

DESIGN OF INTEGRATOR SYSTEM FOR PLASMA REACTOR USING CADENCE

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Abstract –

In a fusion reactor, where tokamaks are used to confine the plasma using toroidal and poloidal magnetic fields, highly accurate magnetic measurements are necessary for automatic control. However, due to extremities in temperature, acquiring uncorrupted signals become a challenging task. Presented in this thesis is a design of a twin operational amplifier based low offset integrating system to eliminate any error in measurement due to temperature dependent DC offset. This integrator system comprises mainly three stages after the inductive sensor. The first stage consists of a dual integrator in which the output signal from the sensor was fed to one integrator and the input terminals of the other integrator were grounded. An instrumentation amplifier which has a very high common mode rejection ratio and large input impedance was implemented in the second stage to find the differential signal between the outputs of the two integrators. Any noise arising in the environment was eliminated in the next stage by a Low-Pass Filter. To obtain a full Schematic of the operational amplifier based design Cadence Electronic Design Automation UMC_180 nm tool was used. The primary objective of DC offset elimination was verified through the results.

Key Words: Inductive Sensor, Operational Amplifier, Instrumentation Amplifier, Low-pass Filter.

1.INTRODUCTION

1.1 Plasma State

Plasma is the fourth state of matter after solid, liquid and gaseous states. This state of matter has similarities with the gaseous state but the particles are ionised. The ionised gas consists of nearly same number of negatively and positively charged particles. The characteristics of plasma are different to that of a normal gas. Being composed of charged particles, plasma is strongly affected by electric and magnetic field. In addition to that they are also affected by the magnetic field of the earth.

1.2 Tokamaks

A tokamak is a torus (doughnut) shaped device using powerful magnetic fields to confine the plasma. It is used to study the reactions of plasma which take place at very high temperatures. To get a stable equilibrium of the plasma,

magnetic field lines moving around the torus shaped confinement helically are required. Such a field is generated by adding two individual magnetic field components.

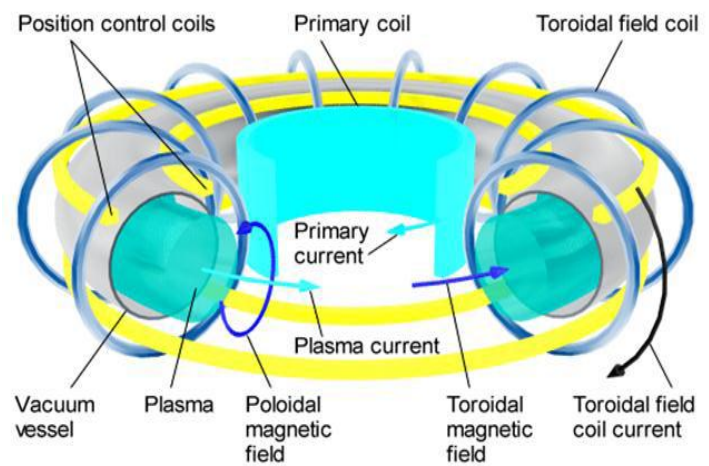


Fig.Magnetic fields in a Tokamak

1.3 Need of an Integrating System

Magnetic pick-up or induction coil circuits are used to measure magnetic fields. Any change in the magnetic flux produces a current whose direction opposes the change. The induced voltage is equal to the rate of change of flux ($N = \oint \mathbf{s} \cdot \mathbf{B} \cdot \mathbf{nds}$) in Webers per second.

$$E.M.F \ E = dN/dt$$

The change in shape of the plasma, change of strength of the magnetic field or movement in the circuit causes a change in the flux. The required flux is measured by integrating the output signal with respect to time.

1.4 Importance of Integrator in Plasma Reactor

The output of the pick-up coil can be integrated digitally or in analog circuit to obtain the value of magnetic field **B**. An easy integration method is to use passive elements like a resistor (R) and a capacitor (C) is called Passive Integrator

(or) The integrator circuit can be obtained without using active devices like op-amp, transistors etc.

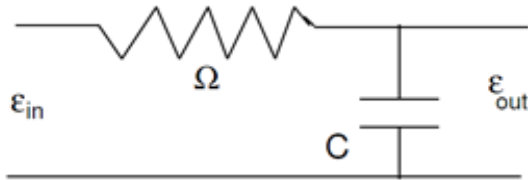


Figure 1.2 Passive Integrator

The output voltage can be expressed as

$$\frac{d\epsilon_{out}}{dt} + \frac{\epsilon_{out}}{\tau} = \frac{\epsilon_{in}}{\tau} \dots\dots\dots(1.1)$$

where $\tau = \Omega C$ is time constant. The solution of this equation gives the integration of the input signal.

Another method is to use an op-amp based active integrator. An integrator using an active devices like op-amp is called Active Integrator. The circuit is as shown below:

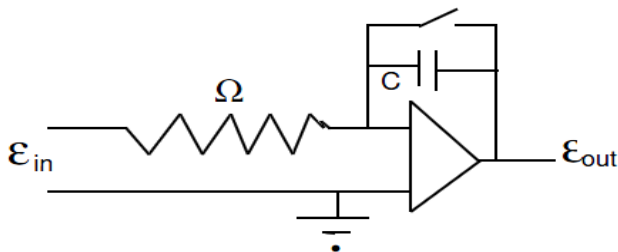


Figure 1.3 Active Integrator

The output voltage is given by the following equation:

$$\epsilon_{out} = \frac{1}{\Omega C} \int_{t_1}^t \epsilon_{in} dt \dots\dots\dots(1.2)$$

2. BLOCK DIAGRAM OF INTEGRATOR SYSTEM:



Fig. Block Diagram of Integrator System

2.1 MAGNETIC SENSORS IN THE FIELD

Plasma needs accurate magnetic values so, magnetic sensors provide values. And also they give information to the tokamaks in plasma reactor in order to protect walls inside present in it. Because of excess of heat is produced inside the plasma reactor.

2.2 TWO STAGE AMPLIFIER

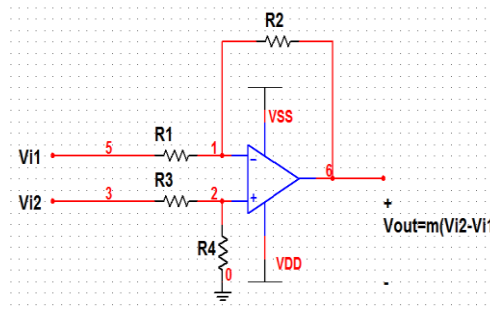


Fig. Differential Amplifier

In common differential amplifier, it has loading effects to minimize the loading effects, the differential amplifier should possess a very high input impedance. And also it cannot provide much gain in which it is necessary.

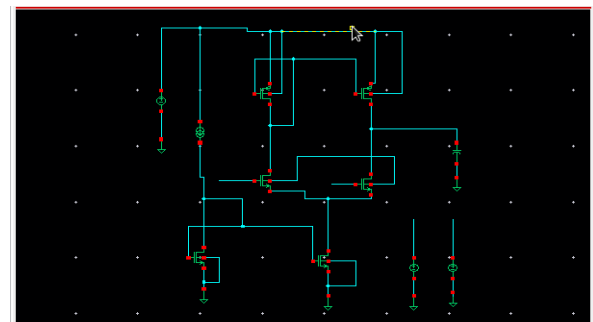


Fig. Schematic of Differential Amplifier

OUTPUT:

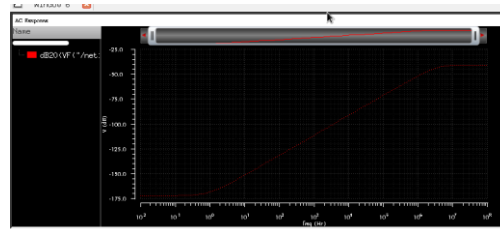


Fig. Gain and Frequency of Differential Amplifier

The shortcomings of a common differential amplifier can be overcome by using an Two stage amplifier.

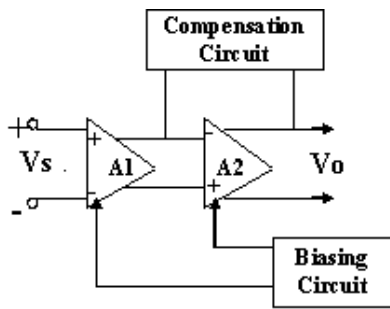


Fig.Two Stage Amplifier

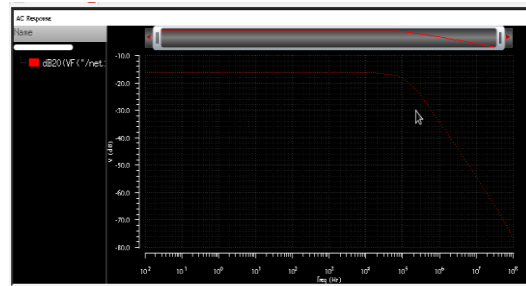


Fig.Gain and Frequency

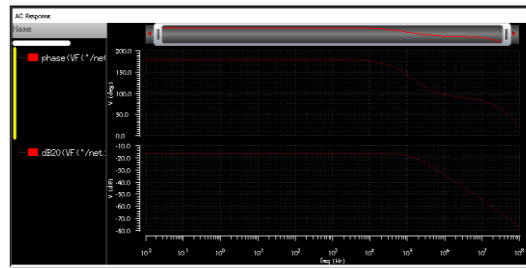


Fig.Phase and Magnitude

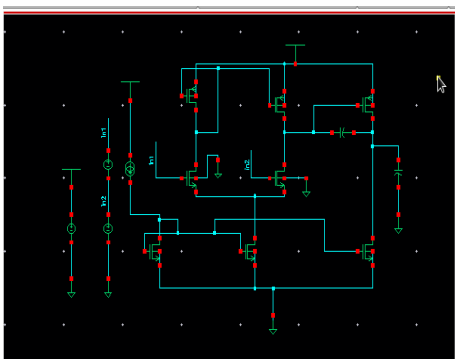


Fig.Schematic of two stage amplifier

In two stage it contains one differential amplifier and one common source amplifier to produce high gain. Amplification is an essential function in most analog and many digital circuit. An important advantage of differential operation over single ended is higher immunity to “environmental” noise. For output stage a common source amplifiers has been used, which is able to provide a large gain in output stage. The advantage of the simple common source (CS) amplifier over differential pair is high output swing.

OUTPUT:

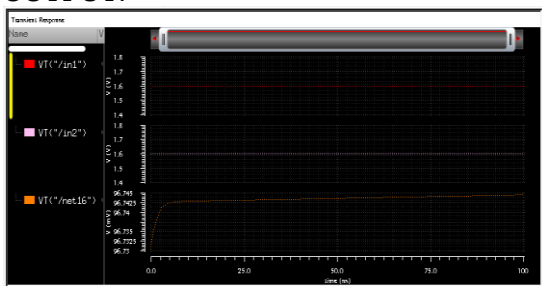


Fig.AC response of two stage amplifier

2.3 INSTRUMENTATION AMPLIFIER

The special amplifier which is used for such a low level amplification with high input impedance to avoid loading, low power consumption and some other features is called an Instrumentation Amplifier. To reduce the dc offset we use instrumentation amplifier. Not only it reduces the dc offset but also it reduces the noise present in the circuit. It differentiates both the differential and common source amplifier and gives us the required signal.

The instrumentation amplifier is also called data amplifier and is basically a difference amplifier. The expression for its voltage gain is generally of the form

$$A = \frac{V_o}{V_2 - V_1}$$

where

V_o = output of the amplifier

$V_2 - V_1$ = Differential input which is to be amplified.

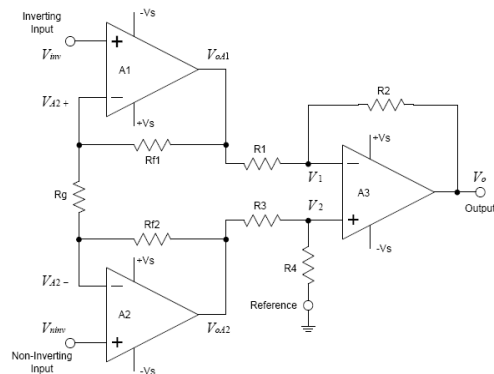


Fig. Instrumentation Amplifier

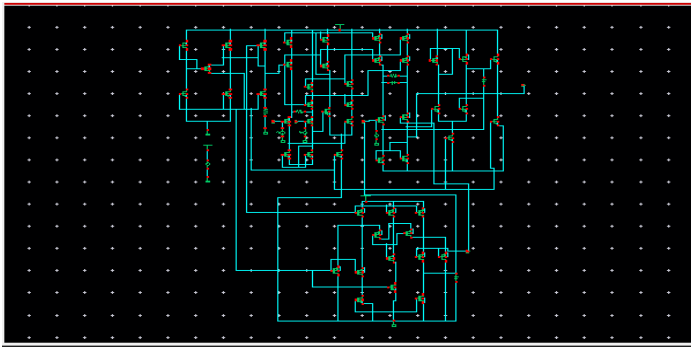


Fig.schematic of instrumentation amplifier

The amplifier must have differential input so that it can be amplified. The instrumentation amplifier is used in many applications like automotive and various data acquisition systems. The instrumentation amplifier has very high input impedance in the order of several mega-ohms and low output impedance. It also had a property to neglect common mode signals.

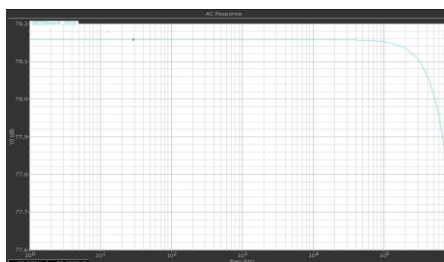


Fig.CMRR vs Frequency response in INAMP

The CMRR of the instrumentation amplifier was found out to be more than 75 dB which is clearly greater than the CMRR value of a normal operational amplifier. Due to this property of the high CMRR, instrumentation amplifier is generally useful in suppressing common mode signals arising out of noise and DC offset

OUTPUT:

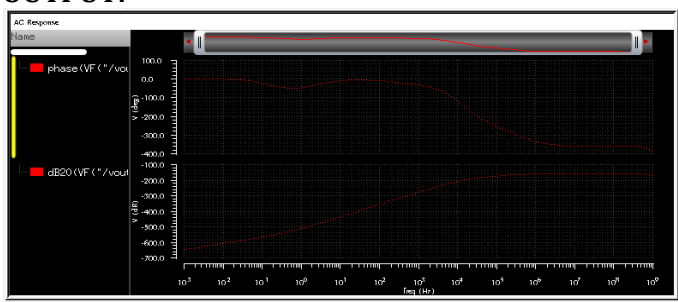


Fig.phase Vs gain

2.4 LOW PASS FILTER

A filter is a circuit which allows signals of a specific range of frequency to pass through it while blocking the signals with frequency outside the range. Based on the components used

filters can be passive or active filters. Passive filters are composed of passive elements like capacitors (C) inductors (L) and resistors (R). They don't need any external power sources to operate, nor do they contain any transistors. Whereas active filters contain active elements like operational amplifiers. They need external power sources to operate. Based on the frequency selectivity, filters are of many types. A high pass filter passes signals of frequency larger than a cut-off frequency. A low pass filter does the exact opposite. A band pass filter passes certain range of frequency specified within the two cut-off frequencies. A band stop filter rejects a certain range of frequency. Analog filters are simple to implement. Noises from the instrumentation amplifier and other environmental noises need to be filtered. A low pass filter with cut-off frequency of 780Hz is used.

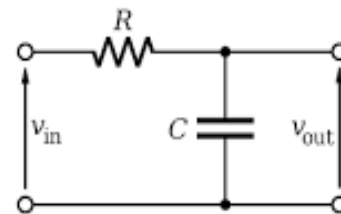


Fig.Low pass Filter

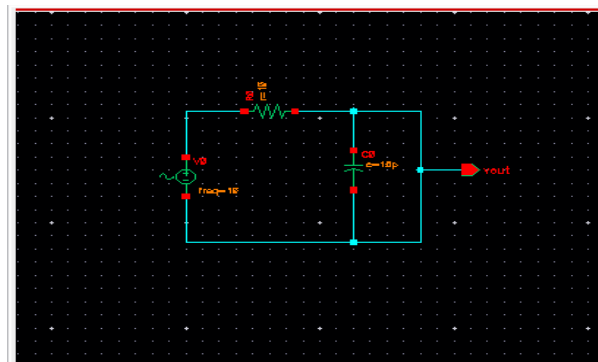


Fig.Schematic of Low pass filter

OUTPUT:

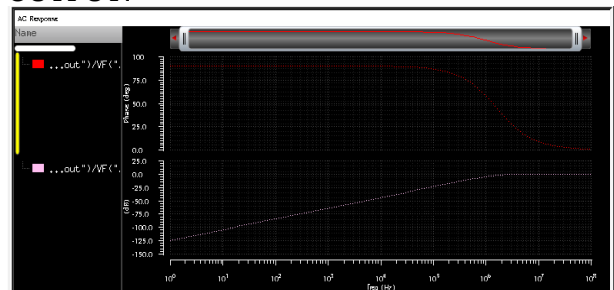


Fig.phase vs gain

2.5 PLASMA CONTROL CIRCUIT

Energy supplies are an essential requirement for economic growth and enhancement of life standards. Plasma is

environmentally attractive source of energy for electricity generation. So, we are using Plasma Reactor in which plasmas are electrically conductive and magnetically controllable. Highly accurate magnetic measurements are necessary for automatic control. So, we are using magnetic sensors and integrator system as input for plasma reactors. In which integrator system is used in a plasma to control system to integrate the output signals of the induction coil sensors and find the magnetic field values for input to the plasma reactor. By this way we can get exact output without any noise and unwanted signals. And so we can use the plasma reactor for energy supply.

3. CONCLUSIONS

In our thesis, the integrator system whose model has been developed not only helps in reducing DC offset effects but also it enables a mixed signal approach for removing any unwanted noises. For low frequency operations the two stage amplifier was used. The instrumentation amplifier stage was designed for avoiding loading effects and for required amplification during subsequent processing. Here the pulse frequencies are assumed to be very low so that a low pass filter with cut off frequency 780Hz can remove the unwanted signals present during data acquisition. The filter is used for providing better accuracy, flexible operations, higher order design implementations and faster response. The basic stage of opamp design was done using Cadence 180 nm technology. The characteristics graphs which were obtained gave desired results. The main objective was develop the complete Schematic circuit for the designed integrator. The opamp was used in realizing the basic INAMP for verifications of results. The cadence tools can be used to produce low power, high efficiency integrator system which can be effectively used in tokamaks.

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