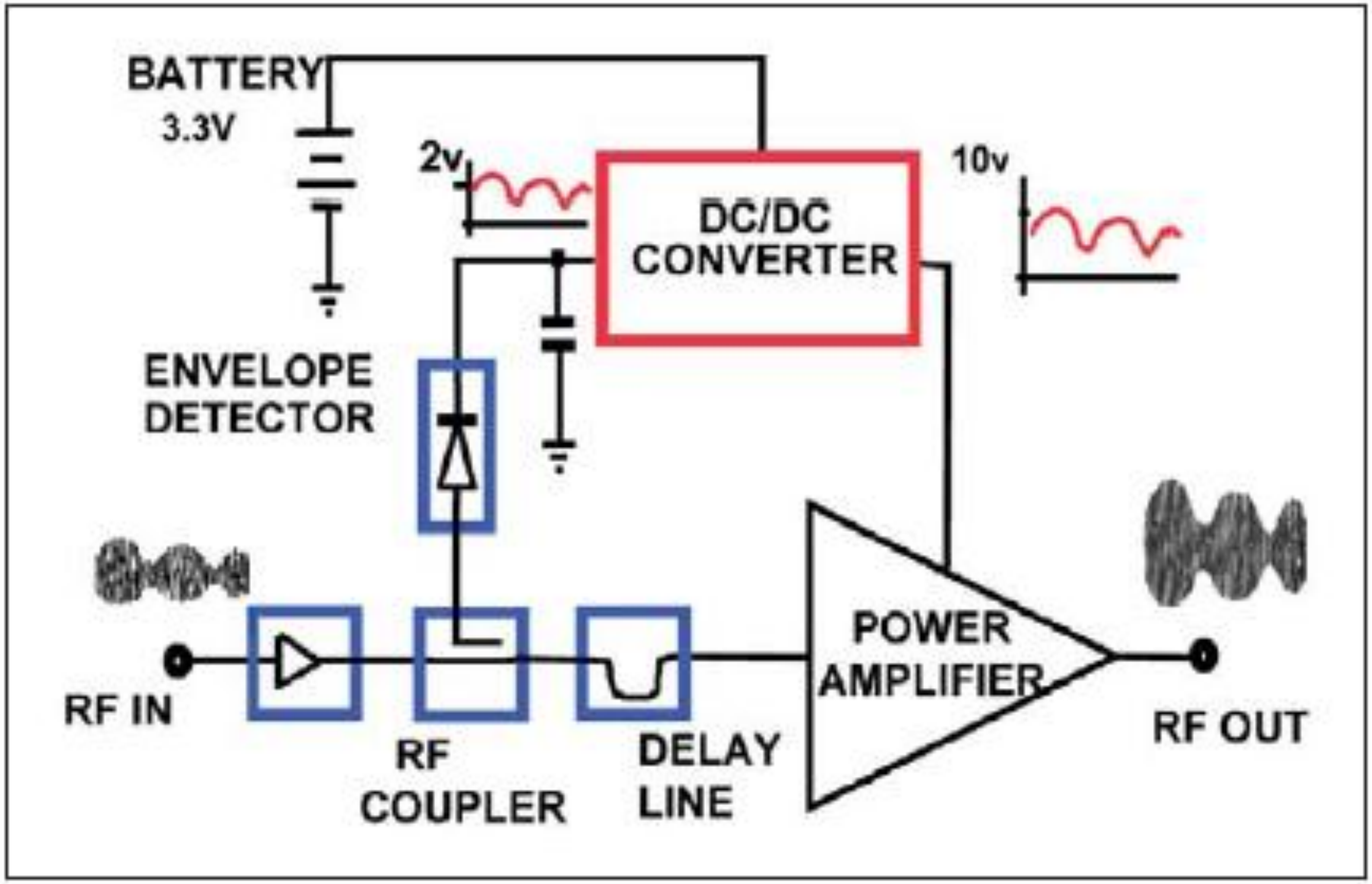
Envelope elimination and restoration



RF and Microwave Power Amplifier and Transmitter Technologies — Part 3, F. H. Raab et. Al.

Envelope tracking



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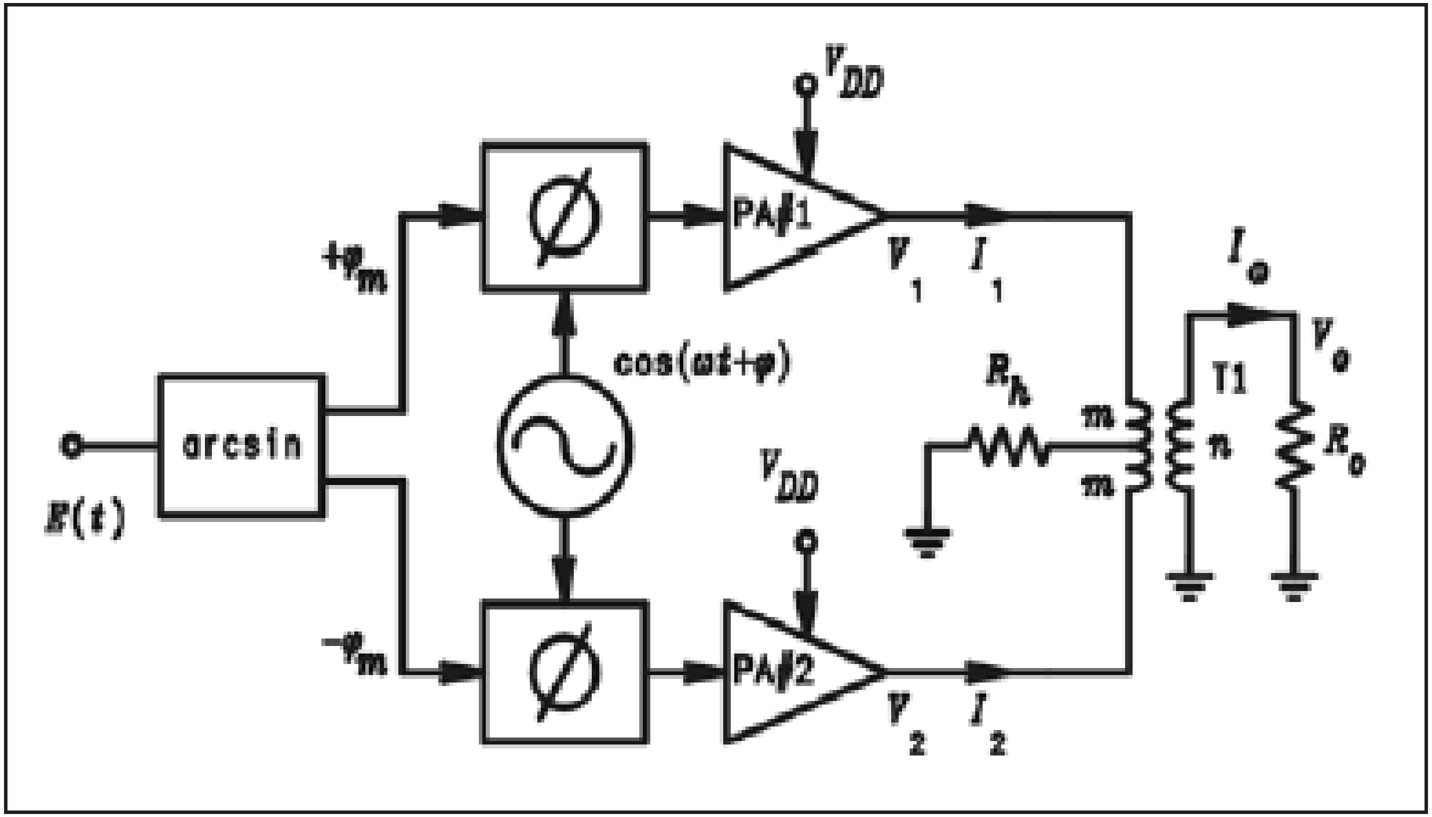
LINC



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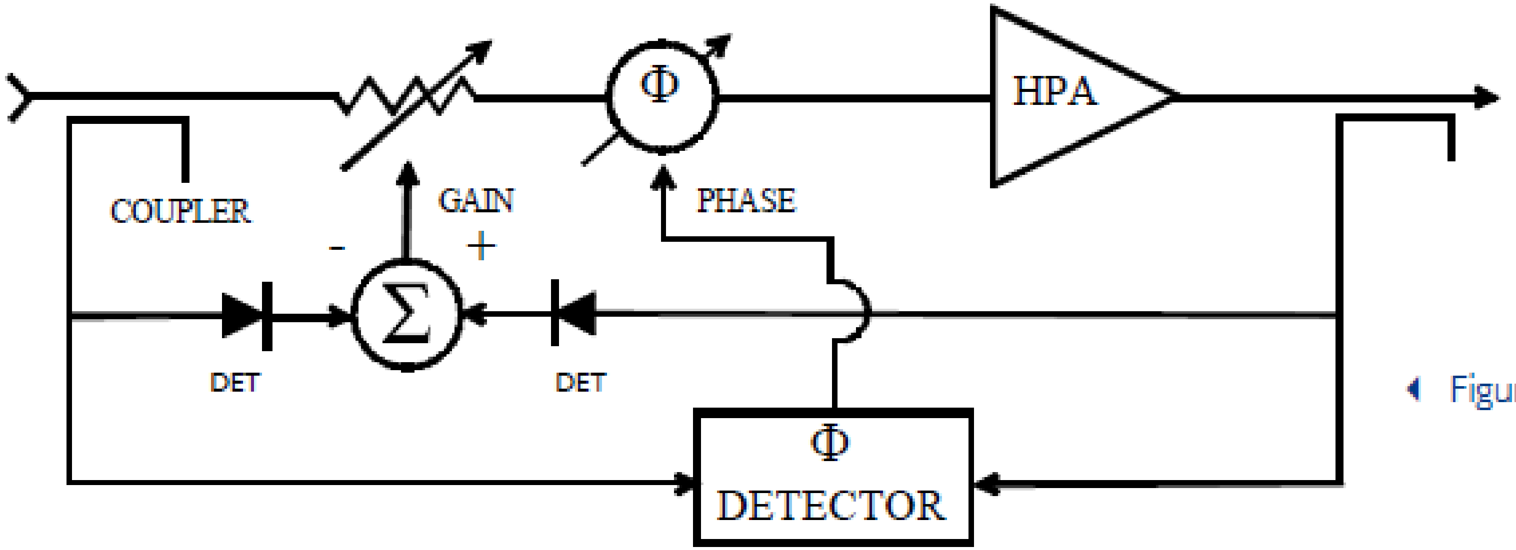
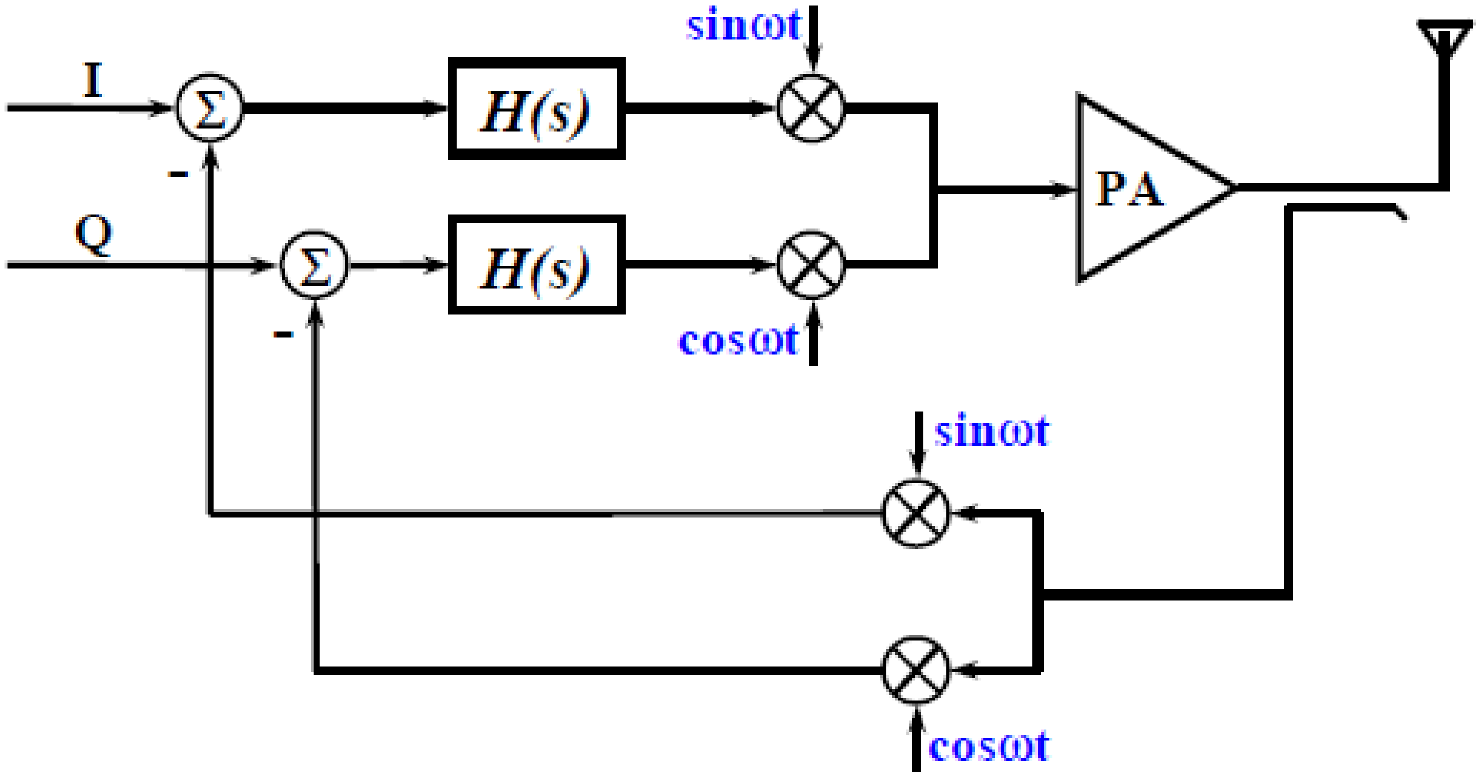
Indirect Feedback



Figur

Linearization High Power Amplifiers, Allen Katz, Linearizing Technologies

LINCartesian Feedback



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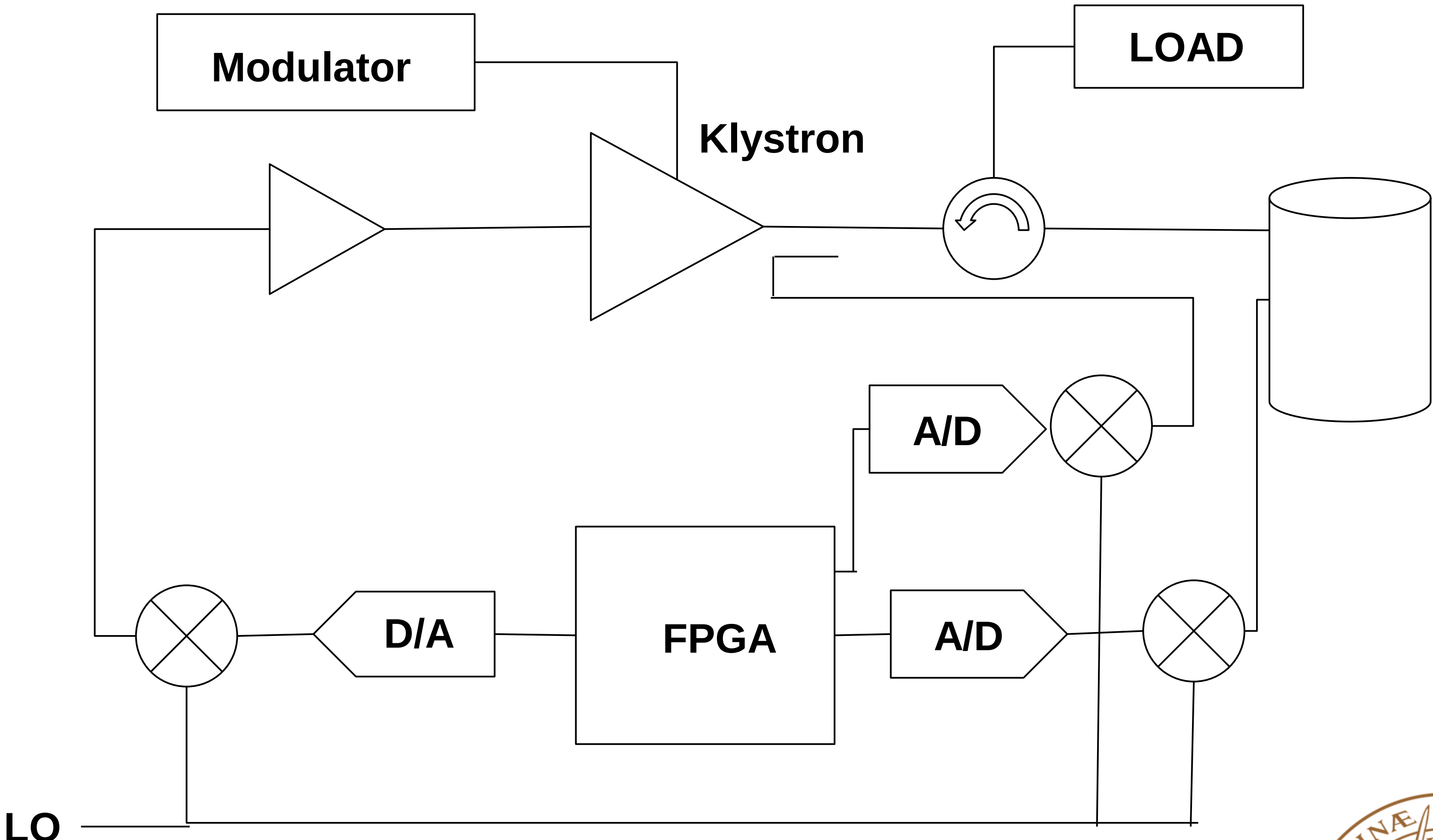
LLRF with linearization



Development of Linearization for ESS

- Investigate the different options from the viewpoint of ESS
  - Klystrons / IOTs
  - Narrow bandwidth
  - Huge power
    - Overhead from FPGA/DSP minimal

- Needs accurate non-linear models of amplifiers!

Time and Synchronization

- ESS needs:
  - A common clock to timestamp events
  - Stable generation and distribution of pulse events
  - Stable reference phase for RF

Phase reference

- Crystal oscillators
  - Very low phase noise
  - Big drift
  - Cheap
- Atomic clocks (cesium /rubidium)
  - Low drift
  - Large phase noise
  - Costly
- Maser
  - Very Low drift
  - Expensive

Stability and phase noise

- Two main measures of oscillators and clocks
  - Allen variance or stability

    $$\sigma_y^2(\tau) = \frac{1}{2}\left\langle (\Delta y)^2 \right\rangle$$

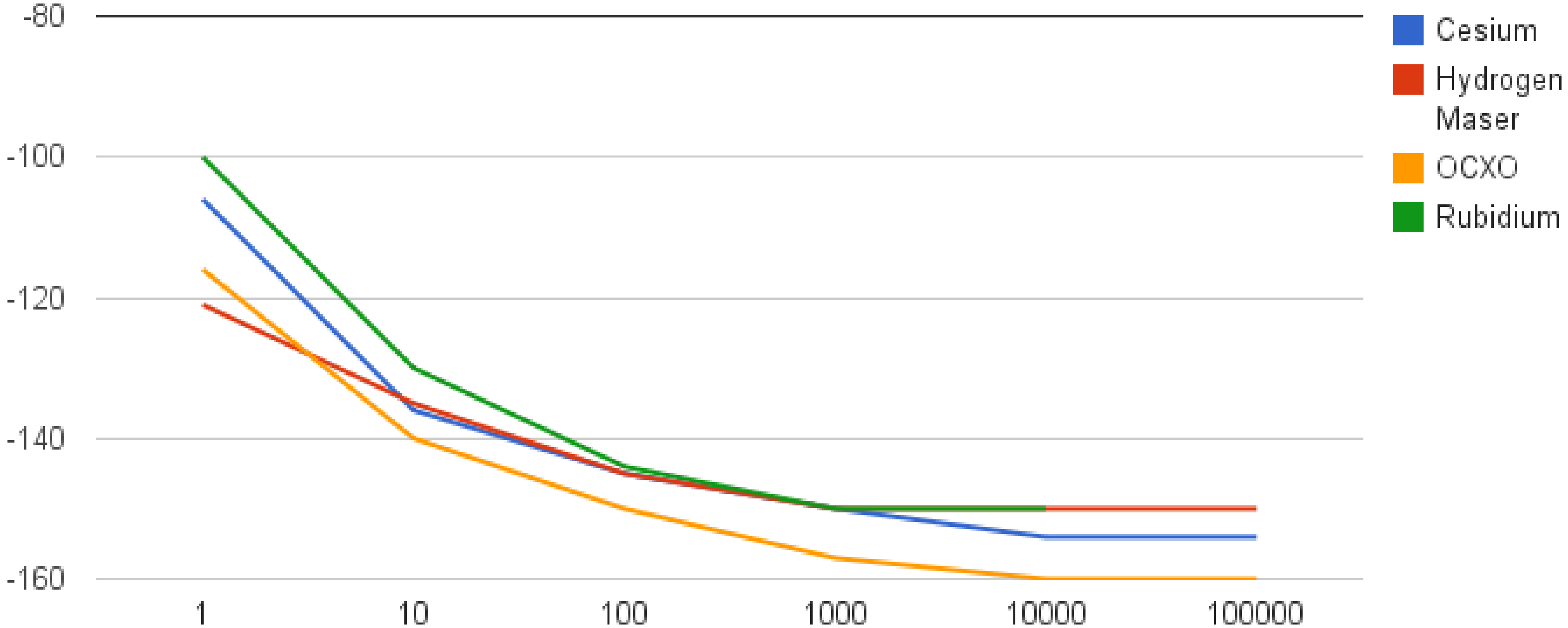
    - Slow variations
    - ” Allan variance is defined as one half of the time average of the squares of the differences between successive readings of the frequency deviation sampled over the sampling period”
  - Phase noise

    $$L(f) = S_\phi / 2$$

    - Fast variations

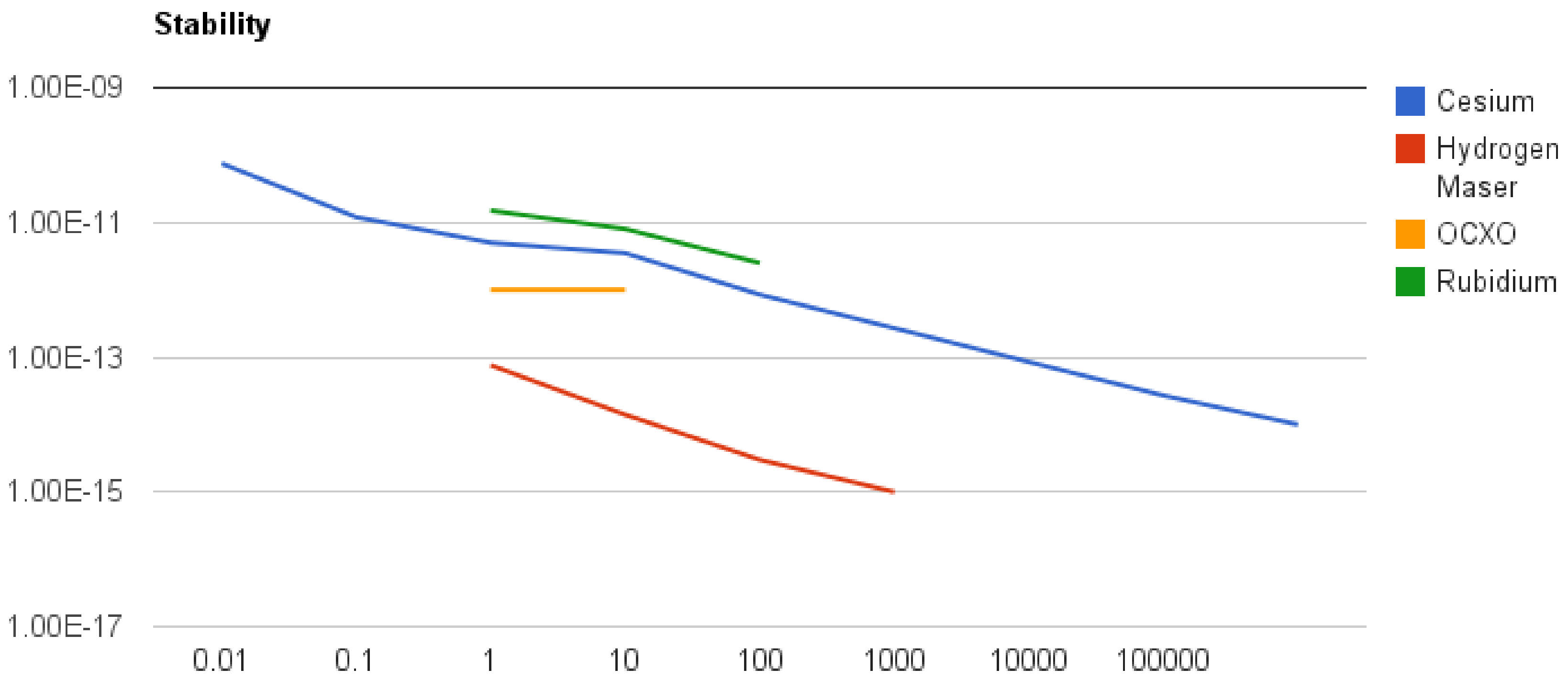
Phase noise

dBc/Hz vs. Offset frequency in Hz



Stability

Allan stability versus integration time (seconds)

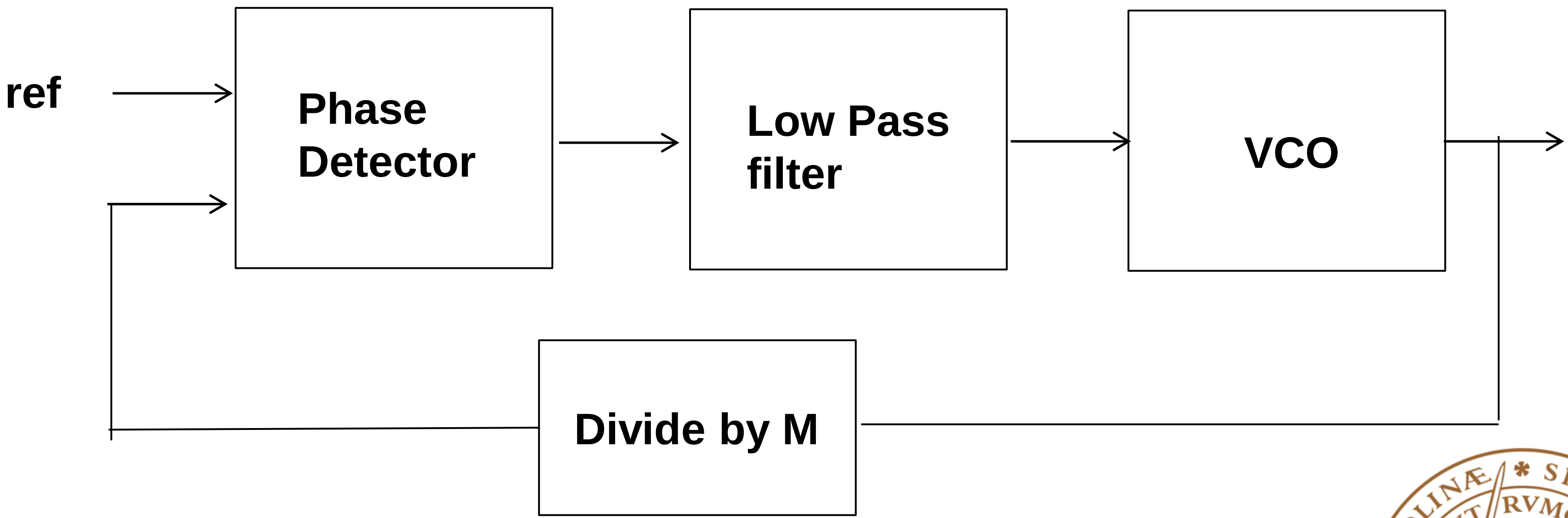


OCXO: Oven Controlled Crystal Oscillators

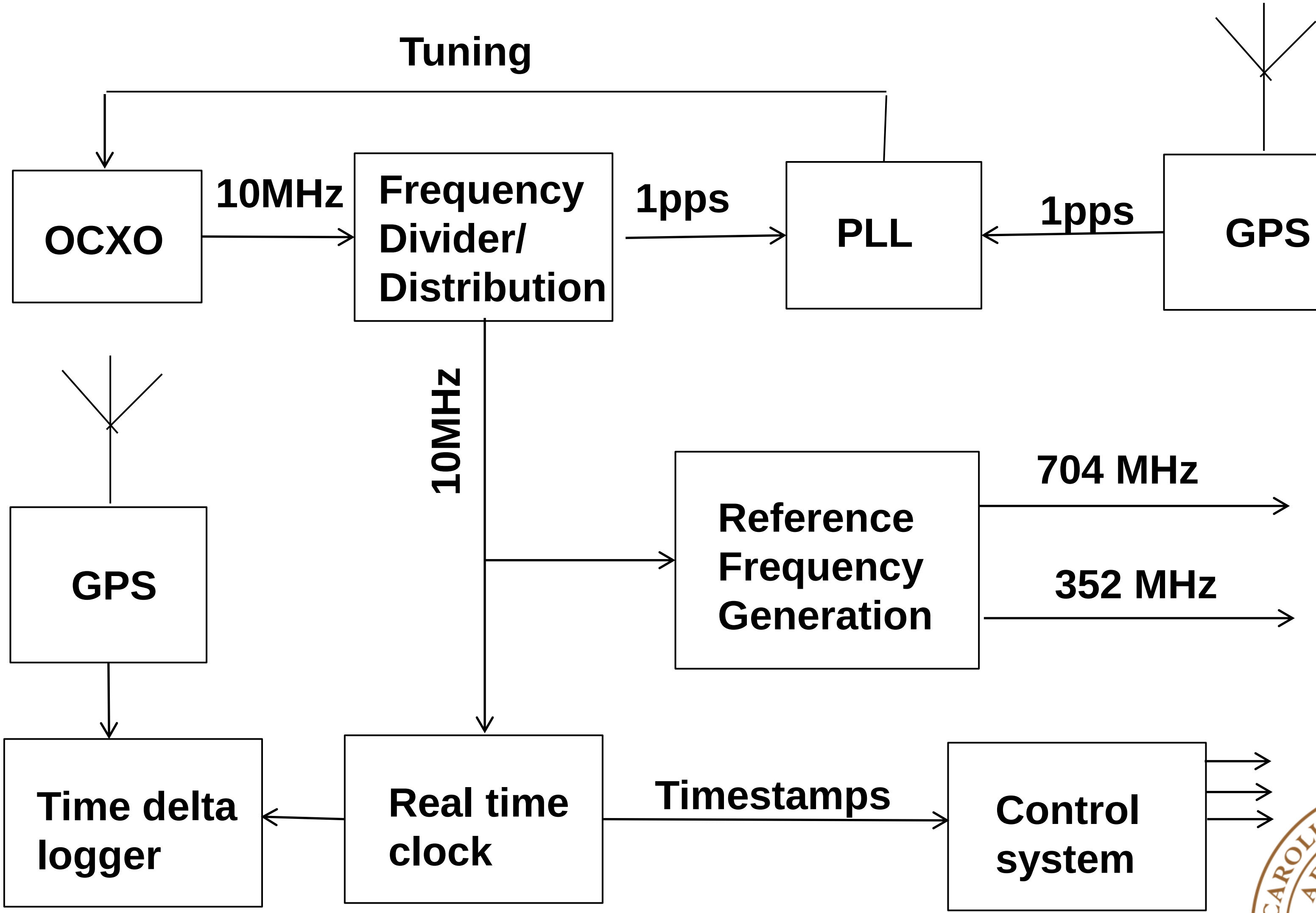
- Stabilize a crystal oscillator by putting it inside a temperature controlled oven
(which in turn may be inside an temperature controlled oven etc.)
- May still be tuned by voltage and/or temperature
- Typically 10 MHz.

PLL: Phase Locked Loop

- How to use a stable low frequency oscillator to control a high frequnecy source.



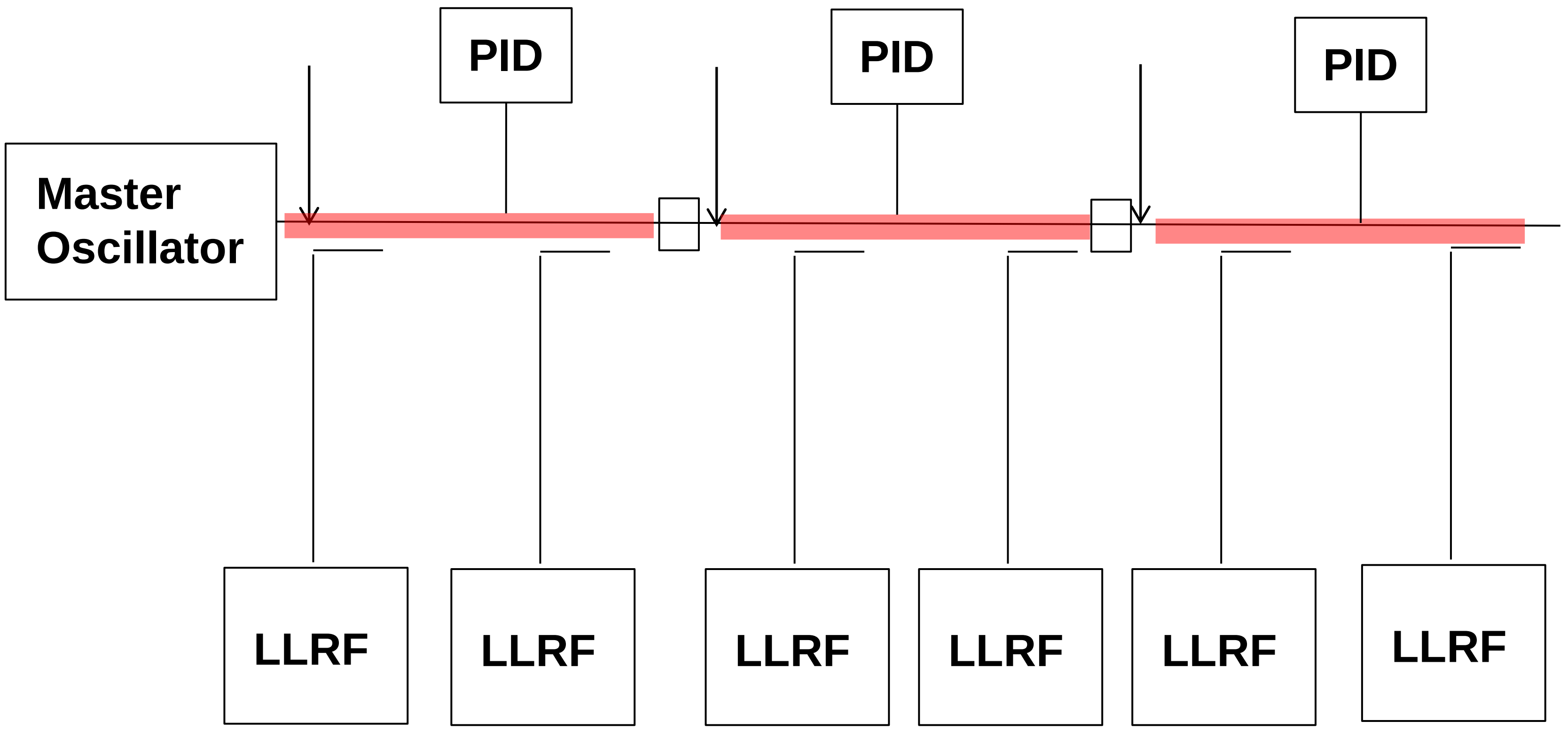
Master clock schematic (tentative)



Reference phase distribution

- The reference phase needs to be distributed to all LLRF stations
- Taken from the master clock
- Linear or star topology
- Example: linear distribution

Reference phase distribution



Conclusions

- Investigate possibility of running the power amplifiers (klystrons) close(r) to saturation.
- Design a master clock
- Design a phase distribution network