Performance and analysis of synchronous voltage mode buck converter using 180nm

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Abstract: Power electronics circuits with high conversion efficiency and flexible output voltage use switched-mode dc-dc converters. These dc-dc converters are designed to regulate the output voltage against the changes of the input voltage and load current in electronic devices. Thus various advanced control methods of dc-dc converters with best performance under any conditions are required to meet the real demands. Conventional dc-dc converters were controlled by linear voltage mode and current mode control methods. In this paper structure of PWM buck converter with different parts are introduced and simulated using cadence software.

Keywords: Linear regulator; Switch mode power supply; PWM (pulse width modulation); Operational amplifier; on time controller; Saw tooth generator

1. INTRODUCTION

The portable electronic devices laptops, MP3 players, cellular phones, using batteries as power supply unit have dc-dc regulators as their back bone. Portable devices usually comprise of several sub-circuits that ought to be furnished with different voltage levels, which aren't an equivalent as battery's voltage level which is that the main supply voltage. Use of dc-dc converter offers a method to generate multiple voltage levels to feed different sub circuits in devices from a single dc supply voltage.

Switching mode power supply (SMPS) and linear regulators are the two main methods employed to convert an unregulated DC voltage to a regulated DC level irrespective of changes in load current and input voltage.

Linear Regulator: Linear regulator is a power supply which uses switches and voltage divider network for adjusting output voltage

The linear regulator operates continuously, thus its efficiency is a smaller amount than switching regulator and it produces far more heat comparison to SMPS. The variable resistance as heat to regulate output voltage and hence a large volume heat-sink would be required to reduce the circuit's temperature.

SMPS (Switching mode power supply): Switching-mode power supply which is also called as switching-mode DC to DC converter is a type of power supply which uses switches (usually in the form of transistor) and low loss components like inductors, capacitors and transformers for regulating output voltage.

2. DC/DC BUCK CONVERTER

Buck convertor could be a form of switching-mode power provide that is employed for stepping-down DC voltage level. Switch controller block and power block square measure 2 main components of buck converter's circuit. "It will operate in Continuous physical phenomenon Mode (CCM) or in Discontinuous physical phenomenon Mode (DCM), counting on the wave of the electrical device current. These 2 ways is applied with either PWM (Pulse breadth modulation) or PFM (pulse frequency modulation) techniques. The PFM is additional economical once the load current is simply too low. Figure 2.1 depicts the DC/DC buck convertor circuit. sometimes P-channel MOSFET (PMOS) is most popular to be used as a high aspect switch (HSS) rather than NMOS, as a result of if the NMOS is used as a high aspect switch since each the gate and therefore the supply square measure connected to the voltage provide then it might be laborious to drive it [1].The diode (which is employed in typical buck convertors) is sometimes replaced by Associate in Nursing n-channel MOSFET (NMOS) as a coffee aspect switch to boost power potency of converter. Since fall in conducted MOSFET is extremely low comparison to conducted diode (even from Schottky diode that has low forward voltage drop), the full power loss in DC/DC convertor are important reduced by this replacement.Figure2.1 illustrates the schematic model of a generic buck convertor.When high aspect switch Q1 is on, a path are provided for the DC input voltage to charge the electrical device and provides the load current. Charging can continue until the output voltage reaches to reference voltage Vref, then the management half turns off the high aspect switch to stay the output voltage getting ready to Vref. so there's no path to charge electrical device, so electrical device changes its voltage polarity and therefore the current flows within the same direction through the low aspect switch Q2 that is turned on by switch controller half. Discharging can continue till the output voltage reaches below of the reference voltage, then management half once more activates the high aspect MOSFET to compensate the output fall and this cycle continues till complete regulation of output voltage [3].

This method is accomplished by sensing the output voltage of the circuit by suggests that of a feedback loop that adjusts the duty cycle (Eq.3.1) to manage on and and off state of the MOSFET switches underneath such that frequency fsw .

$D = t_{on}/T = t_{on}/(t_{on}+t_{off})$ ……………….. 2.1

Where ton is that the measure that power M

PWM Switch Controller: The PWM generator is that the major half in DC/DC converters.It controls the switches' ON and OFF state to manage the output voltage, in different words by dynamical the duty cycle tries to stay output voltage capable set reference voltage.during a buck convertor if the reference voltage is ready to low voltage the PWM generator reduces the duty cycle by holding on the HSS for a brief time whereas the output reference voltage is high, the PWM generator will increase the duty cycle by holding on the HSS for the foremost of cycle to rectify the output voltage.Figure shows the schematic model of a PWM buck convertor.

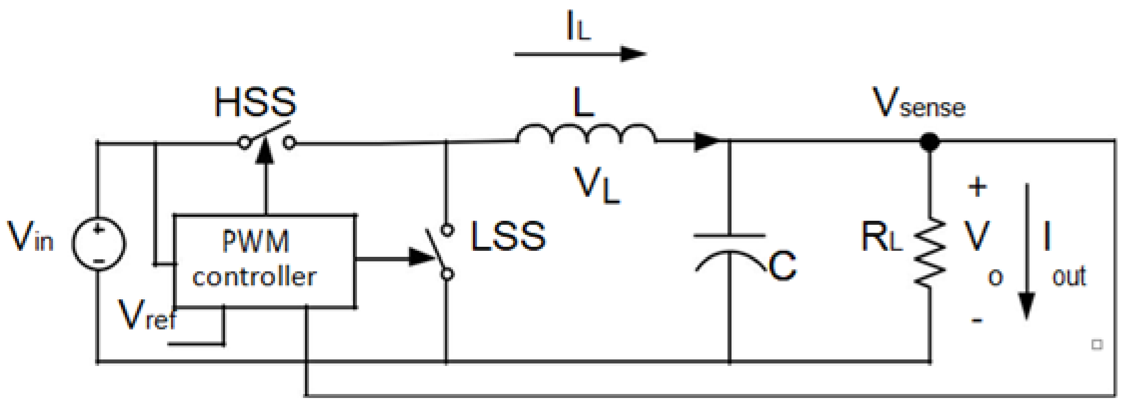

Figure 2.1 PWM Buck converter schematic

PWM controller contains 2 main parts; voltage error-amplifier and voltage comparator.The error-amplifier compares the feedback voltage (applied to inverting input) to reference voltage (applied to non-inverting input) then their distinction that is termed voltage error signal when amplification is Comparator compares this error voltage to saw tooth ramp that's generated by ramp generator, if voltage is higher than output voltage of comparator goes high however once is lower than the output of comparator goes low to regulate the change duty cycle.

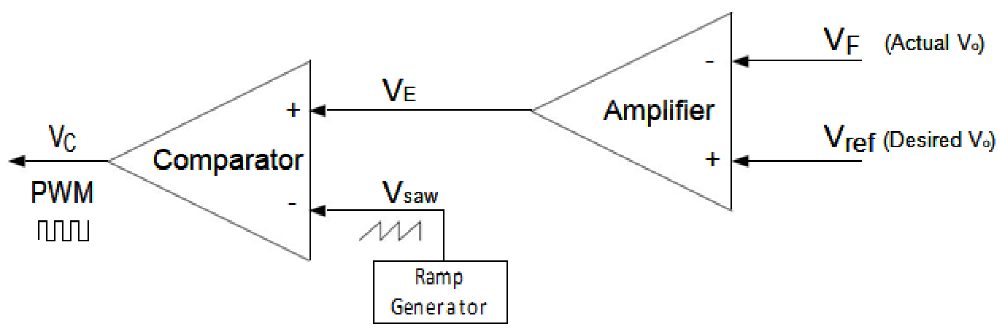

Figure 2.2 PWM generator configurations

Error voltage is inversely proportional to reference voltage for example when the voltage is low the error voltage is increased by error amplifier to adjust the switching duty cycle when the error voltage is high the pulse width of PWM wave at the output of the voltage comparator is increased to keep off high side switch for most of the time of each cycle in order to reduce duty cycle to regulate the output voltage.

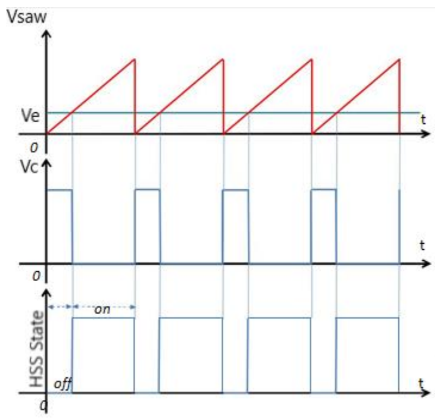

Figure 2.3 Duty cycle Waveform

when V_{ref} is Low

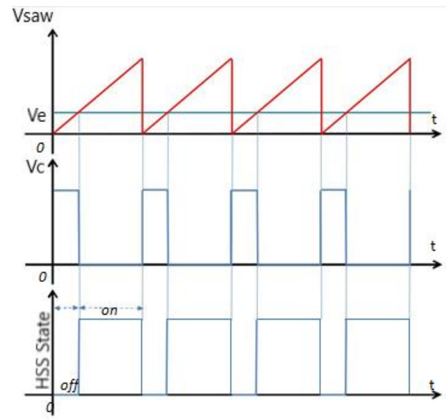

Figure 2.4 Duty cycle Waveform

when V_{ref} is High

3. BUCK CONVERTER DESIGN

OPAMP: An Operational Amplifier, or op-amp for brief , is actually a voltage amplifying device designed to be used with external feedback additives along side resistors and capacitors among its output and enter terminals. These remarks additives decide the resulting function or "operation" of the amplifier and by virtue of the extraordinary remarks configurations whether or not resistive, capacitive or both, the amplifier can perform numerous specific operations, giving upward thrust to its name of "Operational amplifier".

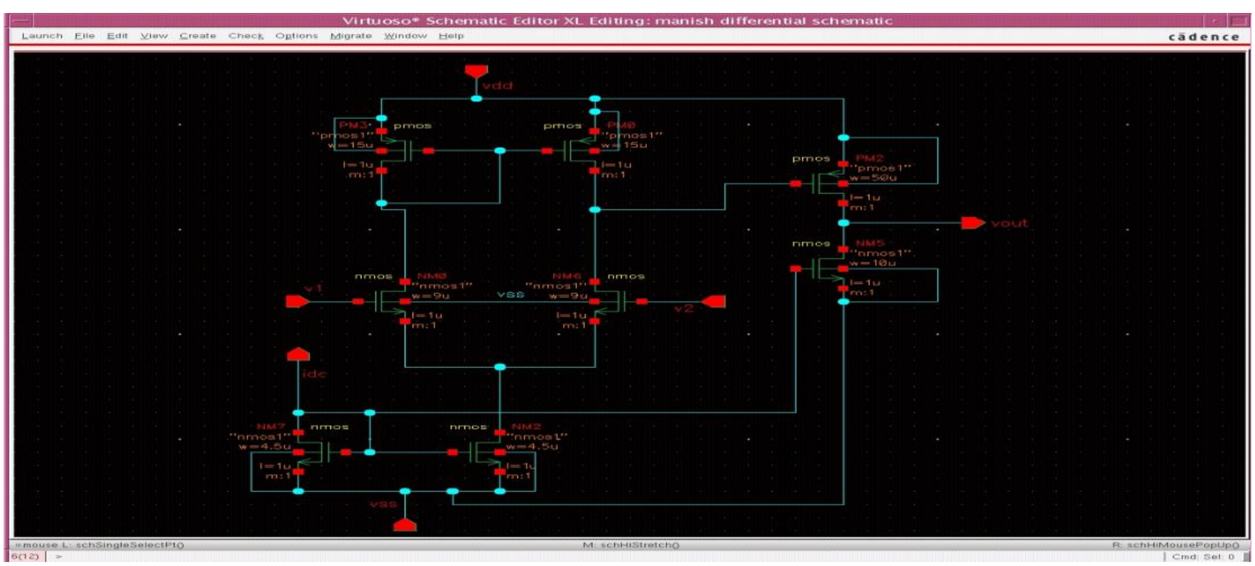

Figure 3.1 Schematic of op-amp

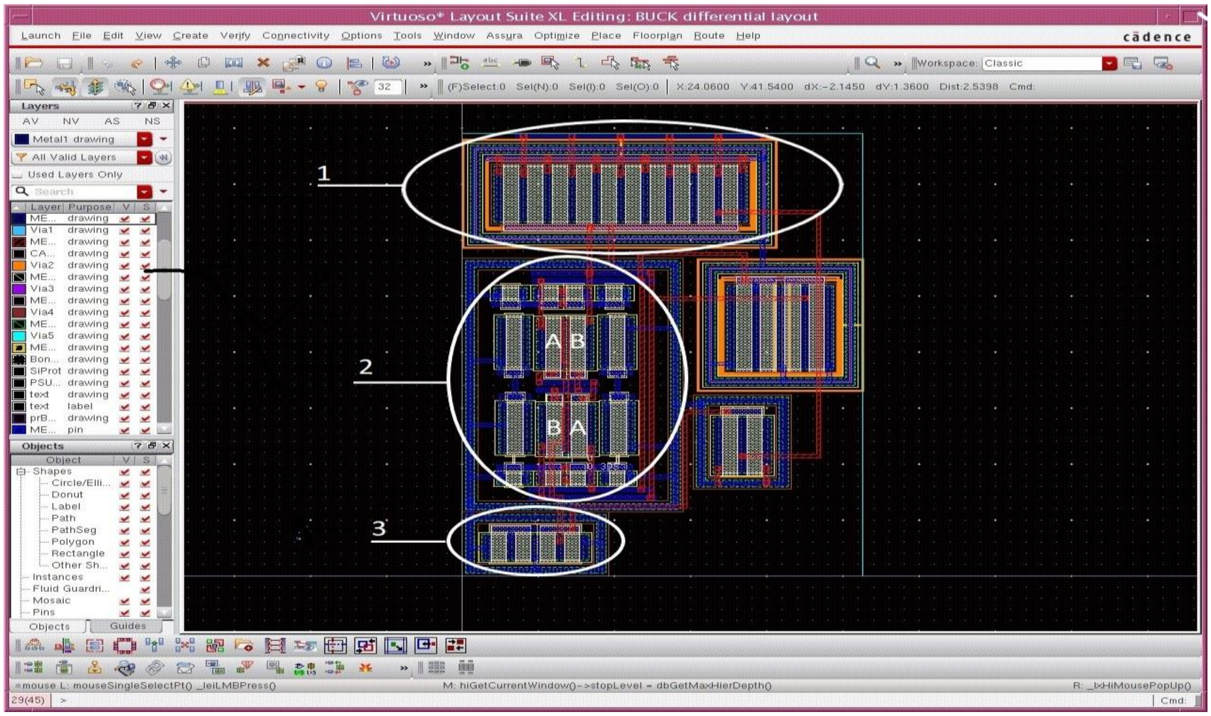

Figure 6.2 Layout of op-amp

Driver: It is used as a buffer which contains two inverters connected in series. The driver is used in the buck converter to stabilize the output.

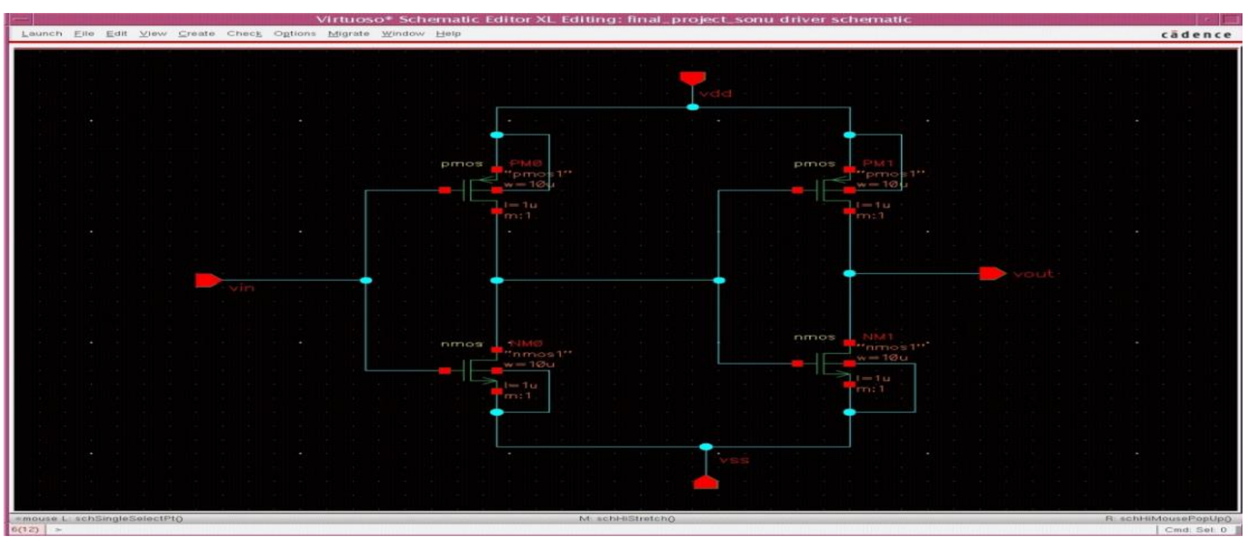

Figure 3.2 Schematic of Driver

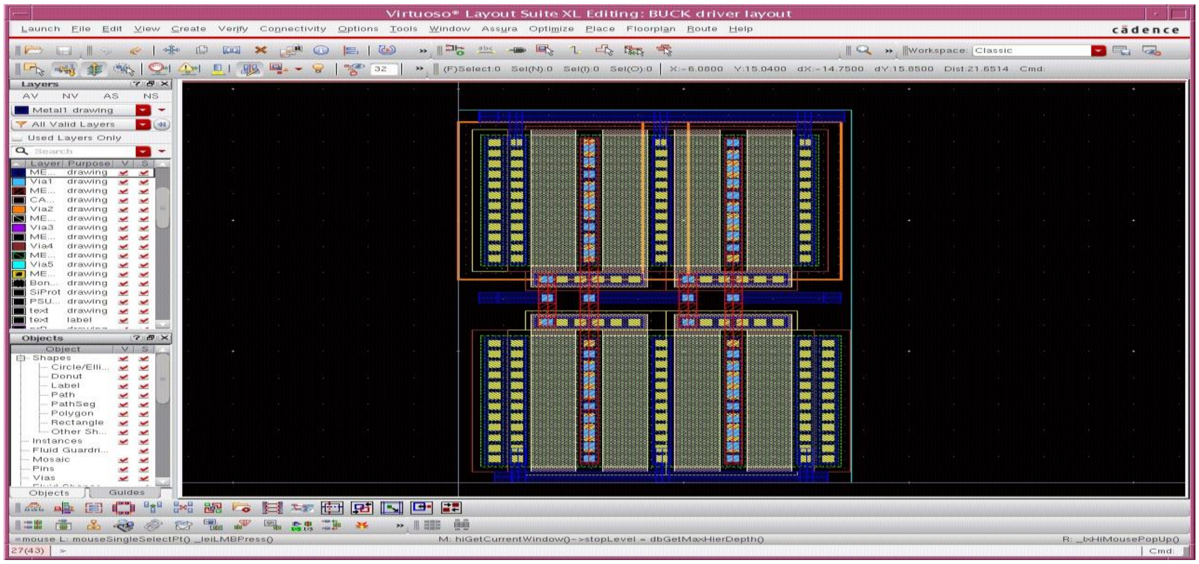

Figure 6.4 Layout of Driver

Ontime Controller: The main purpose of this controller is to provide a delay such that it takes larger time for the capacitor to charge and discharges it at the faster rate. It is basically used in the sawtooth generator for the generation of saw tooth wave.

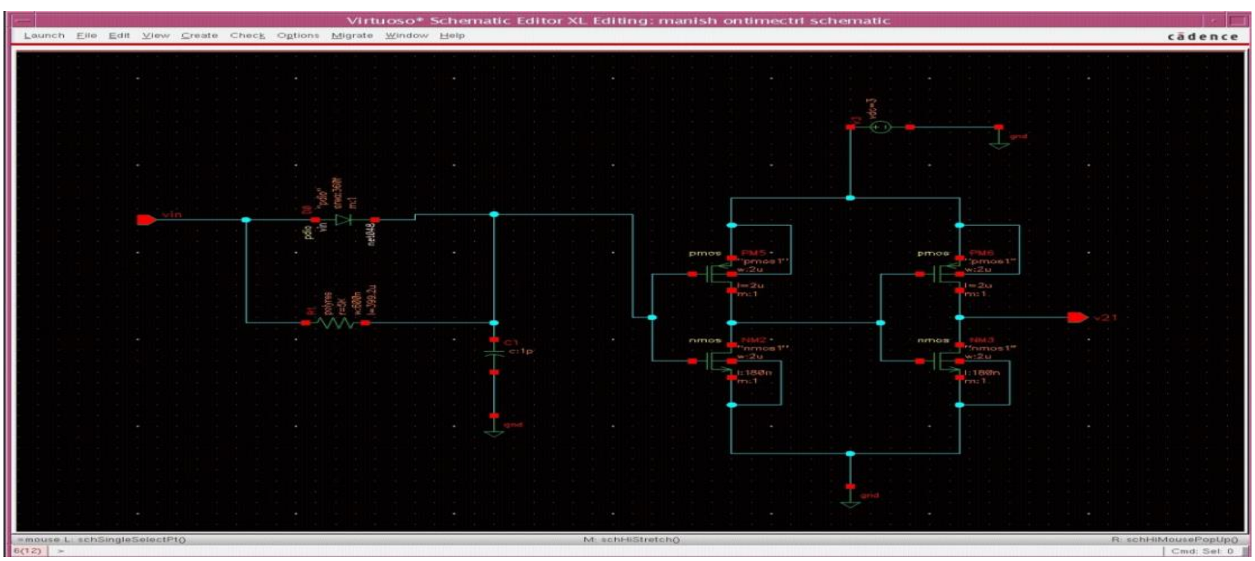

Figure 3.3 Schematic of Ontime

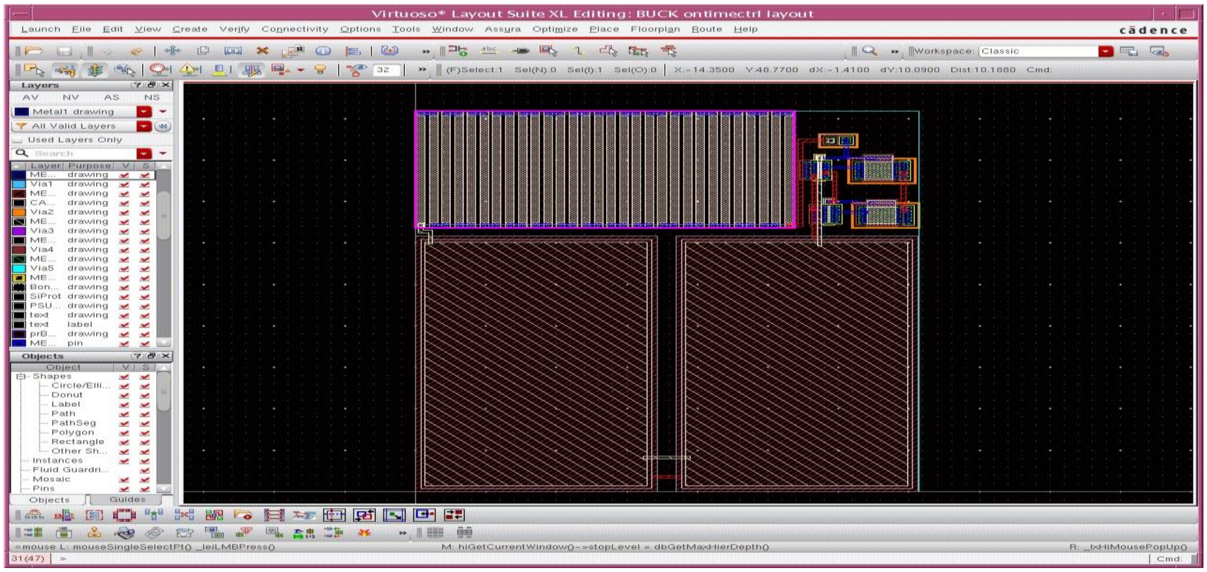

Figure 3.3 layout of Ontime

Saw tooth: The opamp is used as comparator in the saw tooth grnerator .The generated saw tooth wave is fed as an input to the comparator along with the error voltage to obtain the PWM pulse. The current mirror used to maintain constant current throughout the circuit.

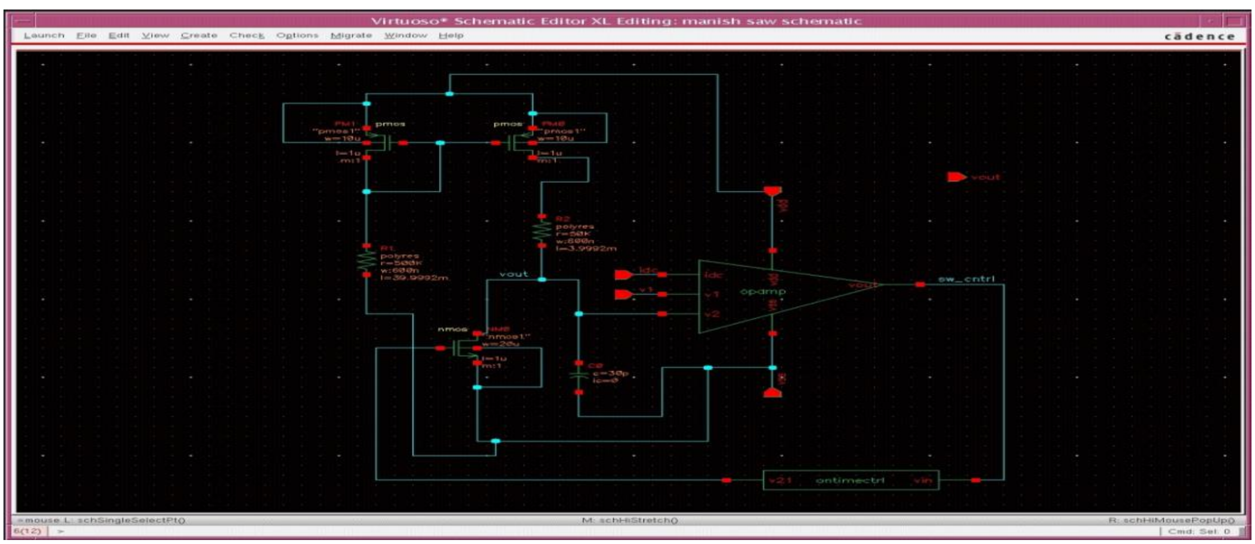

Figure 3.4 Schematic of Saw tooth

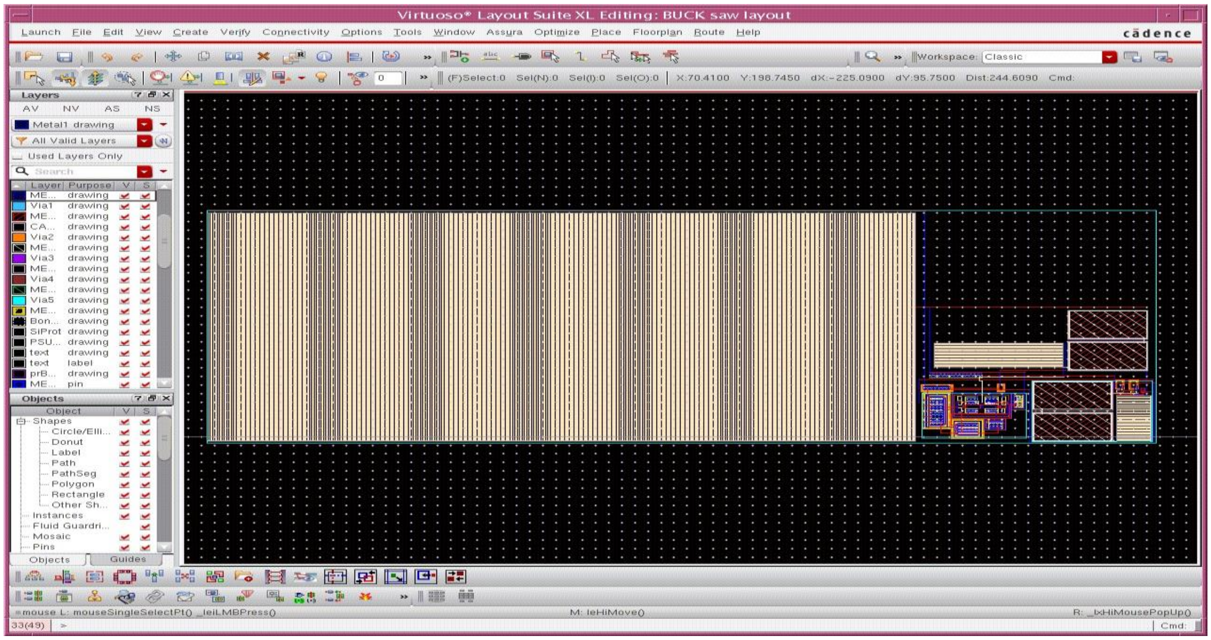

Figure 6.8 Layout of Saw tooth

PWM: The PMOS transistor is used as power mosfet or HSS and used as a switch to control ON and OFF state to regulate the output voltage by changing the dutycycle which keeps the output voltage equal that is set to reference voltage.The opamp is used as the error amplifier and the comparator.Saw tooth wave and erroe amplifier ouput is fed as input to the comparator.

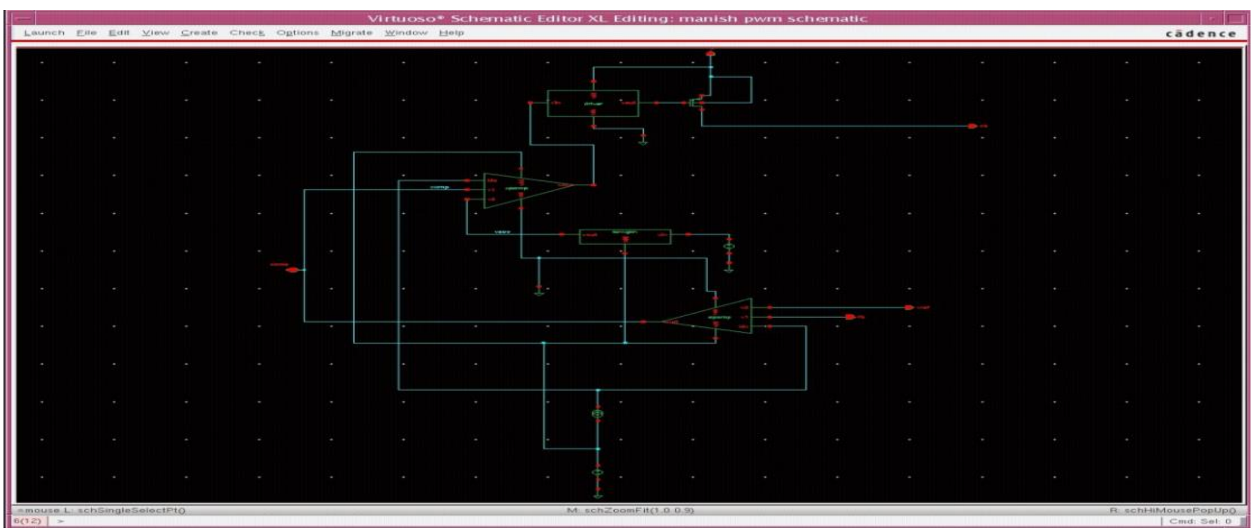

Figure 3.5 Schematic of PWM

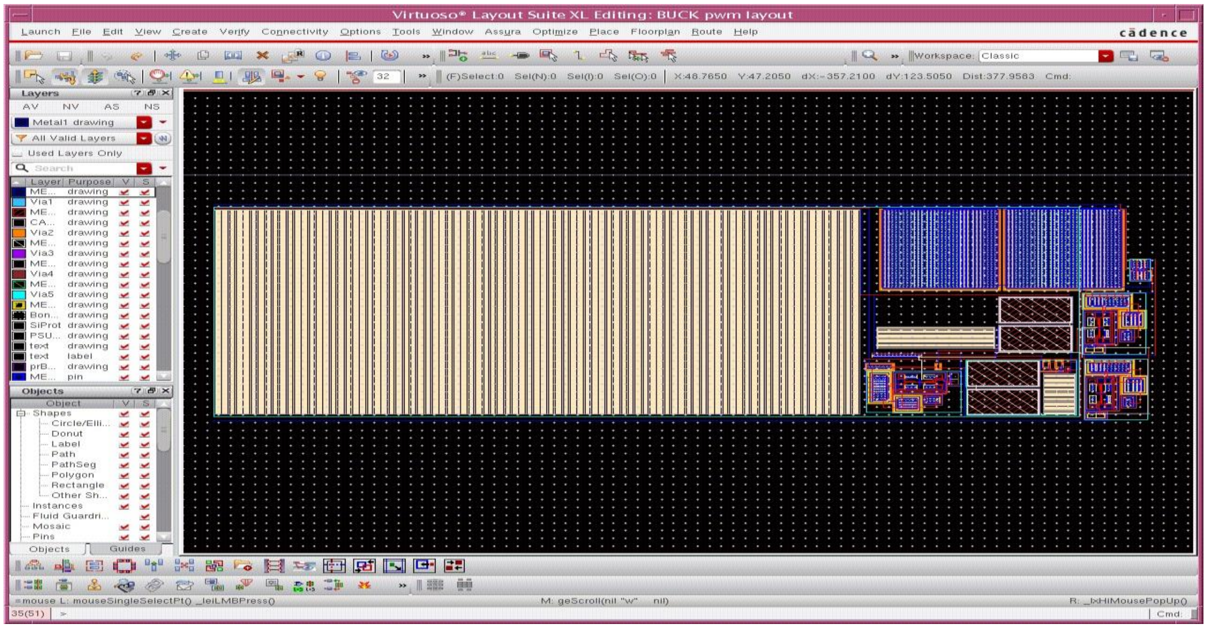

Figure 6.11 Layout of PWM

BUCK: The final schematic of the BUCK converter where the type II compensation circuit is used to maintain the constant voltage at the output. The NMOS transistors are used to regulate the two high load resistors. The diode is used ad LSS switch as it is discussed in the DC/DC BUCK converters.

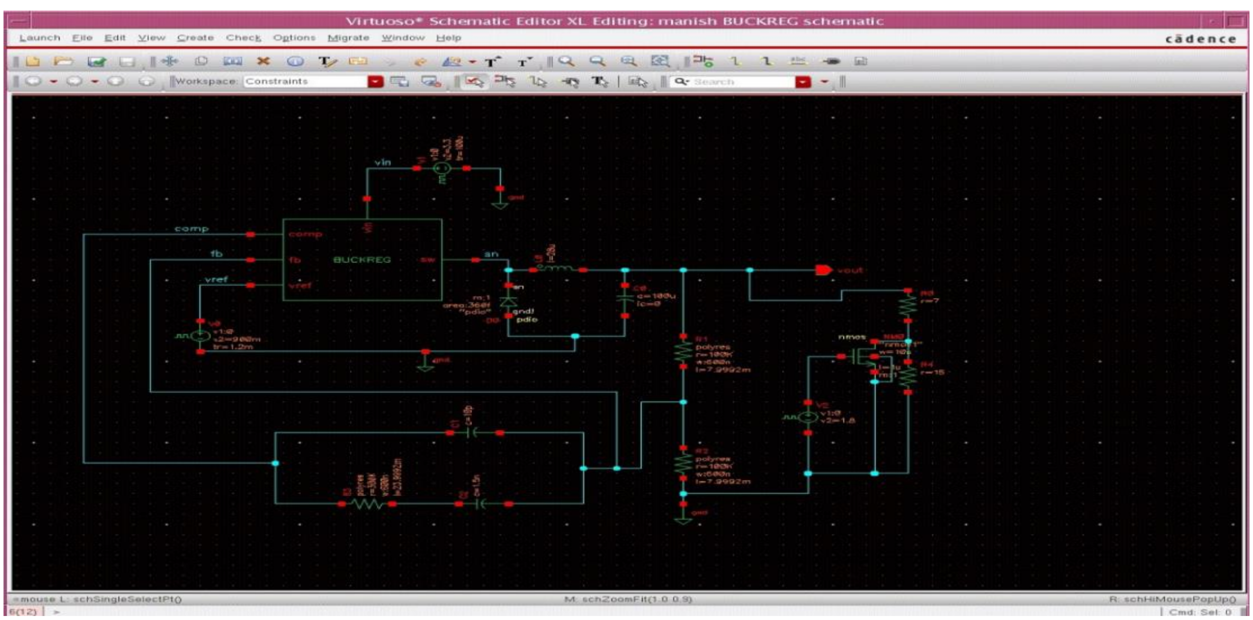

Figure 3.6 Schematic of BUCK CONVERTER

4. RESULTS

The specifications of different components used in each instance with different parameters are listed in the table 6.1as shown below:

Table 6.1 Specifications and total area of each Instance

Serial No.	Instance	No. of Components	Components	W/L ratio	Resistor type	R (Ohms)	Capacitor type	C (Faraday)	Total Area Used in Layout (L*B)
1	Op-amp	3 5	P-mos N-mos	15u/1u,50u/1u 9u/1u,4.5u/1u,10u/1u	-	-	-	-	26.31*40185
2	Driver	2 2	P-mos N-mos	10u/1u 10u/1u	-	-	-	-	35.67*45.96
3	On time	2 2 1	P-mos N-mos P-diode	2u/2u 2u/180n	Polyres	5K	Mim Cap	1p	8.72*14.17
4	Saw	2 1	P-mos N-mos	10u/1u,1u/1u 20u/1u	Polyres	500K 10K	Mim cap	2p	135.43*361.52
5	PWM	1	P-mos	10u/1u	-	-	-	-	391.1*140.545

The transient response simulation results of comparator (with driver), power switches' on-off state, feedback voltage, reference voltage and output voltage waveforms. The specifications are given in the below table

Table 4.1 Specifications of BUCK

Serial No.	V_{in} (volts)	V_{ref} (volts)	Resistor (Ohms)	Capacitor (Faraday)	Inductor (Henry)	Components
1	3.3	0-0.9	300k 100k 15k 7k	100u 10p 1.5n	28u	Nmos (10u/1u)

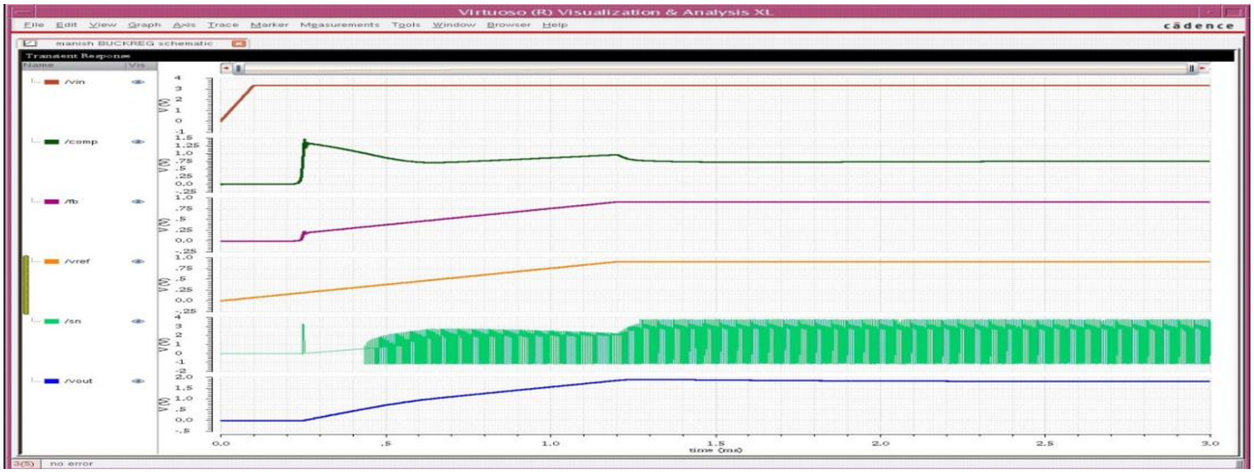

Figure 4.1 Output waveform at different nodes

The final output waveform of the BUCK converter is shown below where the voltage is stepped down from 3.3V to 1.8V

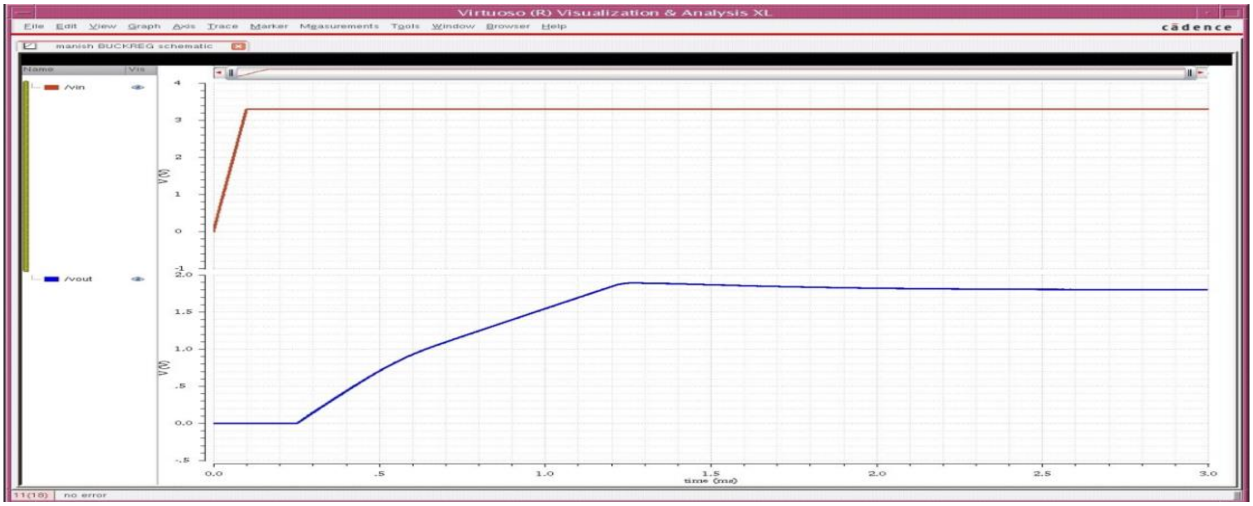

Figure 4.2 Output waveform

References

1]Kazimierczuk, “Pulse-width Modulated DC-DC Power Converters”, Edition, Wiley.

[2]“High voltage tolerant integrated Buck device in 65nm a try of.5V CMOS”, IEEE International conference on Circuits and Systems (ISCAS), pp.

[3]Ajith Jain, “Synchronous vs. Aynchronous Buck Regulators”, SEMTECHCorp.,http://www.digikey.com/Web Export/Supplier Content/Semtech_600/PDF/Semtech
synchronous-vs-asynchronous-buck-regulators.pdf?redirected=1 , accessed: Mar 2012.

[4]Lee, “Multiphase coupled-buck converter-a novel high economical twelve V device module”, IEEE Transactions on Power physics, pp.

[5]Hristov, “Buck device for low power applications”, IEEE twenty sixth International Conference on physics, pp.

[6] Rashid, “Power physics, Circuits, Devices And Applications,” 2nd ed.

[7] Juing-Huei Su; Jiann-Jong Chen; Dong-Shiuh Wu; , "Learning feedback controller form of shift converters via MATLAB/SIMULINK," Education, IEEE Transactions on , vol.45, no.4, pp.

[8] Ang, S.S.; , "A practice-oriented course in shift converters," Education, IEEE Transactions on ,vol.39, no.1, pp.14-18, Feb 1996.

[9] Hyun-Hee Park, Young-Jin Woo, Gyu-Hyeong Cho, “A absolutely integrated wide-band illness controller with capacitor-less compensation for diminution DC-DC converter”, IEEE International conference on Circuits and Systems (ISCAS), pp.

[10] Maxim Integrated product, Inc., “An Introduction to Switch-Mode Power Supplies”, Application Note 4087, Sep 27, 2007.

[11] Daniel Meeks, “Loop Stability Analysis of Voltage Mode Buck Regulator With altogether entirely altogether totally different Output capacitance varieties – Continuous and Discontinuous Modes”, Application Report

[12] SLVA301, state Instruments Knight, “Design of a twenty megacycle DC-DC Buck device with eighty four efficiency for mobile Applications”, IEEE International Conference on VLSI vogue, pp.

[13] Doug Mattingly, “Designing Stable Compensation Networks for Single section Voltage Mode Buck Regulators”, Technical temporary TB417.1, Intersil Americas Iraqi National Congress., Dec 2003.

[14]pwm dc-dc power converter technology underpins many energy conversion systems including renewable energyfollowing the success of pulse-width modulated dc-dc power converters this second edition has beenmarian k. kazimierczuk wright state university, dayton, ohio, usa.