RESEARCH MIGRATION PROJECT

FOSSEE eSim

CMOS Low-Power Absolute-Value Circuit for Analog Signal Processing

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Introduction

An absolute-value circuit is used to obtain the magnitude of an input signal without considering its polarity. A bipolar signal contains both positive and negative portions, while the output of an absolute-value circuit represents the magnitude of the input signal. Such circuits are useful in signal-conditioning and analog signal-processing systems.

This project focuses on the design and simulation of a low-power CMOS absolute-value circuit. The circuit has been designed and studied using LTspice. The circuit is analysed based on its input-output behaviour and transient response, with the aim of obtaining proper absolute-value operation.

Objectives

The main objectives of this project are:

- To design a CMOS low-power absolute-value circuit for analog signal processing.
- To obtain an output proportional to the magnitude of the input signal for both positive and negative input conditions.
- To study the operation and performance of the circuit using LTspice and eSim.
- To analyse the input-output characteristics, transient response, linearity and power consumption of the circuit.
- To study the suitability of the circuit as a low-power signal-conditioning block.

Proposed Architecture

The proposed circuit is a CMOS full-wave absolute-value circuit. It consists of two rectification stages that process the positive and negative portions of the input signal. The currents obtained from the two stages are combined at the output node through the load resistor. Therefore, both positive and negative portions of the input signal contribute to a positive output.

The basic signal flow is:

$$\boxed{\textbf{Input Signal } (V_{in})} \rightarrow \boxed{\textbf{CMOS Rectification Stages}} \rightarrow \boxed{\textbf{Current Summation}} \rightarrow \boxed{\textbf{Absolute-Value Output } (V_{out})}$$

Ideally,

$$V_{out} \approx |V_{in}|$$

The circuit is studied and simulated using LTspice as part of the research migration work.

Circuit Diagram

The following figure shows the CMOS absolute-value circuit designed in LTspice.

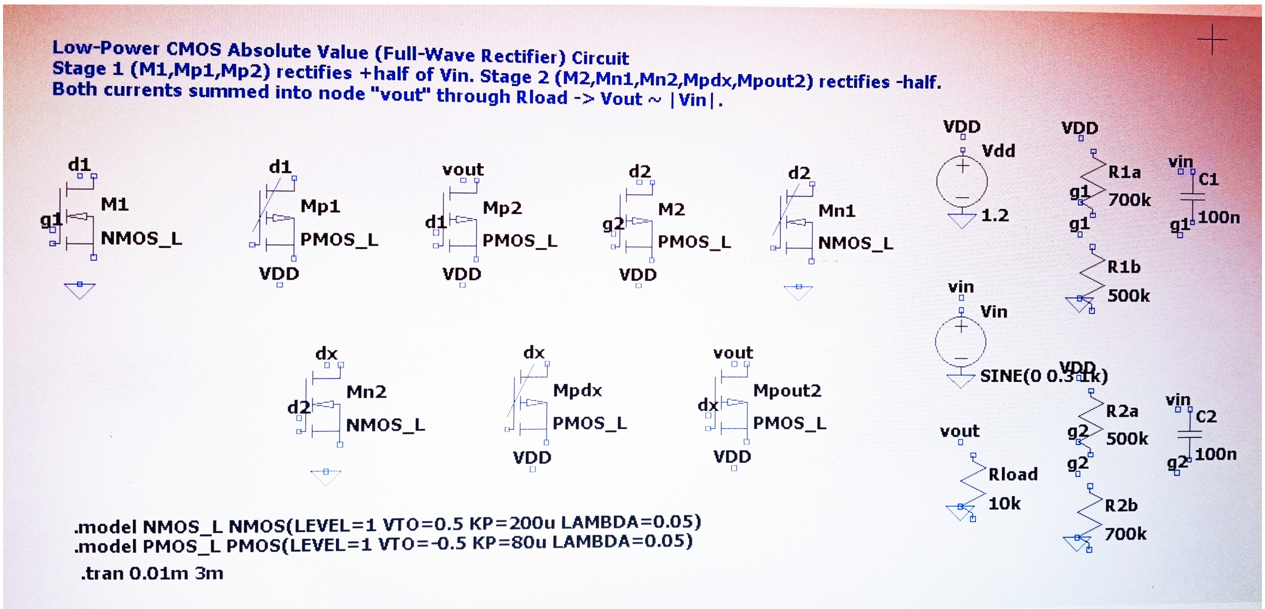

Figure 1: CMOS low-power absolute-value circuit designed in LTspice.

LTspice SPICE Netlist

The following SPICE netlist was generated from the LTspice circuit. It contains the MOS transistor definitions, circuit elements, input source, model parameters and transient simulation command.

```
* C:\Users\BHAVYASRI\Downloads\cmos_abs_value_circuit (1).asc
* Generated by LTspice 24.1.6 for Windows.

M1 NC_01 NC_02 NC_03 NC_04 NMOS_L L=0.5u W=4u
Mp1 NC_05 NC_06 NC_07 NC_08 PMOS_L L=0.5u W=10u
Mp2 NC_09 NC_10 NC_11 NC_12 PMOS_L L=0.5u W=10u
M2 NC_13 NC_14 NC_15 NC_16 PMOS_L L=0.5u W=10u
Mn1 NC_17 NC_18 NC_19 NC_20 PMOS_L L=0.5u W=4u
Mn2 NC_21 NC_22 NC_23 NC_24 PMOS_L L=0.5u W=4u
Mpdk NC_25 NC_26 NC_27 NC_28 PMOS_L L=0.5u W=10u
Mpout2 NC_29 NC_30 NC_31 NC_32 PMOS_L L=0.5u W=10u

Vdd NC_33 0 1.2
Vin NC_34 0 SINE(0 0.3 1k)

R1a NC_35 NC_36 700k
R1b NC_37 NC_38 500k
C1 NC_39 NC_40 100n

R2a NC_41 NC_42 500k
R2b NC_43 NC_44 700k
C2 NC_45 NC_46 100n

RLoad NC_47 NC_48 10k

.model NMOS NMOS
.model PMOS PMOS

.lib C:\Users\BHAVYASRI\AppData\Local\LTspice\lib\cmp\standard.mos

* Low-Power CMOS Absolute Value (Full-Wave Rectifier) Circuit
* Stage 1 (M1,Mp1,Mp2) rectifies half of Vin. Stage 2 (M2,Mn1,Mn2,Mpdk,Mpout2) rectifies
* Both currents summed into node "vout" through RLoad -> Vout ˜ |Vin|.

.model NMOS_L NMOS(LEVEL=1 VTO=0.5 KP=200u LAMBDA=0.05)
.model PMOS_L PMOS(LEVEL=1 VTO=-0.5 KP=80u LAMBDA=0.05)

.tran 0.01m 3m
.backanno
```

Expected Waveforms

For a sinusoidal input signal, the input contains both positive and negative half cycles. The absolute-value circuit converts the negative half cycles into positive values while retaining the positive half cycles.

Therefore, the expected output relationship is approximately:

$$V_{out} \approx |V_{in}|$$

The LTspice waveform shows the input signal and the corresponding rectified output. The output remains positive for both positive and negative portions of the input signal.

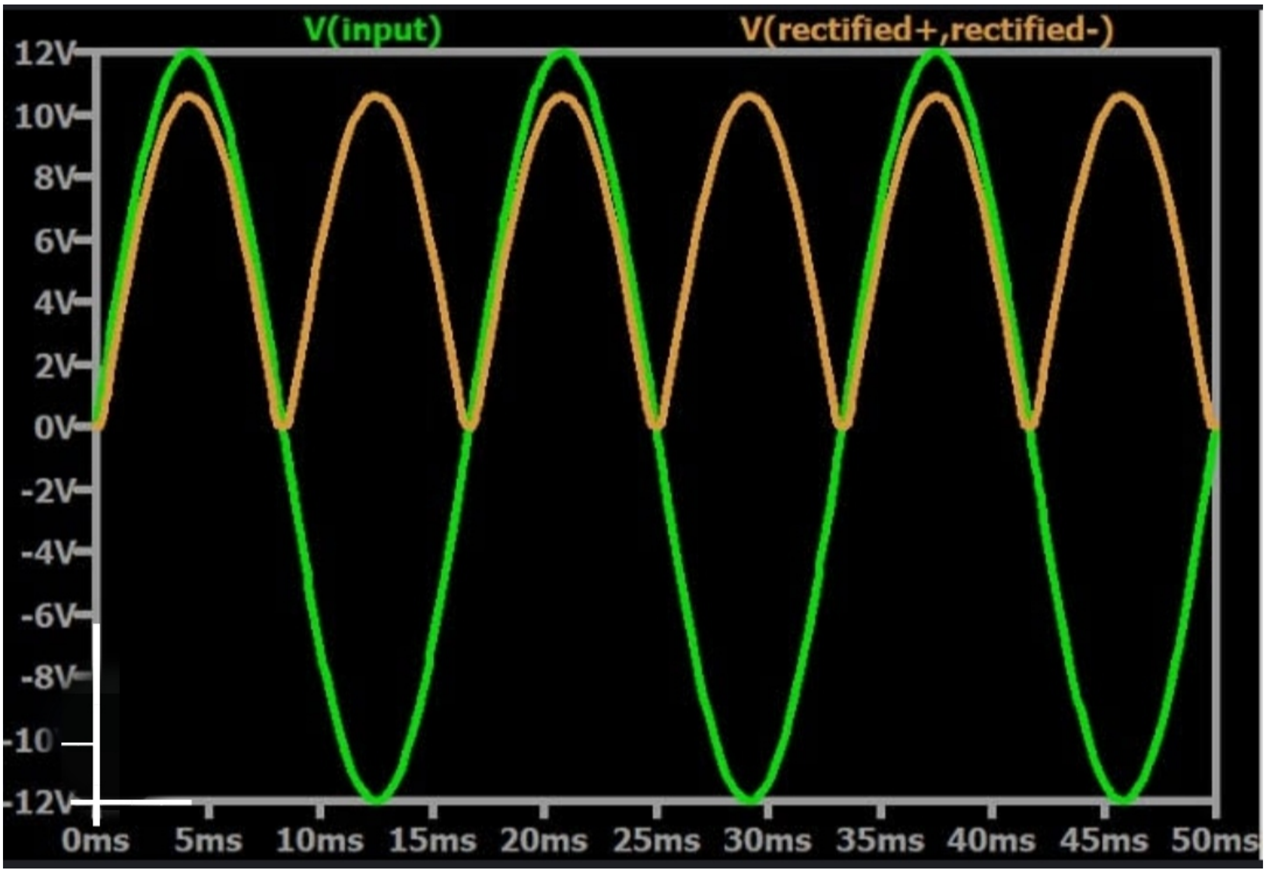

Figure 2: LTspice input and absolute-value output waveforms.

Applications

The proposed CMOS absolute-value circuit can be used in various analog signal-processing systems. Possible applications include:

- Sensor signal-conditioning circuits.
- Analog instrumentation systems.
- Communication signal processing.
- Biomedical signal-processing systems.
- Amplitude and magnitude detection circuits.
- Low-power analog signal-processing applications.

Reference Research Paper

Title: Integrated Precision High-Frequency Signal Conditioner for Variable Impedance Sensors

Journal: Sensors

Year: 2024

DOI: 10.3390/s24206501

The reference paper presents a precision signal-conditioning system for variable impedance sensors. The proposed project takes the relevant signal-conditioning and rectification concept as a reference and focuses on the design and simulation of a low-power CMOS absolute-value circuit.

Reference:

Integrated Precision High-Frequency Signal Conditioner for Variable Impedance Sensors, Sensors, 2024.