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Design of Organic Electronic Circuits: An E-Waste Management Approach

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Abstract— *A Low pass filter is an electronic frequency filter that allows only certain signals to pass through it which have frequency less than the chosen higher critical frequency also known as higher cut-off frequency i.e. it attenuates all the signals with frequencies above the cut-off frequency. This cut-off frequency is selected by carefully choosing the values of resistor and capacitor of the filter circuit. A LPF is usually counted in linear-time invariant system. CMOS based OTA LPF is seldom used in many electronic devices and communication systems which have shown delay in sharp cut-off, resulting in non-attenuation in unwanted signals and consumes very large amount of power for use in microelectronic devices. In this paper we design a LPF using Operational Tran conductance Amplifier which is built upon Organic thin film transistors instead of CMOS transistors. The Organic transistors not only improve the performance like DC gain, bandwidth, steep cutoff slope, requires extremely less power ~ 4.792μW and reduces device size to 18nm, of the OTA but also provides organic features like light weight, transparency, non-toxic electronic waste and most importantly are biodegradable. The organic approach to build and design the devices has found great research interest in current days because these devices are manufactured more easily at low temperatures and can be printed directly on the sheets, foldable substrates etc. This organic method provides an efficient way to reduce the global electronic wastage that is dumped, not recycled and non-biodegradable and proves highly toxic for the soil and environment.*

1. INTRODUCTION

Our environment is the real family in with which we sustain our life and currently its under serious threat due to wastes and pollutants that are causing extinction of flora and fauna. The world is getting smaller with advances in technology, small scale devices, faster responses, lower power consumption, portability, light weight are in great focus. For a device to be mobile and portable, it must provide longer battery life such as in a cell phone, laptop computers, mostly in mobile communication devices. In previous decade, many RF filters have been developed for working in current and voltage modes.

Electronic waste or E-waste is a globally emerging catastrophe in the world in current days [1]. Basically, E-waste is the unusable products left after an electronic device is broken or rendered useless. The components made of elements, plastic, packaged in ceramics or polymers are non-biodegradable and cannot be recycled for further use and are discarded or dumped. This disposal of electronic components is becoming a huge problem for the habitats and environment because they contain hazardous materials. A developed country like USA or China discards more than 30 million computers and 70 million mobile phones every year resulting in very large amount of – E-waste and plastics that cannot be decomposed by the earth but with time pollute the top layer of soil causing environmental pollution. There is a huge need of innovative methods that may check the consequences of E-waste after being dumped. Create a new biodegradable product that can be either recycled or can be disposed into earth without leaving toxic remains after decomposition.

2. A STEP INTO ORGANIC ELECTRONICS

Organic science is the study of materials which are composed of carbon and its compounds which are prime decomposable materials. Chemists, physicists, and other scientists usually deal with organic branch of science and engineers are preparing and synthesizing a variety of new organic substances in such ways that will change the way a person or an intellectual interacts with latest technology. These new materials create extreme properties impossible to counterfeit with silicon, developing the world of electronics in ways unimaginable until now. Innovation, modification and sustainability examines where organic electronics is nowadays, where chemical scientist's vision the field is heading, and the scientific and engineering challenges that must be overcome in order to make this vision a reality. Organic materials for electronics are under studies and are developed for their potential to fabricate devices with a vast features like flexibility, stretching ability and softness ("soft electronics") which are not provided by silicon or any other inorganic material, that is, electronic devices that bend, twist, and conform to any shape and surface. Incorporation of organics in electronics will readily eliminate the non-decomposition problem of the expired electronic devices and also leaves the material non-toxic for environment. Furthermore, organics provide extra features to a system like

light weight, transparent, high performance results, easy fabrication, low cost manufacturing etc. Because of these features and easy, comfortable manufacture of organic-based electronic devices, compared to today's silicon-based devices, organic electronics also promises to expand the area of electronic technology in resource-limited areas where supplies are in scarcity or the necessary infrastructure is lacking.

3. LOW PASS FILTER

A general structure of a high pass filter using operational amplifier is show below.

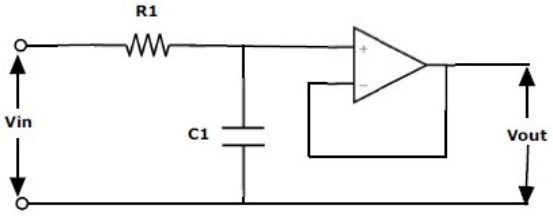

Figure 1: A general low pass Filter

LPF is an electronic device, an active filter that allows signals to pass through it which are below a certain point of frequency called as cut off frequency (f_h) and also attenuates all the frequencies above f_h but reduces the amplitude. The amount of attenuation of the signals varies with respect to filter type and components used [7]. LPF is used in cascade form with other type of filters to create new active filters or circuits for various application like High frequency blocking circuit, band-pass filters etc. LPF contains an op-amp or OTA, a capacitor and resistor in parallel fashion connected to the input voltage source on inverting or non-inverting terminals as shown in figure 1.

4. PROPOSED WORK

I have designed a Low Pass filter using OTA based on carbon TFTs that is non toxic, biodegradable and some can be recycled.

4.1 Operational Tran conductance Amplifier

OTAs are operable from low frequency waves to wide variety of frequencies up to several megahertz. Organic OTAs are designed using Organic TFTs instead of CMOS transistors providing enhanced performance over CMOS-OTA such as high DC gain ~ 60 dB compared to 35 dB gain of CMOS-OTA, improved CMRR, slew rate and greatly reduced power consumption of only 4.729 µW for the entire circuit [8]. OTAs are voltage controlled current sources in which the input differential voltage controls the output current along with the transconductance (g_m), Iout = gm × Vin. An ideal model of an OTA is shown below

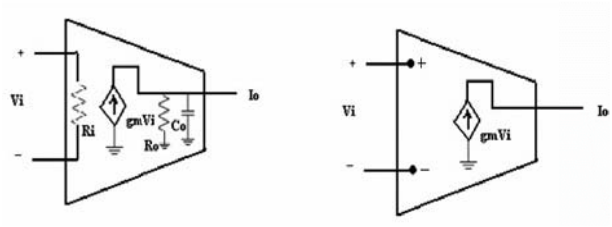

Figure 2: Ideal model of a conventional OTA

5. BASIC ORGANIC OTA

An OTA generates a current on its output which is proportional to the product of transconductance gm and the differential voltage applied at its input terminals hence, making it a voltage controlled current source [9]. For an ideal OTA there is no losses. Therefore

$$Iout = gm \times (Vin - Vm)$$

An OTFT based OTA provides very high input impedance and low output impedance making it more efficient in electronic circuits and reduces the output power dissipation. Transconductance is dependent on the bias current (Ibias) supplied to the OTA shown in figure 3.

The OTFT based OTA designed and simulated is shown in figure 4 which uses 9 Organic transistors instead of CMOS transistors, providing excellent performance and organic features and qualities to the circuit. The organics in the transistors makes the device biodegradable when disposed into soil.

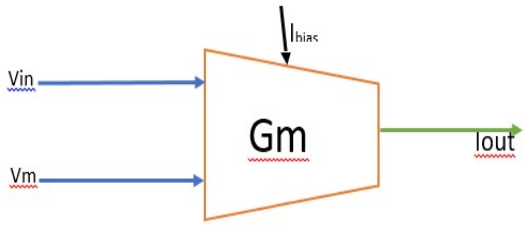

Figure 3: OTA circuit symbol

Since it is carbon based solid state device, it leaves no toxic remains when fully decomposed. Organic transistors are p-type that is they use holes as majority carriers in the active semiconductor layer of the transistors which have very high mobility compared to electrons. This method makes devices organic and eco-friendly thus largely reduce the electronic waste that is currently filling up in the dump sites.

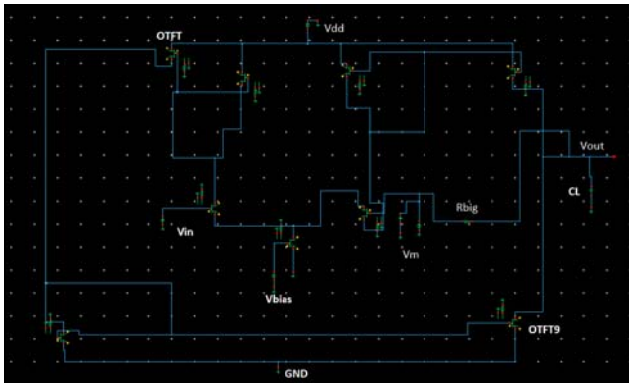

Figure 4: Schematic of OTFT Based OTA in Cadence.

6. LOW PASS FILTER DESIGN USING ORGANIC OTA

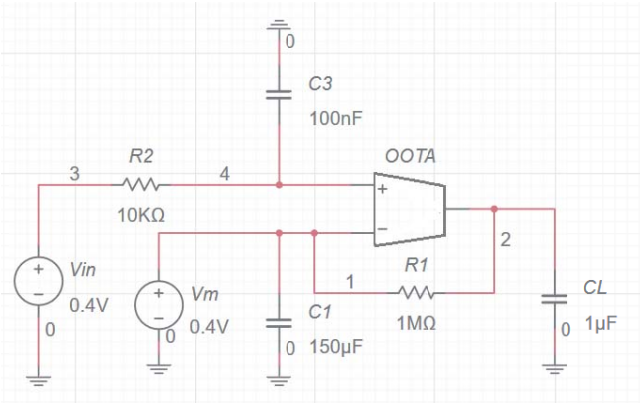

Figure 5: A Low Pass Filter Circuit simulation

LPF is designed and simulated using Organic OTA in cadence CAD tools. Low pass active Filter modulates the amplitude of frequencies, passes all frequencies from DC up to higher cutoff point (f_h) and attenuates the signals having higher frequencies with OTA providing sufficient voltage gain. Cut-off frequency is the point in AC response of the filter where the gain drops by 3 db. The region behind the point is called as pass band and the region beyond f_h is called as stop band. It is very much predominant electronic component in industries, communication devices, radio systems and wireless mobile networks. It is actually modeled on a linear time, along with an invariant system, that is directly proportional to the amount of frequency that is given off by the device, and also reduces the amplitude that is required, hence making sure that the frequency is always below the cut-off frequency. Magnitude of the voltage gain = $\{1 + (R_1/Xc1\}$. This circuit has more input impedance value. Even though the input impedance of the op-amp is high below the cut-off frequency, this input impedance is limited by the series impedance which is equal to $R + (1/j\omega C)$.

The schematic architecture of Low Pass Filter based on Organic Thin film transistors is shown in figure 6.

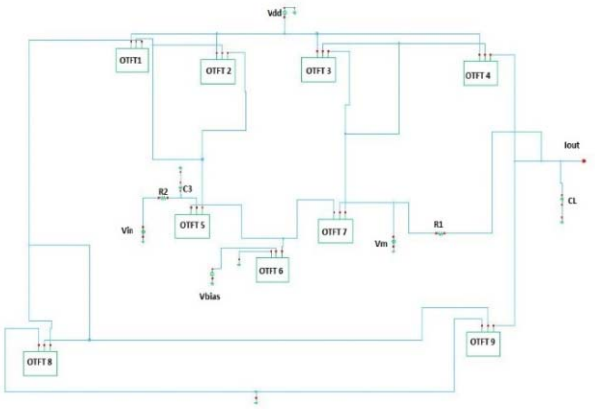

Figure 6: Internal architecture of LPF in CAD.

This circuit consists 9 OTFTs each consuming power approximately 2.793nW, an OTA, feedback network and a parallel combination of resistor and capacitor connected to high input node on the positive terminal, which provide filtering process. Cut-off frequency is chosen by specifying the values of this resistor and capacitor. The OTA stage highly increases the DC gain, CMRR, Slew rate and reduces the power dissipation on the output terminal.

7. GAIN PLOT OF FIRST ORDER LPF

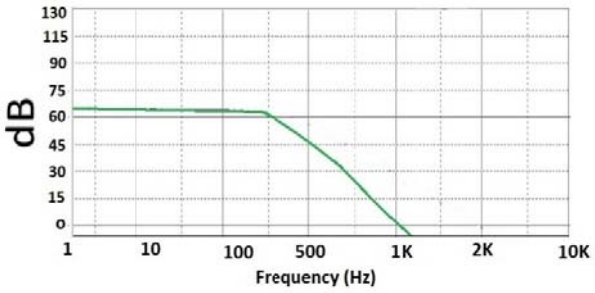

Figure 7: Gain vs. frequency of LPF

Theoretical Result:

The Cutoff frequency of LPF= $(1/2\pi R_2C_3)$

Therefore the f_c is equal to 251.3 Hz.

Practical Results:

From the graph of 1st order low pass filter we obtain the cut-off frequency approximately equal to 300 KHz with higher bandwidth of 15 MHz.

CMRR is found to be 83.91 dB.

Furthermore, there may be more stages of filter added to the circuit to make it more efficient and have sharp cutoff with higher cutoff frequencies.

8. ADVANTAGES

1. OTFT is an organic device that is carbon based which is fully biological and gets decomposed like remains of living things. They have shown higher performance, mobility and non-toxic nature.
2. All electronic circuits and amplifiers desire to have high input impedance and low output impedance and controlled by input voltage is easy to operate for a researcher. OTA provides all these features over op-amps. Thus, organic OTAs prove even better than CMOS versions.
3. These new innovations offer improvements in design simplicity, fabrication, environment friendly and programmability when compared to op-amp based structures as well as reduced component count.
4. All the organic Transistors operate in accumulation mode reducing need for high power input.
5. The transconductance of the OTA is easily adjustable with an external resistance, compromising the bandwidth, quiescent current, and gain. So, Operational Transconductance Amplifiers are widely used as the base of electronics world now-a-days [15].
6. This E-waste when disposed into a pit can decompose in some months to years and leaves a place for new devices for manufacturing and use. Hence, leaving no toxic material into the soil and preserving the natural quality of environment. There is no need to recycle the products which are no longer usable.

9. CONCLUSION AND DISCUSSION

E-waste is an emerging issue, driven by the rapidly increasing quantities of complex but necessary electronic equipment. The global level of production, consumption and recycling induces large flows of both toxic, poisonous and valuable substances out into the environment. The international regulations mainly developed under the Basel Convention [11], focusing on a global ban for transport, movements of e-waste across boundaries, seem to face difficulties in being implemented effectively. On a global scale some attempts have been made to identify past, present and future e-waste sources and attempts to fix the issues have been made. The focus has been laid on quantities and in some cases on routes and spatial distribution, but a global perspective is still lacking[13]. Debate is going over the distinction between "commodity" and "waste" electronics definitions. Some transports are accused of deliberately leaving difficult-to-recycle, obsolete, or non-repairable equipment mixed in loads of working equipment creating difficulties to distinguish. The high value of the computer recycling subset of electronic waste e.g. working and reusable laptops, desktops, and components like RAM, ICs, motherboards, displays etc can help pay the cost of transportation for a larger number of worthless pieces than can be achieved with display devices, which have less (or negative) scrap value. In A 2011 report, "Ghana E-Waste Country Assessment", found that of 215,000 tons of electronic components imported to Ghana, 30% were brand new and 70% were used. Of the used product, the study concluded that 15% was not reused and was scrapped or discarded which is not checked while discarding the components. With the research submitted in this paper regarding a way of managing the global problems of e-waste is a way to solve it up to a large extent. Like the remains of plants and animals are decomposed with some duration of time, the electronic waste if organic can be consumed by earth without defecting its quality. More research must be done on organic electronics as they have proven to be good performers in providing quality assurance and non toxic materials. A pledge is to be taken to stop further climate changes, environment destruction and poisoning our own habitat due to the in organic waste of any kind.

“If we have polluted our own earth we will be the one to heal it”

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