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Enhancement Of Performance Parameters Of Inverterusing Hemt

Dr. MadhuriMavinkurve, Swati Mishra, Karan Sharma, Abhinav Chamola

Associate Professor, Department of Electronics and telecommunication, Thakur College of Engineering and Technology, Kandivali, Mumbai

Student, Department of electronics and telecommunication, Thakur College of Engineering and Technology Kandivali, Mumbai

Student, Department of electronics and telecommunication, Thakur College of Engineering and Technology Kandivali, Mumbai

Student, Department of electronics and telecommunication, Thakur College of Engineering and Technology Kandivali, Mumbai

Abstract: CMOS inverter is widely used devices in most of the electronic circuits as it offers significant noise margins in both states, and will operate over a vast range of source and input voltages **(**provided the source voltage is fixed**)** but they undergo some drawbacks such as propagation delay dependency on mobility, load capacitance and dimensions**.** This paper uses HEMT as an alternative for CMOS inverter**.** HEMT is a heterojunction device which offers high gain and low noise figure or power dissipation, switching speed is less which reduces propagation delay**.** Simulation of inverter using HEMT will be done in TCAD**.**We have simulated and comparedCMOS Inverter and Inverter using HEMT in AIM Spice and observed the enhanced parameters**.**

KeyWords: CMOS, Propagation delay, TCAD, HEMT**.**

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I. INTRODUCTION

An inverter is a circuit which outputs a voltage representing the strobing logic-level to its input. Its main function is to invert the input signal applied. If the applied input is low then the output becomes high and vice versa. Inverters can be constructed using a single NMOS transistor or a single PMOStransistor coupled with a resistor. Since this 'resistive-drain' approach uses only a single type of transistor, it can be fabricated at low cost. However, because current flows through the resistor in one of the two states, the resistive-drain configuration is disadvantaged for power consumption and processing speed. Alternatively, inverters can be constructed using two complementary transistors in a CMOS configuration. This configuration greatly reduces power consumption since one of the transistors is always off in both logic states.

A. CMOS Inverter Applications

Complementary MOS processes were widely implemented and have fundamentally replaced NMOS and bipolar processes for nearly all digital logic applications. Careful study of CMOS characteristics show that CMOS devices used in a system design can be used for linear building blocks as well as digital blocks. Utilization of these new devices will decrease package count and reduce supply requirements. The circuit designer now can do both digital and linear designs with the same type of device.CMOS inverters play a critical role in integrated circuits, including microprocessors, microcontrollers, static RAM, image sensors, data converters, and some types of transceivers. CMOS inverters are found in digital cameras, mobile devices, home computers, network servers, routers, modems, cell phones, and virtually every other electronic device that requires logic functions.

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i. Glitch Suppressor

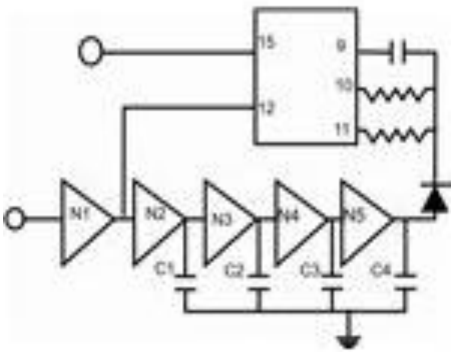

Figure 1. Glitch Suppressor

It becomes highly undesirable to have a digital output that is superimposed by glitches. These are extremely short in the range of nanoseconds (ns) unstable sharp pulses which inevitably finds a place in almost every digital circuit.

CMOS inverter gates can be effectively used to cancel out these glitches. Referring to the figure, IC 4060 is wired as a square wave generator to produce output pulses at pin 15. Its frequency will depend on the values of R and C. These output pulses should be free from the glitches trying to make its way from the input of N1 to pin 12 of the IC. Assume that the circuit can suppress a glitch which is under 70ns. Initially as long as the out put of N6 is logic '0' the IC cannot react to any pulses, because its pin 11 is also at logic '1'. When a pulse (actual data) appears at the input of N1, it resets pin 12 of IC 4060 after 10ns(time taken to pass through N1).

B. Advantages of using a CMOS Inverter

CMOS inverters have several important advantages. For example, CMOS inverters only use electricity when they are turned on and off, resulting in very little power consumption. Consequently, CMOS inverters produce very little heat waste, making them highly efficient and usable in a wide variety of small, delicate electronic devices. Additionally, CMOS inverters have high noise immunity, which allows them to block both incoming and outgoing frequency spikes. Finally, CMOS inverters are inexpensive to mass produce

C. Problems with CMOS Inverter

- The CMOS inverters are difficult to fabricate because you have PMOS and NMOS transistors on the same piece of silica.
- They have a relatively higher switching speed than other inverters.
- The CMOS inverters are difficult to fabricate because you have PMOS and NMOS transistors on the same piece of silica.
- Consumes high power at high frequency
- Some excess power is consumed because the circuit must be precharged after every evaluation, i.e. the evaluation transition takes place only once for one precharge cycle
- Operating frequency is relatively low-45mhz

D. Proposed System for Inverters

By using GaAs instead of Si, higher electron mobilityis available and furthermore GaAs can be operated at higher temperatures. This is important at high frequencies, since drift time and capacitances must be kept to a minimum. Thus High Electron Mobility Transistor (HEMT) is an important device for high speed, high frequency, digital circuits and microwave circuits with low noise applications. These applications include telecommunications, computing and instrumentation. Instead of p-n junction, metal semiconductor junction (reverse-biased Schottky barrier) is used, where the simplicity of Schottky barriers allows fabrication to close geometrical tolerances.

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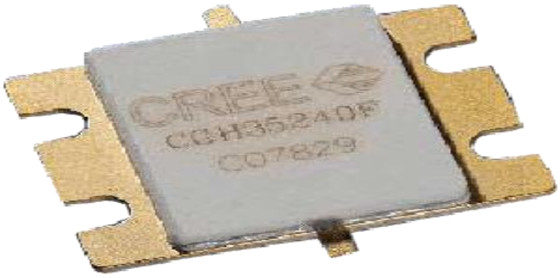

Figure 2.High Electron Mobility Transistor

Many of the advantages offered by HEMTs are:

- High electron mobility,
- Small source resistance,
- High gain-bandwidth product, fT , due to highelectron velocity in large electric fields
- High transconductance due to small gate-to channelseparation

The higher performance of the HEMT translates intoan extremely high cutoff frequency, anddeviceswithfast access times.

II. LITERATURE SURVEY

a) A theory puts forth the choice of the CMOS logic to be used for implementation of a given specification is usually dependent on the optimization and the performance constraints that the finished chip is required to meet. They introduced several design options exist for CMOS combinational gates. As per them, one of the reliable, low-power design uses complementary static gates, where ashigh performance circuits uses dynamic logic styles which is more suitable for high speed. The work concluded that performance of static logic is better than dynamic logic for designing basic logic gates like NAND and NOR however it is observed through studies that dynamic logic performance is better for higher fan in and complex logic circuits and also with the increasing level of integration, high performance, high speed and low power dissipation have become the mandatory requirements for any logic design.Static logic circuits allow versatile implementation of logic functions based on static, or steady-state, behaviour of simple CMOS structures or in other words commonly for combinational circuits (E.M.M.Poncino et al 1996) A typical static logic gate generates its output levels as long as the power supply is provided. This approach, however, may require a large number of transistors to implement a function, and may cause considerable time delay[1].The speed of the static CMOS circuit depends on the transistor sizing and the various parasitics that are involved with it. The problem with this type of implementation is that for N fan-in gate 2N number of transistors are required, i.e., more area is required to implement logic. This has an impact on the capacitance and thus the speed of the gate.

b) Another work presented the effects of W/L ratio parameters of CMOS, which characterized the CMOS structure. They have also analysed the current value, threshold voltage value and other related parameters of CMOS inverter. MOSFET device is the 4 terminal devices GATE, DRAIN, SOURCE AND BODY (substrate)[2]. W/L is the most important factor of CMOS. Hence considering we can change the value of W/L of CMOS and then measure the physical parameters to reach the accepted goal using Microwind 3.1 software.So they concluded W/L is the most effective parameter, which is the ratio of width/length of the NMOS or PMOS device. When we change (increase) the w/l ratio then output voltage (vout) is decrease as well as drain current (Id) is increase or Visa – versa.

c) A separate research proposed the method to accurately calculate the delay and the output transition-time of a CMOS inverter for any input ramp and output loading is considered. This work is an extension of Sakurai'swork on delay modeling of inverters for fast input ramps. They observed that two different mechanisms, that can be adequately modeled analytically, govern the delay and the output transition-time of an inverter in two extreme cases: infinitely fast and infinitely slow inputs.[3]

d) The recent trends in the developments and advancements in the area of low power VLSI Design has been surveyed. Though Low Power is a well established domain, it has undergone lot of developments from transistor sizing, process shrinkage, voltage scaling, clock gating, etc., to adiabatic logic. The paper talks about various losses which takes place in the CMOS inverter such as leakage power loss which is consumed when a device is both static and switching, but generally the main concern with leakage power is when the device is in its inactive state, as all the power consumed in this state is considered "wasted" power and dynamic.[4]

e) T.MIMURA'sworks on the history of the high electron mobility transistorhas proved that it contains a good illustration of the way a new device idea happens and develops toward commercialization.[5] His paper describes about the invention and the idea which came to the author during his journey of discovering HEMT. After completion of HEMT , he went on designing inverted hemt but he failed many times and after that his concentration shifted to improving the characteristics of conventional hemts. The author also mentioned about the application of hemt which was in the satellite communication and discussed about various organization which invested in hemts and helps it flourish.Afterbeingintroducedtothemarketplace,HEMTtechnologystartedtoreceivefeedbackfromthemarketplace.People wanted higher performance and less expensive HEMTs. Responding to thesedemands,manyelectronics companies investedinthetechnology .

f) Si cannot do everything and circuits based on other materials systems are required. A papersummarizes results on the successful integration of GaN HEMTs with Si CMOS on a common silicon substrate using an integration/fabrication process similar to a SiGeBiCMOS process. GaN – Si CMOS process is being scaled to 200 mm diameter wafers and integrated with scaled CMOS and used to fabric.are RF and mixed signals circuits with on-chip digital control/calibration. Thus, heterogeneous integration of GaN with Si CMOS enables a new class of high performance ICs that enhance the capabilities of existing systems, enable new circuit architectures and facilitate the continued proliferation of low cost microelectronics for a wide range of applications.[6]

g) After the findings of HEMT and ways to improve its operation, a paper was presented ondouble heterojunctionGaAs/AlGaAs/InGaAspseudomorphic depletion mode HEMT which has been developed at the gate length of 80nm. The device properties are tested for different biasing potentials at the input and output side. The device is found to exhibit a cut off frequency of 80Ghz. The logic suitability of the device is supported by developing the basic gates used for digital communication i.e., Inverter, NAND and NOR. Thus, enhancement in digital communication can be obtained with the use of HEMTs which provide high speed, low noise applications. Furthermore, with the implementation of universal gates using HEMTs, any digital circuit can be easily implemented. The paper reports a complete method from developing of the structure in Visual TCAD (VTCAD) to further implementing a circuit using the developed structure.[7]

h) Microwave power transistors play a key role in today's wireless communication and HEMT is finding wide application due to its high speed. A work provided analytical results for various DC parameters under the optical illumination. Also, the photovoltaic effect at the gate junction is considered which increases the sheet concentration of 2-DEG layer.[8]

III. PROPOSED SYSTEM

A High-electron-mobility transistor (HEMT) is a field-effect transistor incorporating a junction between two materials with different band gaps (i.e. a heterojunction) as the channel instead of a doped region. AlGaN/GaN high electron mobility transistors is a promising device for high-frequency and high-power applications. Gallium nitride is a great candidate for these applications because of its wide band gaps, strong spontaneous and piezoelectric polarization fields, large breakdown bias voltages and an efficient carrier transport.

A two-dimensional electron gas may occur at the AlGaN/GaN heterointerface with a relatively high density, following this last feature. In addition, the high concentration of carrier sheet and the strong confinement of the two-dimensional electron gas (2DEG) at the AlGaN/GaN HEMT heterointerface are appropriate for high speed applications.
A considerable improvement in the drain current and RF characteristics is also observed in the AlGaN/GaN HEMT

HEMTs are used in integrated circuits as digital on-off switches.HEMT transistors are able to operate at higher frequencies than ordinary transistors, up to millimeter wave frequencies, and are used in high-frequency products such as cell phones, satellite television receivers, voltage converters, and radar equipment. They are widely used in satellite receivers, in low power amplifiers and in the defense industry.

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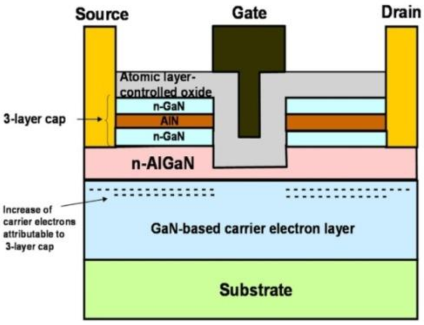

Figure3. HEMT structure

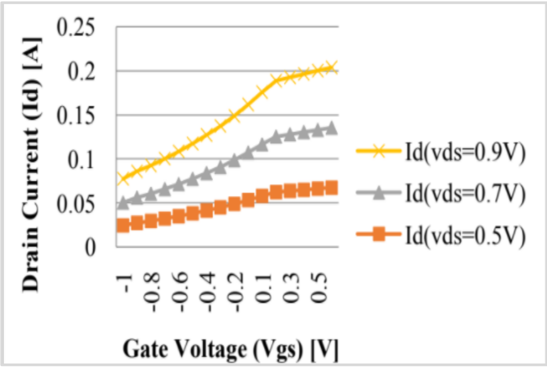

Figure4 Input characteristics of HEMT

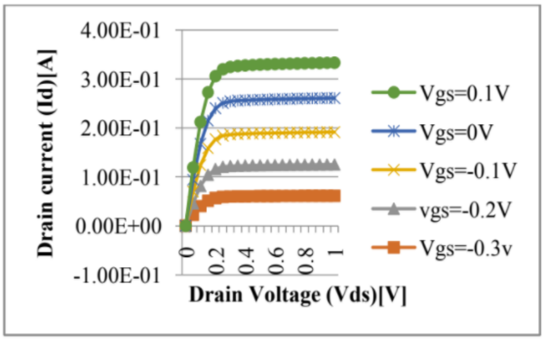

Figure5. Output characteristics of HEMT

Advantages of HEMTs are that they have high gain, this makes them useful as amplifiers; high switching speeds, which are achieved because the main charge carriers in MODFETs are majority carriers, and minority carriers are not significantly involved; and extremely low noise values because the current variation in these devices is low compared to other FETs.

IV. RESULTS

We had simulated a CMOS based Inverter and an Inverter based on HEMT characteristics. These are the obtained results: Comparing the curves of both CMOS inverter and HEMT Inverter, we can clearly see that HEMT gives more output voltage characteristics than CMOS. CMOS switches state at 0.5V whereas HEMT switches its state at 1V. Thus more output voltage is received from HEMT.

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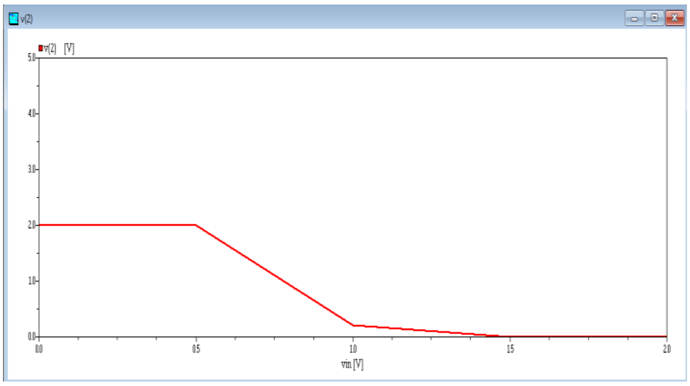

Figure 6. Voltage Transfer Curve of CMOS Inverter

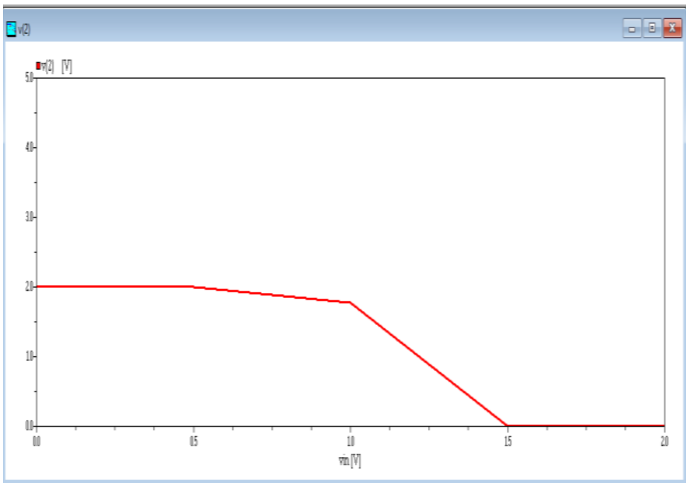

Figure 7. Voltage Transfer Curve of HEMT based Inverter

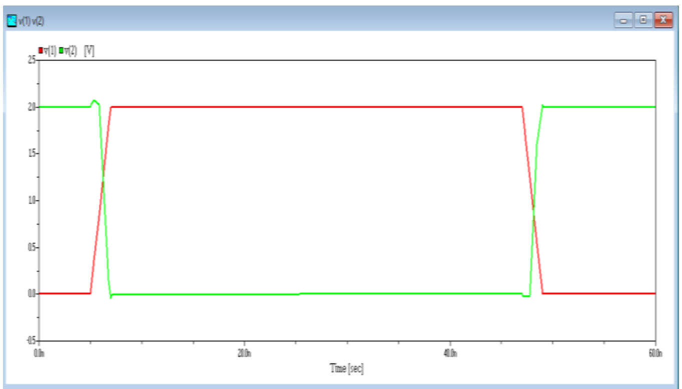

Figure 8. Transient Analysis of CMOS Inverter

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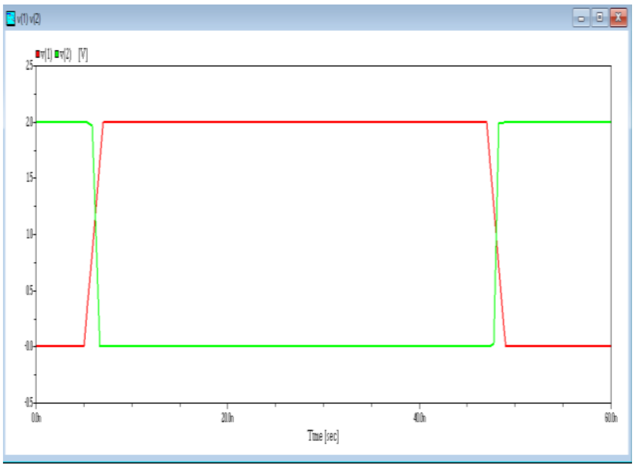

Figure 9 Transient Analysis of HEMT based Inverter

Transient analysis depicts the change of voltage from higher to lower state. An inverter gives high output for low input and vice versa. In a CMOS Inverter, we see an abrupt glitch when the voltage is about to change its state. This happens at both the points, from low to high and high to low. This glitch causes the propagation delay to increase.
In case of HEMT based Inverter, there are no glitches present and thus shows a sharp change of state. This in turn provides a better value for propagation delay.

V. CONCLUSION AND FUTURE SCOPE

HEMT has proved to be a better alternative for CMOS based Inverters as it provides better propagation delay. After we replace CMOS with HEMT, we will observe the following results:

1. Inverter operating on high frequency with low power dissipation
2. Propagation delay of Inverter will be reduced.
3. High electron mobility.
4. High frequency of operation.

HEMT will be simulated in TCAD as shown:

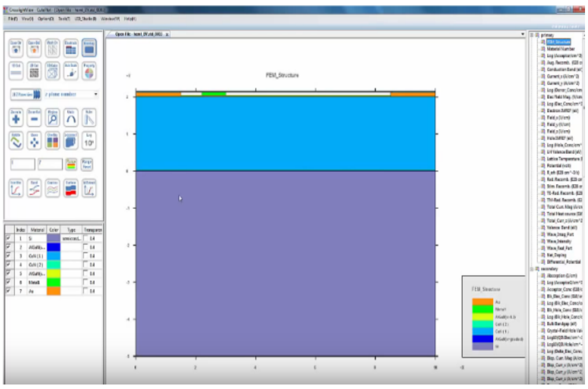

Figure 10. HEMT in TCAD

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