A novel approach to design Charge Pump

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Abstract—Charge Pump is a circuit capable to scale up and down the output level compares to DC supply voltage. A buck converter (down converter) has low output voltage and boost converter (up converter) has high output voltage. In battery an operated hand held device it is frequently required to boost up and down the voltage level, charge pump uses a chain of capacitor for charging and discharging. In this work a programming feature have been enabled to scale up or down voltage level. Multiplexer based programming have limitation buck and boost converter function parallel results in high power consumption. Comparator based programmable charge pump are efficient design, used have choice to set a particular voltage to function each individually; A 5V supply voltage up to 22V and buck down to 320mv.

Keywords—charge pump; Boost; Buck; voltage multiplier

I. INTRODUCTION

Buck-boost converter scale up or scale down dc input voltage to required level. This works presents a DC to DC converter with programming feature. Charge pump is a DC to DC converter contains a number of capacitors as energy storage elements. When outputs of charge pump higher than input voltage known as boost converter similarly output of charge pump lower than input voltage is buck converter. Charge pumps consist of MOS working as diode for switching devices and capacitor. Figure1 shows a simple voltage doublers circuit using charge pump. Switch S1 and S3 charges the capacitor with clock phase to the maximum level of supply voltage V_{DD}. Switch S2 is closed and the bottom plate of the capacitor assumes a potential VDD, while the capacitor maintains its charge of V_{DD}.C during anti clock phase [1].
Here (Vout -VDD).V=VDD.C

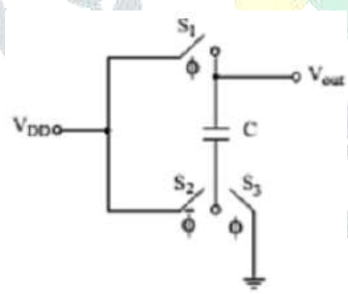

Fig. 1 Voltage Doublers using charge pump

II.CHARGE PUMP AS DC TO DC CONVERTER

A. Boost Converter

A boost-converter is an up-converter which boost up output voltage that of input voltage source. Dickson charge pump is the fundamental dc-to-dc converter. The circuit consist of two anti-phase clocks with voltage same as supply voltage VDD as shown in figure2. N stage Dickson charge pump contains N diode (implemented using MOS) connected in series, each stage have capacitors as energy storing element. During clk phase 1st diode conduct capacitor charge to Vclk-Vth. When clk is at logic low, the node 1 becomes Vin+(Vclk -Vth). During clkbar phase diode D2 conducts until voltage at node 2 reaches Vin + (Vclk Vth) Vth. When clk goes to logic low again voltage at node 2 reaches Vin + 2(Vclk Vth). For N stage output voltage is given as [2-4]. In presence of a load which draws the current, the output voltage is the Output voltage of each node which is function of previous node voltage and oscillating frequency. Voltage change occur at each node of a charge pump is voltage fluctuation V.

$$V_{out} = V_{in} + N(V_{clk} - V_{th}) - V_{th}$$

In presence of a load the output voltage is given by

$$V_{out} = V_{in} + N(V_{clk} - V_{th} - I_{out}.f_{osc} / C) - V_{th}$$

Output voltage of each node is function of previous node voltage and oscillating frequency. Voltage change occur at each node of a charge pump is voltage fluctuation ΔV

$$\Delta V = V_{clk} - I_{out}.f_{osc} / C$$

Voltage pumping gain of a charge pump Gv is given as

$$G_V = V_N - V_{N-1}$$

All the coupling capacitor has the same value C and operating frequency fosc, 5th MOSFET is used to drive the output. Limitation of Dickson charge pump is body effect; though the successive boost of the voltage on internal nodes causes an increase in the threshold voltage of each transistor which consequences in the degradation of the voltage gain. All the simulation work is carried out using cadence virtuoso cmos 180nm technology. Figure3 shows the dc analysis of simulation result for input voltage ranges from 1 to 5V; output boosted up 2 to 22 V

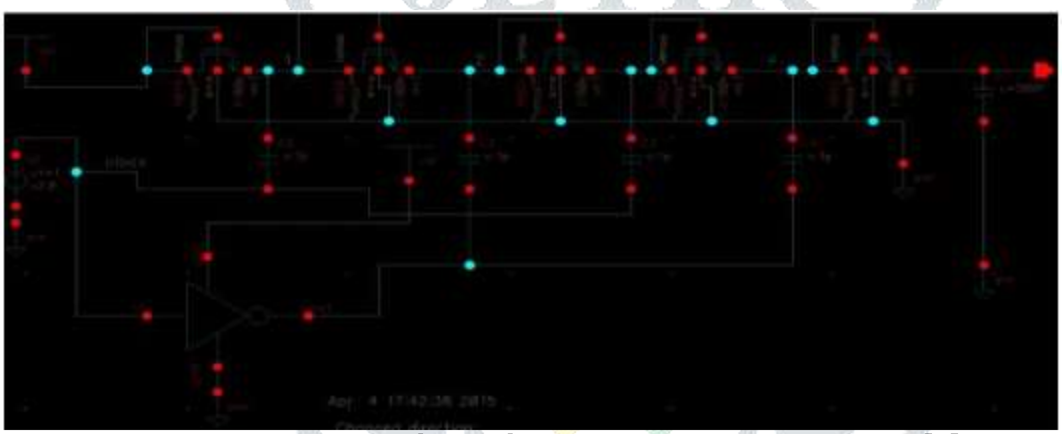

Figure 1 Dickson Charge Pump as Boost Converter [5]

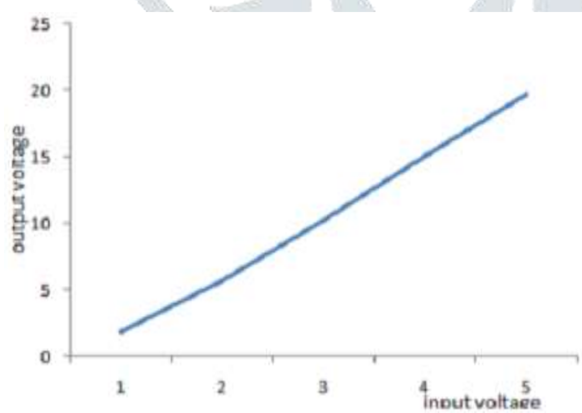

Figure 2 DC Analysis of Dickson CP

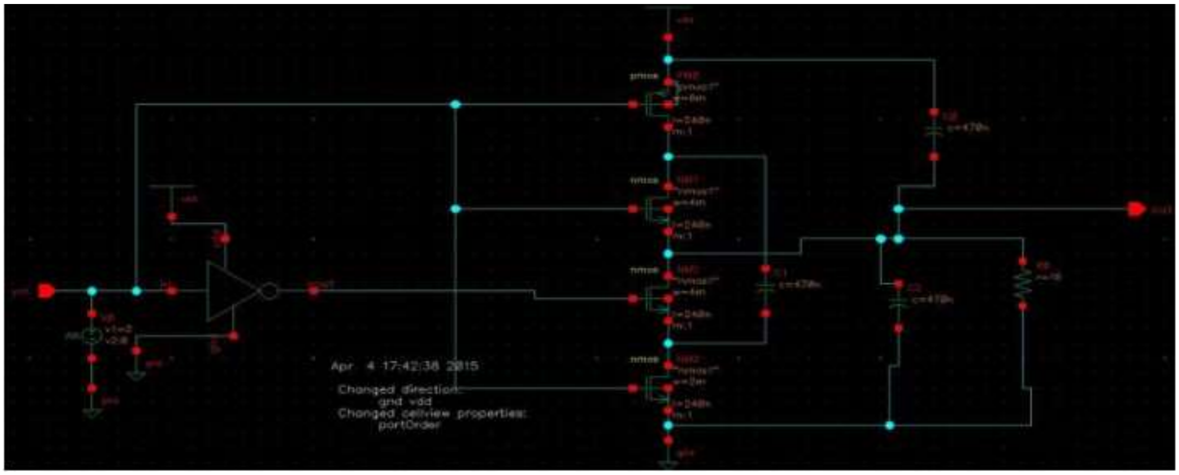

Figure 3 Buck Converter [2]

B. Buck Converter

Buck-converter is a down-converter which scales downs the output voltage that of higher input voltage source. It generates the output voltage which is lower than the input voltage [6,7,8].

Figure4 shows the DC-DC buck converter. It contains four transistors one PMOS and other three are NMOS. When CLK is high transistors M1, M3 are turned off and M2, M4 are turned on. Load current charges the output capacitor C1. Simultaneously it discharges parallel capacitors C2 and CX. In the second phase, when CLK is low switches M1, M3 are on and M2, M4 are off. The top capacitor C1 is connected in parallel with flying capacitors CX. It means that load current charges C1 and CX while discharging the bottom capacitance C2. Figure5 shows the DC simulation result of buck converter for input ranges from 0 to 5V. for input 2V output falls to 450mv for 5V output falls to 320mv.

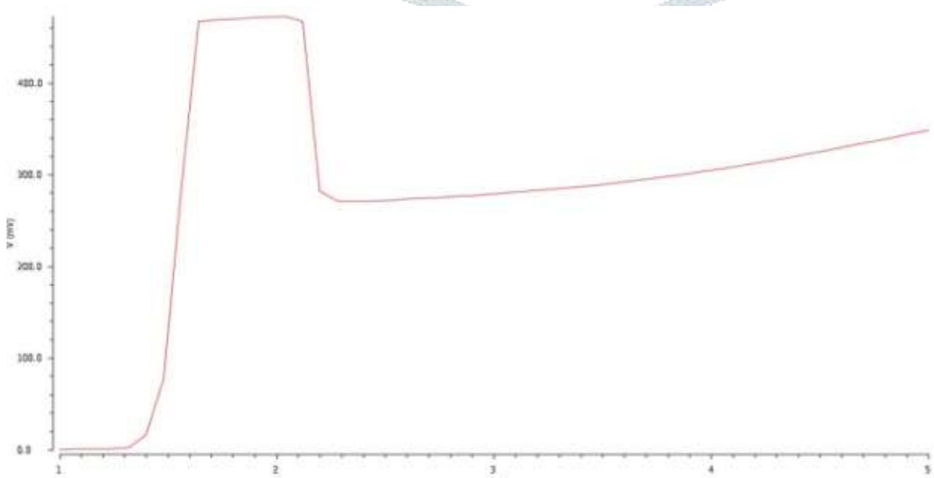

Figure 4 DC Analysis of Buck Converter

III. **PROGRAMMING OF BOOST BUCK CONVERTER**

A. Programming Using Multiplexer

Instead of using buck and boost converter individually the buck-boost converter has been combining in single circuitry, they are considered as spare device which may be taken as to required output level shown in table1.

Table1 Boost-buck conversion methodology

Boost converter	Vin < Vout	Iout < Iin
Buck Converter	Vin > Vout	Iin < Iout

In this proposed work a 2:1 multiplexer is used for selection of converter shown in figure6. Boost and buck converter operated separately at common clock signal. Depending on multiplexer select line any one of the voltage routed out. When select line is 0 then the output will be of boosted high, if select line is 1 the buck converter functions and output voltage level falls as shown in fig when S=0 Vout is boost output and when S=1 Vout is the buck output. Figure7 shows the simulation

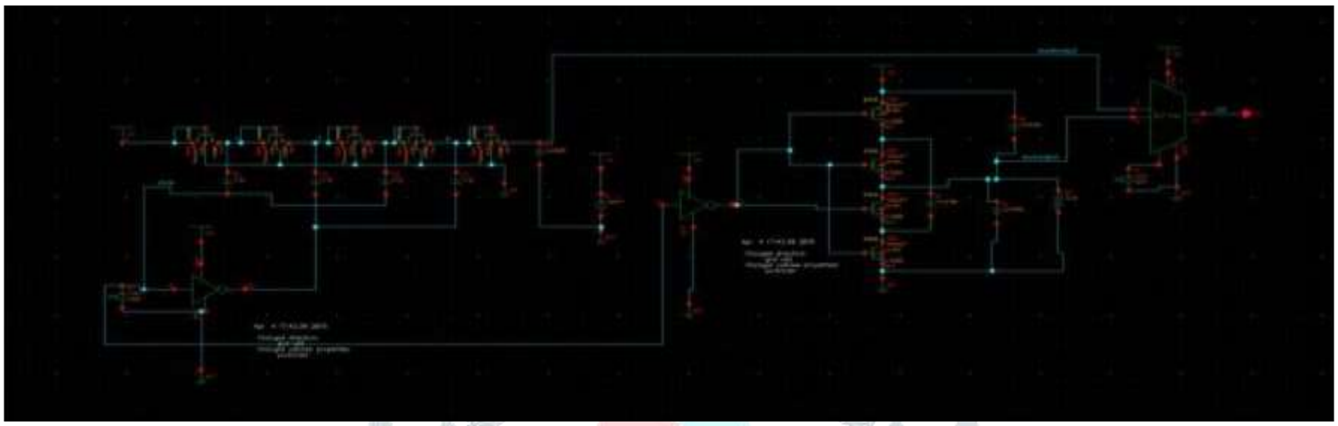

Figure 5 Buck-Boost Converter with mux

result of programming feature with 2:1 multiplexer for sel=1 boost output selected and mux output is 1.3939V, for Sel-0 buck output selected and mux output is 1.0981mv

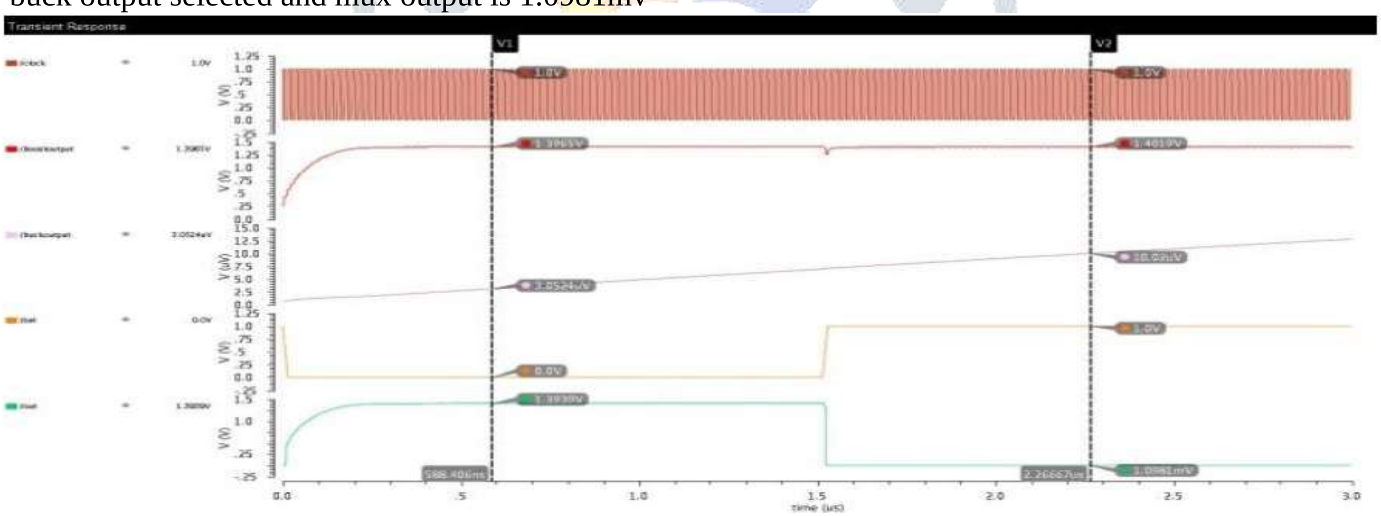

Figure 6 Transient Analysis of Buck-Boost Converter with multiplexer

B. Programming Using Comparator

As the name itself signifies programming feature is enable by comparing to reference voltage. Output of boost converter is compared with reference voltage. Reference voltage is set by user. If Vin > Vref boost converter operate and output is higher. When output of boost converter exceeds Vref buck converter functions it reduced the output level. If Vin < Vref boost converter functions and same output level passed through upper part of circuitry. Output of buck converter is feedback to boost converter as shown in figure8.

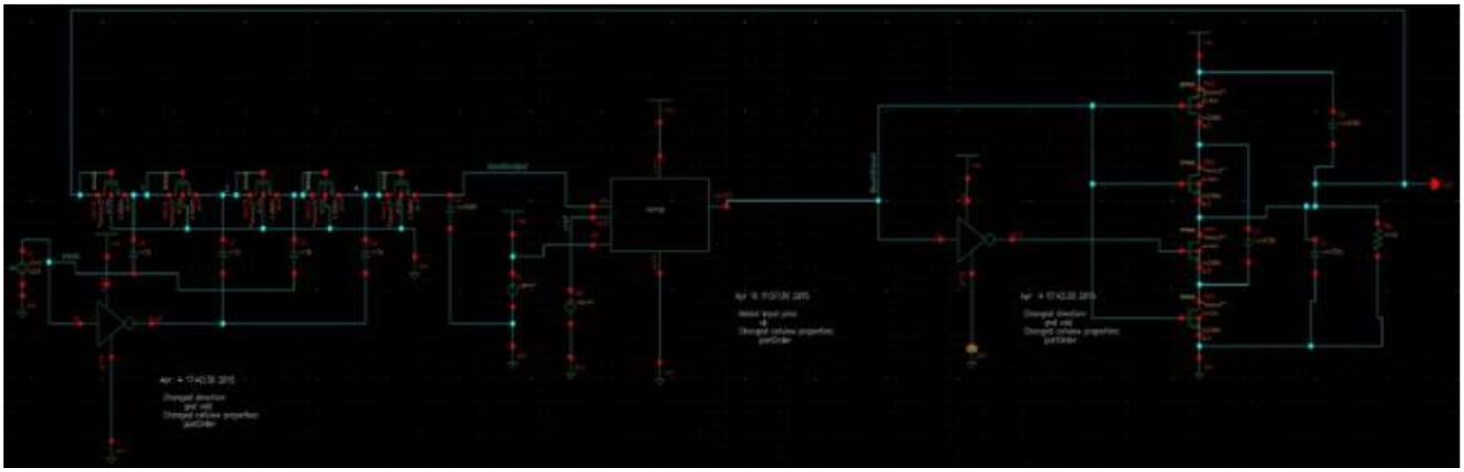

Figure 7 Buck-Boost Converter with comparator

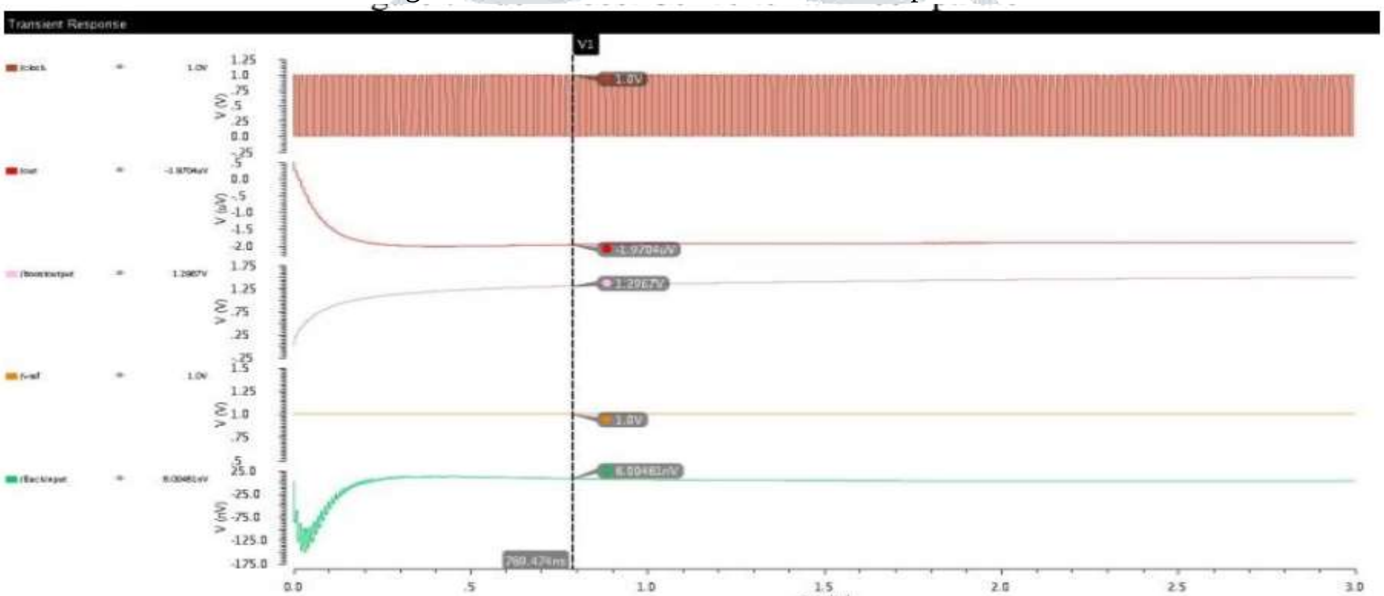

Figure 8 Transient Analysis of Buck-Boost Converter with comparator

Figure9 shows the simulation result of buck-boost converter with comparator. Initially Vin=1V which is up converted to 1.2967V by boost converter; compared with user defined Vref=1 V. As boost output level exceeds 1V buck converter start functions and output level reduced to -1.97uV, which is feedback to boost converter. This process is repeated continuously.

IV. CONCLUSION

In this paper a programming feature in DC-DC converter included using multiplexer and comparator discussed. Output level boosted up to 22V for 5V supply and bucked down to 320mV. User has choice to set threshold limit to below which boost and beyond buck functions. Comparator based charge pump contain feedback part of output voltage in input result in low power consumption 82.32uW.

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