Inter Partes Review
U.S. Patent No. 9,207,701

Western Digital Technologies, Inc. v. Longitude Licensing LTD, IPR2023-01230

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Hong Shi,
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Representing Petitioner Western Digital

Claim 1 of ’701 Patent

The inventive concept of the ’701 Patent is changing the number of booster stages of a booster circuitry according to a selected power supply voltage.

1. A method for generating a supply voltage, comprising:

selecting one of a first input node supplied with a first power supply voltage and a second input node supplied with a second power supply voltage that is higher than the first power supply voltage;

coupling a selected one of the first and second input nodes to booster circuitry comprising a plurality of booster stages to provide an output voltage, wherein selection of the first input node corresponds to a first number of booster stages and selection of the second input node corresponds to selection of a second number of booster stages, the second number being less than first number; and

changing the booster circuitry from the first number of booster stages corresponding to selection of the first input node to the second number of booster stages when the second input node is selected.

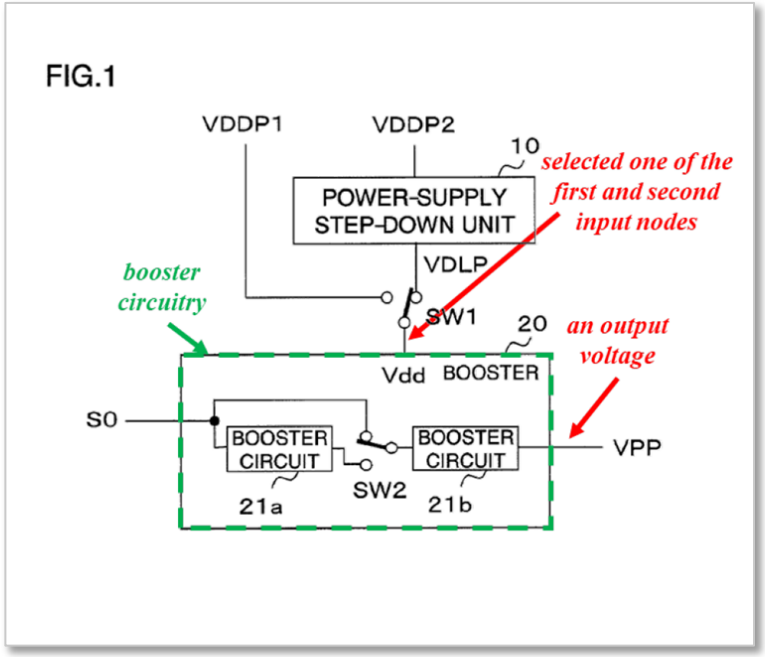
Selecting between two input power supply voltages

Booster circuitry with a configurable number of booster stages

EX1001, claim 1.

Claim 1 of ’701 Patent

The inventive concept of the ’701 Patent is changing the number of booster stages of a booster circuitry according to a selected power supply voltage.



’701 Patent, FIG. 1; Reply, 3; Pet., 1-3 (summary of ’701 Patent), 3 (discussing prosecution history).

Selecting between two input power supply voltages

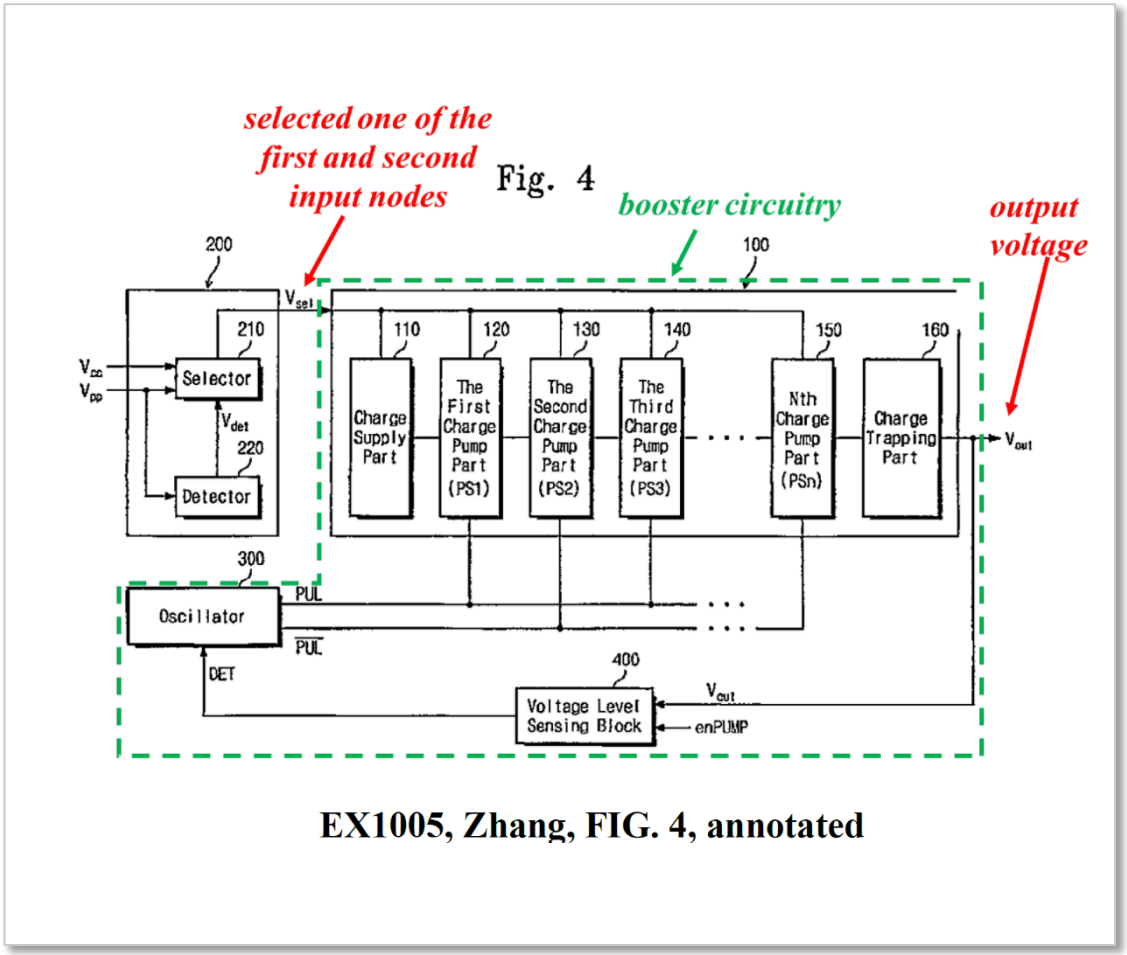
Booster circuitry with a configurable number of booster stages

Background: Charge Pump Provides Voltage Boost

A conventional charge pump includes a fixed number of charge pump stages.

"a POSITA would readily recognize that Zhang does encompass generating multiple voltages by varying Zhang's VREF reference voltage."

POR, 14, n.5, (citing Ex2003 ¶¶110, 78 n.1).



EX1005, Zhang, FIG. 4, annotated

EX1005, Zhang, FIG. 4; Pet. 27.

Javanifard's Variable Stage Charge Pump

A charge pump including a configurable number of booster stages was also well-known.

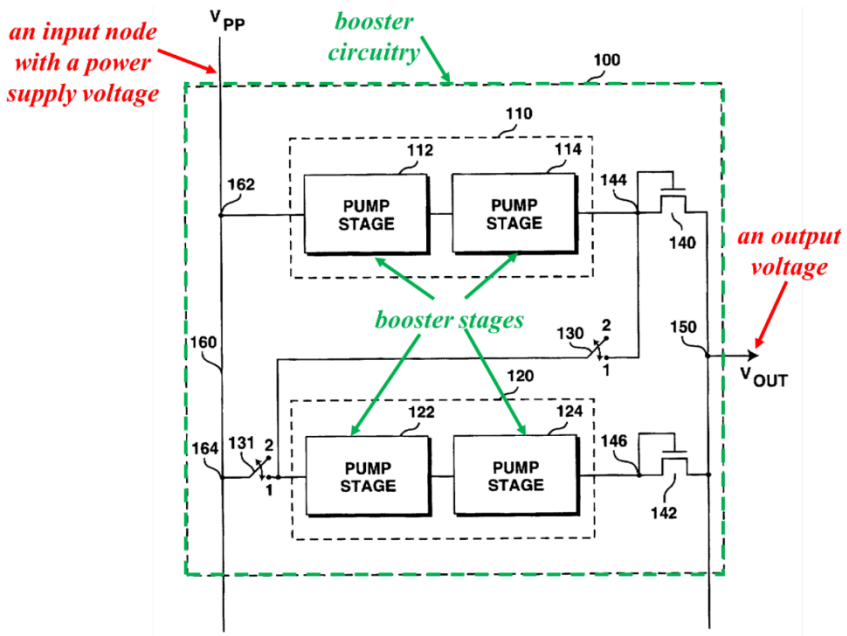


Figure 1

EX1006, Javanifard, FIG. 1, annotated

Pet. 28.

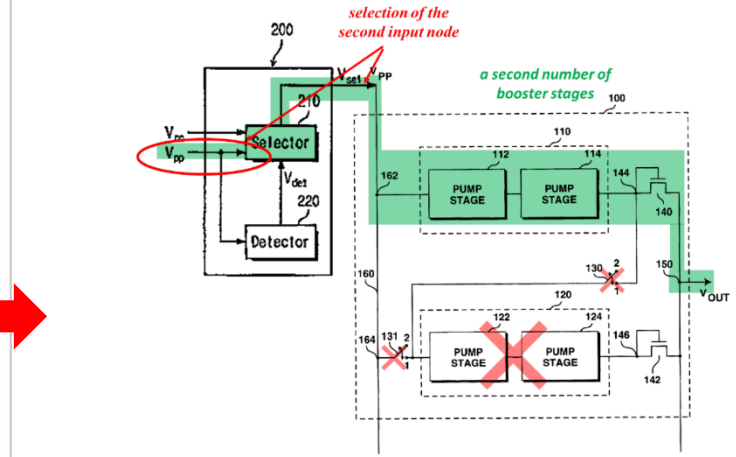
Javanifard's Variable Stage Charge Pump

Low Power / Low Current Mode

TABLE 1

Switch 130	Switch 131	Charge Pump 110	Charge Pump 120
OFF	OFF	ON	OFF
OFF	ON	ON	parallel-coupled to charge pump 110
ON	OFF	ON	series-coupled to charge pump 110
ON	ON	N/A	N/A

EX1006, Javanifard, Table 1



Example A of Zhang Combined with Javanifard

(Selection of Second Input Node with Higher Supply Voltage)

EX1006, Javanifard, Table 1, annotated; Pet. 37-38.

Pet. 37-38.

Javanifard's Variable Stage Charge Pump

High Power / High Current Mode

TABLE 1

Switch 130	Switch 131	Charge Pump 110	Charge Pump 120
OFF	OFF	ON	OFF
OFF	ON	ON	parallel-coupled to charge pump 110
ON	OFF	ON	series-coupled to charge pump 110
ON	ON	N/A	N/A

EX1006, Javanifard, Table 1

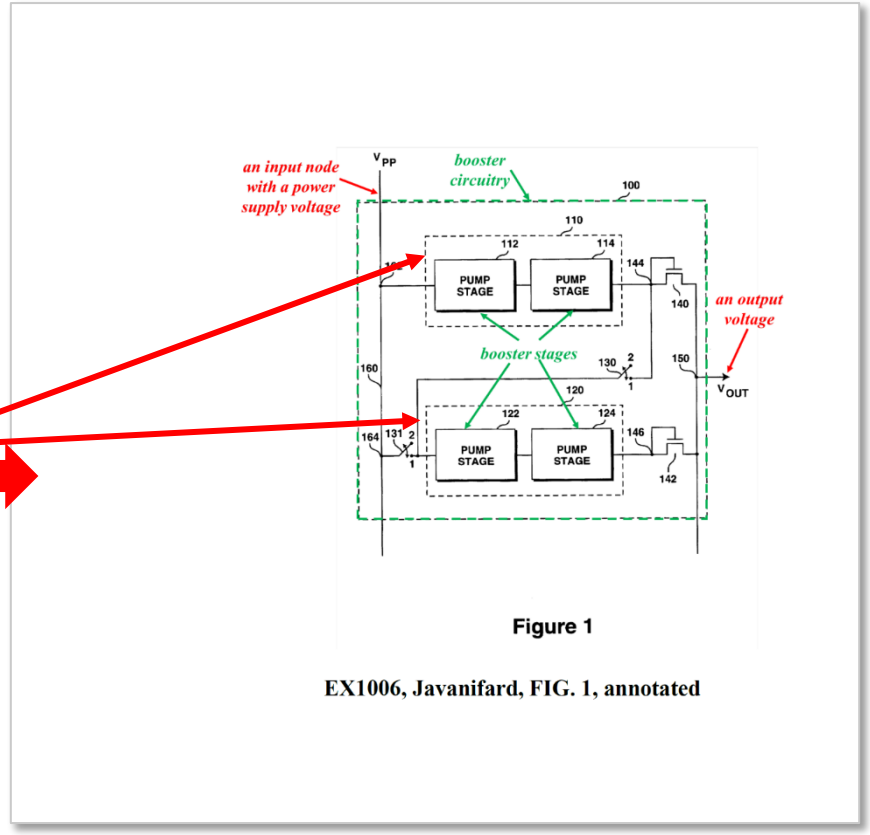


Figure 1

EX1006, Javanifard, FIG. 1, annotated

EX1006, Javanifard, Table 1, annotated; Pet. 33-35, 38, 70.

Pet. 33-35, 38, 70.

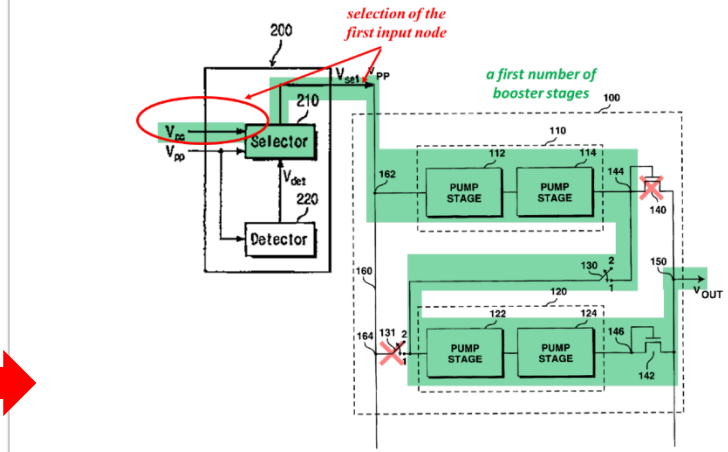
Javanifard's Variable Stage Charge Pump

Low Power / Low Current Mode

TABLE 1

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EX1006, Javanifard, Table 1



Example A of Zhang Combined with Javanifard

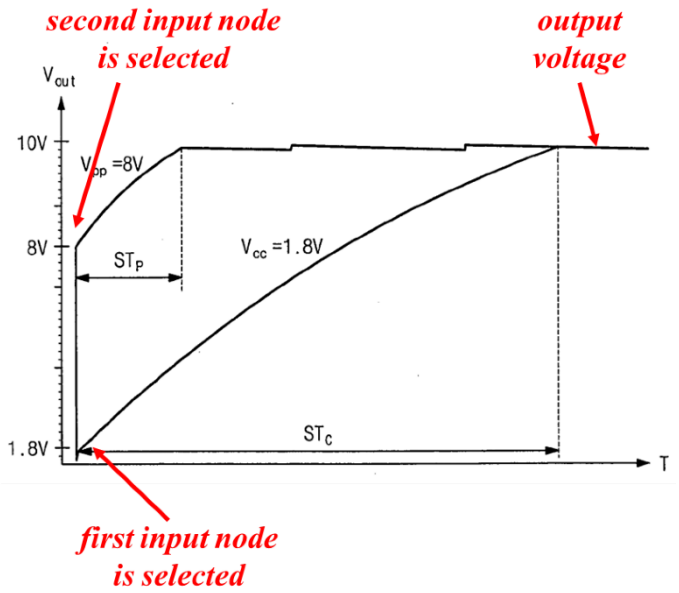
(Selection of the First Input Node with Lower Supply Voltage)

EX1006, Javanifard, Table 1, annotated; Pet. 33-34.

Pet. 33-34.

Both Zhang and Javanifard Teach Providing the Same Output Voltage Level for Different Input Power Supplies

Fig. 8



EX1005, Zhang, FIG. 8, annotated

Ex1005, Zhang, FIG. 8; Pet. 43.

One object is to provide a charge pump that can accommodate different output levels for a given charge pump power supply input level.

Another object is to provide a charge pump that can accommodate a given output level for different charge pump power supply input levels.

EX1006, Javanifard, 2:18-24; Pet. 21.

Although 5 volts is a popular standard for Vpp, 3.3 volts is gaining in popularity. The variable stage charge pumps might be incorporated into the flash memory device in order to simplify external circuitry. To maximize the utility of a flash memory system, however, the variable stage charge pump must be able to generate approximately 5 volts, 9 volts, and 12 volts from either a 3.3 volt or 5 volt power supply.

EX1006, Javanifard, 6:53-60; Reply, 25.

Instituted Claims and Grounds

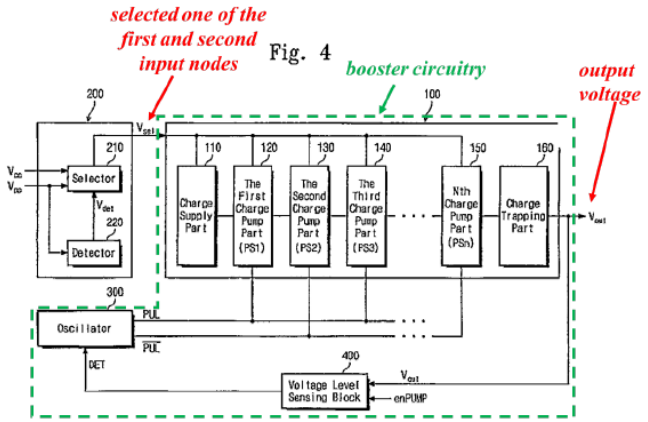
Ground	Claims	Basis
#1	1-18	§103(a) over Zhang in view of Javanifard
#2	1-18	§103(a) over Javanifard
#3	9 and 18	§103(a) over Zhang in view of Javanifard and Kang
#4	9 and 18	§103(a) over Javanifard in view of Kang

Pet.,5; Inst. Dec. 8, 56.

Patent Owner does not contest specific limitations, and does not dispute the combination with Kang in Grounds #3 and #4. Reply, 1; *see* POR, generally.

Thus, the only remaining issues are motivation to combine of Grounds #1 and #2.

Ground 1: Combination of Zhang-Javanifard



EX1005, Zhang, FIG. 4, annotated

Pet. 27.

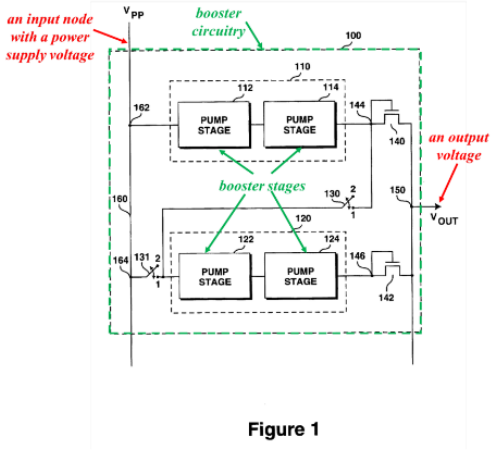
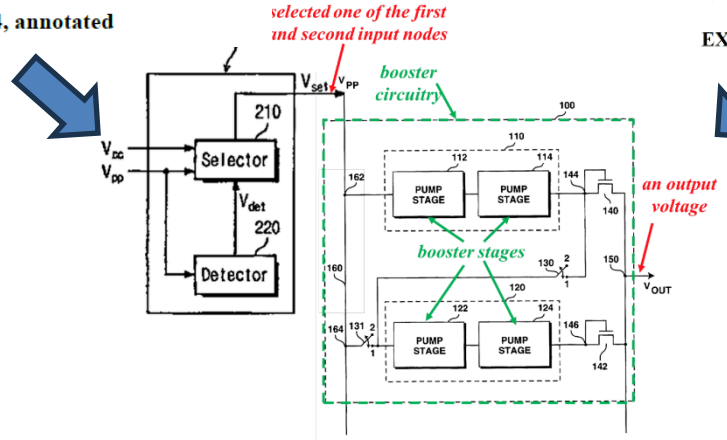


Figure 1

EX1006, Javanifard, FIG. 1, annotated

Pet. 28.



Example A of Combination of Zhang and Javanifard

Pet. 30.

Reasons to Combine Zhang and Javanifard

Petition explains numerous technical advantages achieved by applying Javanifard's configurable booster circuitry with a variable number of stages in Zhang. PO failed to rebut any of these advantages.

1. **Larger Range of Output Voltages:** "accommodate different output levels for a given charge pump power supply input level" (Petition, 20);
2. **Larger Range of Input Voltages:** "accommodate a given output level for different charge pump power supply input levels" (Petition, 20);
3. **"Area Reduction"** (Petition, 20);
4. **Performance Improvement with High Power Efficiency:** "improves performance (e.g., pump efficiency) by configuring the number of pump stages" (Petition, 21); and
5. **Power/Current Design Flexibility:** "flexibility for various design needs (e.g., configurations based on power saving mode, and/or current requirements)" (Petition, 21).

Advantages #1 and 2:
Larger Range of Output Voltages and Larger Range of Input Voltages

By having a *variable* number of pump stages, as taught by Javanifard, one can accommodate both a larger range of output voltages and a larger range of input voltages.

36. It was well-known that a charge pump may include one or more stages. EX1016, Daga, FIGS. 2A-2B (describing a single-stage charge pump), 4 (describing an N-stage charge pump using cascading basic stages of FIG. 2B). Connecting more stages in series can provide a higher voltage boost compared to using a smaller number of stages in series. Each stage in the charge pump contributes to increasing the voltage level, and the total voltage boost is the cumulative effect of all the stages. By connecting multiple stages in series, the voltage boost may be multiplied. In a simplified example, if each stage provides a voltage multiplication factor of 2 (doubling the voltage), and there are 3 stages connected in series, the total voltage boost = Vout – Vin = (2^3 – 1)*Vin = 7*Vin.

Pet. 1 (citing EX1003, ¶36).

Advantage #3: Area Reduction

Said differently, by having a *variable* number of stages, as taught by Javanifard, one can supply a larger range of output voltages with a single charge pump.

Although 5 volts is a popular standard for Vpp, 3.3 volts is gaining in popularity. The variable stage charge pumps might be incorporated into the flash memory device in order to simplify external circuitry. To maximize the utility of a flash memory system, however, the variable stage charge pump must be able to generate approximately 5 volts, 9 volts, and 12 volts from either a 3.3 volt or 5 volt power supply.

EX1006, Javanifard, 6:53-60; Reply, 25.

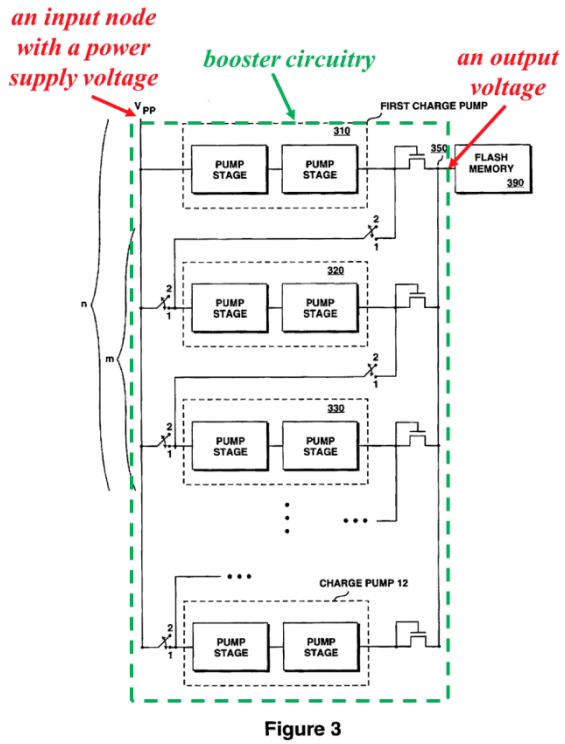


Figure 3

EX1006, Javanifard, FIG. 3, annotated

Pet. 29, 53.

Advantage #4:
Performance Improvement with High Power Efficiency

By having a variable number of stages, as taught by Javanifard, one can improve performance including power efficiency.

> *Abstract*—In this paper, an optimized strategy for designing charge pumps with minimum power consumption is presented. The approach allows designers to define the number of stages that, for a given input, and an output voltage, maximize power efficiency. Capacitor value is then set to provide the current capability required. This approach was analytically developed and validated through simulations and experimental measurements on 0.35-μm EEPROM CMOS technology. This approach was then compared with one which minimized the silicon area and it was shown that only a small increase in area is needed to minimize power consumption.

EX1026, Palumbo, 1535; Reply, 8; Pet. 20-21.

> "Another disadvantage is that the fixed stage method typically sacrifices performance at one power supply voltage to accommodate another power supply voltage."

Pet. 20; EX1006, Javanifard, 1:66-2:2.

Advantage #5: Power/Current Design Flexibility

By having a variable number of stages, as taught by Javanifard, one can provide flexibility for design needs (e.g., low/high power/current modes).

From the above table, if both switches are off, charge pump **110** will be the only charge pump providing voltage to node **150**. Thus, because charge pump **110** is a two stage charge pump, this configuration of switches **130** and **131** will effectively result in a two stage charge pump. This configuration might be used in a power saving mode if charge pump **100** is otherwise providing sufficient current and voltage output levels.

If switch **130** is off and switch **131** is on, charge pump **120** will be coupled so that charge pumps **110** and **120** are coupled in parallel to common output node **150**. Because both **110** and **120** are two stage charge pumps, this means that charge pump **100** will effectively be a four stage charge pump having two sets of two stages coupled in parallel. In this configuration, charge pump **100** will provide approximately the same output voltage at node **150**. Because **110** and **120** are parallel-coupled, charge pump **100** will be able to provide approximately twice the amount of current as was the case when only charge pump **110** was operating.

EX1006, Javanifard, 3:33-53; Pet. 34-35, 38, 78.

Conclusion

Each of Petition's technical advantages is sufficient for motivation to combine.

1. **Larger Range of Output Voltages:** "accommodate different output levels for a given charge pump power supply input level" (Petition, 20);
2. **Larger Range of Input Voltages:** "accommodate a given output level for different charge pump power supply input levels" (Petition, 20);
3. **"Area Reduction"** (Petition, 20); and
4. **Performance Improvement with High Power Efficiency:** "improves performance (e.g., pump efficiency) by configuring the number of pump stages" (Petition, 21); and
5. **Power/Current Design Flexibility:** "flexibility for design needs (e.g., power saving mode, and current requirements)" (Petition, 20).

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Prior Art: Zhang Describes Power Supply Selection

FIG. **4** is a block diagram of an embodiment of the charge pump circuit according to the present invention. Referring to FIG. **4**, the charge pump circuit comprises a charge pump block **100**, a selecting circuit block **200**, an oscillator **300**, and a voltage level sensing block **400**.

EX1005, Zhang, 2:54-58; Pet.,23.

The selecting circuit block **200** comprises the selector **210** and the detector **220**. The selector **210** selects between the power voltage VCC and the high voltage VPP. The detector **220** detects the level of the high voltage VPP to generate detection signal VDET. The detector **220** enables the detection signal VDET when the high voltage VPP is higher than the power voltage VCC. The selector **210** switches between the power voltage VCC to the high voltage VPP responsive to the detection signal VDET. Put differently, the signal VSEL is VCC in the general operation mode and VPP in the test operation mode allowing for a high voltage within a short time. The selector **210** and the detector **220** are more fully described referring to FIGS. **6** and **7**.

EX1005, Zhang, 3:28-40; Pet.,24-25.

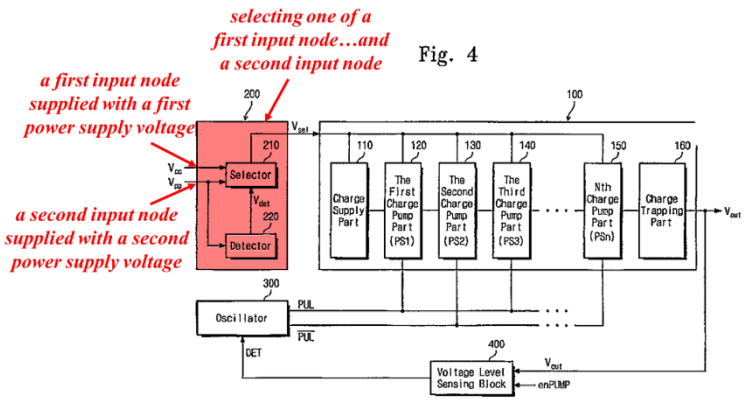


Fig. 4

EX1005, Zhang, FIG. 4, annotated

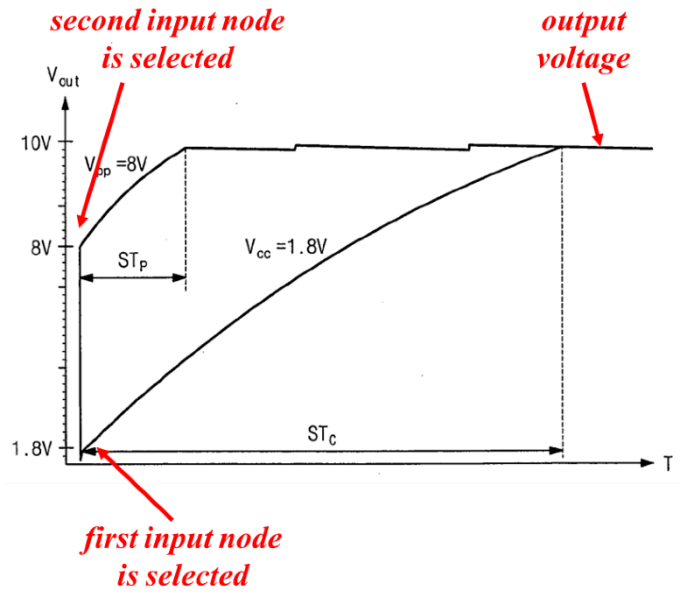
Pet.,25.

Prior Art: Zhang Describes Achieving the Same Voltage Output using Two Different Voltage Power Supplies

FIG. **8** is a graph of the output voltage Vout depending on whether the charge pump circuit uses the power voltage VCC or external high voltage VPP. Settling time is a time required for the pumping operation to obtain a wanted output voltage Vout. Referring to FIG. **8**, if the selected voltage VSEL is under the condition that the power voltage VCC is equal to 1.8V, and the external voltage VPP is equal to **8**V, it is known that four times settling times (STp) is required to obtain an output voltage Vout of 10V. That is, when external high voltage VPP is supplied with the power voltage VCC, a wanted output voltage Vout can be obtained within a shorter time.

EX1005, Zhang, 5:1-11; Pet.,43; ID., 20-21.

Fig. 8



EX1005, Zhang, FIG. 8, annotated

EX1005, Zhang, FIG. 8; Pet.,43.

Prior Art: Javanifard Describes Configurable Booster Circuitry with a Variable Number of Stages

One object is to provide a charge pump that can accommodate different output levels for a given charge pump power supply input level.

Another object is to provide a charge pump that can accommodate a given output level for different charge pump power supply input levels.

EX1006, Javanifard, 2:18-23; Pet. 21.

By choosing a different one of the four position combinations, the number of stages and the coupling of the charge pump stages to each other can be varied. The table below indicates the results of the four combinations:

TABLE 1

Switch 130	Switch 131	Charge Pump 110	Charge Pump 120
OFF	OFF	ON	OFF
OFF	ON	ON	parallel-coupled to charge pump 110
ON	OFF	ON	series-coupled to charge pump 110
ON	ON	N/A	N/A

EX1006, Javanifard, Table 1

EX1006, Javanifard, 3:19-22, Table 1; Pet. 12-13.

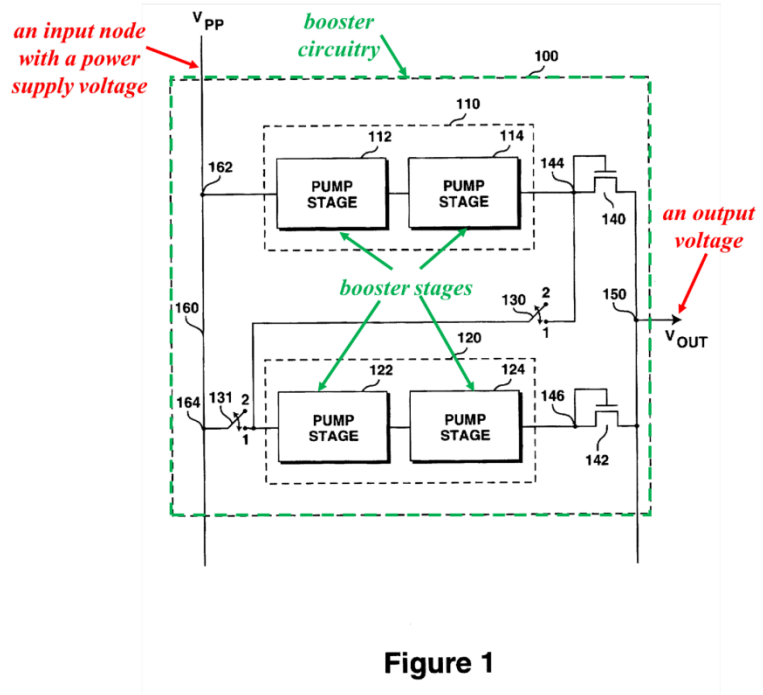
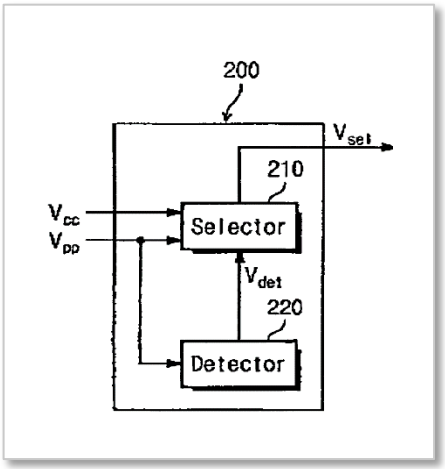


Figure 1

EX1006, Javanifard, FIG. 1, annotated

Pet., 28.

In Combination, Zhang-Javanifard Achieves Flexibility with Multiple Possible Configurations



EX1005, Zhang, FIG. 4 (portion); Pet., 27.

TABLE 1

Switch 130	Switch 131	Charge Pump 110	Charge Pump 120
OFF	OFF	ON	OFF
OFF	ON	ON	parallel-coupled to charge pump 110
ON	OFF	ON	series-coupled to charge pump 110

EX1006, Javanifard, Table 1 (portion), Pet., 12-13.

Configuration # of Zhang-Javanifard	Selected Power Supply Source	Boost Circuitry Configuration of Javanifard, Table 1	Output Voltage Level
1	Vcc	Row 1 (two stages series-coupled)	Vout Level 1
2	Vcc	Row 2 (charge pumps 110 and 120 parallel-coupled)	Vout Level 1
3	Vcc	Row 3 (four stages series-coupled, as annotated in green in Table 1 above)	Vout Level 2
4	Vpp	Row 1 (two stages series-coupled, as annotated in red in Table 1 above)	Vout Level 2
5	Vpp	Row 2 (charge pumps 110 and 120 parallel-coupled)	Vout Level 2
6	Vpp	Row 3 (four stages series-coupled)	Vout Level 3

Reply, 6; *see also*, Pet., 38.

"while configurations of rows 1 and 2 of Table 1 may provide substantially the same voltage boost, a POSITA would have used row 1 based on a design need for power saving mode."

Pet., 38.

Petition's Evidence Supports *KSR* analysis

"[C]ombining known elements (power supply selection e.g., using a power switch) and voltage conversion (e.g., a DC/DC converter including charge pumps) was a basic and well-known practice prior to the '701 Patent."

Pet. 22-23; Reply, 13.

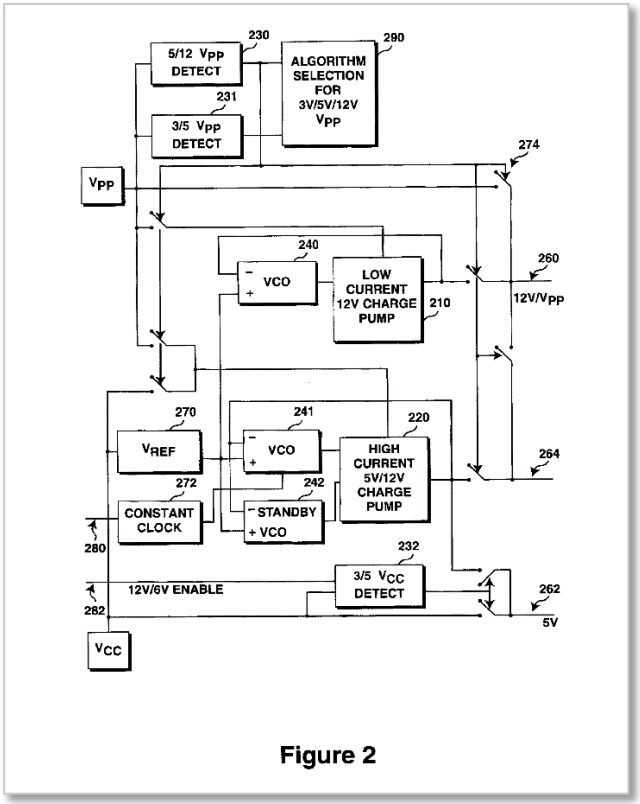
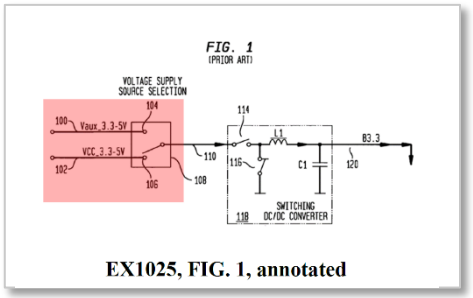


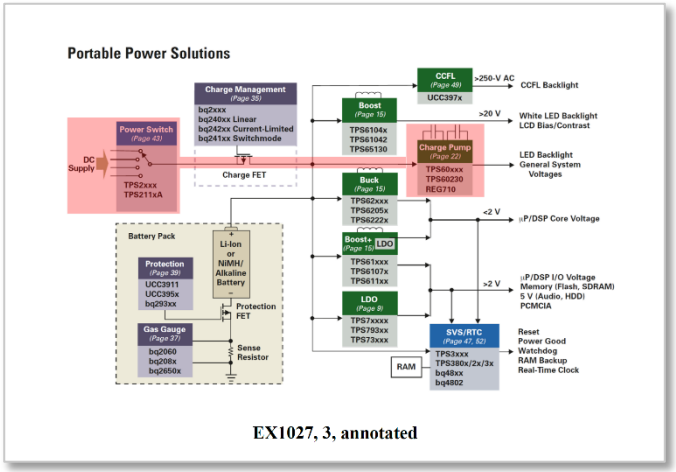
Figure 2

EX1006, Javanifard, FIG. 2; Reply 14-15.



EX1025, FIG. 1, annotated

EX1025, Lopata, FIG. 1; Reply 13-15.



EX1027, 3, annotated

EX1027, TI-Guide, 3; Reply 13-15.

Charge Pump Efficiency

The number of stages impacts critical performance factors such as efficiency, current output, and overall circuit complexity.

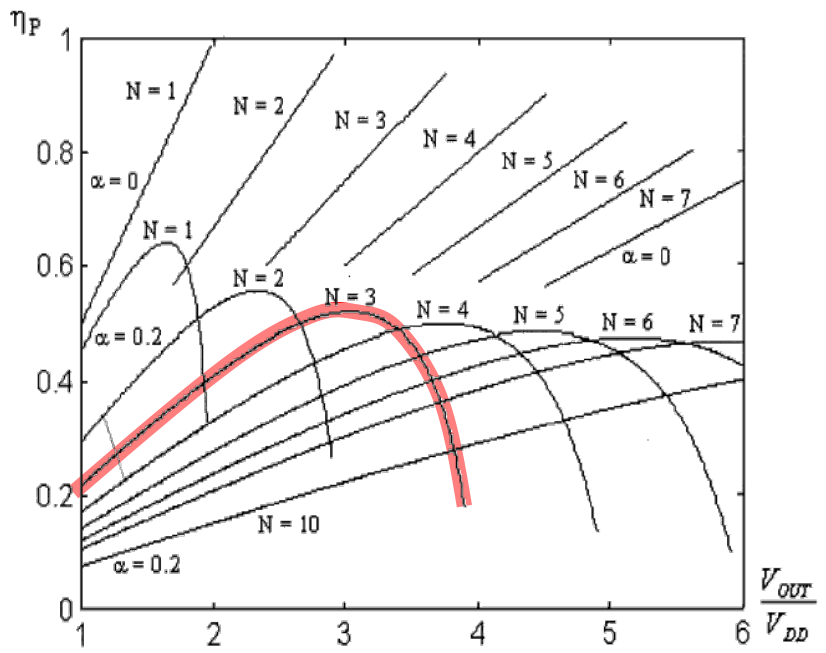


Fig. 4. Charge-pump efficiency versus the multiplier factor for different numbers of stages with $\alpha = 0.2$ and $\alpha = 0$ (ideal case).

C. Charge-Pump Efficiency

The efficiency η_p of the charge pump is equal to

$$\eta_P = \frac{I_L V_{\text{out}}}{I_{\text{power}} V_{DD}} = \frac{K}{N + 1 + \alpha \frac{N^2}{N+1-K}} \qquad (12)$$

and is plotted in Fig. 4 versus the multiplier factor for a different number of stages and assuming $\alpha = 0.2$. The figure also includes the efficiency of the charge pump for the ideal case in which $\alpha = 0$. By inspection of Fig. 4, we derive that the advantages

EX1026, Palumbo, 1537; Reply, 8; Pet. 20.

Background: Charge Pump Provides Voltage Boost

Charge pumps are switched-capacitor circuits widely used in many applications to obtain an output voltage higher than that of the power supply.

33. Charge pumps are switched-capacitor circuits commonly employed to obtain an output voltage higher than that of the power supply. EX1008, Pan, 43 ("Charge pumps are circuits that generate a voltage level higher than the chip supply voltage from which they operate."); EX1014, Frulio, 1:11-14 ("Charge pumps are switched-capacitor circuits employed to obtain either an output voltage higher than that of the power supply (V) or a negative voltage in an electronic system.").

34. Charge pumps are widely used in the integrated circuit industry to supply voltages in many applications such as power ICs, filters, memories, etc. Flash memory devices are among these applications since high voltage levels are needed to perform flash memory operations such as program and erase. Moreover, due to the trend of increasingly lower voltage supply requirements, a voltage level higher than the voltage supply may also needed for flash memory read operation. EX1014, Frulio, 1:11-22.

Pet. 1 (citing EX1003, Stiegler Decl., ¶¶33-34).