Intensity Controlled by Touch Capacitive Sensor Built with Interfacing CNFET Characteristics

Sarita Chauhan, Anshita Arya, Laxmi Bagri, Raveena Sharma, Shikha Gupta

Abstract- ***Intensity controller plays vital role in todays life as it has numerous applications such as it reduces energy consumption, it can be used to control intensity of many devices such as light, fan, can be used in false ceiling, mood lighting etc. . In our paper we have implemented a light intensity dimmer whose intensity is controlled by characteristics of CNFET. We are soon going to reach hard limit of Silicon chip so we need a new technology to replace it. Here CNFET emerges as best alternative. Applications based on low power utility such as sensing are becoming increasingly important and are in demand in terms of minimizing energy consumption, promoting the search for new and innovative interface architectures and technologies. Carbon-nanotube FETs (CNFETs) has emerged as a new technology for further energy reduction. CNFET has various features such as process robustness, low power consumption,low voltage capability,smaller chip area.In this paper we are presenting a device whose intensity is changed repeatively by a touch capacitive sensor.***

Keywords- Carbon nanotube FET (CNFET), sensor interface circuit, matlab.

I. INTRODUCTION

I.a.CNFET

Low-power applications, are becoming increasingly important and demanding in terms of minimization of energy consumption with increase in performance. This demand for increased energy efficiency, expressed as performance per watt is encouraging the search for alternative energy-efficient technologies. Carbon nanotube field-effect transistors (CNFETs) are promising alternatives to complement silicon-CMOS in the future, because of its excellent electrostatic control and transport properties. Experimental results show that, at highly scaled nodes (9-nm channel length), CNFETs can outperform FINFETs and Si-nano wires, providing the best current density at a low operating voltage of 0.5 V.

Due to these device-level benifits, CNFET circuits are assumed to outperform current Si-CMOS. A typical CNFET is shown in Fig. 1. Multiple carbon nanotubes (CNTs) consist of the channel of the transistor, whose conductance is modulated by the gate. The gate, source, and drain are defined according to traditional lithography, and the source drain separation is limited by the minimum lithographic pitch.

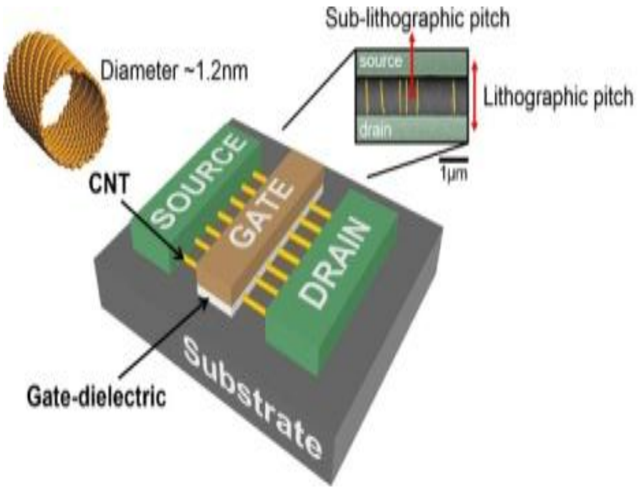

Fig. 1: Single CNFET. The scanning electron microscopy (SEM) image shows the source, drain, and channel region of a CNFET.

There have been important achievements in CNFET technologies since the initial discovery of CNTs and the first demonstration' of CNFETs . Some of the important feature which has been shown experimentally are ballistic transport, sub-10-nm channel length, high CNT density, gate-all-around, and improved contact resistance.

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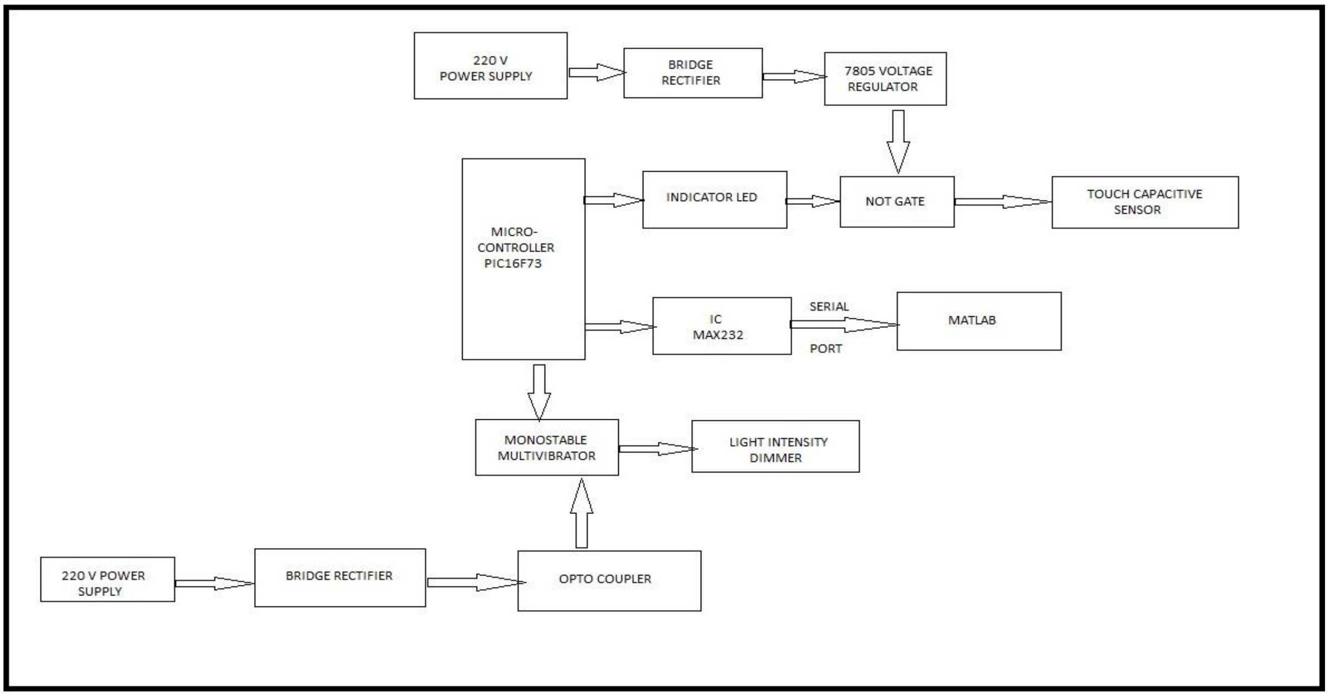

Fig. 2: Block diagram

The rapid progress in carbon nanotube field-effect transistors creates a need for device simulations. Detailed numerical simulations will be useful, but there is also a need for simple, conceptual models to help interpret experiments and guide device design. In this talk, we present a new, analytical theory of the ideal CNTFET and use it to examine device performance limits and design issues. The CNFET characteristics used in our project is of Ballistic CNFET.

II. BACKGROUND

Early dimmers were directly controlled through the manual manipulation of large dimmer panels. This required all power to come through the lighting control location, which could be inconvenient, inefficient and potentially dangerous for large or high-powered systems, such as those used for stage lighting.

When solid-state dimmers came into use, analog remote control systems (such as 0-10 V lighting control systems) became feasible. The wire for the control systems was much smaller (with low current and lower danger) than the heavy power cables of previous lighting systems. Each dimmer had its own control wires, resulting in many wires leaving the lighting control location.

More recent digital control protocols or one of the many Ethernet-based protocols enable the control a large number of dimmers (and other stage equipment) through a single cable.

While challenges towards realizing high-performance and highly energy-efficient CNFET circuits still remain, there have been several promising solutions that can potentially overcome these challenges.

III. ARCHITECTURE

We demonstrate a complete subsystem built entirely out of CNFETs characteristics via matlab: a capacitive sensor interface circuit that converts a capacitive sensor signal to a digital output by a light intensity dimmer. By touching the sensor, a signal is sent to the circuit corresponding to which intensity of light is changed. It has four main blocks: Sensor block, Microcontroller IC block, ICMAX232 block and Intensity control block.

All these blocks are later explained in detail.

Architecture of this project consists of four major circuits, which are:

III.a. Sensor circuit.

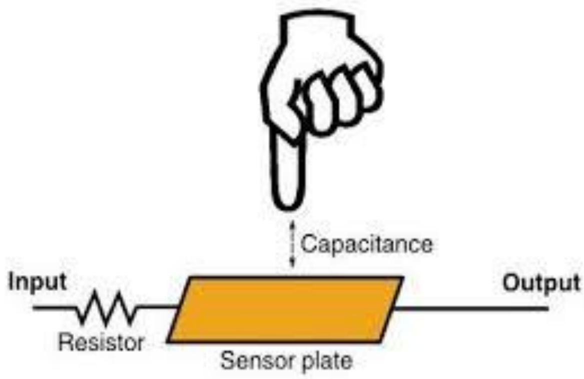

Fig. 3: Touch capacitive sensor

The sensor used during the measurements is touch capacitive sensor which maintains the light intensity of the object. Sensor is used to send input in form of touch signal. The output of sensor cicuit is connected to NOT gate which have six output pins which are connected to six LEDs which glow according to logic passed as input to them via NOT gate.

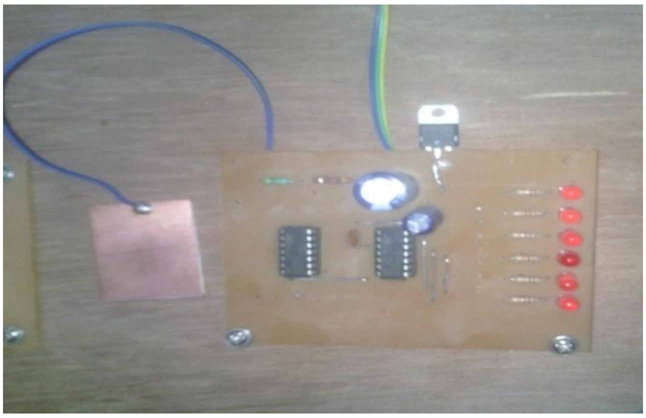

Fig. 4: Circuit with capacitive touch sensor and a set of LEDs

The correct operation of the entire sensor interface circuit is experimentally verified by measuring the digital output for different sensor values. The output, as mentioned above, is taken as the intensity of light through a light sensitive dimmer. An example of the experimentally measured and digitized output of the circuit over time is shown for a range of touch capacitive sensor values. The intensity increases monotonically for increasing sensor values. This shows that the implemented circuit functions correctly.

III.b. Microcontroller IC circuit:

It consists of: Bridge rectifier , 7805 voltage regulator , Crystal oscillator and a microcontroller IC PIC16F73.
The IC has three main functions:
On receiving the signal from the LED circuit, it sends the signal via RS232 protocol IC to PC.
To provide desired frequency.
On receiving signal through cnfet based mat lab coding, it passes the signal to 555timer IC circuit.

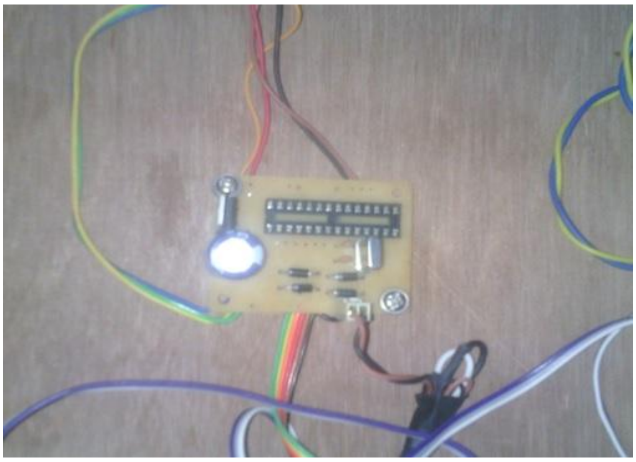

Fig. 5: Circuit containing micro-controller IC PIC16F73, bridge rectifier and a capacitive filter.

Bridge rectifier is used to convert AC signal to DC signal and remove fluctuations and noise. 7805 voltage regulator is used to provide a constant power supply of 5v. Crystal oscillator is used to provide circuit with required frequency.
This circuit further pass on signal to MAX232 cicuit. 21 to 25 pin number of PIC16F73 are the output pins, which provide us with different outputs.

III.c. ICMAX232 circuit:

Contains IC MAX232 which converts RS232 protocol into TTL and vice versa. We know that our hardware is working on Embedded C and CNFET characteristics is implemented via matlab coding. And these two codings cannot relate to each other on its own. So to inter-relate these two software we require this circuit.
Also it contains a 9-pin D-type connector to connect hardware to our computer.This D-type connector gives ICMAX232 circuit output to computer as input and output of computer as input to ICMAX232 circuit.

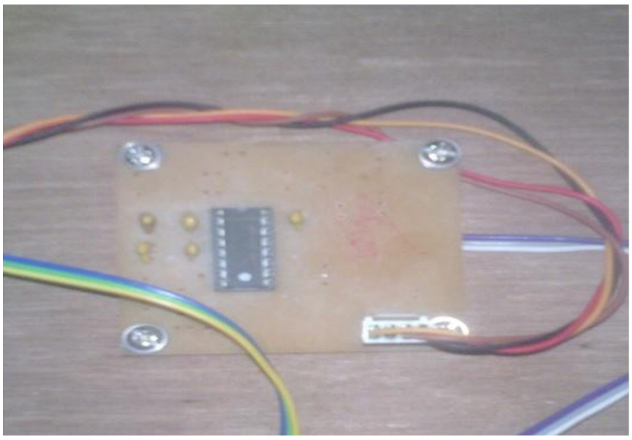

Fig. 6: Circuit with IC MAX232

III.d. Intensity control circuit:

It has a monostable multivibrator consisting of a 555 timer IC which provides a constant clock pulse to the circuit.
It contains a pair of opto-diac coupler used as a zero crossing detector. Along with this, it contains 5 diode-resistor pair, a bridge rectifier, and a capacitive filter to remove noise.

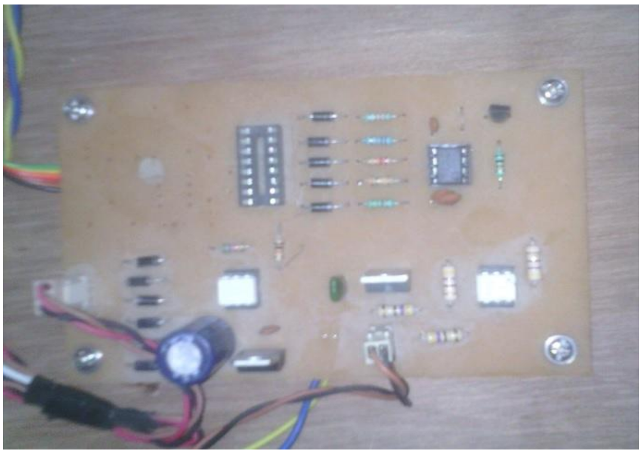

Fig. 7: Light control circuit

This circuit receives the signal via PIC16F73 in form of matlab coding and passes this signal to the bulb in form of corresponding light intensity .It also contains a 7805 voltage regulator to provide system with constant voltage supply.

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IV. IMPLEMENTATION

The advantages of CNFET include smaller chip area, low power consumption, scalability to smaller technologies, robustness to process variations, and low-voltage capabilities [39]. The capacitive sensor interface circuit we have implemented has two key attributes:

Digital architecture

Direct conversion from the capacitive sensor information to the frequency domain, avoiding any intermediate trans- formation of the capacitive sensor to the voltage domain.

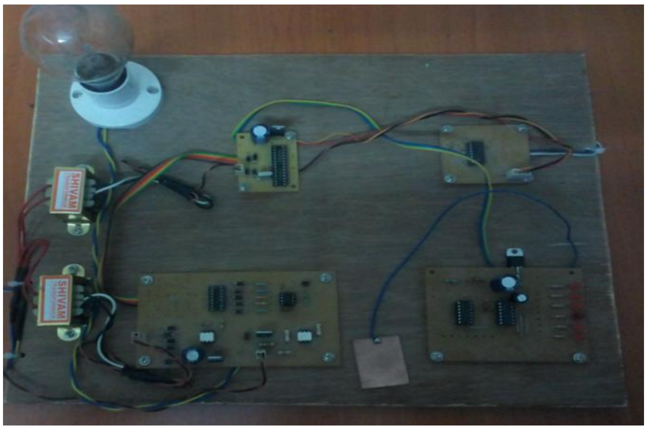

Fig. 8: Circuit implementation of light intensity dimmer

The complete circuit of our project is shown in the figure. In this, input in form of touch is given to the sensor. The sensor passes this signal to the microcontroller which forward the signal to MAX232 IC. It converts the TTL logic to RS232 logic signal which is sent to matlab through a 9-pin D-type connector. The matlab code reads the received signal and send a corresponding signal back to the hardware circuit. The complete coding is controlled by CNFET characteristics. Now this signal is again converted from RS232 to TTL logic and it activates an output pin of microcontroller IC which in turn activates a diode-resistor pair. According to this, the intensity of dimmer is changed.

V. EXPERIMENTAL CIRCUIT PERFORMANCE

The CNFET circuit has been demonstrated in previous section. Now the experimental circuit performance will be demonstrated. In this paragraph we describe the procedure to model the current in SB-CNTFETs., operating in the low voltage, subthreshold regime, in order to determine the functionality of future subthreshold CNTFETs in digital design. The total current in a CNFET depends on the tunnelling current both of the holes and of the electrons through the source and drain Schottky barriers: the current in a CNFET exponentially increases, reducing the thickness of the Schottky barrier at source, with also an increase of the subthreshold current. In comparison with MOSFETs, in CNTFETs we have not the minimum current for Vgs = 0 V, but to Vgs = Vds/2. This is true for all CNFETs having the same metal used for the gate, drain and source. This minimum condition (Vgs = Vds/2) is independent on metal work function. In order to model the Id-Vgs characteristics, we have implemented a Matlab code, characterized by a minimum current at Vds/2, threshold voltage and exponential subthreshold current. In particular the following equations allow to value the current for a n-channel transistor (for a p-channel transistor we have the same expressions with negative voltages values):

$$V_{th} = c*\left(\frac{D_t}{2}\right)+d \quad (1)$$

$$V_{min} = \frac{Vds}{2} \quad (2)$$

$$I_{Dm0} = 6.96*10^{-20}*e^{(9.17D_t)} \quad (3)$$

$$I_{Dmin} = I_{Dm0}*e^{(h_n|Vds|)} \quad (4)$$

$$I_{Dnchannel} = I_{Dmin}*e^{(a_n|Vgs-V_{min}|)} \quad (5)$$

where c is equal to -0.125*10-9 V/m, d is equal to 0.6625 V and hn is a constant depending on the process variations. Moreover an is a fitting parameter, dependent on gate oxide thickness (tox) and on CNT diameter (Dt). In the proposed model we have assumed EFermi = ECNT midband_gap and therefore the p-channel current characteristics are equal to the n-channel I-V data. The obtained Id-Vgs characteristics, for a n-channel and a p-channel CNTFETs, are shown in Fig. 4 and 5 respectively. In Fig. 4 we have assumed Dt = 1.3 nm and hn=16 .1 V-1s, while in Fig. 5 Dt = 2.5 nm and hn = 14 .1 V-1s.

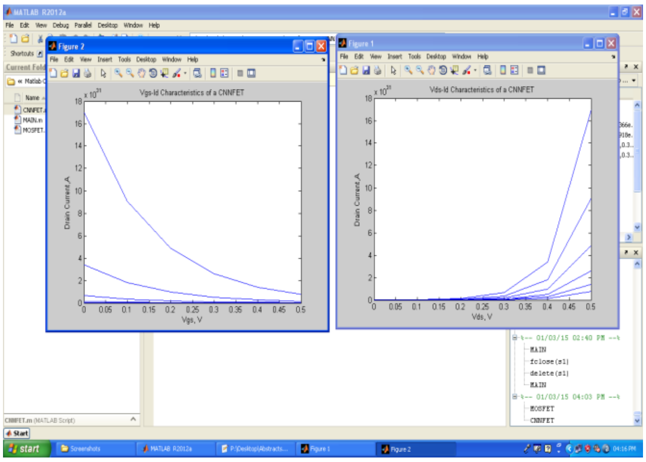

Fig. 9: Output waveform of the Vds-Id and Vgs-Id characteristics of cnfet for different values of the capacitive sensor

We show that by varying the values of resistance, the Vds vs Id and Vgs vs Id characteristics can be varied. The CNTFET subthreshold regime is verified between the two threshold voltage (Vth) points.

These points have the same distance from the minimum voltage. The distance from the minimum to the threshold is VSUB (Vds) = Vth - Vmin. In order to compare our model with experimental results, in Tables 1a) and 1b) we have reported the numerical values of Vmin, IDmin and Vth.

Table1: Numerical values of Vgs and Idn(channel)

State	Vgs	Idnchannel
1	2.5	9.56
2	3	4.95
3	3.5	2.56
4	4	1.32
5	4.5	6.88
6	5	3.56

VI. CONCLUSION

CNFETs offer the potential for significant improvements in energy efficiency. However, while high-performance isolated CNFETs and stand-alone logic elements have been demonstrated, inherent CNT imperfections and variations have prohibited larger and more complex CNFET circuits. We experimentally demonstrate the ability to control light intensity variations through CNFET characteristics through matlab. As a result, these experimental realizations enable integration and successful demonstration of larger and complex CNFET circuits, such as the presented complete capacitive sensor interface circuit. We experimentally demonstrate the following factors. Effectiveness of microcontroller is shown Yield enhancement of CNFET circuits is demonstrated through matlab version r2012a. Robust and repeatable CNFET circuits are shown, allowing for multiple and repeatable working circuits. The complete subsystem built entirely using CNFETs is demonstrated: a capacitive sensor signal-to-digital interface circuit, which has been interfaced with a light intensity dimmer for demonstration. Thus, from the experimental characterization of smaller CNFET circuits to the demonstration of th complete sub system of a sensor interface built entirely out of CNFETs via matlab, we have shown that CNT-based technologies are indeed a viable emerging technology with promising potential for low-energy and high-performance circuit implementations.

VII. FUTURE SCOPE

Switching from a traditional to an LED based lighting system can yield significant energy savings. Additional reductions in power consumption can be achieved by intelligent lighting systems that incorporate monitoring, control and communication networks. Such systems offer features ranging from dimming, motion sensing, ambient light sensing and daylight harvesting, wireless and powerline communication, to monitoring various parameters such as energy consumption, potential LED failures and LED temperature.

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