Wide Bandwidth 90 Degrees Phase Shifter for Lock-in Amplifiers

Marco Vergani – Davide Bianchi
Advising Professor: Giorgio Ferrari
90° Phase shifter for lock-in Amplifiers

IMPEDANCE MEASUREMENTS

BIO-APPLICATIONS

MATERIAL SCIENCE

OPTICS

Typical architecture: local oscillator required

From Hz to MHz frequency span

REFERENCE

INPUT SIGNAL

\[ \frac{A}{2} \cos(\alpha + \varphi) \]

\[ A \cos(\varphi) \]

\[ A \sin(\varphi) \]

DC OUTPUT

90° shifter

90° shifter
90° Phase Shifter Concept

Precise 90° delay
Single-pole filter
Amplitude Recovering
Variable Gain Amplifier

Negative feedback loop

Signal processing

Variable Gain Amplifier (VGA)

Phase Shifter Concept

Single-pole filter

Negative feedback loop

VGA
V OUT
V IN

Precise 90° delay

Signal processing

V IN
A IN

V OUT
A IN

V IN
A IN
90° Phase Shifter Concept

Specifications
- 90° shift
- Output amplitude independent to frequency

Proposed Solution
- Precise 90° delay through single pole network
- Input and output amplitude matching through a Variable Gain Amplifier and a DC negative feedback
Quasi-peak detector configuration

Asynchronous peak sampling and discharge → ripple on $V_g$

Harmonic distortion increasing at low frequency
Synchronous peak comparison

Asynchronous peak sampling

Synchronous discharge

NO RIPPLE TO BE FILTERED
90° Phase Shifter architecture

3 ICs
- OPA4354
- TLC3704
- LMH6503

Wide bandwidth CMOS OTA amplifiers
Logic ±5V push-pull linear comparators
Linear VGA amplifier
Experimental Results & Outlook

4 decades frequency span: 30Hz - 300kHz

- Phase Error < ±3°
- Amplitude precision limited by mismatched charge injection of the discrete MOSFETs switches.

Designing of a complete IC embedded lock-in

Leakage from the switches

Switches speed

DC Real OUT
DC Imaginary OUT

Reference
Input

90° shifter
Thank you for the attention
Amplitude error

\[ V_{in} \rightarrow V_{int} \rightarrow R_{int} \rightarrow V_{out} \]

\[ V_A, V_B \]

\[ V_{out} \]

\[ V_{in} \]

\[ V_{g} \]

\[ C_{int} \]
Digital signal generation

- Required to control the switches (discrete MOSFETs)
- No external clock required: synchronous with the input signal

- Squared input sinusoids
- Logic elaboration