Lock-in amplifier

Introduction:

http://www.signalrecovery.com/_AppsNotes/TN1007.pdf

Refresh: Synchronous Detection (Sensors and Transducers):

http://measure.feld.cvut.cz/system/files/files/cs/vyuka/predmety/A3M38MSZ/SynchrDetectBW.pdf

LIA Key parameters

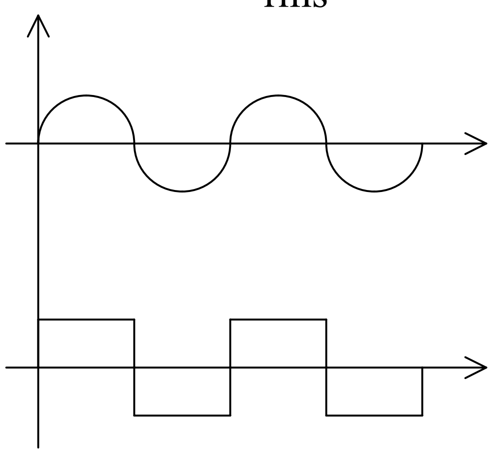
- Full-scale sensitivity
  - Synchronous input sine RMS (uVrms ~ ±10Vdc)
- Linearity and Out-of-phase rejection
  - Maximum asynchr. signal causing distortion < limit
- Dynamic reserve – defined as
  - Out-of-phase rejection ratio for distortion <5%
  - Or simply as ratio of full scale signal to clipping level
- Output stability and drift
- LP filter parameters

M.L.Meade – Lock-in amplifiers: principles and applications, ISBN 090604894X

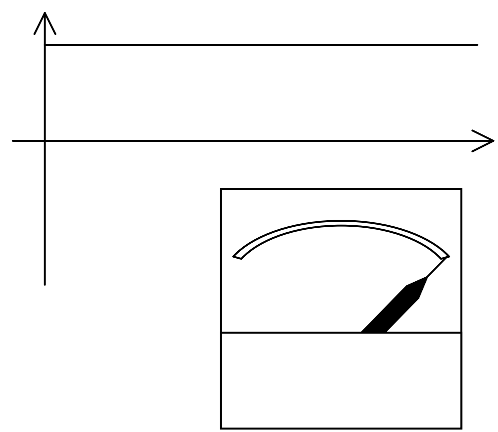
Full-scale sensitivity

- RMS value of ***synchronous*** input sinewave giving ***Full scale output*** (typ. 10Vdc)
- Ex.: S_D=1nV … Output +10V

1 nV_{rms}



+10 V_{DC}



Linearity and Out-of-phase rejection

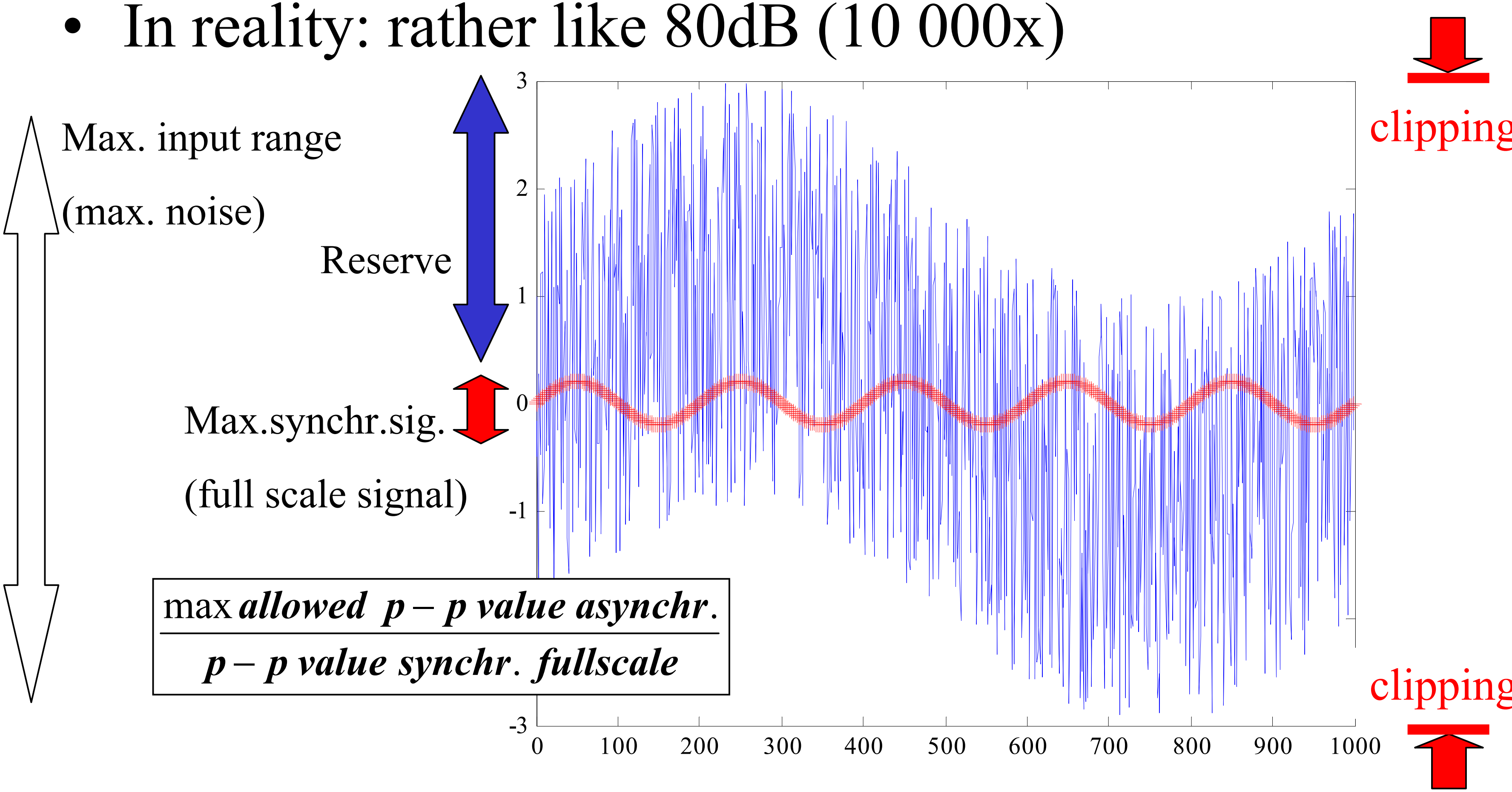
- =Maximum asynchronous signal causing distortion < limit
- Theoretically (linear): no sensitivity to asynchr. signal
- Practically: high noise (below clipping level) -> some influence on output
- (Noise *above* clipping level -> gross errors)
- Out-of-phase rejection = ratio of:
  - synchr. (sine) signal ~ full scale
  - asynchronous (sine) signal: maximum amplitude causing change < (say) 1%

$$\frac{\boldsymbol{rms\ value\ asynchr.}}{\boldsymbol{rms\ value\ synchr.\ fullscale} \cdot 1\%} \approx \frac{1\,000\ \boldsymbol{nV}}{1\ \boldsymbol{nV} \cdot \frac{1}{100}} \approx 100\,000\times \approx 100\boldsymbol{dB}$$

- Linearity: also main reason to use switching SD (rather than analog multiplier)

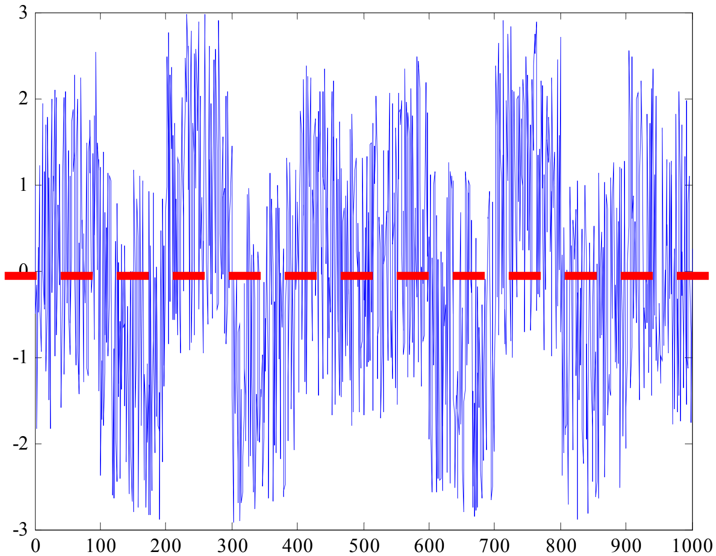
Dynamic reserve

- Max. synchronous signal vs. Max. tolerable noise
- In reality: rather like 80dB (10 000x)

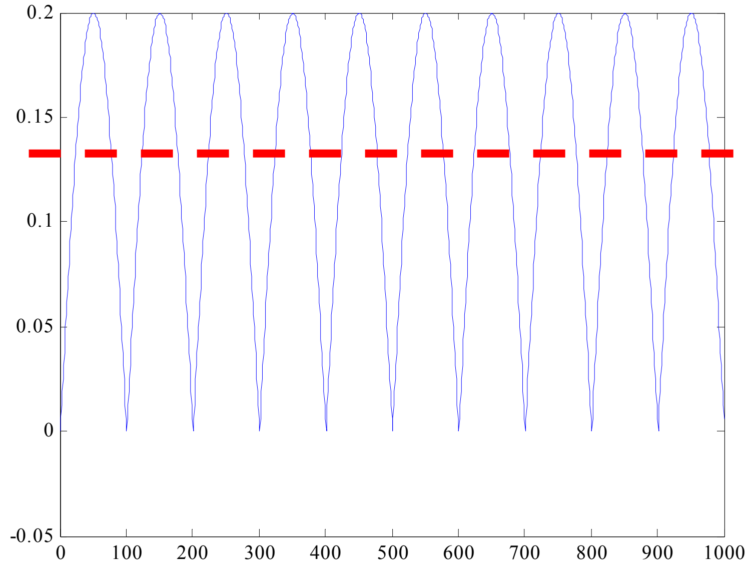


$$\frac{\max \boldsymbol{allowed\ \ p-p\ value\ asynchr.}}{\boldsymbol{p-p\ value\ synchr.\ fullscale}}$$

Syn. detected noise and signal



Mean = -0.0029



Mean = 0.1273

Output (LF) gain 1x -> 10x … Dynamic reserve + 10x = +20dB

Ex.: S_D = 1mVrms ≈ 3mVpp, clipping 3V => D.R. = 1000x = 60dB

Output Expand 10x:

S_D = 0.1mVrms ≈ 0.3mVpp, clipping 3V => D.R. = 10 000x = 80dB

Output stability and drift, Minimum detectable signal

- LIA output: DC offset (teoretically 0, practically compensated – [AUTO OFFSET]) *Note:+/-180°*
- Drift („output stability“): e.g. 100 ppmFS / K
- Minimum detectable signal:
- $_{Smin}$ = 100ppm x 100 nV = 0.01nV

$$s_{\min} = \delta \times S_D$$

Output expand 10x => + 10x D.R. ☺

- 10x s_{min} ☹

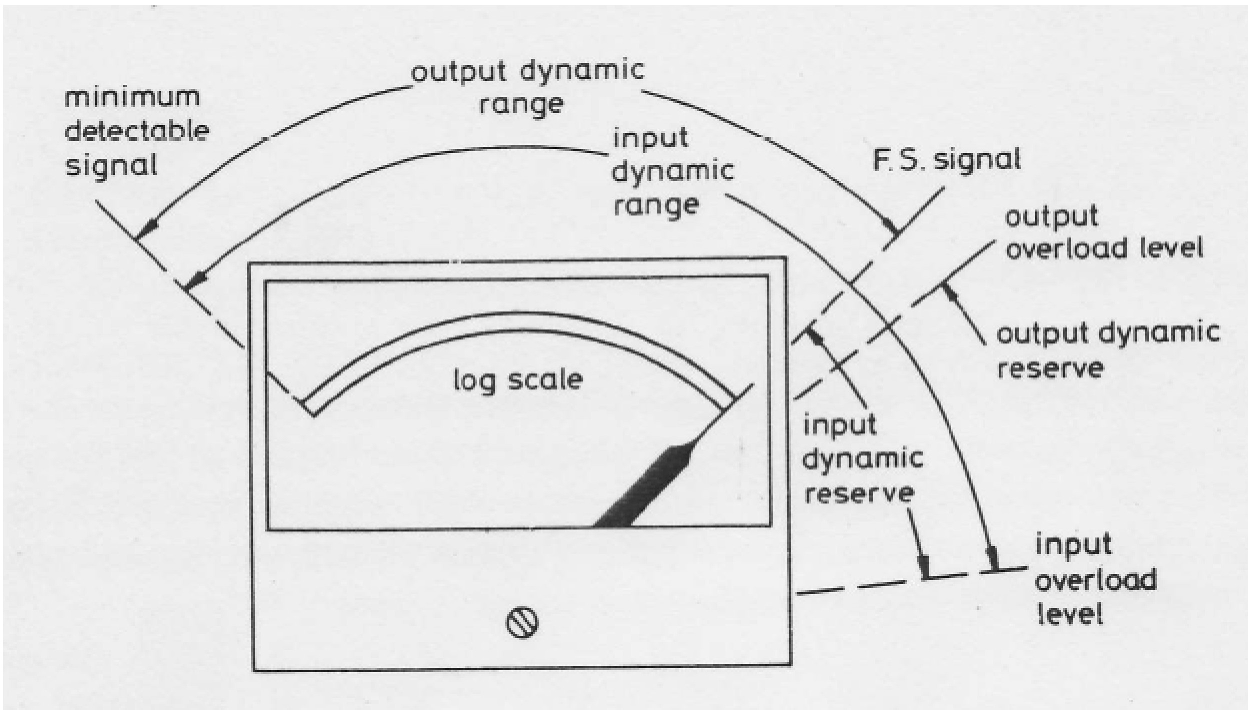
(input) Dynamic range

- Not Dynamic *reserve*
- Maximum voltage swing / minimum detectable signal

$$\boldsymbol{D_I} = \Delta \boldsymbol{v} / \boldsymbol{s}_{\min}$$

- Δv = dynamic reserve x S_D
- $\boldsymbol{s}_{\min} = \delta \times \boldsymbol{S_D}$
- => D_I = dynamic reserve / δ
- Ex.: $D_I = 1\,000 / 100$ ppm $= 10^7 = 140$dB

LIA Parameters



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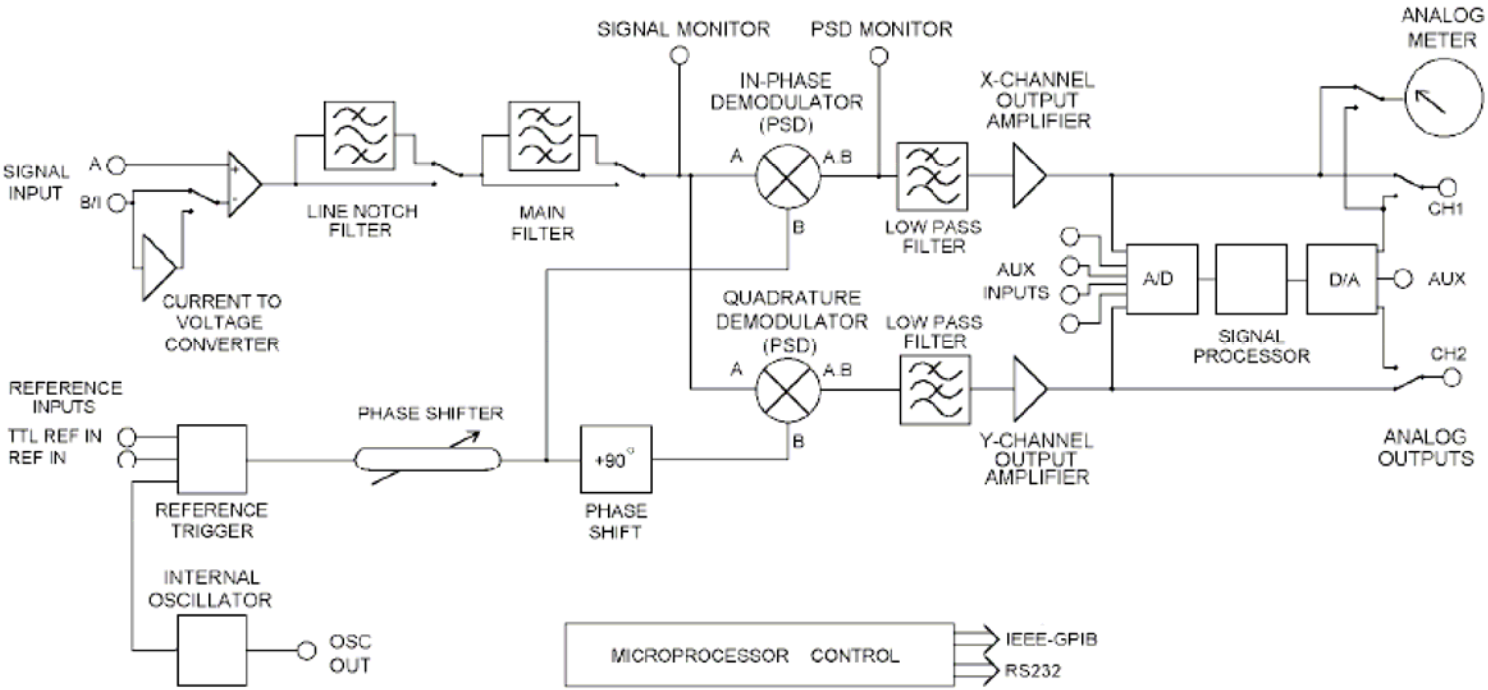
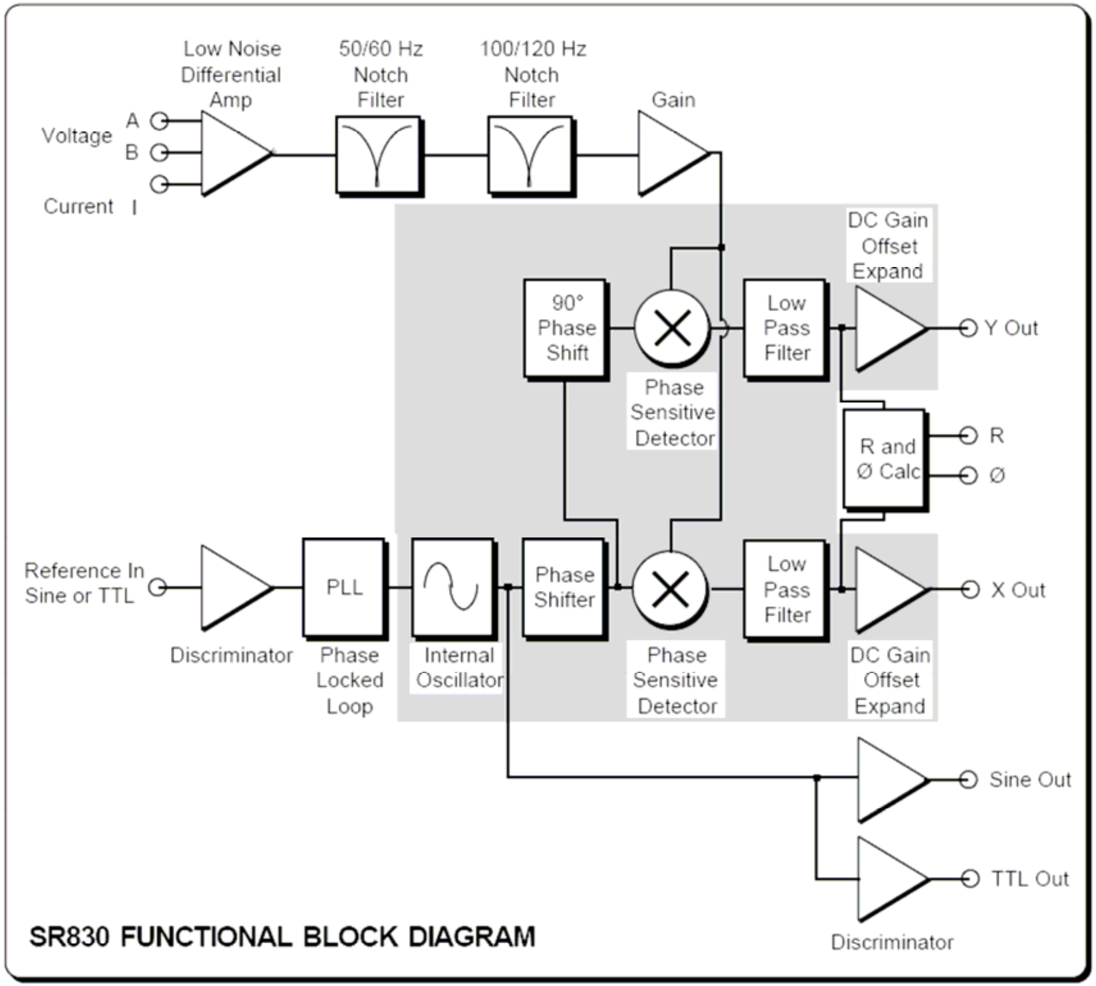
Analog LIA - EG&G 5210



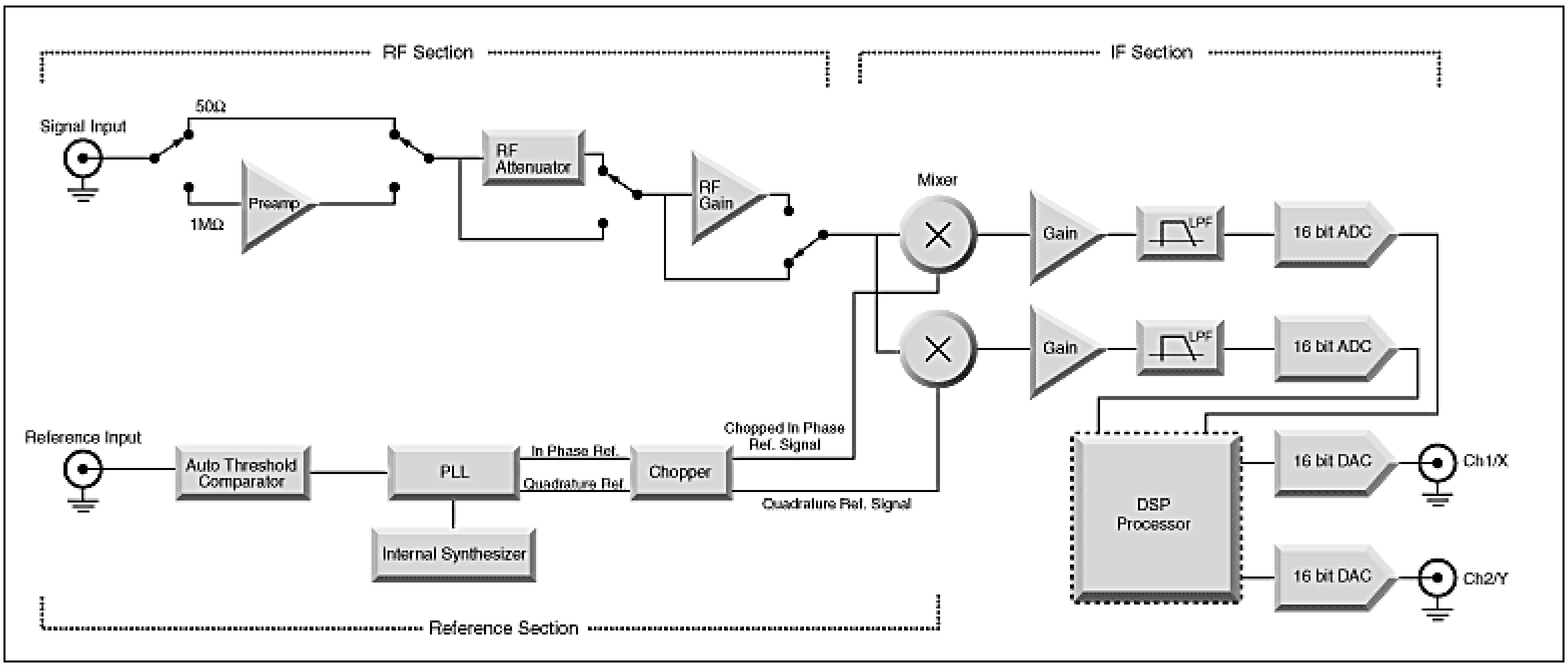
DSP LIA – SR830

Stanford Research Systems

http://www.thinksrs.com/products/SR810830.htm



RF (200MHz) LIA – SR844



What is it good for?

- Signal spectra transposition via modulation
- Avoiding noisy bands

- Note: spread spectrum modulation, CDMA