ABSTRACT

There has been considerable research investigating the Ferroelectric Field-Effect Transistor (FeFET) in memory circuits. However, very little research has been performed in applying the FeFET to analog circuits. This paper investigates the use of FeFETs in a common analog circuit, the differential amplifier. The two input Metal-Oxide-Semiconductor (MOS) transistors in a general MOS differential amplifier circuit are replaced with FeFETs. Resistors are used in place of the other three MOS transistors. The FeFET model used in the analysis has been previously reported and was based on experimental device data. Because of the FeFET hysteresis, the FeFET differential amplifier has four different operating modes depending on whether the FeFETs are positively or negatively polarized. The FeFET differential amplifier operation in the different modes was analyzed by calculating the amplifier voltage transfer and gain characteristics shown in figures 2 through 5. Comparisons were made between the FeFET differential amplifier and the standard MOS differential amplifier. Possible applications and benefits of the FeFET differential amplifier are discussed.
Figure 1: FeFET Differential Amplifier Circuit

Figure 2: FeFET Diff. Amp. Voltage Transfer at -1.2V

Figure 3: FeFET Diff. Amplifier Voltage Transfer at 2V

Figure 4: FeFET Differential Amplifier Gain vs. Time

Figure 5: FeFET Differential Amplifier Gain vs. Input
FERROELECTRIC FIELD-EFFECT TRANSistor DIFFERENTIAL AMPLIFIER CIRCUIT ANALYSIS

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INTRODUCTION

• There has been considerable research investigating the Ferroelectric Field-Effect Transistor (FeFET) in memory circuits.
• However, very little research has been performed in applying FeFETs to analog circuits.
• This paper investigates the use of FeFETs in a common analog circuit, the differential amplifier.
• Goal to determine feasibility of using the FeFETs in the differential amplifier circuit.

FERROELECTRIC TRANSISTOR

• Initially the FeFET 4 x 400 transistors were characterized.
  - Channel length = 4 μm
  - Channel width = 400 μm
• FeFET active and remanent experimental data is shown in Figures 1 and 2, respectively. [1]

FERROELECTRIC DIFFERENTIAL AMPLIFIER

• The FeFET differential amplifier circuit is shown in Figure 3. [3]

EXPERIMENTAL RESULTS

• Oscilloscope plots for various amplifier inputs are shown in Figures 4 through 7. Vp and Vn are the blue and yellow traces and VO is the red trace.

CONCLUSION

• The FeFET differential amplifier circuit produced some interesting results.
• Output signal characteristics changed with changes to input signal frequency and DC bias.
• The circuit operated over the tested frequency range of 100 Hz to 1MHz.
• From Figures 8 and 10, the common-mode gain of the FeFET diff. amp. and the MOSFET diff. amp. are both approximately zero, as desired.
• From Figures 9 and 11, the difference-mode gain of the FeFET differential amplifier is less than the MOSFET differential amplifier.

REFERENCES


Figure 1: Active (On) Mode
Figure 2: Remanent (Off)
Figure 3: FeFET Differential Amplifier Circuit
Figure 4: Vp @ 100 Hz, 8 Vp-p, 0° phase difference. VO1 is shown.
Figure 5: Vp @ 100 Hz, 4 Vp-p, 180° phase diff., -1.0 Vdc offset. VO2 is shown.
Figure 6: Vp @ 1MHz, 4 Vp-p, 180° phase difference. VO2 is shown.
Figure 7: Vp @ 1MHz, 8 Vp-p, 90° phase difference. VO2 is shown.
Figure 8: Vp @ 1KHz, 16 Vp-p, 0° phase difference
Figure 9: Vp @ 1KHz, 16 Vp-p, 180° phase difference
Figure 10: Vp @ 1KHz, 16 Vp-p, 0° phase difference
Figure 11: Vp @ 1KHz, 16 Vp-p, 180° phase difference

• Discontinuities in data are due to the experimental test setup data acquisition limitations. [2]