DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

EEE 466 (July 2023)

Analog Integrated Circuit Laboratory

Designing A Phase Shifter Circuit

Section: G2   Group: 07

Course Instructors:

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Shafin Shadman Ahmed, PT

Signature of Instructor: ______________________________

Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. Type the student ID and name, and put your signature. ***You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.***

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

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Abstract:

In this talk, we propose a voltage-mode (VM) first-order phase shifter, commonly referred to as an all-pass filter, that uses a mere six NMOS transistors, one PMOS, and a negligible amount of passive parts (two capacitors and one resistor). With its high input impedance, this novel VM phase shifter does away with the requirement for exact passive component matching. It also works well at low voltages since it just uses two NMOS transistors to switch between the positive and negative supply voltages. Simply replace the resistor with an NMOS transistor that operates in the triode region to obtain electronic tunability. To demonstrate the outstanding performance of this proposed phase shifter, we give simulation results based on gpdk045 CMOS characteristics with ±4 V supply voltages.

Introduction:

An essential electrical component for adjusting the time connection between two or more signals is a phase shifter circuit. It is widely used in many different signal processing, electronics, and telecommunications applications. Typical uses for phase shifter circuits include the following:

Antenna Arrays and Beamforming: Phase shifters are used in antenna arrays used in wireless communication systems, radar, and sonar to direct the beam's direction. A beam can be directed in a particular direction to improve signal transmission or reception by varying the phase of signals in each antenna element.

Frequency Synthesis: Frequency synthesizers use phase shifters to produce precise and steady output frequencies. An output frequency can be produced using a phase-locked loop (PLL) or other frequency synthesizer circuit by adjusting the phase relationship between various oscillators or signals.

RF and Microwave Systems: For many different applications in RF (Radio Frequency) and microwave systems, such as phase-locked loops, modulators, and demodulators, phase shifters are essential components. They are employed in communication systems to modify the phase of signals in order to establish particular temporal correlations.

Phased-Array Radar Systems: Phase shifters are used in phased-array radar systems to modify the phase of signals in individual antenna elements, enabling electronic radar beam steering. This makes it possible to track and scan targets with the beam quickly.

Audio and Acoustic Systems: Phase shifters can be used for effects processing in audio systems and acoustic applications, such as producing phase-shifted or phaser-like sounds in musical compositions. They are also used in communication systems' echo cancellation algorithms to reduce noise.

Medical Imaging: Phase shifters can be used in medical imaging systems such as ultrasound scanners to regulate the phase of ultrasonic waves. This helps to focus and steer the ultrasonic beam for precise imaging.

Interferometry: Phase shifters are crucial parts of interferometry systems because they provide exact control over the relative phase of waves, such as light. Applications like optical coherence tomography (OCT), astronomy, and metrology depend on this.

Communication Systems: To preserve synchronization and reduce interference, phase shifters are employed in a variety of communication systems, including satellite communications. They are also used in modulation techniques such as QPSK (Quadrature Phase Shift Keying) for phase modulation and demodulation procedures.

Test and Measurement Instruments: Phase shifters are essential parts of test and measurement equipment including signal generators and vector network analyzers, where they assist in manipulating signals for different testing and calibration needs.

Electronic Filters: Phase shifters are used in several electronic filter types, like all-pass and phase-shift filters, to achieve particular phase characteristics in the filter response.

Phase shifter circuits have a wide range of uses; here are just a few of them. They are essential in a variety of electronic systems where accurate timing and phase relationships are critical because to their adaptability and phase control precision.

A phase shifter's main job is to change an input signal's phase angle without changing its magnitude. Phase shifters can be found in a variety of forms, from active circuits with integrated circuits or transistors to passive parts like inductors and capacitors. We will examine the types, applications, and design considerations of phase shifter circuits in this investigation, illuminating their significance in contemporary electronics.

Design:

Problem Formulation (PO(b)):

Our project was to build a Phase Shifter Circuit maintaining some specifications.
The given specifications are:

Frequency Range	1-100	kHz
Phase Shift Range	0-90	Degree
Control Voltage	0-1	V
Supply Voltage	2-5	V

We attempted to construct the phase shifter circuit using transistors after reviewing the works of several experts. The phase shifter circuit is constructed once the circuit has been divided into several segments. We had to follow certain trial and error processes in order to maintain the control voltage (the turn on voltage was 0.5) and keep the load MOS in the saturation area (apart from the controller). their significance in contemporary electronics.

Identification of Scope:

We must build an all-pass filter circuit (or a circuit that passes the signal of the given region) because we need to design a phase shifter circuit over a broad frequency range of 1 kHz to 100 kHz. We constructed the phase shifter circuit that complied with all requirements using an Op-amp, a variable load resistor, and a CMOS inverter circuit.

Design Procedures and Circuit Build:

First, using MOSFETS, we developed a single stage op-amp. We only wanted to shift between 0 and 90 degrees, therefore a single stage op-amp would do. Greater phase shift may have been achieved by designing a multistage op-amp.

The phase shift was then implemented by connecting a voltage-controlled load register and a capacitor in parallel with the differential outputs.

The controlled gate voltage was swept from 0 to 1 volt, and since the voltage controlled resistor is composed of an n-type MOSFET, it was kept in the triode zone.

When we took the output after designing this, it was moving the output from -90 to 0 degrees. To invert the resultant output, we thus added a CMOS inverter as a second component. The output was rotated by 180 degrees. And the circuit we wanted was prepared.

We discovered that the value of the capacitor utilized at the Op-amp's output did not preserve the supposition in the high frequency range after using a trial-and-error approach in various frequency ranges. After adjusting the capacitor value from 50 nF to 120 nF, our circuit satisfies all of our requirements.

Circuit Diagram:

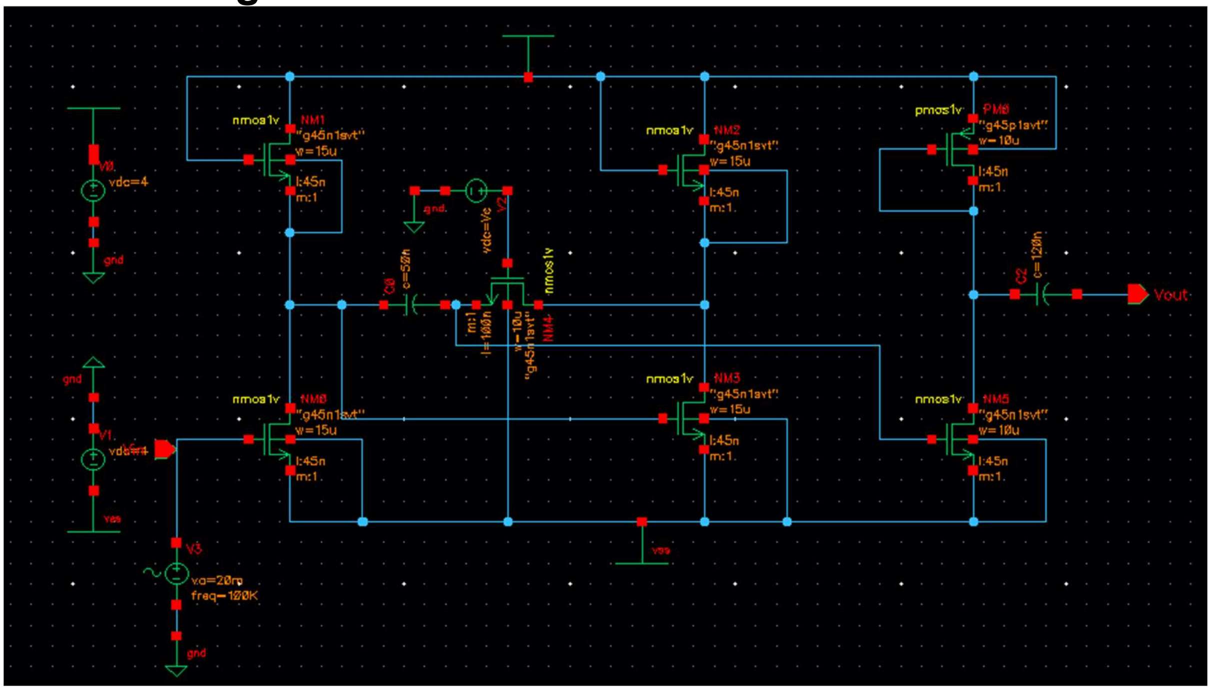

Figure 1: Entire Phase Shifter Circuit

Implementation:

Description:

The gpdk045 library's components were used in the construction of the phase shifter circuit. Six NMOS transistors, one PMOS transistor, one resistor, and two capacitors were included in the original scheme. For electronic tunability, the circuit architecture makes it simple to replace the resistor in the triode area with an NMOS transistor.

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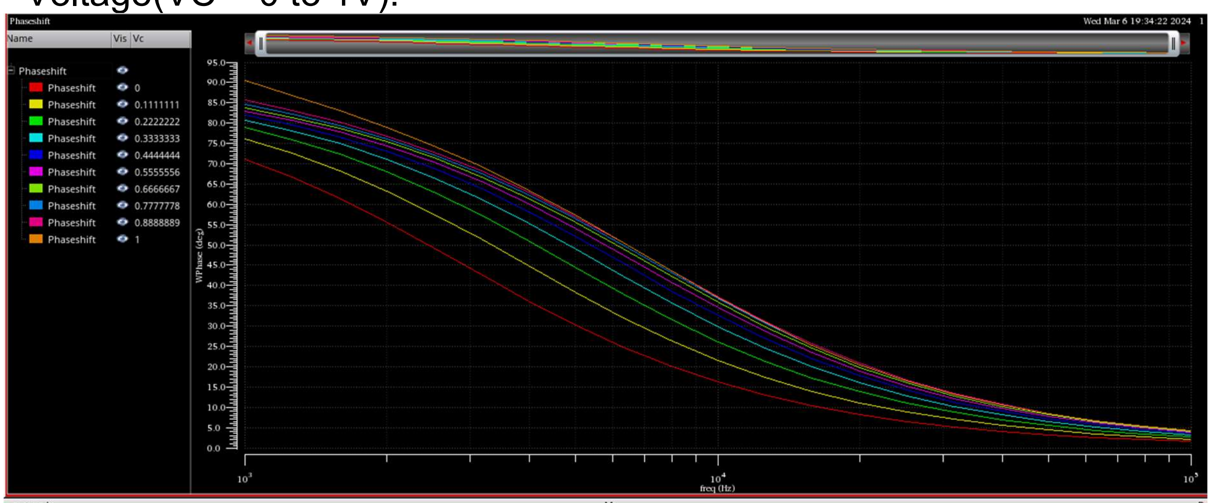
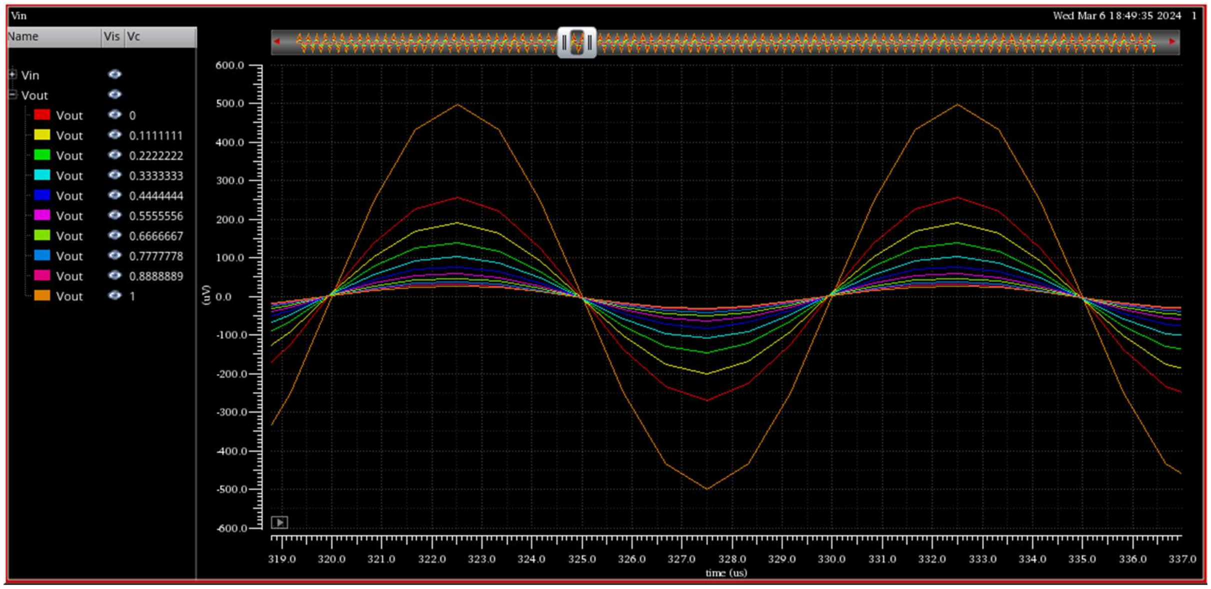
Experiment and data collection:

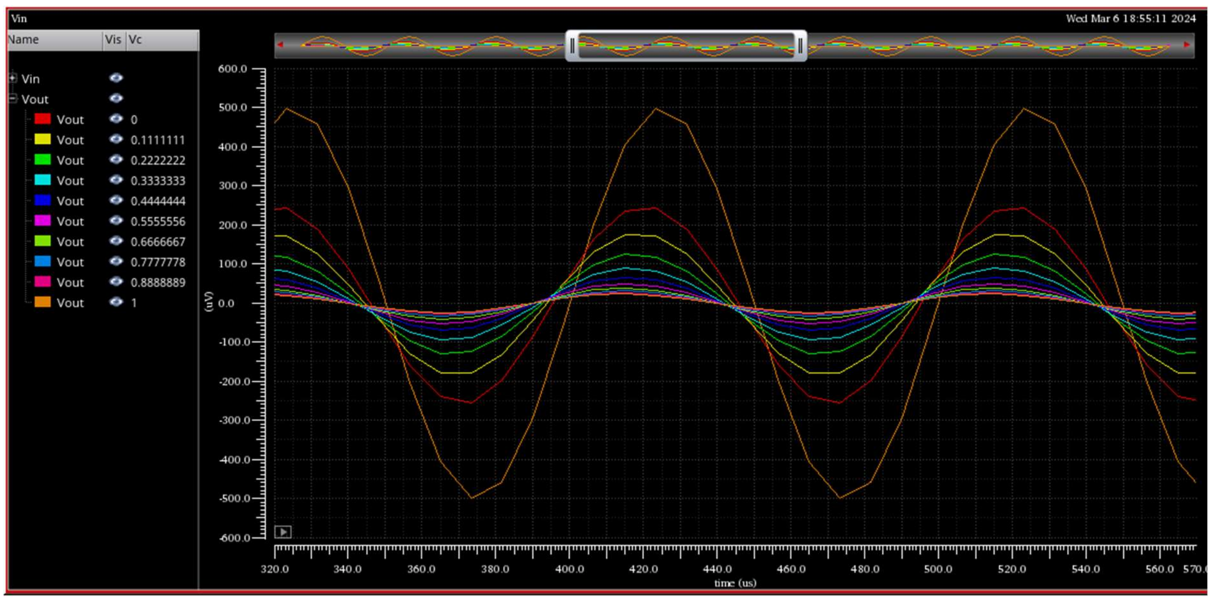
- For frequency= 1k to 100kHz, Phase Response for different control Voltage(VC = 0 to 1V):



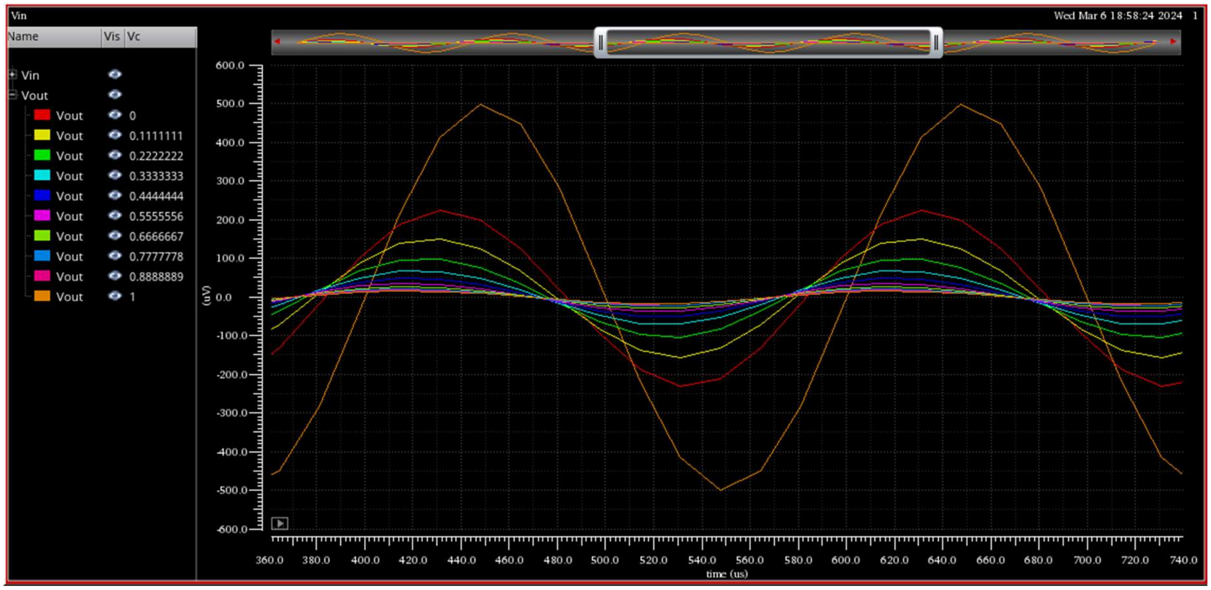
- For frequency= 100kHz, Transient Response for different control Voltage (VC = 0 to 1V):



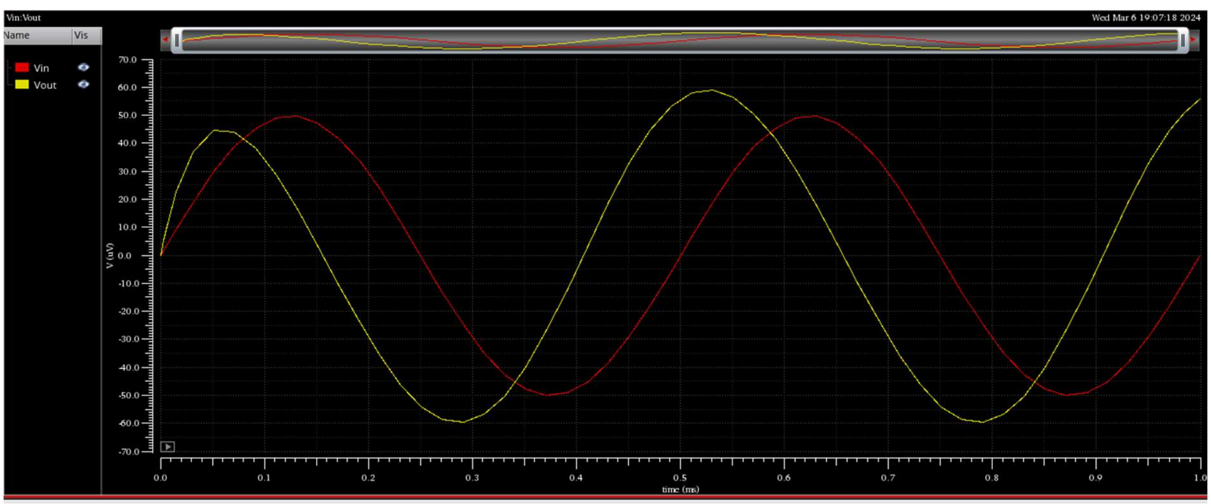
◦ For frequency= 10kHz, Transient Response for different control Voltage (VC = 0 to 1V):



◦ For frequency= 5kHz, Transient Response for different control Voltage(VC = 0 to 1V):



For Input Frequency = 2K Hz and Control Voltage =0.2 V



Data Analysis:

Simulations were conducted using Cadence Virtuoso to assess the circuit's performance. The following key parameters were analyzed

a) Frequency Response:
The phase response was assessed for three distinct frequencies (1 kHz, 10 kHz, and 100 kHz) over the control voltage range of 0 V to 1 V.To ascertain the tunability of the circuit, measurements were made of the phase shift range and control voltage relationship.

b) Transient Response:
The transient response offered insights into the circuit's behavior during signal transitions. Transient simulations were run for the identical frequency and control voltage settings.

Results:

Features	Required Specification	Achieved Specification
Frequency Range	1k - 100kHz	1k - 100kHz
Phase Shift Range	0 - 90 degree	0 - 90 degree
Control Voltage	0 -1 V	0 -1 V
Supply Voltage	2 - 5 V	4 V

Design Analysis and Evaluation:

Novelty:
Customized Design for Application:

We demonstrated our capacity to adapt solutions for particular needs by designing our Phase Shifter to precisely match the specifications.

Iterative Optimization:

We were able to optimize the performance of our Phase Shifter through the iterative design process, demonstrating our dedication to attaining superiority.

Advancing Analog IC Design:

Our initiative addresses practical issues and pushes performance limits, which advances the field of analog integrated circuit design.

Project Management and Cost Analysis:

Cost Analysis (Simulation Phase):

As It was a software project during the simulation phase, costs were minimal, primarily involving software licenses and lab resources.

Environmental impact evaluation:

low-power settings to use less energy while in standby. dynamic power management to change with the load.
methods for emission control to lessen electromagnetic interference (EMI).

Reflection on Individual and Team work

Individual Contribution of Each Member:

Collaboration was at the heart of our project's success:

[Raihan Amin Rana 1906186]: Circuit Design and Analysis & Presentation

[Md. Julkar Naim Joy 1906181]: Circuit Design and Analysis & Presentation

[Bickrom Roy 1906185]: Simulation and Analysis, Report & Presentation

[Safin Ahammed 1906100]: Simulation and Analysis & Presentation

Logbook of Project:

Our project was executed with a well-defined timeline:

- Research and Planning Phase
- Circuit Design and Simulation Phase
- Iterative Optimization

Communication:

The project's success depended on the team working well together. Team meetings were conducted on a regular basis to review project status, resolve issues, and decide on important design elements. To enable fast sharing of updates and ideas among team members, clear routes of communication were set up. The atmosphere of cooperation encouraged creativity and facilitated quick problem-solving.

Future Work:

As part of future work, several areas can be explored to enhance the phase shifter's capabilities and applicability:

• Look at ways to achieve even more exact phase adjustments using even finer electronic tunability.

• For better control, investigate other tunable components as varactor diodes or digitally controlled components.

• Use digital control interfaces to automate or remotely modify phase.
Create control algorithms for real-time dynamic phase monitoring and correction.

• Optimize the phase shifter to use less power, particularly in gadgets that run on batteries.

• Use power management tools to cut down on energy use while in standby.

• Additional investigation on emission control systems to lessen electromagnetic interference (EMI).

• Look into eco-friendly production techniques and materials.

References:

1. Minaei, Shahram, and Erkan Yuce. "High input impedance NMOS-based phase shifter with minimum number of passive elements." Circuits, Systems, and Signal Processing 31 (2012): 51-60.

2. Allen, Phillip E., Robert Dobkin, and Douglas R. Holberg. CMOS analog circuit design. Elsevier, 2011.

3. Razavi, Behzad. Design of analog CMOS integrated circuits.