

Implementation of OTA in 90nm Technology with Bandgap Reference Application

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Abstract

Operational Transconductance Amplifier (OTA) is the basic building block of Analog circuit with linear input/output characteristics. Because it associates closely linked parameters like noise and settling performance, the current design methodologies for two-stage OTAs frequently result in sub-optimal solutions. The study discusses the implementation of an Operational transconductance amplifier (OTA) with a bandgap reference (BGR) circuit and its importance in providing a stable and accurate reference voltage for various analog and digital circuits. The combination of OTA and BGR provides a stable and accurate reference voltage that can be used in various analog and digital circuits. OTAs are used to drive high capacitive loads. To scale the dimensions of Complementary Metal Oxide Semiconductor (CMOS) technology requires proportional scaling, also taking supply voltage into consideration. In addition to the simplicity and strong performance that the Band Gap Reference (BGR) achieves as a load for the OTA circuit, the architecture of OTA with BGR as load is easily adaptable to attain high accuracy. Because the performance of the used amplifier has a significant impact on the OTA's performance, consideration must be given to the design and its architecture. Therefore, it is essential to carry out a comparison analysis in order to get the optimal results of the outputs of OTA having BGR as the load.

Keywords: OTA, Band gap Reference, CMOS, VLSI, VCO, VCF, SC.

1. Introduction

As the technology advance in VLSI (Very Large-Scale Integration) by scaling of CMOS devices to achieve less power dissipation with decrease in power supply. OTA being one of the building block of analog circuit with linear input/output characteristics. OTA is often used to implement voltage-controlled oscillator (VCO) and voltage-controlled filter (VCF) for music synthesizer circuits, Neural Networks, and Instrumentation amplifier that functions with a two-quadrant multiplier. Operational transconductance amplifiers (OTAs) with high speed and gain are an integral part of switched capacitor (SC) circuits. OTAs are used to drive high capacitive load. To scale the dimensions of CMOS technology requires proportional scaling taking into consideration the supply voltage. However, with the low power supply voltage, power consumption is lower than supply current. The phase margin adjustments have been suggested in the literature to improve the phase margin adjustments. This is achieved by utilizing a two-stage amplifier. The term "operational" refers to a voltage-controlled current source since it requires the difference between two voltages as an input for current flow. The optimum output is achieved using the improved design specification.[11].

The idealised constant transconductance g_m serves as the proportionality factor between the input voltage and the output current. The transconductance depends on temperature and the input differential voltage. Two input voltages with infinite impedance—i.e., no input current—would be present in a perfect OTA. In the output, an ideal current source is driven using the differential signal between these two inputs, meaning that the output current is independent of the output voltage. The input range for common mode is similarly limitless. The factor that shows the relation across the output current and input differential voltages is called transconductance [12].

The bandgap reference is one of the fundamental building blocks because it is utilized in numerous analog and digital circuit applications. Demand for battery-powered mobile products is particularly strong for low voltage reference circuits such as PDAs, cameras, laptops, mobile phones, etc. To maintain device reliability, supply voltage has to be reduced proportionately while scaling technology feature size. The most recent deep submicron technology cannot make use of an energy gap measured in electron volts since conventional bandgap reference implementation often results in output voltages near to silicon.

Recently a CMOS bandgap reference circuit power supply voltage circumvented by technological constraints were published. The main concern is whether the operator can be scaled. This study uses a transconductance amplifier (OTA) bandgap reference [13-15].

Bandgap voltage reference circuits are very important in integrated circuit design. It serves as a key component for providing a stable and accurate voltage reference regardless of temperature and power supply variations. The primary function of this circuit is to generate a voltage that remains constant despite changes in the environment, enabling accurate and reliable operation of various analog and digital circuits. The stability and accuracy of bandgap voltage reference circuits are critical to achieving accurate voltage references in applications such as analog-to-digital converters, voltage regulators, and sensor interfaces. Providing a stable reference voltage ensures consistent performance and reliable operation of the circuit over temperature and supply variations. In addition, bandgap voltage reference circuits help reduce the effects of process variations encountered during integrated circuit manufacturing. This compensates for variations in transistor characteristics and allows designers to achieve consistent voltage references across process corners and manufacturing lots. In summary, bandgap voltage reference circuits play an important role in maintaining the stability, accuracy, and reliability of integrated circuits. The ability to generate a constant voltage reference contributes to the overall performance and functionality of various analog and mixed-signal systems and improves the quality and accuracy of electronic devices.

2. Literature Survey

OTA design on 90nm technology is developed by analysing parameters such as AC response, phase response, transient analysis, and calculated power and bandwidth values. The article also covers the design and analysis of a switched capacitor OTA. Simulation results show that the 90nm prototype amplifier achieves 1.6 ns settling time with reduced integrated noise while consuming 2.4 mW from a 1.2 V supply with a phase diagram of 175 degrees [1]. Design of a two-stage operational transconductance amplifier (OTA) implemented in 180 nm technology and incorporating Miller compensation is put forth. Simulation results show that the design meets the specified requirements. A two-stage OTA is particularly suitable for applications requiring high gain, high common-mode rejection ratio (CMRR), and large gain-bandwidth product (GBW). Additionally, mathematical analysis was performed to determine the width-to-length ratio (W/L) of all MOS transistors to ensure optimized performance and accurate circuit component size [2]. Comparison of three cutting-edge bio-inspired heuristics

for the two-stage Miller OTA's automatic sizing was also carried out. Analog integrated circuit sizing is a modellable optimization problem that can be resolved with heuristics. In this study, three bio-inspired algorithms are examined for calculating the dimensions of a two-stage CMOS mirror transconductance amplifier: Particle Swarm Optimization (PSO), Cuckoo Search (CS), and Firefly Algorithm (FA). It was shown that by considering the circuit to be modelled as an optimization problem and using heuristics for sizing, it was possible to achieve target values that the circuit specifications allow while optimizing gate area and power consumption [3].

Design of a hybrid technique-based current-mirror operational transconductance amplifier (OTA) that shunts current from the primary differential pair. This OTA's capacity to deliver high gain up to 60dB and high output resistance up to 3.1Mohm is demonstrated here [7]. a self-biased OTA with a 0.5V operating supply voltage. use a positive feedback system to supply bias current. Issues with stability and starting were taken into account. Experimental results demonstrate that the proposed OTA's performance is appropriate for low voltage and low-power applications when it is used in a low-voltage bandgap reference circuit. Here the self-biased OTA idea is implemented using an additional MOS to realize a circuit or model, or simply a voltage regulator design that regulates the output voltage below the bandgap [4] a linear-range operational transconductance amplifier (OTA) with low-voltage input. A resistive source degeneration topology-based ground-controlled flip voltage follower receives the voltage-to-current ratio from its differential pair input stage. Utilizing two diode-connected transistors in a physically symmetric class AB ground-controlled flip voltage follower differential pair input stage gives the proposed OTA its benefit [8-10].

The synchronized startup circuit is a crucial component in ensuring the proper functioning of the bandgap reference circuitry. It addresses the startup issue that arises due to the absence of current flow in the core of the bandgap reference circuit. The startup circuit is designed to operate synchronously with the reference circuitry, and it consists of a transistor, typically labeled as NM3, operating in the cut-off region [3]. When the power supply is turned off, the OTA and the core of the bandgap reference do not operate as intended since there is no current flowing through them. To overcome this, the startup circuit comes into play. Its purpose is to initiate the proper functioning of all the circuits within the bandgap reference. When activated, NM3 effectively pulls the output potential of the OTA to the ground. By doing so, it provides the necessary starting condition for the bandgap reference circuitry [3]. The synchronized startup circuit ensures that the core and self-biased OTA begin operating

simultaneously, addressing the no-current flow issue. This sequential activation scheme guarantees that all the necessary components of the bandgap reference circuit receive the required startup conditions for proper operation. By utilizing the startup circuit, the bandgap reference can overcome the initial lack of current flow in the core and ensure that the reference voltage is generated accurately and reliably [3]. Figure 1 in the PDF file shows the circuit implementing both the OTA with BGR circuit. The input is given to the OTA and the BGR part in parallel. The output is taken from the BGR output terminal which is analyzed further. The specifications of the design such as voltage, frequency, PSRR (Power Supply Rejection Ratio) are specified in Table 1 [3].

3. Design and Implementation

The strongest constraint on CMOS M1 to maintain saturation is placed by the lowest common-mode input voltage, $V_{cm}; \min$. The offset condition consistently aligns the drain voltages of M1 and M2 for both devices. Thus, the prerequisites for M2 are: The same conditions as for M1 Saturation apply to M2 Saturation. Pay attention to the minimum permitted value. The lowest value permitted by the linear region of M1 and M2 is V_{cm} . $V_{gd3}=0$ causes CMOS M3 to always be on. Due to saturation, no extra restrictions are necessary. Additionally, systematic offset requirements have the following effects: The M4's drain voltage must match the M3's drain voltage. M4 will therefore likewise be saturated. $V_{cm} \max$, which is the maximum common-mode input voltage, is the strictest restriction for CMOS M5 systems. Minimum value is Determined by M5 entering the linear region. The problem arises at the output. The voltage has a minimum value $V_{out} \min$. The strictest conditions apply to M7. The output voltage has a maximum value $V_{out} \max$. Since $V_{gd8}=0$, CMOS M8 is always in saturation.

The bandgap reference circuit often encounters a startup issue due to the absence of current flow in the core. This problem can be effectively addressed by employing a startup circuit that operates synchronously with the reference circuitry. A startup circuit that uses a sequential activation strategy is created for both the core OTA and the self-biased OTA in order to guarantee appropriate startup. Since there is no current running through the OTA and the core of the bandgap reference when the power supply is off, it does not function as intended. The main cause of this is a low potential at the OTA's output. The starter circuit is used to get around this. Its objective is to initiate the correct operation of the several circuits of the bandgap reference.

A transistor, commonly identified as type NM3, that is operating in the cut-off region makes up the starter circuit. When turned on, NM3 actually drags the OTA's output potential to the ground. By doing so, it provides the necessary starting condition for the bandgap reference circuitry. The synchronized startup circuit ensures that the core and self-biased OTA begin operating simultaneously, addressing the no-current flow issue. This sequential activation scheme guarantees that all the necessary components of the bandgap reference circuit receive the required startup conditions for proper operation. By utilizing the startup circuit, the bandgap reference can overcome the initial lack of current flow in the core and ensure that the reference voltage is generated accurately and reliably.

The transistor NM3, operating in cutoff mode, plays a crucial role in initializing the circuit and establishing the appropriate operating conditions [3]. The transistor operates in three different regions: cutoff, active, and saturation. The transistor is off and does not conduct in the cutoff region. The transistor is activated and functions as an amplifier in the active region. The transistor is fully turned on and functions as a switch when it is in the saturation area. [4-6]. In the startup circuit, NM3 operates in the cutoff region. When the power supply is turned off, NM3 is in the cutoff region, and no current flows through it. When the power supply is turned on, the startup circuit is activated, and NM3 is turned on. As a result, it effectively pulls the output potential of the OTA to the ground, providing the necessary starting condition for the bandgap reference circuitry [3]. The operation of the transistor in different regions can be observed by analyzing its output characteristics. A transistor's output characteristics display the correlation between the collector current and the collector-emitter voltage for various base current values. The output characteristics indicate that the collector current is zero for all values of the collector-emitter voltage in the cutoff zone. The output characteristics demonstrate that the collector current grows linearly with the collector-emitter voltage in the active area. The output characteristics demonstrate that the collector current is constant in the saturation area for all values of the collector-emitter voltage. The output characteristics of a transistor in the active, cutoff, and saturation areas are shown in Figure 6. The graph demonstrates that for all values of the collector-emitter voltage, the collector current is zero in the cutoff zone. In the active region, the collector current increases linearly with the collector-emitter voltage. In the saturation region, the collector current is constant for all values of the collector-emitter voltage. By analyzing the output characteristics of the transistor, its operating region and its corresponding behavior is determined [4].

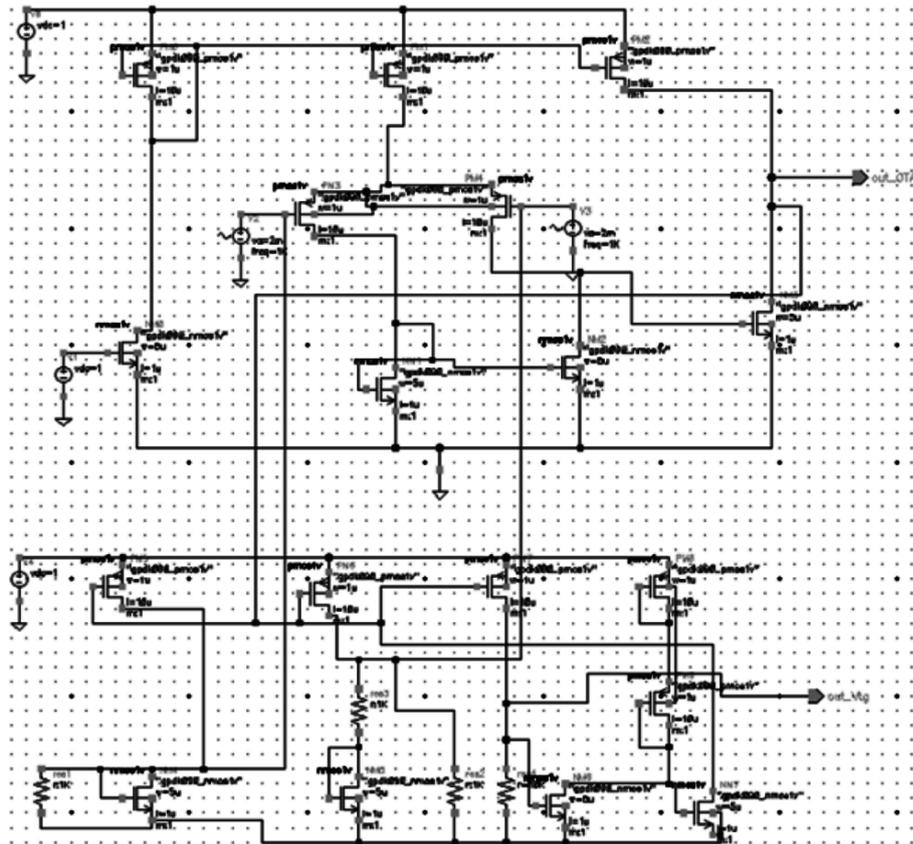


Figure 1. Schematic of OTA with BGR as a Load

Overall, the startup issue in bandgap references can be effectively managed by incorporating a synchronized startup circuit. This sequential activation scheme guarantees the proper functioning of the core and self-biased OTA, ensuring accurate and stable reference voltage generation. The transistor NM3, operating in the cutoff regime, aids in the startup process by establishing the required potential conditions for the entire bandgap reference circuit. The circuit implementing both the OTA with BGR circuit is as shown in Figure 1. The input is given to the OTA and the BGR part in parallel. The output is taken from the BGR output terminal which is analysed further. A specification of the design such as voltage, frequency, PSRR is specified in table 1.

Table 1. Specifications of the Design

Parameters	Values
Supply Voltage	1V
Example Input at Vin+ and Vin-	2mV

Frequency	1 KHz
(w/l)nmos	10/2
(w/l)pmos	1/10
Slew Rate	25mV/us
PSRR	64.12 dB

4. Results and Discussion

For the incorporation of continuous-time filters, OTA design is crucial. In this regard, enhanced steady-state responsiveness up to 10MHz 90nm dual OTA architecture with amplification has been suggested. OTA power usage is roughly 2.4mW using this method, therefore power consumption can also be decreased.

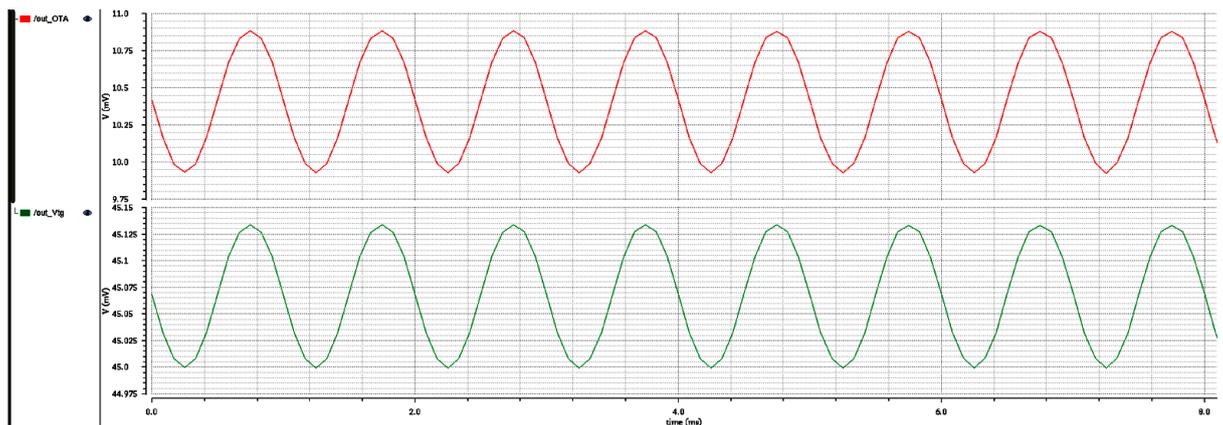


Figure 2. Transient Analysis

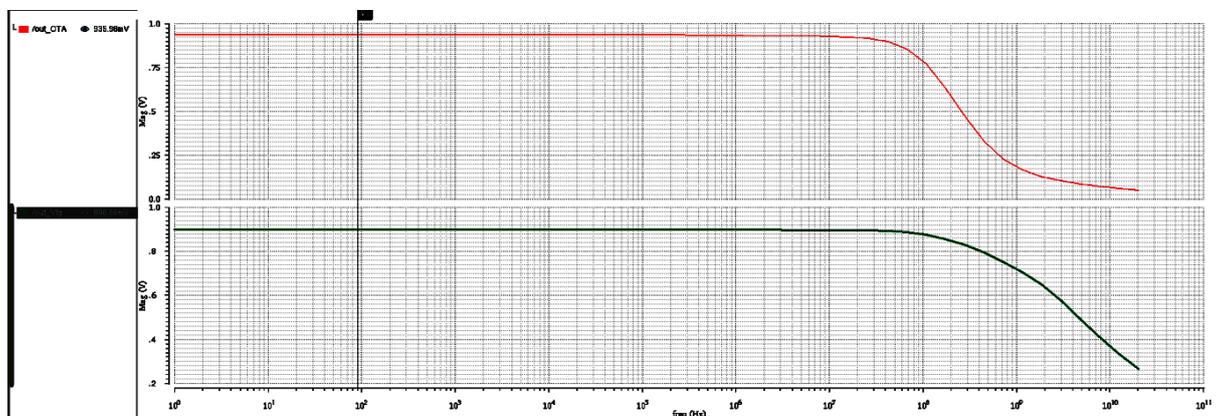


Figure 3. AC Response

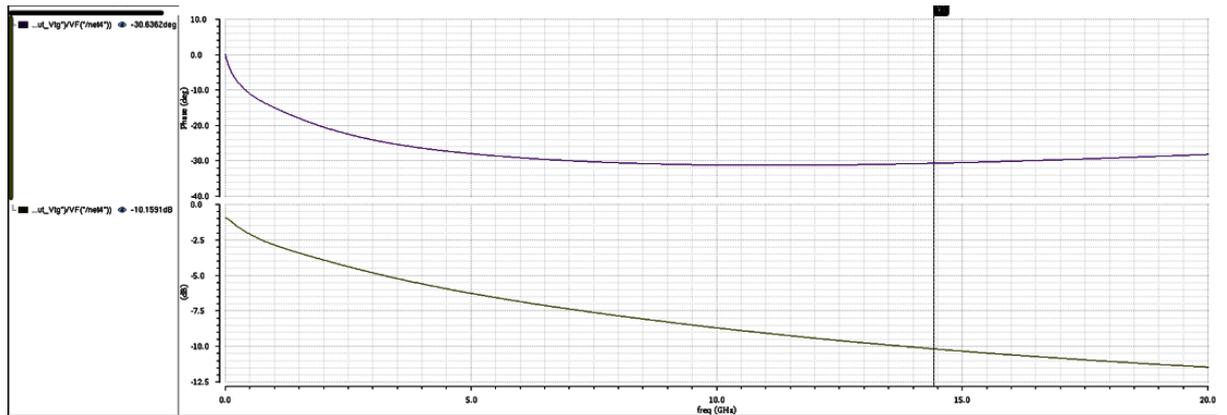


Figure 4. AC Gain and Phase Plot

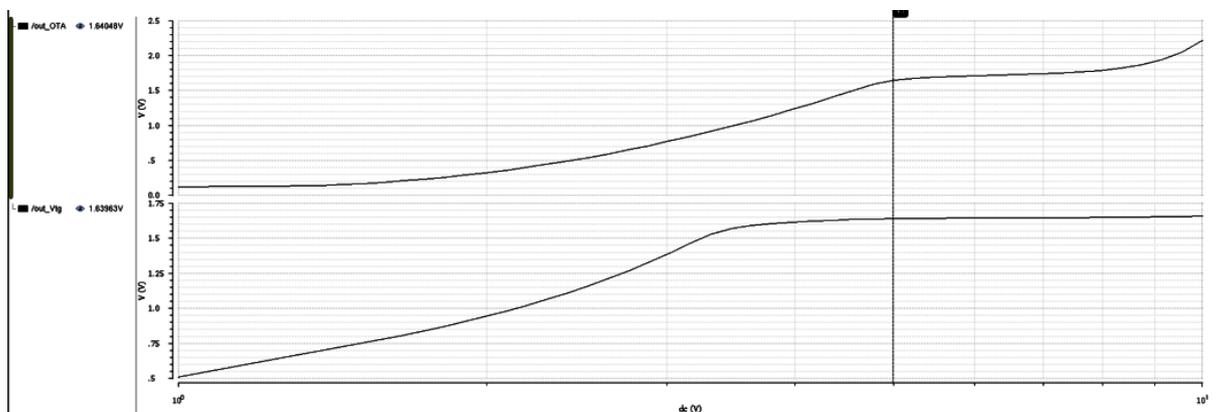


Figure 5. DC Response

The Figure 2 shows the transient analysis of the circuits of OTA and BGR. The output voltage from the OTA without BGR connection is found to be 13.7mV and with the drop at BGR it is found to be 0.94mV for the supply of 2mV at both inputs (V_{in+} and V_{in-}). The supply voltage was fixed at 1V constant DC supply. The bias was given with 1V of Dc voltage for the analysis purpose. The total output power from BGR is 0.0169 mW. The output current is found to be 0.13 μ A. The power was found to be used lesser when compared to previous works and the current output is varied according to the load at the output. Figure 3 shows the AC analysis of the circuit. The voltage gain of the OTA is found to be 935.98 mV and that of the BGR is found to be 896.66 mV. The bandwidth of the OTA is 0.438 GHz and bandwidth of BGR is 17.87 GHz. Gain of operational transconductance amplifier is 60.53 dB and for BGR is 77.72 dB. Figure 5 shows the Gain and Phase margin plots of the output of the BGR with respect to AC input. The gain margin is 10.15 dB and phase margin is 30.63 degrees. Figure 4.4 shows the DC response of the circuit of OTA and BGR. In this response, the output of the BGR is stabilized after the voltage of 1.64V. The output from the OTA is increasing with respect to the gain of the output.

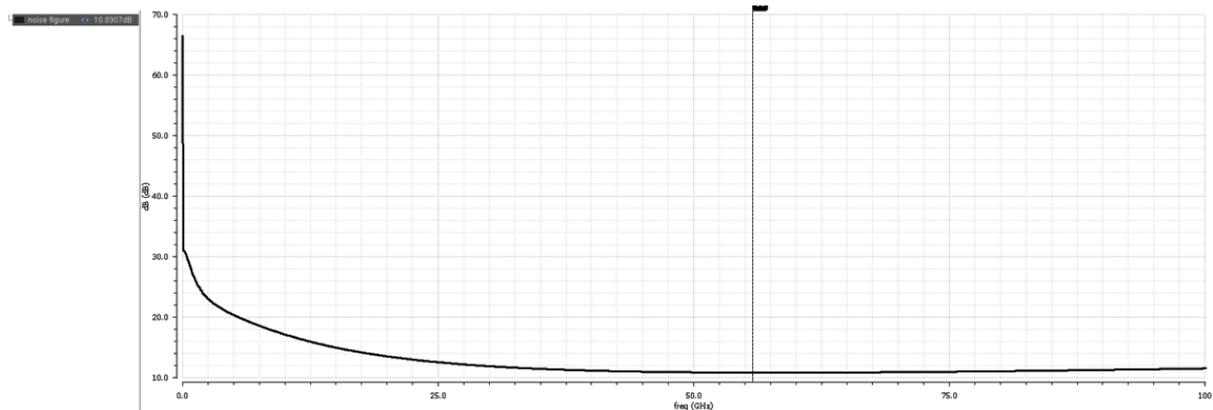


Figure 6. Noise Figure

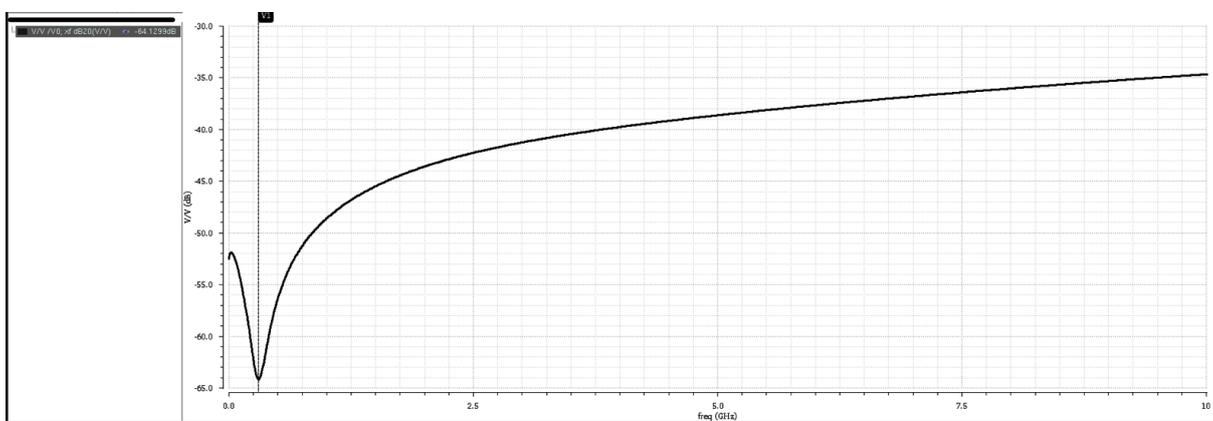


Figure 7. PSRR

Figure 6 shows the response of noise figure of the output of the BGR with respect to input. The response shows that the noise figure is giving a value of 10.886 dB. This value is obtained after the decrease of the noise figure from the value of 66.35 dB. Particularly in delicate situations where a high SNR is crucial, noise figure is a crucial design parameter. This aids in determining the system’s overall noise performance and enables the designer to choose components and balance system requirements wisely. The noise value is often stated only for a specific frequency or bandwidth. At various frequencies and operating conditions, various devices and components may have varying noise figures. Therefore, when analysing noise figure parameters, it’s crucial to take the suitable frequency range and operating circumstances into account. Figure 7 shows the analysis of the PSRR factor of the output of the circuit. The value is 64.12 dB. The device is less influenced by fluctuations in the power supply voltage when the PSRR value is larger since it implies better rejection of power supply variations and noise. In contrast, a lower PSRR number denotes a higher susceptibility to changes in the power supply. PSRR is a significant characteristic in applications where the power supply voltage may be prone to noise or fluctuations, such as in portable devices or in locations with unstable

power sources. It makes sure that even when the power supply voltage deviates from its nominal value, the device continues to function as intended.

The proposed idea of implementing OTA with Bandgap Reference has several real-time applications. One such application is in the design of analog-to-digital converters (ADCs). ADCs are used to convert analog signals into digital signals, and requires a stable and accurate reference voltage to operate correctly. The Bandgap Reference circuit provides a stable and accurate reference voltage, making it an ideal choice for use in ADCs [1]. Another application of OTA with Bandgap Reference is in the design of voltage regulators. Voltage regulators are used to maintain a constant output voltage regardless of changes in the input voltage or load current. The Bandgap Reference circuit can be used to provide a stable reference voltage for the voltage regulator, ensuring that the output voltage remains constant [5]. The OTA with Bandgap Reference can also be used in the design of low-power, high-precision sensors. These sensors require a stable and accurate reference voltage to operate correctly, and the Bandgap Reference circuit can provide this reference voltage. The low-power consumption of the OTA with Bandgap Reference makes it an ideal choice for use in battery-powered sensors [5]. Overall, the OTA with Bandgap Reference has several real-time applications in the field of analog circuit design, including ADCs, voltage regulators, and low-power sensors.

5. Conclusion

In summary, technology scaling in VLSI has been the driving force behind the advancement and miniaturization of electronic devices. This allows more transistors to be integrated onto a single chip, resulting in more computing power, less power consumption, and more functionality, explaining the operation of the synchronized start-up circuit and the different regions of operation of the transistor used in the circuit. The observation done here is to explain the importance of the BGR circuit in integrated circuit design and its role in providing a stable and accurate voltage reference regardless of temperature and power supply variations.

The advantages of this OTA architecture also apply to applications for analogue portable devices. It has been demonstrated that this design provides options for quick optimisation, ensures dependable and effective performance, and does so while preserving a high degree of circuit-level simulation agreement.

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