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Implementation of Broad band and Zero Distortion CMOS Current Driver Circuit for Bio-medical Applications

S. MD. Imran Ali*1, Syed Noorullah2, P. Anusha Reddy3, U Gayathri4

[1,3,4] Department of Electronics and Communication Engineering, Brindavan Institute of Technology and Science, Kurnool, Andhra Pradesh, India
[2] Department of Electronics and Communication Engineering, Safa College of Engineering & Technology, Kurnool, Andhra Pradesh, India

ABSTRACT

Multi frequency Electrical Bio-impedance has been widely used as noninvasive technique for characterizing tissue. Most systems use wide band current sources for injecting current and instrumentation amplifiers for measuring resultant potential difference. Tissue electrical properties exhibit frequency characteristics over a broad bandwidth (typically 1KHz to 100MHz).Such applications require wide band accurate ac current drivers with low distortion and high output impedance. An integrated current driver is presented that fulfils the requirement of maximum output current of 888µAp-p, and at 100MHz the measured total harmonic distortion is below 0.01%.For accurate setting of output current amplitude into load current driver uses negative feedback. Active electrodes applications make use of current driver circuit.

Keywords : Active electrodes, Bio-impedance, current driver, low distortion, Tissue impedance.

I. INTRODUCTION

Electrical Impedance Spectroscopy (EIS), has been widely used as a noninvasive technique for measuring many passive electrical properties from biological materials such as: cancerous tissues; tumors, meninguits and brain cellular oedeman. It can also be used for analyzing body composition. Also, it is considered as fast, inexpensive practical and efficient.

Microelectronics systems applied to health care solutions provide advantages of small size devices, possible wireless signal and power transmission, portability, long time implant for low power circuits, and possibility of improving the sensing of weak signal (on the order of millivolts) by taking them out in-suit.

A widely used method for measuring bio impedance is the tetrapolar electrode configuration. Which involves applying an ac current through one pair of electrodes and separates current electrode and voltage electrode and measures the resulting voltage potentials on a second pair of electrodes? Tissue impedance characteristics can be measured using techniques such as synchronous detection. Synchronous detection is a signal processing technique that makes possible extracting even weak signal in strong noise.

The ac current driver must have sufficient accuracy over the total operational bandwidth and its output must be independent of load variations. As a result, the current driver requires a relatively high output impedance relative to the load and low distortion (total harmonic distortion; thd<0.5% typically) particularly for multi frequency drive currents.

EIS techniques have shown good resulting normal and cancerous skin in superficial tissues. Most EIS systems consist of applying multi frequency sinusoidal current of constant amplitude into the tissue sample, measuring the resulting potential and then calculating transfer impedance.

II. METHODS AND MATERIAL

A. Literature Survey

A Variety of current drivers have been reported in the literature, mainly using discrete designs such as the Howland circuits in which a output impedance is degraded due to large common voltage at the load, Modified mirror howland current circuit that suffers from instability problems with more power consumption.

The Howland circuit does not lend itself easily to a fully integrated circuit implementation due to the requirement for very accurate resistors(<0.1%).Modified Howland and current conveyor current sources have a linearity error of 0.5% from -0.5V to 0.5V peak to peak input voltage. Operational trans conductance amplifier exhibit more power consumption along with 10% of linearity error from -0.5V to 0.5V peak to peak input voltage. Hence the need for wideband operation, which is limited in existing, integrated current drivers. From the above discussion it is clear that all the techniques proposed so far fail to achieve a complete optimized current driver that can effectively increase the utility of the cancer detection system.

B. Proposed Architecture

Current Driver Architecture

Here it uses two identical single input differential output current drivers (Sub drivers), one for sinking current and the other for sourcing current to establish a balanced voltage across the load ZL. Each sub driver consists of a pre- amplification stage realized by a differential difference Trans conductance amplifier (DDTA1 or DDTA2), followed by a Trans conductance (GM1 or GM2), which performs the voltage to current conversion operation and drives the load. An on-chip sense resistor (R_{s1} or R_{s2}) is used to monitor the output current I_L of each subdriver, and the voltage across the resistor is fed back via a pair of voltage buffers [(B_1,B_2) or (B_3,B_4)] to the appropriate terminals of the respective DDTA, thus forming a negative-feedback loop. The control voltage V_{ref} applied to transconductors serves to accurately set the dc voltages levels. Conversion operation and drives the load. An on-chip sense resistor (R_{s1} or R_{s2}) is used to monitor the output current I_L of each subdriver, and the voltage across the resistor is fed back via a pair of voltage.

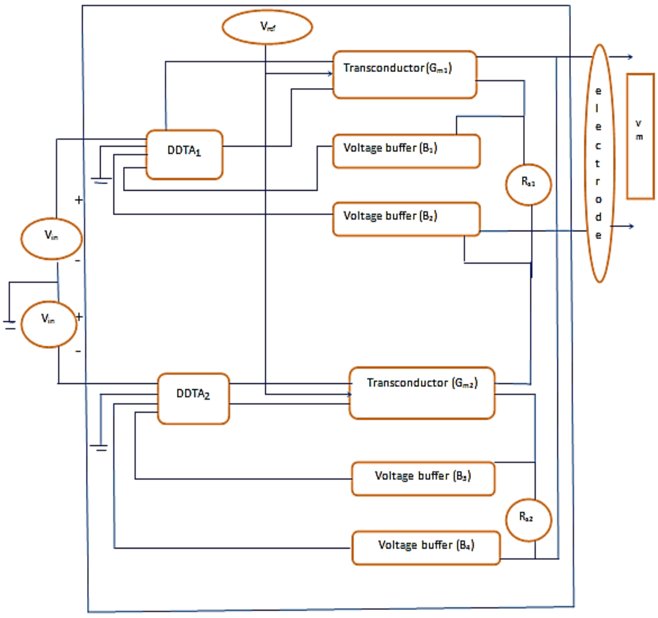

Figure 1. Current Driver Architecture

A. DDTA

DDTA is a Differential Difference transconductance amplifier. DDTA transistor –level schematic uses a differential topology. From the figure the transistors Q5, Q6, Q7, Q17, Q16, Q9, Q8, Q15 form two differential pairs (input transconductance stage) whose output currents are summed at the drain of the diode- connected transistors Q2 and Q4. Transistors Q6 and Q7 provide source degeneration to enchance the input common-mode range. In this circuit we use current mirror transistors. The current mirror is a circuit which are widely used in integrated circuit technology. The current mirror is used to provide bias currents and active loads to circuits.

In the circuit current mirror comprising transistor pairs Q1,Q2 and Q3,Q4 from a differential output stage with transistors Q11 and Q20.This topology allows for independent control of the output stage of the circuit without affecting the input transconductance stage. Transistors Q19 and Q21 provide common mode feedback control operated in triode region.

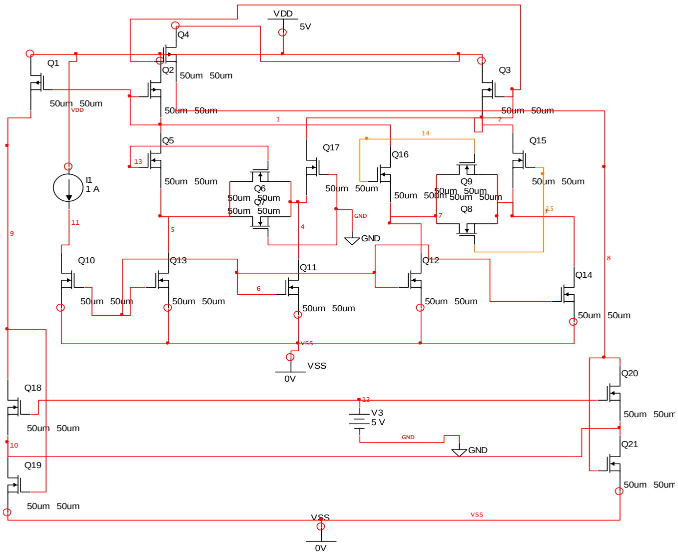

Figure 2 : DDTA Transistor – level schematic

B. Transconductance

The Operational Transconductance amplifier (OTA) is an amplifier whose differential input voltage produces an output current. Thus it is a voltage controlled current source. In the figure the circuit schematic of the transconductance that uses a three current mirror operational transconductance amplifier topology. The low supply voltage specification of the design dictates the use of simple current mirrors with reduced over drive voltage operation of the output transistors.

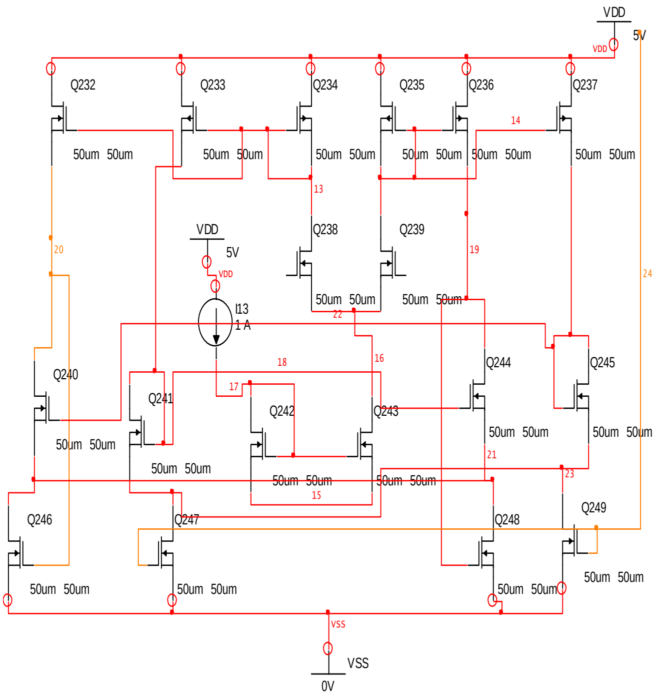

Figure 3. Transistor level schematic of the transconductor

Here the circuit uses triode transistors Q246 and Q248 in order to approximate output dc-level stabilization. Thus due to the variations in the process determination of accurate output common –mode level is not possible. In order to overcome this transistors Q247 and Q249 are used whose gate voltages are controlled by external voltage. V_{ref} are added in the secondary n-type metal oxide semiconductor (MOS) current mirror branches. Output dc levels can be altered by adjusting V_{ref} . Thus care must be taken to ensure that V_{ref} holds Q247 and Q248 in the triode region.The transistors Q241 and Q244 forms the current mirror pairs. Through current mirroring, the drain currents of Q241 and Q244. Here V_{DD} is a positive supply voltage. The OTA voltage compliance was designed to be 2V by ensuring low saturation voltage operation of the output transistors.

C. Voltage Buffer

A circuit which transfers a voltage from a circuit with high output impedance to a circuit with low input impedance is called as a voltage buffer. Generally Buffer amplifier is a circuit which transforms electrical impedance from one circuit to another circuit. The main purpose of buffer is to prevent the loading of a preceding circuit by the succeeding one. For example, a sensor may have the capability to produce a voltage or current corresponding to a particular physical quantity. The voltage buffer connected between these two circuits prevents the load input impedance current.

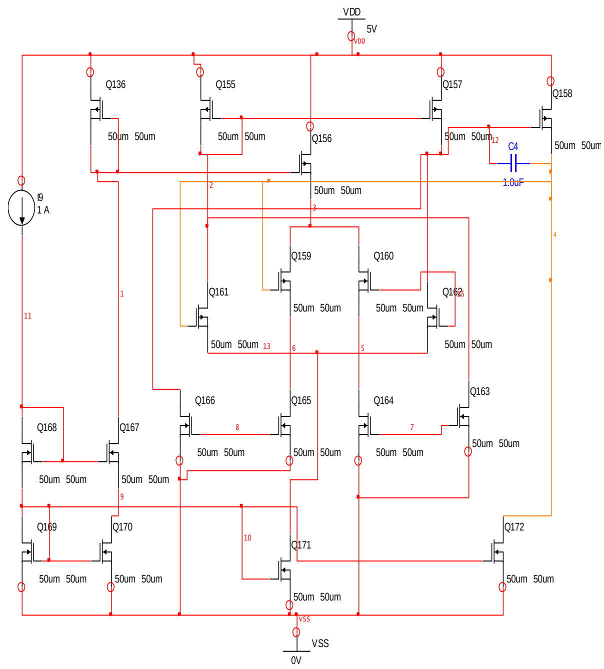

Figure 4. Transistor- level schematic of the voltage buffer

This is the circuit schematic of voltage buffer. The transistors Q159 to Q162 forms two complementary input differential input pairs for enhanced input common mode range , whereas the current mirror pairs Q163 Q164 and Q165-Q166 sense the P- type MOS differential pair currents. Current mirror pairs Q156 and Q157 performs the differential to single- ended operation , Whereas Q158 and Q172 form a second stage gain for enhanced operation loop gain. Capacitor C4 ensures a sufficient phase margin when output is fed back to a negative input terminal for unity gain operation.

III. RESULTS AND DISCUSSION

Simulation Results

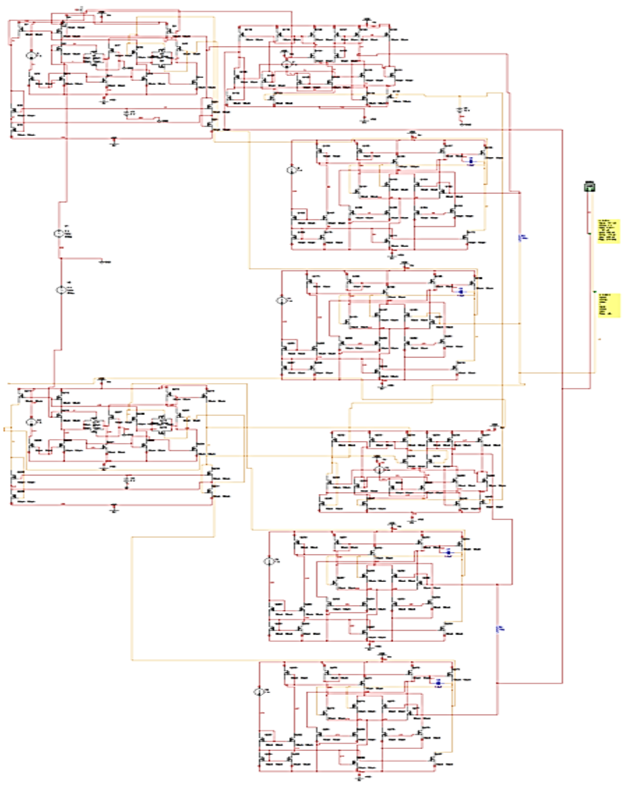

Figure 5. Detailed Architecture of current driver Layout

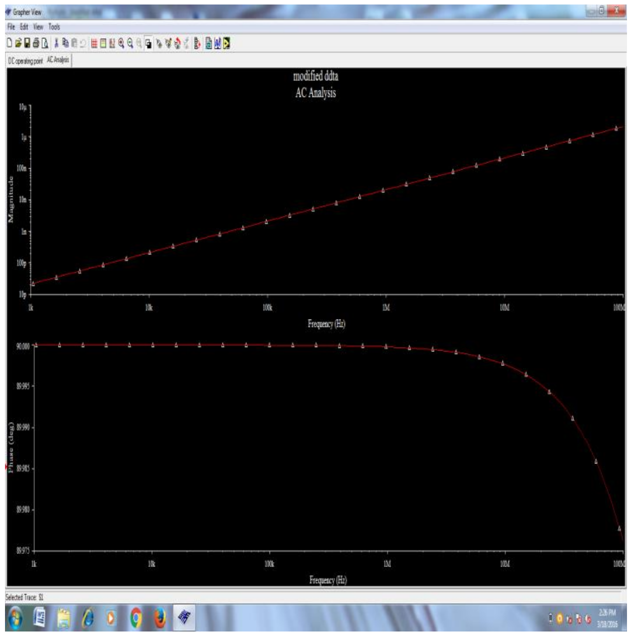

Figure 6. AC Analysis of current driver

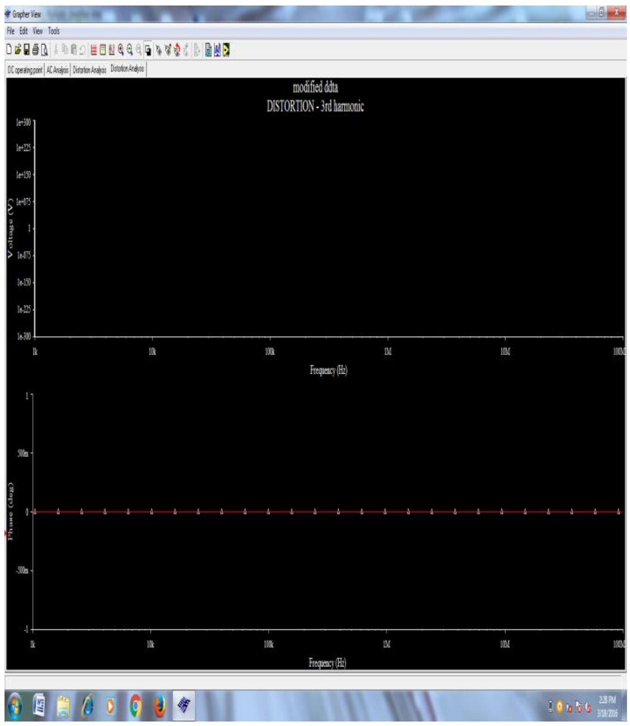

Figure 7. Frequency vs phase with zero distortion

Table 1 : Measured esults

Parameters	Modified Howland Circuit	Mirror Modified Howland	Differential OTA	Negative Feedback
Maximun output Current	1mA	1mA	500μA	888μA
Bandwidth	1KHz-	1KHz-	1KHz-	1KHz-

	1MHZ	1MHZ	10MHZ	100MHZ
Total Harmonic Distortion	2%	1%	0.1%	0%
Supply Voltage	5V	5V	5V	3.46V

IV. CONCLUSION

A Broad band integrated current driver has been presented. For setting the output current amplitude into load current makes use of negative feedback and achieve zero distortion. The circuit is intended for active electrode realization capable of being mounted on clinical tools for real time Bio-medical applications. The output current and impedance of the circuits were investigated over the 1 KHz to 100MHz. Thus the proposed work implements a current driver circuit which exhibits stabilized response over broad band frequencies. It enhances performance by reducing total harmonic distortion to zero. Thus it is clear that an optimized current driver circuit is implemented with maximum current of 888μA. This circuit can still be modified for ultra-band frequencies by further increasing input current and output impedance.

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