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First Inventor Name: Patrizio VINCIARELLI
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: Unknown
Filing Date: Herewith
Examiner: Unknown
Art Unit: Unknown

UTILITY PATENT APPLICATION
TRANSMITTAL

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Transmitted herewith for filing under 37 C.F.R. § 1.53(b) is the nonprovisional utility patent application of:

Patrizio VINCIARELLI
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Enclosed are:

- [X] Description, Claim(s), and Abstract (37 pages).
- [X] Informal drawings (14 sheets, Figures 1, 2, 3A-3G, 4, 5, 6, 7A-7H, 8, 9A-9E, 10, 11, 12, 13, 14A-14G, 15, 16A-16H).

[**X**] Application Data Sheet (37 CFR 1.76).

[**X**] Request for application not to be published with certification under 35 USC
122(b)(2)(B)(i).

The adjustment to the number of sheets for EFS-Web filing follows:

Number of Sheets		EFS-Web Adjustment	Number of Sheets for EFS-Web
51	x	75%	39

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	Number Filed	Included in Basic Fee	Extra		Rate	Fee Totals
Basic Filing Fee					\$390.00 =	\$390.00
Search Fee					\$620.00	\$620.00
Examination Fee					\$250.00	\$250.00
Size Fee	39	- 100	= 0	x	\$320.00	\$0.00
Total	35	- 20	= 15	x	\$62.00 =	\$930.00
Claims:						
Independents	1	- 3	= 0	x	\$250.00 =	\$0.00
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If any Multiple Dependent Claim(s) present:				+	\$460.00 =	\$0.00
Surcharge under 37 CFR 1.16(f) for late filing of Executed Declaration				+	\$130.00 =	\$130.00
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Basic Filing Fee Reduction for Filing via EFS-Web						\$0.00
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Assignment Recordation Fee:				+	=	\$0.00
Processing Fee under 37 CFR 1.17(i) for Late Filing of English Translation of Application:				+	\$130.00 =	
Publication Fee				+	=	\$0.00
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Respectfully submitted,

Date 2013-03-14

By /Matthew A. Smith/

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	092377-VND044
		Application Number	
Title of Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

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☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
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	Sergey		LUZANOV			
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	092377-VND044
		Application Number	
Title of Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS		

☐ An Address is being provided for the correspondence information of this application.

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Application Information:

Title of the Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS		
Attorney Docket Number	092377-VND044	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	14	Suggested Figure for Publication (if any)	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
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Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	092377-VND044
		Application Number	
Title of Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS		

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	092377-VND044
		Application Number	
Title of Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS		

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	092377-VND044
		Application Number	
Title of Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS		

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Applicant: VLT, Inc.
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: Unassigned
Filing Date: Herewith
Examiner: Unassigned
Art Unit: Unassigned
Confirmation Number: Unassigned

REQUEST AND CERTIFICATION UNDER 35 U.S.C. 122(b)(2)(B)(i)

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Alexandria, VA 22313-1450
Commissioner:

Applicants hereby certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral agreement, that requires publication at eighteen months after filing. Applicants hereby request that the attached application not be published under 35 U.S.C. 122(b).

Respectfully submitted,

Date 2013-03-14

By /Matthew A. Smith/

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Digital Control of Resonant Power Converters

TECHNICAL FIELD

[01] This invention relates to apparatus and methods for digital control of resonant power converters, more particularly the invention relates to digital control of resonant zero-current and zero-voltage switching resonant power converters.

BACKGROUND

[02] Certain types of power converters use resonant processes to efficiently transfer energy from an input source to a load. One example of such a power converter, called a Sine-Amplitude Converter (“SAC”), is described in detail in *Factorized Power Architecture with Point of Load Sine Amplitude Converters*, Vinciarelli, U. S. Patent 6,984,965 (assigned to VLT, Inc. of Sunnyvale, CA, the entire disclosure of which is incorporated herein by reference) (the “SAC Patent”). A block diagram of a half-bridge sine amplitude converter 10 is shown in Fig. 1. The SAC comprises SAC power conversion circuitry 100 (shown connected to power source 50 and load 60) and a SAC controller 20 which controls the turning ON and OFF of switches within the power conversion circuitry 100. A simplified and idealized summary of the operation of the sine amplitude converter 10 is as follows (a detailed description of operation may be found in the SAC Patent): switches S1 110 and S3 130 are closed when the voltages across switches S1 110 and S3 130, and the resonant portion of the primary current I_{pri} , are each substantially zero, initiating a power transfer interval. Closing switch S1 110 causes an essentially sinusoidal flow of resonant current I_{pri} in the primary winding at a characteristic resonant frequency, F_R , and period, T_R , defined by a resonant circuit comprising a resonant inductance L_s 150 and a resonant capacitance C_{res} 160. When the sinusoidal current flow completes a half-cycle, and the current I_{pri} returns substantially to zero, switches S1 110 and S3 130 are opened. An energy recycling interval following the opening of switches S1 110 and S3 130, allows the transformer 80 magnetizing current to charge and discharge circuit parasitic capacitances such that the voltages across switches S2 120 and S4 140 decline toward zero. When the voltage across switches S2 120 and S4 140 are at their minimum, i.e. substantially zero (or at a relatively low value, dependent upon the magnitude of the magnetizing energy), they are turned ON to initiate another power transfer interval. Each converter operating cycle

comprises two power transfer intervals of equal length and two energy recycling intervals of equal length; one half-cycle of the converter operating cycle comprises a single power transfer interval and an associated energy recycling interval. Each power transfer interval is substantially equal to one-half of the characteristic period, $T_R/2$; each operating cycle, of duration T , is therefore greater than or equal to T_R , depending on the length of the energy recycling interval. The converter operating frequency, F_{op} , is defined as the inverse of the length of the converter operating cycle: $F_{op} = 1/T$. Typical SACs may have converter operating frequencies between 1 MHz and 4 MHz, or higher.

[03] Conventionally, control of a SAC requires that circuit conditions be monitored in order to determine the proper times at which to turn switches ON and OFF. As shown in Fig. 1, the SAC controller 20 may comprise End-of-Cycle Sense circuitry 30 to receive information from the SAC power conversion circuitry 100 to establish when switches should be turned ON and OFF. For example, the voltage across one or more of the switches may be monitored to establish the timing of a zero-voltage switching (“ZVS”) or zero-current switching (“ZCS”) event, or the current flowing in the transformer 80 may be monitored to establish the timing of a ZCS event. The monitoring circuitry may provide a feedback signal to the End-of-Cycle Sense circuitry 30 in the controller 20 which responds to the feedback signal by altering the states of one or more switches.

[04] Contemporary high-frequency power converters typically use MOS-gated power switching devices, such as MOSFETs and IGBTs, which have an essentially capacitive gate control terminal. Efficiently recycling the energy during the turning ON and OFF of such a device may increase overall converter operating efficiency. One way to efficiently recycle the energy is to use a resonant technique. Apparatus and methods for resonant recycling of capacitive gate energy are described in: *High Efficiency Floating Gate Driver Circuit Using Leaking Inductance Transformer*, Vinciarelli, U. S. Patent No. 6,107,860; *Lossless Gate Driver Circuit for a High Frequency Converter*, Steigerwald, U. S. Patent No. 5,010,261; *High Frequency Control of a Semiconductor Switch*, Toile et al, U. S. Patent No. 7,602,229; and *Gate Driving Circuit*, Inoshita, U. S. Patent No. 7,091,753.

SUMMARY

[05] In general, in one aspect, a method of synchronously operating a power converter in a series of converter operating cycles includes providing an oscillator for generating clock signals at an oscillator frequency and generating timing control signals for each of a plurality of events based upon the clock signals in a standard converter operating cycle having a standard operating period and frequency. The timing and control signals may turn a primary switch ON and OFF at times when essentially zero voltage is impressed across and essentially zero resonant current is flowing in the primary switch and turn a secondary switch ON and OFF at times when essentially zero current is flowing in and essentially zero voltage is impressed across the secondary switch. The oscillator frequency may be preset and the timing of the timing control signals for one or more selected events may be set independently of other timing control signals and events.

[06] Implementations of the method may include one or more of the following features. A current monitor trigger synchronized with a predetermined time during the converter operating cycle, when a signal indicative of a current flowing in the converter may be sampled, may be generated. The current monitor trigger may be synchronized with a time at which a resonant current reaches a peak and a magnetizing current is essentially zero. The current monitor trigger may be synchronized with a time that follows the start of the ON time of the at least one primary switch by approximately one fourth of the characteristic resonant period of the power train.

[07] Timing control signals may be generated based upon the clock signals in a modified converter operating cycle, having a modified operating period and frequency, to turn the primary switch ON at times when essentially zero voltage is impressed across and essentially zero resonant current is flowing in the primary switch and to turn the primary switch OFF at selected times before a resonant current flowing in the primary switch returns to zero. The selected times may be based upon when a current flowing in the selected switch is expected to meet or exceed a predetermined threshold, e.g. for current limiting. The selected times may be based upon when a current flowing in the selected switch is expected to fall below a predetermined threshold, e.g. for no-load or light-load operation. The modified operating frequency may be greater than the standard operating frequency. Timing

control signals may be generated based upon the clock signals to turn selected switches in the converter ON to form a clamp phase during which at least one winding of the transformer is shunted by a low resistance circuit to essentially losslessly trap energy in the transformer. The modified operating frequency may be essentially equal to the standard operating frequency. The duration of the clamp phase may be adjusted based upon the magnitude of a current flowing in the converter. The duration of the clamp phase may be increased as the magnitude of the current flowing in the converter increases, e.g. to increase the output resistance of the converter such as for in-rush current limiting. The duration of the clamp phase may be decreased as the magnitude of the current flowing in the converter decreases, e.g. for reducing power dissipation for operation with a reduced load.

[08] A gate drive circuit may be provided for operating selected switches in the converter and generating timing control signals based upon the clock signals to (a) initiate a transition of the selected switches from ON to OFF or OFF to ON, (b) hold the selected switches ON, and (c) hold the selected switches OFF. The level of the control signal for the primary switch may be adjusted to increase the effective resistance of the converter in a modified converter operating cycle, e.g. to maintain a desired current level in the converter or to maintain a desired power dissipation in the primary switch. The gate drive circuit may include a resonant circuit including the gate capacitance and having a characteristic resonant gate drive period that is at least five times less than the characteristic resonant period of the power train.

[09] An encoder may be adapted to receive selected timing control signals for turning the secondary switch ON and OFF and generate an interface signal comprising a synchronization signal for indicating the start of a half period, and timing features to signal (a) the start of a transition of the secondary switch from OFF to ON, (b) the start of holding the secondary switch ON, and (c) the start of holding the secondary switch OFF. The interface signal may include a polarity signal to indicate an identity of the half period. A secondary side control circuit may be adapted to receive the interface signal and generate timing control signals including (a) the start of a transition of the secondary switch from OFF to ON or ON to OFF, (b) the start of holding the at least one secondary switch ON, and (c) the start of holding the at least one secondary switch OFF; for operating the secondary switch. The secondary side control circuit may derive power for operation from the interface

signal. The secondary side control circuit may be adapted to measure aspects of the interface signal to generate timing control signals not encoded in the interface signal.

[010] The timing control signals may be generated by counting the clock signals from the oscillator, setting a count threshold for each event, and generating the respective timing control signal for each event as the counting matches the respective count threshold. The oscillator and timing events may be open-loop with respect to the power train, may be adjusted with feedback from measurements in the power train, e.g. as a calibration step during manufacturing or as part of a closed-loop feedback system during operation.

DESCRIPTION OF DRAWINGS

- [011] FIG. 1 shows a block diagram of a prior-art SAC converter.
- [012] FIG. 2 shows a block diagram of a SAC converter comprising a digital controller.
- [013] FIG. 3A through FIG. 3G show waveforms for the converter of FIG. 2.
- [014] FIG. 4 shows a timing block architecture for use in a digital controller.
- [015] FIG. 5 shows a current monitor block.
- [016] FIG. 6A through FIG. 6G show waveforms for the current monitor block of FIG. 5.
- [017] FIG. 7A through FIG. 7H show waveforms for a sine amplitude converter operating in accordance with an inrush current limiting method.
- [018] FIG. 8 shows a gate driver circuit.
- [019] FIG. 9A through 9E show waveforms for the gate driver circuit of FIG. 8.
- [020] FIG. 10 shows a block diagram of an inrush current limiting circuit for use with a sine amplitude converter.
- [021] FIG. 11 shows a half bridge sine amplitude converter primary circuit with a clamp circuit.
- [022] FIG. 12 shows a full bridge sine amplitude converter primary circuit with a clamp circuit.
- [023] FIG. 13 shows a full bridge sine amplitude secondary circuit that may be also used to clamp a sine amplitude converter.

- [024] FIG. 14A through FIG. 14G show waveforms for a converter with the primary circuit of Fig. 11.
- [025] FIG. 15 shows a block diagram of a digital controller comprising a primary-side and a secondary-side controller.
- [026] FIG. 16A through FIG. 16H show waveforms for the controllers of FIG 15.
- [027] Like reference designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[028] In Fig. 2, a SAC converter 40 is shown including SAC power conversion circuitry 100 and a Digital SAC Controller 200. The SAC power conversion circuitry 100 shown in Fig. 2 is essentially the same as shown in Fig. 1 and includes a transformer 80, a half-bridge primary circuitry connected to receive power from the input source 50 and drive the primary winding 82. The primary circuit as shown includes switches S1 110 and S2 120 and bridge storage capacitors 170, 172. The resonant inductance L_s 150 and resonant capacitance C_{res} 160 define a characteristic resonant frequency, F_R , and period, T_R , for the transfer of energy between the input source 50 and the load 60:

$$T_R = 1/F_R = 2\pi\sqrt{L_s * C_{res}} \quad (1)$$

[029] The secondary circuitry is connected between secondary winding 84 and load 60 and includes switches S3 130 and S4 140 and output storage capacitor 90.

I. Digital Timer Controller

[030] The Digital SAC Controller (“DSC”) 200 as shown in Fig. 2 includes an oscillator 210 for generating a series of timing pulses at a frequency, F_{osc} ; a timing block 220 for generating one or more control signals or event outputs; and current monitoring circuitry 230. The DSC 200 may, as shown in Fig. 2, also include temperature monitoring circuitry 240, primary gate drivers 250, secondary gate drivers 260, and storage memory 270 for storing set-point values and other parameters. Alternatively, the primary gate drivers 250 or secondary gate drivers 260, or both may be external to the digital SAC controller 200.

[031] The beginning and end of a converter operating cycle, the beginning and end of each power transfer interval, and the points during each operating cycle at which switches are turned ON and OFF may be controlled by the DSC 200 based upon pre-defined timing

parameters. The pre-defined timing parameters may be pre-programmed into the DSC as circuitry logic or stored as parameters for example in storage memory 270. Fig. 4 shows a block diagram of the timing block 220 in greater detail. The oscillator 210, as shown in Fig. 4, delivers a series of clock pulses at a frequency, F_{OSC} , to the timing block 220.

Architecturally, the timing block may comprise a counter 222 that increments (or decrements) in response to each clock pulse received at its oscillator input 221. (The clock frequency, F_{OSC} , may be made much greater than the characteristic resonant frequency, F_R , of the converter to provide adequate resolution for the various timing events.)

[032] An n-bit count value corresponding to the contents of the counter 222 may be delivered from the counter to one or more digital comparator registers, e.g. comparator registers 224a, 224b, through 224x (where the suffix x signifies the last in the series of comparator registers having an integer number greater than 1) as shown in Fig. 4. The number, n, of counter bits will be determined by the timing resolution and the total duration of the converter operating period (or half-period). Each comparator register may receive a digital set-point value, e.g. set-point values 226a, 226b through 226x as shown in Fig. 4 or be otherwise programmed to respond to a particular count value or range of values, for example, by comparing the count value from the counter 222 to its respective set-point value and generating a respective event output, e.g. event outputs 228a, 228b...228x in Fig.4, when the two values satisfy a predetermined condition, such as the count value is less than, greater than, or is equal to, the set-point value. As shown in Fig. 4, the output of one of the comparator registers (e.g., register 224X) may be used as an end of cycle signal, which may be connected to a reset input 229 of counter 222, resetting the counter to a pre-determined digital reset value 227 (e.g. zero) in response to the clock pulse following receipt of the counter reset signal.

[033] By this process, the counter increments (or decrements) between two pre-defined count limits, the reset value 227 and the set-point value of the end of cycle comparator, during a continuous series of counter cycles. The length of each counter cycle depends on the difference between the pre-defined count limits and the oscillator period. During each counter cycle, event outputs are generated as the counter contents (counter value) matches a predetermined digital set-point. Each event may be set independently of the other events and the timing signals for controlling various aspects of the converter may also

be set independently of the other timing signals and events. As many or as few event outputs as are necessary may be generated in the manner shown. It being understood that the block diagram of Fig. 4 is illustrative of one way to implement the functions of the timing block 220 which may be implemented using various other logic functions or controllers.

[034] Referring to Figs. 3A through 3G, operating waveforms are shown for a converter 40 of the kind illustrated in Fig. 2 using MOSFET devices for switches S1 110, S2 120, S3 130, S4 140 and a timing block 220 of the kind illustrated in Fig. 4. The waveforms are drawn to illustrate specific features under discussion and therefore may not be to scale in either the vertical or horizontal axes. Fig. 3G shows the count value output 225 of the counter 222 (Fig. 4) as a staircase starting at zero, which is in this example the digital reset value (227 Fig. 4) and increasing with time, indicating that the counter value increments with each successive clock pulse received from the oscillator 210.

[035] A first half-cycle of the converter operating cycle may be initiated with the counter reset to its reset value of zero as shown at time t_0 in Fig. 3G. At time t_0 , a first comparator register (Fig. 4) generates an event output (S3 On Trans Code=0: Fig. 3G) that initiates the turning ON of switch S3 130 (see, S3 Control voltage: Fig. 3E) by activating a secondary gate driver 260 (Fig. 2) connected to a respective MOSFET gate. A first digital set-point for the first comparator register (Fig. 4) may be pre-determined based upon the known characteristics of the particular MOSFET device that is selected for switch S3 130. As shown by the switch S1 110 control voltage in Fig. 3C, a second comparator register (Fig. 4) generates an event output (S1 On Code: Fig. 3G) that initiates the turning ON of switch S1 110 at time t_1 by activating a primary gate driver 250 (Fig. 2) connected to a respective MOSFET gate. A second digital set-point for the second comparator register may be pre-determined based upon the known characteristics of the particular MOSFET device that is selected for switch S1 110. The pre-determined first and second digital set-points may be selected so that the gate voltages of switches S1 110 and S3 130 rise above their respective gate threshold voltages, and become conductive, at essentially the same time, t_2 (Figs. 3C and 3E). Because, at time t_2 , the voltage V_p (Fig. 2) is essentially equal to the input voltage, V_{in} , the voltage across switch S1 110 is essentially zero and switches S1 110 and S3 130 turn on at essentially zero voltage. With switches S1 110 and S3 130 ON (time t_2), a power transfer interval ("PTI") is initiated and a resonant current, at the characteristic frequency F_R ,

flows in the primary winding 82 and the secondary winding 84. Fig. 3B shows the primary winding current, comprising both the resonant current (solid line) and the primary magnetizing current (dashed line). It may be desirable, e.g. in certain gate drive circuits (one of which is described below), to generate an event output indicating that a MOSFET gate has been fully charged, for example, S3 On code (Fig. 3G) at time t3 corresponding to the switch S3 130 control voltage (Fig. 3E) reaching a fully charged state may be generated by a third digital comparator (Fig. 4).

[036] As shown at time t4, a fourth comparator register (Fig. 4) generates an event output (S3 Off Trans Code: Fig. 3G) that initiates the turning OFF of switch S3 130, by de-activating a secondary gate driver 260 (Fig. 2) connected to the respective MOSFET gate (see S3 control voltage in Fig. 3E). A fourth digital set-point for the fourth comparator register may be pre-determined based upon the characteristics of the particular MOSFET device that is selected for use as switch S3 130. As shown at time t5, a fifth comparator register (Fig. 4) generates an event output (S1 Off code: Fig. 3G) that initiates the turning OFF of switch S1 110, by de-activating a primary gate driver 250 (Fig. 2) connected to the respective MOSFET gate (see S3 control voltage in Fig. 3C). A fifth digital set-point for the fifth comparator register may be pre-determined based upon the characteristics of the particular MOSFET device that is selected for use as switch S1 110. The pre-determined fourth and fifth digital set-points may be selected so that the gate voltages of switches S1 110 and S3 130 fall below their respective gate threshold voltages, and become non-conductive, at essentially the same time, as shown in the example at time t6 in Figs. 3C and 3E. Preferably, the time at which the switches become non-conductive (time t6 in Figs 3C, 3E) is selected to correspond to one-half of the characteristic period of the converter, $T_R/2$, at which time the resonant portion of the primary current will return to zero (Fig. 3B). (The duration of each PTI, e.g. time t2 to time t6 in Fig. 3B during normal converter operation, T_{PTI-OP} , is essentially equal to one half of the resonant period: $T_{PTI-OP} = T_R/2$.) Similar to the fully-charged-gate event mentioned above, it may be also desirable in certain gate drive circuits, to generate an event output indicating that a MOSFET gate has been fully discharged. As shown in the example, the S3 Off code (Fig. 3G) may be generated at time t7 corresponding to the switch S3 130 control voltage (Fig. 3E) reaching a fully discharged state, e.g. by another digital comparator (Fig. 4), the sixth digital comparator in this example.

[037] With the switches OFF, an energy recycling interval following time t_6 may begin during which the magnetizing current (dashed line, Fig. 3B) flowing in the primary winding 82 of the transformer 80 (Fig. 2) charges and discharges capacitances at the node between switches S1 110 and S2 120 causing the voltage, V_p , across switch S2 120 to decline, and in ideal cases to reach zero, in preparation for ZVS turn ON of switch S2 120 during the next converter half cycle. Another digital comparator (the seventh comparator in the example) detects when the counter reaches a value equal to the half-of-period code, which is preferably chosen to coincide with the time that voltage, V_p , reaches its minimum. As shown in the example of Fig. 3G at time t_8 , the seventh comparator generates the $\frac{1}{2}$ -of-period code which may be used to reset the counter to the reset value (zero in the example) on the next clock cycle, thereby initiating the next converter half-cycle.

[038] The second half-cycle differs from the first half-cycle in the switches being controlled: switches S2 120 and S4 140 are controlled during the second half-cycle instead of switches S1 110 and S3 130 in the first half-cycle. A de-multiplexer may be used to route the signals to the appropriate switches for the alternating half cycles. The first half-cycle ends at $t_0 + T/2$, where T is the length of an operating cycle; the second half-cycle completes an operating cycle at time T . Thereafter, the converter operates with a continuing sequence of first and second half-cycles.

[039] By using pre-determined set-points for initiating switching and other events during an operating cycle, the need for feedback circuits, such as those required to establish the end of a power transfer interval or ZVS period are eliminated, thereby simplifying circuit design. Furthermore, using pre-determined set-points may improve efficiency through anticipation of event timing. For example, with reference to Figs. 3E and 3C, activation of the switch S3 130 gate driver at time t_0 , prior to the activation of the switch S2 120 gate driver at time t_1 , may be used to compensate for the differences in component and circuit parameters so that the gate voltages of switches S1 110 and S3 130 rise above their respective gate threshold voltages, and become conductive, at essentially the same time, t_2 .

[040] Use of pre-determined set-points may require that circuit tolerances, or specific circuit values, be taken into account or established. However, unit-to-unit reproducibility of certain parameters, or parametric dependencies, may relieve requirements for precision: e.g., the length of an power transfer interval in a sine amplitude converter may

be set to $T_R/2 = \pi \sqrt{L_s + C_{res}}$, where L_s 150 and C_{res} 160 are nominal values for a particular design. Because of the square root dependency, a variation in L_s or C_{res} as large as 5% may not result in an error in timing of the power transfer interval of more than 2.5%. Timing of ZVS intervals may also be non-critical, as capacitive energy storage is a function of the square of the voltage -- reducing the voltage to within 10% of zero may reduce stored energy by more than 99%. Methods for calibration and adjustment of timing may comprise: adjustment of the oscillator 210 frequency (e.g., in some embodiments the oscillator 210 may comprise a precision low frequency oscillator driving a phase-locked-loop for generating the relatively high frequency F_{OSC} , and a counter in the phase-locked-loop may be adjusted to calibrate F_{OSC}); and/or adjustment of the start and end counts of each digital comparator register. Pre-determined timing count values may be established based upon published component or circuit data and specifications and/or they may be set on a unit-by-unit basis using measurements made during a manufacturing process. Furthermore, a closed-loop feedback path may be provided to adjust the oscillator frequency or adjust the count of selected events based upon circuit conditions during operation to reduce any timing errors.

II. Current Monitor

[041] Referring to Fig. 5, a block diagram of a current monitor circuit 230 that may be used in the current monitor block 230 of the controller 200 of Fig. 2 is shown. The current monitor circuit 230 accurately infers the output current, I_{out} , or secondary current, I_{sec} , using a measurement of primary current, I_{pri} , thereby eliminating the need to make measurements across a primary-secondary isolation barrier. The current monitor circuit 230 may be used by the SAC controller 200 to limit inrush current during startup operation of the converter, or to perform current limiting during normal converter operation, e.g. in the event of an overload or short circuit.

[042] Waveforms for the current monitor 230 of Fig. 5, during normal converter operation--which may be defined by power transfer intervals being one half of the characteristic resonant period ($T_R/2$) in duration--are shown in Figs. 6A through 6D. The current in the secondary winding, I_{sec} , and the current in the primary winding, I_{pri} are respectively illustrated in Figs. 6A and 6B. As noted earlier, the primary winding current comprises both a resonant component, I_{res} , that is essentially equal to the secondary current

I_{sec} multiplied by the secondary-to-primary turns ratio, N , of the transformer 80, and a magnetizing current component, I_{mag} :

$$I_{\text{pri}} = I_{\text{mag}} + N \cdot I_{\text{sec}}. \quad (2)$$

[043] Therefore, at times when the magnetizing current, I_{mag} , crosses through zero (e.g., at times $tx1$, $tx2$, Fig. 6B) the primary current, I_{pri} , is directly proportional to the secondary current, I_{sec} : $I_{\text{pri}} = N \cdot I_{\text{sec}}$ @ $T_{\text{Imag}}=0$. For the converter shown, the magnetizing current crosses through zero at the midpoint of each power transfer interval (e.g., at time $T_R/4$, Fig. 6C). When a MOSFET device is used for switch S2 120 (Fig. 5), the voltage across switch S2 120 is proportional to the primary current:

$$V_p(t) = I_{\text{pri}}(t) \cdot R_{\text{DS-ON}}(T); \quad (3)$$

where $R_{\text{DS-ON}}(T)$ is the ON resistance of the FET at its operating point, e.g. operating temperature T and gate bias, V_{GS} .

[044] The timing block 220 of Figs. 2 and 4 may be used to generate a signal at the midpoint of each power transfer interval, e.g., in Fig. 6 at time $tx = T_R/4$, for example using the digital comparator techniques described above in connection with Fig. 4. Similarly, the timing block 220 may also generate a control signal, I_{sense} (Figs. 2, 6D), for use by the current monitor block 230, that begins when switch S2 120 turns ON and ends at the midpoint of the power transfer interval. In operation, the I_{sense} control signal may be used by the sampling control block 232 to turn the first sampling switch 234 ON and OFF (SH1: Fig. 5). When ON the first sampling switch 234 causes the voltage, V_{HI} , across the first sampling capacitor 238 (Fig. 6E) to follow the voltage, $V_p(t)$, across switch S2 120. At time $tx = T_R/4$ (with I_{mag} crossing zero), the first sampling switch 234 may be turned OFF to hold the voltage, V_{HI} , corresponding to the voltage, V_p , at the time, $T_{\text{Imag}}=0$, when $I_{\text{mag}} = 0$. After the first sampling switch 234 is turned OFF, the sampling controller 232 may generate a second sampling pulse, SH2 (Fig. 6F), causing the second sampling switch 236 to momentarily close and then open, transferring the voltage from the first sampling capacitor 238 to the second sampling capacitor 235. With switch 236 closed, the voltage, V_{H2} (Fig. 6G) across the second sampling capacitor 235 will be proportional to the voltage V_{HI} across the first sampling capacitor 238 and with switch 236 opened, the second sampling capacitor

235 will hold the voltage V_{H2} until the next sampling period. The two stage sample and hold circuit provides a voltage, V_{H2} , that is maintained constant at a level that is proportional to the peak value of I_{res} during the power transfer interval and while the first sample and hold acquires the next sample.

[045] Because the sampled voltage V_{H2} is measured across a MOSFET resistance, the calculation of secondary current may need to account for the temperature dependence of the MOSFET resistance. In general the on resistance of the MOSFET, $R_{DS-ON(Tx)}$, at temperature T_x , may be related to the ON resistance of the MOSFET, $R_{DS-ON(TF)}$, at a fixed temperature, T_F :

$$R_{DS-ON(Tx)} = f(R_{DS-ON(TF)}, T_x, K2, K3 \dots Kn) \quad (4)$$

where $K2, K3 \dots Kn$ are constants specific to the MOSFET being used. The secondary current may then be calculated as:

$$I_{sec} = K1 * V_{H2} / R_{DS-ON(Tx)} = K1 * V_{H2} / f(R_{DS-ON(TF)}, T_x, K2, K3 \dots Kn) \quad (5)$$

where $K1$ is a constant that accounts for, e.g., the transformer turns ratio and the relative values of the sampling capacitors 238, 235. Because the average converter output current, I_{out} , is equal to the average value of the rectified secondary current, measurement of I_{out} requires only that the constant $K1$ be modified. Function Block 233 (Fig. 5) may be used to perform calculation of I_{sec} , I_{out} , or both.

[046] Although the current monitor has been described when used with a MOSFET as a current sensing element, alternative embodiments are possible. For example a resistor in series with the resonant circuit, or a combination of a resistor in series with a MOSFET, may be used for sensing the current.

III. Current Limiting

[047] In the absence of inrush current limiting, turning on a converter having a capacitive load could result in very large resonant currents flowing at the input of the converter at least until the output capacitance is charged to a sufficiently high voltage. The digital controller 200 may provide inrush current limiting and current limiting during normal operation using the current monitor 230 to sense the current.

A. Truncated Power Transfer Intervals

[048] One possible way to limit the inrush current is to operate the SAC power train with truncated power transfer intervals, i.e. the duration of the power transfer intervals is reduced to less than the characteristic resonant half period ($T_{PTI} < \frac{1}{2} T_{Res}$). With PTIs shorter than the resonant half period, $T_{PTI} < \frac{1}{2} T_{Res}$, the converter's series resonant circuit will exhibit an essentially inductive impedance (inductance L_s 150, FIG. 2), thereby limiting the current that flows into the converter. The truncated PTIs may be used in converter operating cycles that include two shortened PTIs and two intervening energy recycling intervals (which will be somewhat longer as a result of the reduced magnetizing current in the transformer) resulting in an elevated operating frequency, F_{hi} , which is greater than the characteristic frequency, F_R . Alternatively, the truncated PTIs may be used in converter operating cycles that include one or two clamp phases (discussed in detail below) in addition to intervening energy recycling intervals to control the operating frequency to be greater than, equal to, or less than the characteristic frequency, F_R .

[049] A method for controlling inrush current in a resonant converter, such as a SAC, that exhibits an inductive input impedance with truncated power transfer intervals or at frequencies above a normal operating frequency, F_{op} , may be implemented in a controller such as the digital controller 200 and may include the following steps:

[050] A. The controller may initially use an operating period, T_n , or a power transfer interval that is shorter than the normal operating period or power transfer interval (i.e., at an operating frequency, F_n , that is higher than the normal operating frequency, F_{op}) during start-up operation.

[051] B. Operation of the converter may continue at the present operating interval, e.g. T_n , or PTI, as long as the peak current, e.g. the primary current, which may be sensed by the controller, e.g. using the current monitor 230, exceeds a pre-defined inrush threshold, I_{Th} .

[052] C. When the controller detects that the current has declined below the threshold, I_{Th} , it may increase the operating period (or PTI) incrementally by ΔT to a longer operating period, $T_{n+1} = T_n + \Delta T$.

[053] D. Operation may continue in the above manner, repeating processes B and C, incrementally increasing the period as the peak current falls until the period has been increased to the normal operating period, T_{op} , (or normal PTI) of the converter.

[054] Application of the truncated PTI (without clamp phases, high frequency) inrush current limiting method in a SAC converter is illustrated in Figs. 7A through 7H which assume that the output storage capacitor 90 (FIG. 2) is discharged and power is applied to the converter at time t_0 (Figs. 7A, 7B). For clarity and ease of illustration of the truncated PTI operation, Figs. 7A and 7B do not show energy recycling intervals or clamp phases (discussed below). Fig. 7A shows the ON times for switch S2 120, which are representative of the conductive half of the converter operating period, i.e. one of the two power transfer intervals in each converter operating cycle. Although not shown in Figs. 7A-7H, the converter operating cycles in high frequency operation may include energy recycling intervals during which the magnetizing energy may be used as described above to charge and discharge parasitic capacitances to reduce switching losses. The initial duration of the power transfer intervals, e.g. the ON time of switches S1 110 or S2 120, may be set to a fraction, e.g. $1/6^{\text{th}}$ of their normal duration ($T_{PTI-OP} = T_R/2$ during normal operation) for current limiting operation. For example, the initial PTI duration, $T_{TPI} = T_a$, shown in Fig. 7A is substantially shorter than half, $T_R/2$, of the resonant period. In a SAC whose resonant frequency is 1 MHz, resonant period is 1 μs , and each power transfer interval has a duration $T_{PTI-OP} = 0.5 \mu\text{s}$, the initial ON time, T_{PTI-N} , may for example be set to be $1/6$ of the normal operating half-period ($T_{PTI-N} = T_{PTI-OP}/6 = 83 \text{ nS}$).

[055] As shown in Fig. 7B, during the first PTIs (A1, A2 in Fig. 7A) having a duration $T_{TPI} = T_a$, the peak value of the primary current, I_{pri} (Fig. 7B) increases above a pre-defined threshold, I_{Th} . The peak value of the current may be sensed by the current monitor 230 (Fig. 5) during power transfer intervals having a duration less than one quarter of the resonant period ($T_{PTI} < T_R/4$) by ending the sample and hold period either when switch S2 120 turns OFF (Fig. 7D) or a fixed time ($T_R/4$) after switch S2 120 is turned ON (Fig. 7G), whichever occurs first. For example, as shown in Fig. 7C, the timing block 220 may send an Isense signal to the current monitor circuit when switch S2 120 turns ON and capture a sample of the current when switch S2 120 turns OFF by turning the Isense signal OFF and

briefly asserting SH2 to capture the sample. The calculated value of the peak current (from function block 233) may be compared to the threshold value, I_{Th} , to determine the length of the next half-period in accordance with the method.

[056] The peak value of the primary current will eventually decline as energy is transferred to, and the voltage across the output capacitor rises, until, as shown in Fig. 7B the peak primary current remains below the threshold, I_{Th} , in the power transfer interval ending at time, t_x . In response to the sensed peak current remaining below the threshold, I_{Th} , during a half-period, the controller may increase the duration, T_{TPI} , of the power transfer interval as described above. The duration, T_{TPI} , of the PTIs (B1, B2, B3, B4: Fig. 7A) immediately following PTI (A3 ending at time t_x) in which the current remains below the threshold, is shown longer than the duration, T_a , of those PTIs (A1, A2, A3: Fig. 7A) preceding it in Fig. 7B: $T_b = T_a + \Delta T$, where T_b is the duration of the PTIs following t_x . For the converter operating parameters cited earlier, the value of ΔT may be 5 nS, making $T_b = 88$ nanoseconds. Because of the incrementally longer power transfer interval (T_b), the peak current, I_{pri} , may again exceed the threshold, I_{Th} , for one or more operating cycles following the increase shown after time t_x . The controller may continue to operate the converter continues with PTIs (B1, B2, B3, B4: Fig. 7A) having a duration of T_b until time the peak current once again declines below the threshold, I_{Th} , as shown in Fig. 7B in PTI B4 ending at time, t_y . Thereafter, the PTI duration may again incremented to the next larger value, e.g. $T_c = T_b + \Delta T$ as shown for PTIs C1, C2, and C3 in Fig 7B, and the process may continue until the peak current once again remains below the threshold, I_{Th} , in PTI C3 ending at time t_z . The process may continue in this manner until the duration of the PTIs has reached the normal PTI duration, i.e. until $T_{TPI-N+1} = T_{PTI-OP} = T_R/2$.

[057] In a SAC converter, the current sampling may continue to use the turn OFF of switch S2 120 until the duration of the PTI becomes greater than or equal to $T_R/4$, corresponding to the time during each half-period at which the peak value of the sinusoidal primary current is at a maximum. Thereafter, sampling of the peak current may be done at a time $T_R/4$ after the PTI has started (instead of when switch S2 120 turns OFF). Thus, for a SAC converter, the high frequency inrush current limiting method may comprise the following algorithm:

[058] 1. Begin converter operation with a power transfer interval duration that is shorter than normal, e.g. $T_{PTI-N} < T_{PTI-OP} = T_R/2$, at an operating frequency, f_a , that may be lower than, equal to, or higher than the normal operating frequency, F_{op} depending on the existence and duration of clamp phases.

[059] 2. Sample the primary current at the first to occur of: (a) the end of the power transfer interval, e.g. when switch S2 120 turns OFF (as shown in Figs. 7C-7E); or (b) a time equal to $T_R/4$ after the start of the PTI (as shown in Figs. 7F-7H), i.e. at the zero-crossing of the magnetizing current, at the midpoint of a normal power transfer interval.

[060] 3. When the peak input current fails to exceed a maximum current threshold, I_{Th} , increase the PTI duration incrementally, e.g. $T_{TPI-N+1} = T_{TPI-N} + \Delta T$.

[061] 4. Continue steps 2 and 3 until the duration of the PTI has been increased to the norm, i.e. until $T_{TPI-N+1} = T_{PTI-OP} = T_R/2$.

[062] In Fig. 7B, the length of the half-period is shown to exceed $T_R/4$ after time t_w . In accordance with the SAC truncated PTI (high frequency) inrush current limiting method, the samples (Figs. 7G, 7H) are not taken when switch S2 120 is turned OFF (e.g., at time T_d), but are taken at time $T_R/4$, corresponding to the time of peak primary current flow.

[063] Because a SAC power train with a low leakage inductance transformer may require significant reduction, e.g. by a factor of 10, of the PTIs during start up with large capacitive loads, high frequency operation with relatively constant duty cycle can result in greatly increased current demands by the control circuitry, e.g. ten times the nominal control current levels, which may in turn require oversized internal voltage regulators. It may therefore be advantageous and more efficient to operate the power train with truncated PTIs at or near the normal operating frequency, i.e. by increasing the duration of the clamp phases (described below) as the PTI are shortened during startup. Shorter power transfer intervals may require adjustment of the secondary gate driver circuitry to allow for short pulses. Alternatively, where the ring-up and ring-down times and minimum pulse hold times for the secondary drivers do not allow the secondary switches to respond to very short PTIs, the body diodes of the secondary switches (MOSFETs) may be used to rectify the output

voltage, i.e. during initial startup. Use of the body diodes works particularly well for converters delivering higher output voltages, such as bus converters.

B. Regulated Gate Drive

[064] Because MOSFET gate drive power may increase with increasing converter operating frequency, implementation of the high frequency inrush current limiting method may require that gate driver circuitry be scaled up to handle the higher transient gate power required during inrush. This scaled-up circuitry may operate less efficiently at the normal operating frequency, F_{op} , than might circuitry designed to operate at a lower fixed frequency, F_{op} .

[065] Figure 10 shows a block diagram of an inrush current limiting circuit 400 for use with SAC power conversion circuitry 100 operating at the normal converter operating frequency, F_{op} . Unlike the truncated PTI current limiting described above, the current limiting in Fig. 10 fixes the converter operating frequency at F_{op} . Thus, the SAC switches S1 110 and S2 120 (shown in Fig. 10) are turned ON and OFF as described above in connection with the digital controller (220 in Fig. 4) and with the timing illustrated in Figs. 3C and 3D. The secondary switches S3 130 and S4 140 (not shown in Fig. 10) are also operated in the same way as described above.

[066] Switch S5 370 may be turned ON when switch S2 120 is ON and may be turned OFF prior to switch S2 120 being turned OFF and the ensuing ZVS transition of switch S1 110 prior to turn ON. When OFF, switch S5 370 prevents the rising voltage at V_p from propagating back into the ground-referenced circuitry within the inrush limiting circuitry 400. When switch S2 120 is ON, primary node 402 is connected to ground through the small resistance of switch S2 120 and a ground-referenced feedback loop is formed comprising sample-and-hold circuit 395, error amplifier 390, adjustable voltage regulator 380, switch S5 370 (which is ON), and floating gate driver 350. As described earlier, the sample-and-hold circuit 395 receives a measurement (which may include sensing the voltage V_p across switch S2 120) indicative of the current, I_{S2} , flowing in switch S2 120 when it is ON. The set-point for the feedback loop may be provided by a constant level source (not shown) or by a ramp generator 397, which may provide an output ramp that starts at a predetermined starting level (e.g., zero) and ends at a predetermined ending level. The rate-of-change of the ramp may be relatively slow so that the incremental change in the current

set-point is small during each converter operating cycle. Inrush current ramping may be used to keep the power dissipation in switch S1 110 during inrush current limiting at a constant level to reduce heating during startup.

[067] In operation, the sample-and-hold circuit 395 samples I_{S2} at the midpoint of the switch S2 120 power transfer interval, corresponding to the zero-crossing of the magnetizing current as described earlier. Error amplifier 390 compares the sampled value of I_{S2} to the output of ramp generator 397 and delivers an error voltage, V_{set} , to the set-point input of adjustable voltage regulator 380. With switches S5 370 and S2 120 ON, the voltage regulator 380 regulates the voltage, V_{drive} , across storage capacitor 360, which holds the voltage, V_{drive} , while switches S2 120 and S5 370 are OFF. Switch S5 370 may be turned OFF when switch S2 120 is turned OFF.

[068] With switch S2 120 OFF (and switch S5 370 OFF), the controller may begin conduction of switch S1 110 by asserting the “S1 ON” control signal (at time t_1 in Figs. 3C, 3G) as described above. The floating gate driver 350 connected to drive the gate of switch S1 110 drives the gate of switch S1 110 with a voltage proportional to the voltage V_{drive} held by capacitor 360. The gate voltage of switch S1 110, V_{gs1} , may be substantially equal to V_{drive} for some circuits, however, using the resonant gate drive circuit discussed below, the gate voltage may be substantially equal to twice V_{drive} . The feedback loop adjusts V_{drive} to a value that is just sufficient to enable the sampled value of I_{S2} to follow the output of the ramp generator 397. It does so by adjusting V_{drive} (and, therefore, V_{gs1}) so that the channel resistance of switch S1 110 is at a value consistent with limiting the MOSFET current to the set-point value. Thus, rather than fully enhancing switch S1 110 into a fully ON state, in which the channel resistance of the MOSFET is relatively low and insensitive to variations in V_{gs1} , during inrush limiting the feedback loop operates the MOSFET within its “saturation” region, in which the channel resistance is a strong function of V_{gs1} . By this means, the current is controlled to increase, in a pre-determined fashion determined by the ramp generator, and an inrush current surge may be prevented.

[069] As the input current increases the converter output voltage will also increase. When the converter output voltage reaches some pre-determined value, the inrush current limiting process may be terminated. One way to sense the relative value of the output voltage is to measure the primary voltage, V_p , when the current in the switches has returned

to zero (e.g., at time t_6 , Figure 3), because V_p is substantially equal to the primary-reflected value of V_{out} at that time. Once the inrush limiting process is terminated, normal converter operation may be initiated by increasing V_{drive} to a value consistent with operating switch S1 110 in its fully ON state. One way to increase V_{drive} is to force the output of the voltage regulator 380 to an appropriate pre-determined value; another way is to provide an alternate source of power to the floating gate drive circuit.

[070] Alternate embodiments of the circuitry of Figure 10 are possible. For example, sampling and measurement of I_{s2} may be implemented using the technique described above with reference to Figure 5. The error amplifier function may be implemented digitally, as may the ramp generator function.

IV. Gate Driver

[071] A gate driver circuit 300 for efficiently driving the gate-control input of MOS-gated switching devices such as MOSFETs or IGBTs suited for use in the primary and secondary gate drivers 250, 260 shown in Fig. 2, will be described in connection with Fig. 8. A MOS-gated device 316 to be controlled by the driver circuit 300 is shown having an input capacitance, C_g , represented by gate capacitor 318 in Fig. 8. The driver 300 itself includes a storage capacitor 306, having a capacitance substantially larger than the gate capacitor 318; a resonant inductor L1 309; a clamp circuit 304; switches Sa 312, Sb 314 and Sc 310; and is fed by a voltage source 302, which supplies a voltage, V_{drive} , for turning the MOS-gated switch 316 ON. Waveforms illustrating the operation of the gate driver circuit 300 are provided in Figs. 9A through 9E. Initially, i.e. at a time just prior to time t_0 : storage capacitor C_s 306 is charged to a voltage, V_{CS} , approximately equal to $V_{Drive}/2$; switches Sa 312 and Sc 310 are OFF; and switch Sb 314 is ON, shunting the gate capacitor 318 and maintaining the gate voltage, V_g , at zero volts (and switch 316 OFF).

[072] Turn 316 ON: At time t_0 , switch Sb 314 may be turned OFF (allowing the gate capacitor to be charged) and switch Sc 310 may be turned ON, initiating a resonant transfer of energy from storage capacitor 306 (which has been charged V_{CS} to $V_{Drive}/2$ volts) into gate capacitor 318, via inductor L1 308, the resonant period, T_2 , of which will be determined primarily by the gate capacitance, C_g , and the inductance, L1, assuming that the

storage capacitance is much greater than the gate capacitance: $T2 = 2\pi\sqrt{L1 * Cg}$. During the time that switch Sc 310 is ON, an essentially sinusoidal current flows in the inductor L1 308, as shown in Fig. 9D. At time t3 ($t3 = t0 + T2/2$), the inductor current returns to zero and the gate voltage, Vg, has rung up to essentially $2*V_{CS} = V_{Drive}$ (Fig. 9E). Ideally, the voltage, Vg, across Cg will have rung all the way up to $V_{Drive} = 2*V_{CS}$; however, losses that may have occurred during the resonant energy transfer, a difference between the voltage across Cs 306, V_{CS} , and the value of $V_{Drive}/2$, or both may cause the gate voltage, Vg, to ring up to a value that is less than the voltage, $V_{Drive} = 2*V_{CS}$.

[073] Hold 316 ON: At time t3, switch Sc 310 may be turned OFF (disconnecting the inductor L1 308 and storage capacitor 306 from the gate and terminating the resonant transfer), and switch Sa 312 is turned ON connecting the gate to V_{Drive} . As shown in Fig. 9E, there may be a (small) step in Vg when switch Sa 312 is turned ON at time t3 as the gate fully charges to V_{Drive} . Switch Sa 312 may remain ON from time t3 and to t4 keeping the gate voltage, Vg equal to V_{Drive} (and switch 316 ON).

[074] Turn 316 OFF: At time t4, switch Sa 312 may be turned OFF permitting the gate capacitor to be discharged (to turn OFF switch 316), and switch Sc may be turned ON, initiating a resonant transfer of energy from gate capacitor 318 into storage capacitor 306, via inductor L1 308. During the interval that switch Sc 310 is ON from time t4 to t7, an essentially sinusoidal current flows in the opposite direction through inductor L1 308, as shown in Fig. 9D. At time t7 ($t7 = t4 + T2/2$), the inductor current returns to zero and the voltage Vg has rung down to a value essentially equal to zero.

[075] Hold 316 OFF: At time t7, switch Sc 310 may be turned OFF (disconnecting the inductor L1 308 and storage capacitor 306 from the gate and terminating the resonant transfer), and switch Sb 314 may be turned ON, shunting the gate and bringing the voltage Vg to essentially zero volts. Ideally, the voltage Vg across the gate capacitor will have rung all the way down to zero, however, as noted above losses that may have occurred during the resonant energy transfer and mismatch between V_{CS} and $V_{Drive}/2$ may result in the voltage Vg ringing down to a value that is slightly greater than zero. Thus, as indicated at time t7 in Fig. 9E, there may be a (small) step in Vg when switch Sb 314 is turned ON and the gate

fully discharges to zero. Between time t_7 and the beginning of the next operating at time t_0+T , switch Sa 312 may remain ON shunting the gate capacitor and maintaining the gate voltage, V_g , at zero volts (and switch 316 OFF).

[076] The clamp 304 may be used to guard against the voltage across the storage capacitor 306 creeping up to a value greater than $V_{Drive}/2$, e.g. due to extraneous charge being transferred into the capacitor by circuit noise coupling or other transient effects. The clamp 304 may be set to a predetermined clamp voltage, V_{clamp} , which may be slightly greater than $V_{Drive}/2$, to remove excess charge from the storage capacitor 306 while maintaining the capacitor at a voltage essentially equal to $V_{Drive}/2$.

[077] The gate drive circuit 300 (Fig. 8) may be used advantageously in a converter of the kind illustrated in Figs. 2 and 3 preferably with the resonant frequency of the gate drive, F_{G-Res} , being at least five times greater than the resonant frequency of the converter power train, F_R , ($F_{G-Res} \geq 5 F_R$). Referring to Fig. 3E, the times labeled t_0 , t_3 , t_4 and t_7 may correspond to the same times illustrated in Fig. 9. Thus, a set of pre-determined set-points in the converter of Fig. 2 may be used to time the turning ON and OFF of the switches in a gate driver 300 of the kind illustrated in Figs. 8 and 9. If gate drivers 300 are used for both primary and secondary gate drivers 250 and 260 in the converter of Fig. 2, adapted as necessary to the particular switches being driven, it may be possible to more accurately align the times at which converter switches turn ON and OFF, thereby increasing conversion efficiency.

V. Light Load Operation

[078] As the power processed by the converter is reduced, for example during light-load or at the extreme no-load operation, the core losses and conduction losses become dominant, reducing overall converter efficiency. The primary winding current in the SAC is the sum of the load-dependent resonant current, I_{res} , and the magnetizing current: $I_{pri} = I_{res} + I_{mag}$. At no load, the magnetizing current, I_{mag} , dominates the current flowing in the primary winding.

A. High Frequency Operation

[079] One way to reduce losses at low or no load recognizes that the magnetizing current, which is dependent on the primary reflected inductance, the input voltage, and the

power transfer interval, decreases in inverse relation (which is faster than proportionate) to increases in operating frequency. In other words, as the power transfer intervals are shortened the peak magnetizing current will decrease. As a result, the peak flux density in the core, being a function of the peak magnetizing current, also decreases in turn reducing core losses. As the level of magnetizing current decreases, the energy recycling intervals will become longer because the lower value of magnetizing current takes longer to charge and discharge circuit capacitances for the ZVS transitions. The increased duration of the ZVS transitions reduces the overall duty cycle of the power train beneficially compounding the reduction in duration of the power transfer intervals and magnetizing current.

[080] The increase in effective winding resistance (proportional to the square root of increase in operating frequency) at the higher operating frequency has a small adverse effect on conduction losses, ($P_{d-cond} = I_{mag}^2 * (R_{W-pri} + R_{FETS})$); however in comparison to the much greater reduction in magnetizing current and core losses, the increase is a tolerable tradeoff in reducing the total fixed losses. Because the gate-drive energy is recycled as described above, the operating frequency may be increased without significant penalty in switching losses. The controller may accordingly increase the converter operating frequency to improve the no-load efficiency, e.g. using the truncated power transfer intervals described above in connection with the current limiting mode of operation. By way of example, the controller may operate the power train at a no load operating frequency, F_{op-0} , that is twice the normal operating frequency, F_{op-nom} , resulting in greater than 50% reduction in core loss, greater than 50% reduction in winding losses, and greater than 50% reduction in conduction losses in the switches.

[081] The controller may transition between two modes of operation, high-frequency operation and normal-frequency operation in a binary manner when predetermined conditions are detected. For example, when the load current, resonant portion of the primary current, or primary current reaches a predetermined threshold, e.g. $I_{res} > 0$ or $I_{pri} > I_{Threshold}$, the controller may switch to operation using the normal (full) PTI (half of the resonant period), i.e. normal converter operating frequency, and when the load current or resonant portion of the primary current reaches a predetermined threshold, e.g. $I_{res} = 0$ or $I_{pri} < I_{Threshold}$, the controller may switch to operation using the truncated PTI, i.e. high-frequency operation. The controller may provide for operation at several PTI durations, e.g.

transitioning between high-frequency operation using a very short truncated PTI at no-load, to a lower, intermediate-frequency operation using a longer but still truncated PTI at light-load, and normal-frequency operation using the full PTI above a load-threshold. The number of PTI duration set-points may be increased as desired to provide for operation at various light load levels, switching PTI set-points as detected load conditions change. Alternatively, the controller may smoothly vary the duration of the PTI over a range, e.g. from a very short truncated PTI at no load to increasingly longer but still truncated PTIs at light load as the load increases. Because above some load level, the use of a truncated PTI will lead to greater losses than during normal operation, the controller may switch from the variable PTI duration to the normal (full) PTI duration when the detected primary current, or load current, or resonant current exceeds a threshold.

[082] As noted above, current in the SAC primary winding is the sum of the load-dependent resonant current, I_{res} , and the magnetizing current: $I_{pri} = I_{res} + I_{mag}$. The magnetizing current, which peaks near the end of the power transfer intervals, prevents full zero current switching of the SAC primary switches. For example, in a SAC in which the primary resonant current reaches 10 amps peak at full load and the magnetizing current reaches 1 amp peak, the primary switches may be carrying 10% of the peak current when they are switched OFF at the end of the PTI, achieving 90% ZCS. As the load current increases above zero, the resonant current increases, which means that truncating the PTI, i.e. turning of the primary switches before the resonant current returns to zero at the end of the resonant half-period, will mean that both the magnetizing current and some of the resonant current will be flowing in the primary switches at a time when they are transitioned to OFF. At very light loads the ZCS error may be tolerable, but may cause objectionable increases in noise as the load increases. The level of current flowing in the primary switches may be used as another condition for limiting operation with truncated PTIs. The controller may for example use the truncated PTI mode of operation when a combination of operating conditions are satisfied and use the normal (full) PTI when they are not. For example, the controller may exit truncated PTI mode when the load current exceeds a threshold such as 15% of full load as described above; or additionally exit truncated PTI mode if the current in the primary switches is greater than or equal to 20% of the peak primary current at when the

primary switches are turned OFF (at the end of the truncated PTI), or a combination of such criteria. The current monitor described above may be used to detect such conditions.

B. Low Frequency Clamp Operation

[083] Another method for reducing losses in the converter during light load operation (or alternatively to increase the effective output resistance of the converter, e.g. for inrush current limiting) is to clamp the primary or secondary winding of the transformer, elongating the converter operating period and lowering the operating frequency without changing the duration of the power transfer intervals and disrupting resonant operation. Referring to Fig. 11, a half-bridge primary-side SAC circuit is shown with a clamp switch SC connected across the primary winding (and leakage inductance or external inductance if any). The clamp switch SC, 180, is a bidirectional switch capable of blocking current in both directions. Because the clamp switch 180 SC will need only carry the magnetizing current, it may be much smaller than the primary switches, S1, S2. The clamp switch 180 SC may be turned ON to clamp the current in the transformer, essentially non-dissipatively for the time scale required, during a clamp phase suspending power processing in the converter operating cycle. Introduction of the clamp phase(s) lowers the effective operating frequency and lowering the effective duty cycle reduces the fixed converter losses.

[084] Operation of the clamp will be described with reference to the waveforms shown in Figs. 14A-14G which depict selected portions, but not necessarily all, of the respective waveforms. For example, Figs. 14D through 14F show current waveforms through switches S1, S2 and SC respectively without depicting the transitions immediately before or after the selected portions.

[085] At time t_0 , switch S1 may be turned ON initiating a first power transfer interval, PTI_1 , as shown in Fig. 14A. As shown in Figs 14A-14G, the duration of the PTIs are one half of the resonant period at the end of which (e.g. times t_1 , t_5) the resonant portion of the primary current (Fig. 14G) returns to zero and the magnetizing current (dashed line) reaches a peak.

[086] At time t_1 , switch S1 may be turned OFF (Fig. 14A) ending the first power transfer interval PTI_1 , allowing the magnetizing current to begin charging and discharging the capacitances at node 402 during a first energy recycling interval, ER1. The magnetizing current is shown declining during the first ER1 (t_1 to t_2). The voltage across the clamp

switch 180 may be reduced to a minimum, preferably zero, during the first energy recycling interval ER1, in preparation for the first clamp phase CL1. The voltage V_p across primary switch S2 is also reduced in partial preparation of the next power transfer interval, PTI₂.

[087] At time t₂, preferably when the voltage across the clamp switch reaches essentially zero volts, the clamp switch 180 SC may be turned ON (Fig. 14C, Fig. 14F) trapping the magnetizing current, I_{mag} , in the primary winding 82 (any external inductance 150 and any primary reflected inductances), i.e. the magnetizing energy is trapped in the transformer and primary reflected inductances. The duration of the clamp phase may be as long as necessary, but preferably not so long as to result in significant dissipation of the magnetizing current. As shown in Fig. 14G, the primary current is shown declining slightly over the course of the clamp phase.

[088] At time t₃, the clamp switch 180 SC may be opened ending the first clamp phase and allowing the trapped magnetizing current to resume charging and discharging the capacitances at node 402 (as shown by the slight decline in magnetizing current in Fig. 14G) during a second energy recycling interval, ER2. The second energy recycling interval ER2, may be used to reduce the voltage across primary switch S2 to a minimum, preferably zero, completing the ZVS transition in preparation of the next power transfer interval, PTI₂.

[089] At time t₄, primary switch S2 may be turned ON (Fig. 14B) when the voltage V_p at node 402 reaches a minimum, preferably zero, beginning the next power transfer interval, PTI₂ (Fig. 14G).

[090] At time t₅, primary switch S2 may be turned OFF (Fig. 14B) ending the second power transfer interval, PTI₂, and allowing the magnetizing current to charge and discharge the capacitances at node 402 (as depicted by a slight decline in magnetizing current in Fig. 4G) during a third energy recycling interval, ER3. The voltage at node 402 may be increased reducing the voltage across the clamp switch 180 SC to a minimum, preferably zero, in preparation for the next clamp phase, CL2 during the third energy recycling interval. The voltage V_p across primary switch S1 is also reduced in partial preparation of the next power transfer interval, PTI₁.

[091] At time t₆, preferably when the voltage across the clamp switch 180 SC reaches essentially zero volts, the clamp switch 180 SC may be turned ON (Fig. 14C, 14F) trapping the magnetizing current, I_{mag} , in the primary winding 82 and any external inductance

150 beginning a second clamp phase. The duration of the second clamp phase may preferably be made commensurate with the duration of the first clamp phase for symmetrical converter operation. As shown in Fig. 14G, the primary current is shown declining slightly over the course of the second clamp phase.

[092] At time t_7 , the clamp switch 180 SC may be opened (Fig. 14C, Fig. 14F) ending the second clamp phase and allowing the trapped magnetizing current to resume charging and discharging the capacitances at node 402 during a fourth energy recycling interval, ER4. The fourth energy recycling interval ER4, may be used to reduce the voltage across primary switch S1 to a minimum, preferably zero, completing the ZVS transition in preparation of the next power transfer interval, PTI₁ which is also the beginning of the next converter operating cycle.

[093] In this manner the clamp phase (clamp switch engaged) may be employed to reduce the operating frequency of the converter, reducing the fixed losses per unit time by virtue of a reduced number of operating cycles. For example, the duration of the clamp phases may be increased as the load (sensed using the above described current monitor) decreases for reducing power dissipation during light load operation. The clamp phased may also be adjusted to control inrush current during start-up operation. For example, in a SAC having a normal operating period, T_{nom} , operated with full power transfer intervals, $T_{PTI} = T_{res} / 2$, and the output resistance, R_{out} , may be doubled by introducing a clamp time per cycle, $T_{clamp} = \frac{1}{2} T_{op}$, and quadrupled the effective output resistance of the converter, R_{out} , may be doubled using a $T_{clamp} = \frac{3}{4} T_{op}$. The clamp phase may also be used to adjust the output resistance to compensate for changes in temperature or adjust the loadline for power sharing arrays. For example the controller may sense the converter operating conditions, including the temperature and introduce a clamp phase or adjust the clamp phase duration to maintain a desired level of output resistance. The clamp phase may be used to control the operating frequency with truncated PTIs, e.g. keeping the converter operating frequency constant while adjusting the PTI duration for in-rush current limiting or light load operation.

[094] Alternative embodiments of clamped SAC topologies are shown in Figs. 12 and 13. A SAC primary circuit as shown in Fig. 12 includes primary switches 191, 192, 193, 194 for driving the resonant circuit including the transformer primary winding 82 in a full-bridge configuration. The full bridge configuration allows the primary switches to be turned

ON in pairs to form a clamp, e.g. switches 192 and 194, or alternatively switches 191 and 193, across the resonant circuit. However, because the resonant capacitor is in series with the transformer an auxiliary clamp switch SA 180A as shown in Fig. 12 may be connected across the resonant capacitor to complete the clamp circuit. Alternatively, as shown in Fig. 12, an auxiliary clamp switch SB 180B may be used instead of switch SA. Alternatively as shown in Fig. 13, in embodiments having a full-bridge secondary configuration including secondary switches 195, 196, 197, and 198, pairs of the secondary switches, e.g. 196 and 198, or 195 and 197, may be used to clamp the secondary winding of the transformer eliminating the need for auxiliary clamp switches altogether.

VI. Cross-Isolation Control Interface

[095] Referring to Fig. 15, the digital controller 200 of Fig. 2 may be implemented as separate primary-side 200A and secondary-side 200B controllers that may communicate across an isolation boundary 290 via a transformer 272 if necessary. Alternatively a direct connection shown as broken line 275 in Fig. 15 may be used if isolation between the primary and secondary side controllers is not required, eliminating transformer 272 and capacitor 273. The primary side controller 200A may be essentially the same as the controller 200 of Fig. 2, except the secondary gate drivers 260 are moved to the secondary side controller 200B and a coder 270 and driver 271 are added to the primary side controller 200A. The secondary side controller 200B also includes a decoder 280 and power rectifiers 281 and 282.

[096] The waveforms of Figs. 16A through 16H illustrate features of the interface signal (Fig. 16A) which provide power and synchronization information to the secondary side controller 200B. Referring to Fig. 3E, the times labeled t_0 , t_3 , t_4 and t_7 for the switch S3 control may correspond to the same times for switch S3 and analogous times for switch S4 illustrated in Figs. 16A-H. The timing block 220 (Fig. 15) generates timing signals used to turn the primary and secondary switches ON and OFF as described above in connection with Fig. 2. In Fig. 15 however, a primary side coder 270 generates a binary interface signal from the signals for the secondary side switches (S3 and S4). The output of driver 271 (interface signal) may be connected to drive transformer 272 for isolation or directly to the input of the secondary controller for no isolation. The interface waveform (Fig. 16A) includes lower frequency components, e.g. from time t_0 to t_3 , time t_3 to t_4 , and t_4 to t_7 in each converter

half cycle that when rectified by the power rectifiers 281 and 282 in the secondary side controller 200B provide bias power for operating the secondary side controller 200B.

[097] The interface signal (Fig. 16A) additionally includes relatively fast synchronization transitions (shown between times t_s and t_0) in each converter half cycle that provide timing information. The synchronization transitions occur at a faster rate than any other transitions to facilitate easy detection by the decoder 280 in the secondary side controller 200B. The synchronization transitions also include a polarity that may be used to indicate the identity of the converter half cycle, i.e. the first half period or the second half period, and thus the identity of the secondary switch S3 or S4, respectively to be turned ON. A fast Lo-Hi-Lo transition during the interval from t_s to t_0 indicates the start at t_0 of the first half period (HP1 in Fig. 16H) and a fast Hi-Lo-Hi transition during the interval from t_s to t_0 indicates the start at t_0 of the second half period (HP2 in Fig. 16H).

[098] The secondary side controller generates the appropriate control signals for the secondary switches S3 and S4 based upon the subsequent transitions. For example, the Lo-Hi transition at time t_0 in HP1 initiates the transition of secondary switch S3 to the ON state. The control signals for the switches Sc (transition), Sa (ON), Sb (OFF) in gate driver 300 described above in connection with Figs. 8 and 9 are shown in Figs. 16B, 16C and 16D respectively for secondary switch S3. Gate driver switch Sc is turned ON at t_0 beginning the transition from OFF to ON for switch S3. The Lo-Hi transition in interface signal at time t_3 , may be used by the decoder to turn switch Sc OFF and turn switch Sa ON (holding switch S3 ON). At time t_4 , the interface signal transitions Hi-Lo signaling to the decoder 280 to turn switch Sa OFF and switch Sc ON thus beginning the transition of switch S3 from ON to OFF. The timing for turning switch Sc OFF and switch Sb ON (holding switch S3 OFF), i.e. time t_7 , may be signaled by the next transition after t_4 , i.e. the Lo-Hi transition at time t_7 ($=t_s$) in the interface signal as shown in Figs. 16A-D during HP1. This technique for generating the t_7 timing allows t_7 to be independently programmed from other time points but because $t_7 = t_s$ it would be followed by the start of the next cycle by a small but constant delay precluding operation with a variable clamp phase. Alternatively, the decoder may generate the t_7 timing using a measured duration of the preceding t_0 - t_3 interval from time t_4 (assuming that gate charge and discharge times are equal) allowing the primary side controller to insert a variable clamp interval (T_{CL}) after t_7 and before the start of the next

half-period as shown in Figs. 16A-D in HP1 with the clamp phase (HP1 w/CL in Fig. 16H). A similar sequence of the opposite polarity may be used to operate secondary switch S4 as shown in Figs. 16A, 16E, 16F, 16G and 16H.

[099] A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, the power conversion circuitry may use alternative primary circuits, such as a full-bridge primary circuitry. The primary and secondary gate drivers may be internal or external to the DSC. Combinations of the above described control methods may be deployed. For example, the controller may use high frequency operation together with a clamp phase for no-load and light load operation. Accordingly, other embodiments are within the scope of the following claims.

CLAIMS

1. A method of synchronously operating a power converter in a series of converter operating cycles, the converter having at least one primary switch to drive a resonant power train and at least one secondary switch, the resonant power train including a transformer and having a characteristic resonant frequency and period, the method comprising:

providing an oscillator for generating clock signals at an oscillator frequency;

generating timing control signals for each of a plurality of events based upon the clock signals in a (A) standard converter operating cycle, having a standard operating period and frequency, to:

(i) turn the at least one primary switch ON and OFF at times when essentially zero voltage is impressed across the respective at least one primary switch and essentially zero resonant current is flowing in the respective at least one primary switch; and

(ii) turn the at least one secondary switch ON and OFF at times when essentially zero current is flowing in the respective at least one secondary switch and essentially zero voltage is impressed across the respective at least one secondary switch; and

wherein the oscillator frequency is preset, and

the timing of the timing control signals for one or more selected events may be set independently of other timing control signals and events.

2. The method of claim 1 further comprising generating a current monitor trigger synchronized with a predetermined time during the converter operating cycle when a signal indicative of a current flowing in the converter may be sampled.

3. The method of claim 2 wherein the current monitor trigger is synchronized with a time at which a resonant current reaches a peak and a magnetizing current is essentially zero.

4. The method of claim 2 wherein the current monitor trigger is synchronized with a time that follows the start of the ON time of the at least one primary switch by approximately one fourth of the characteristic resonant period.

5. The method of claim 1 further comprising:

generating timing control signals based upon the clock signals in a (B) modified converter operating cycle, having a modified operating period and frequency, to:

- (i) turn the at least one primary switch ON at times when essentially zero voltage is impressed across the respective at least one primary switch and essentially zero resonant current is flowing in the respective at least one primary switch;
- (ii) turn the at least one primary switch OFF at selected times before a resonant current flowing in the respective at least one primary switch returns to zero.

6. The method of claim 5 wherein the selected times are determined by when a current flowing in the selected switch is expected to meet or exceed a predetermined threshold for current limiting.

7. The method of claim 5 wherein the selected times are determined by when a current flowing in the selected switch is expected to fall below a predetermined threshold for no-load or light-load operation.

8. The method of claim 5 wherein the modified operating frequency is greater than the standard operating frequency.

9. The method of claim 5 further comprising:
generating timing control signals based upon the clock signals to (C) turn selected switches in the converter ON to form a clamp phase during which at least one winding of the transformer is shunted by a low resistance circuit to essentially losslessly trap energy in the transformer during the clamp phase.

10. The method of claim 9 wherein the modified operating frequency is essentially equal to the standard operating frequency.

11. The method of claim 9 wherein a duration of the clamp phase is adjusted based upon the magnitude of a current flowing in the converter.

12. The method of claim 11 wherein the duration of the clamp phase is increased as the magnitude of the current flowing in the converter increases.

13. The method of claim 12 wherein the duration of the clamp phase is increased to increase the output resistance of the converter.

14. The method of claim 11 wherein the duration of the clamp phase is decreased as the magnitude of the current flowing in the converter decreases.

15. The method of claim 14 wherein the clamp phase is increased to reduce power dissipation for operation with a reduced load.

16. The method of claim 1 further comprising:
generating timing control signals based upon the clock signals to (B) turn selected switches in the converter ON to form a clamp phase during which at least one winding of the transformer is shunted by a low resistance circuit to essentially losslessly trap energy in the transformer during the clamp phase.

17. The method of claim 16 wherein a duration of the clamp phase is adjusted based upon the magnitude of a current flowing in the converter.

18. The method of claim 17 wherein the duration of the clamp phase is increased as the magnitude of the current flowing in the converter increases.

19. The method of claim 17 wherein the duration of the clamp phase is increased to increase the output resistance of the converter.

20. The method of claim 17 wherein the duration of the clamp phase is decreased as the magnitude of the current flowing in the converter decreases.

21. The method of claim 20 wherein the clamp phase is increased to reduce power dissipation for operation with a reduced load.

22. The method of claim 1 further comprising providing a gate drive circuit for operating selected switches in the converter and generating timing control signals based upon the clock signals to (a) initiate a transition of the selected switches from ON to OFF or OFF to ON, (b) hold the selected switches ON, and (c) hold the selected switches OFF.

23. The method of claim 22 further comprising adjusting the level of a control signal for the at least one primary switch to increase an effective resistance of the converter in a modified converter operating cycle.

24. The method of claim 22 further comprising adjusting the level of the control signal to maintain a desired current level in the converter.

25. The method of claim 22 further comprising adjusting the level of the control signal to maintain a desired power dissipation in the at least one primary switch.

26. The method of claim 22 wherein the gate drive circuit comprises a resonant circuit including a gate capacitance and having a characteristic resonant gate drive period, wherein the characteristic resonant gate drive period is at least five times less than the characteristic resonant period of the power train.

27. The method of claim 1 further comprising:

providing an encoder adapted to receive selected ones of the timing control signals for turning the at least one secondary switch ON and OFF and generate an interface signal comprising a synchronization signal for indicating the start of a half period, and timing features to signal (a) the start of a transition of the at least one secondary switch from OFF to ON, (b) the start of holding the at least one secondary switch ON, and (c) the start of holding the at least one secondary switch OFF.

28. The method of claim 27 wherein the interface signal further comprises a polarity signal adapted to indicate an identity of the half period.

29. The method of claim 27 further comprising:

providing a secondary side control circuit adapted to receive the interface signal and generate timing control signals for operating the at least one secondary switch including (a) the start of a transition of the at least one secondary switch from OFF to ON, (b) the start of holding the at least one secondary switch ON, and (c) the start of holding the at least one secondary switch OFF;

the secondary side control circuit being further adapted to derive power for operation from the interface signal.

30. The method of claim 29 wherein the secondary side control circuit is further adapted to measure aspects of the interface signal to generate timing control signals not encoded in the interface signal.

31. The method of claim 1 wherein the generating timing control signals based upon the clock signals further comprises:

counting the clock signals from the oscillator;

setting a count threshold for each event;

generating the respective timing control signal for each event as the counting matches the respective count threshold.

32. The method of claim 31 wherein the oscillator and timing events are open-loop with respect to the power train.

33. The method of claim 31 wherein the oscillator or timing events are adjusted with feedback from measurements in the power train.

34. The method of claim 33 wherein the measurements and adjustments are performed during the manufacturing process.

35. The method of claim 33 wherein the measurements and adjustments are performed during operation as part of a closed-loop feedback system.

ABSTRACT

Techniques for digitally controlling resonant converters are described. Digital timer control circuitry may be used open-loop to generate signals for controlling the switches in a resonant power train. The timing may be readily adjusted to account for tolerances in the power train's resonant components. Techniques for primary side current monitoring and converter current limiting, including truncated operating intervals and regulated gate drive circuitry, are also disclosed. A resonant gate drive circuit allows for efficient turning ON and OFF of MOS-gated switches in the power train. The controller may increase or decrease the operating frequency of the resonant converter to reduce converter losses during selected operating conditions. Clamp phases may be used to control inrush current or to reduce dissipation during no-load or light-load operation.

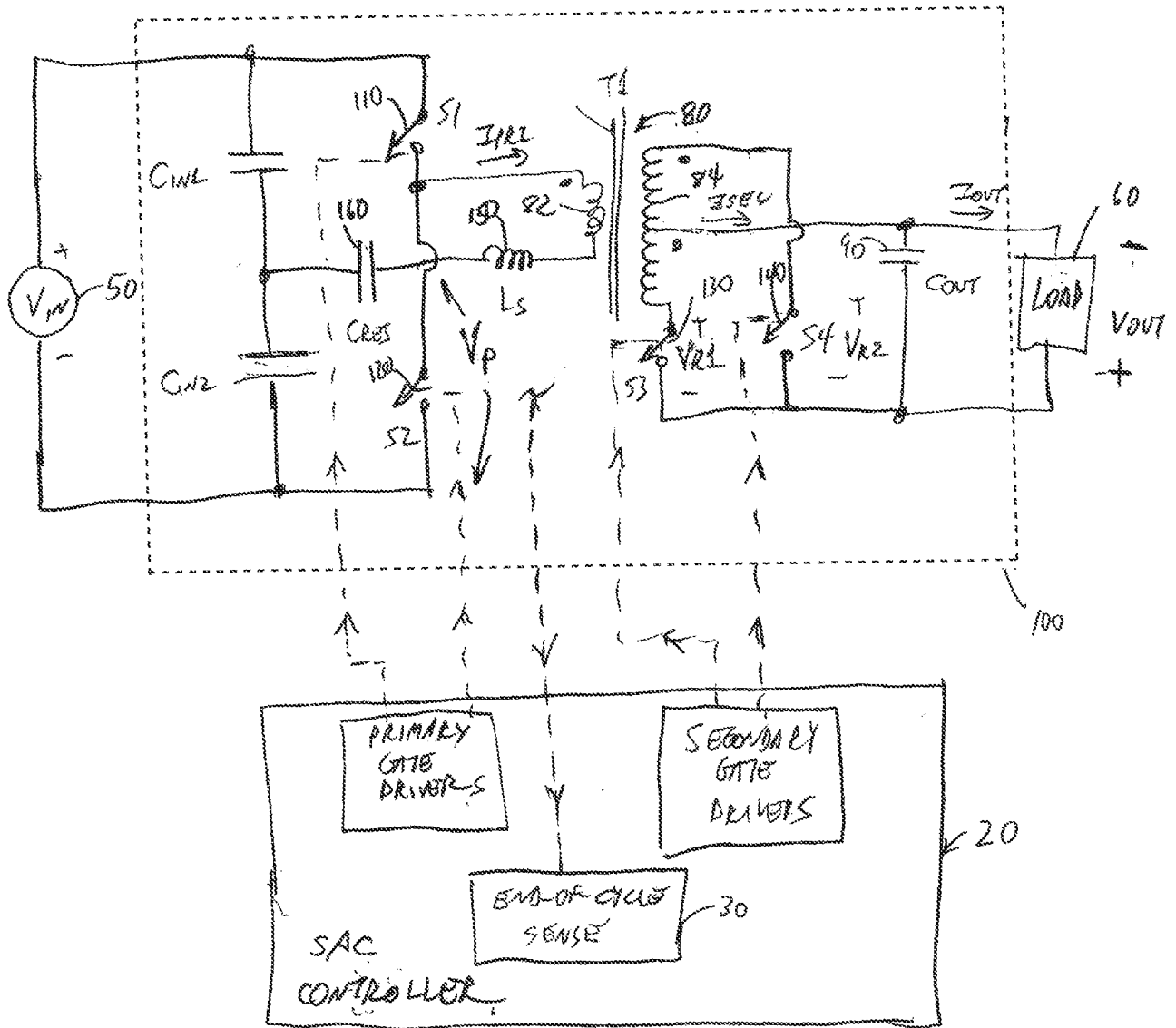


FIG. 1

10

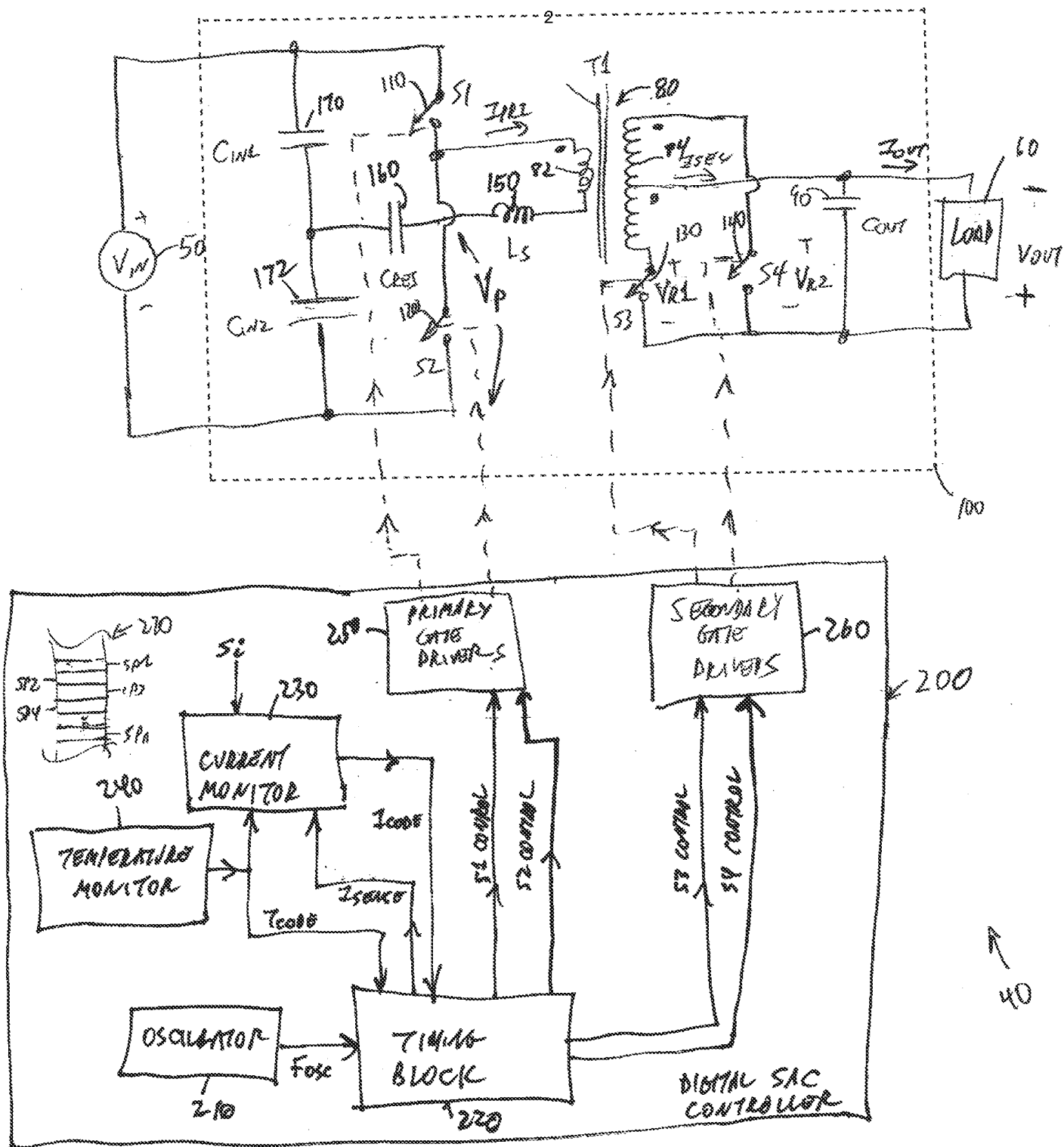
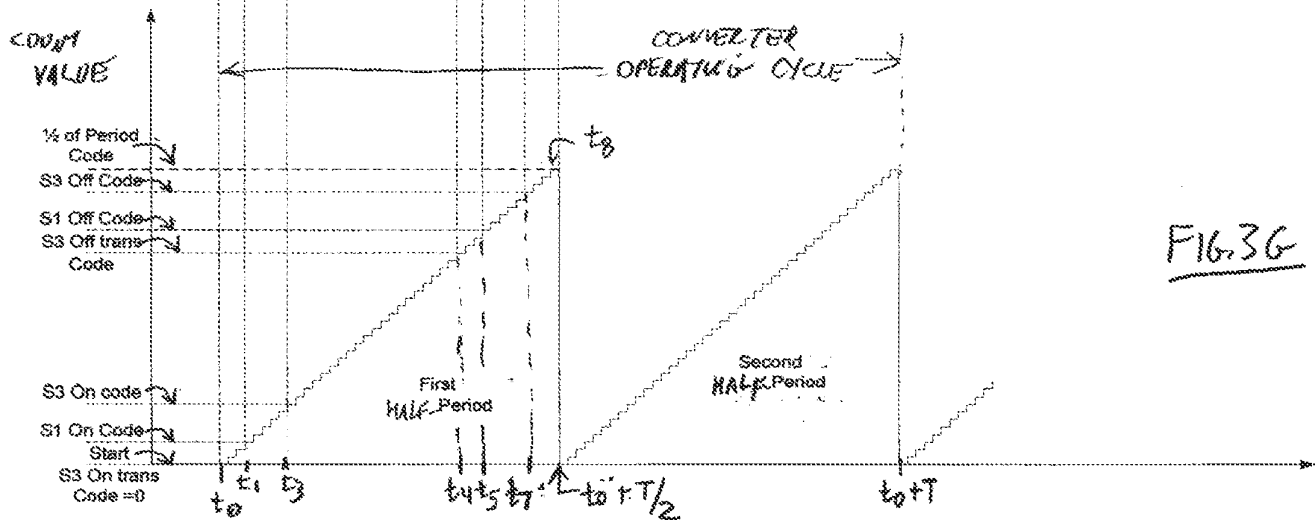
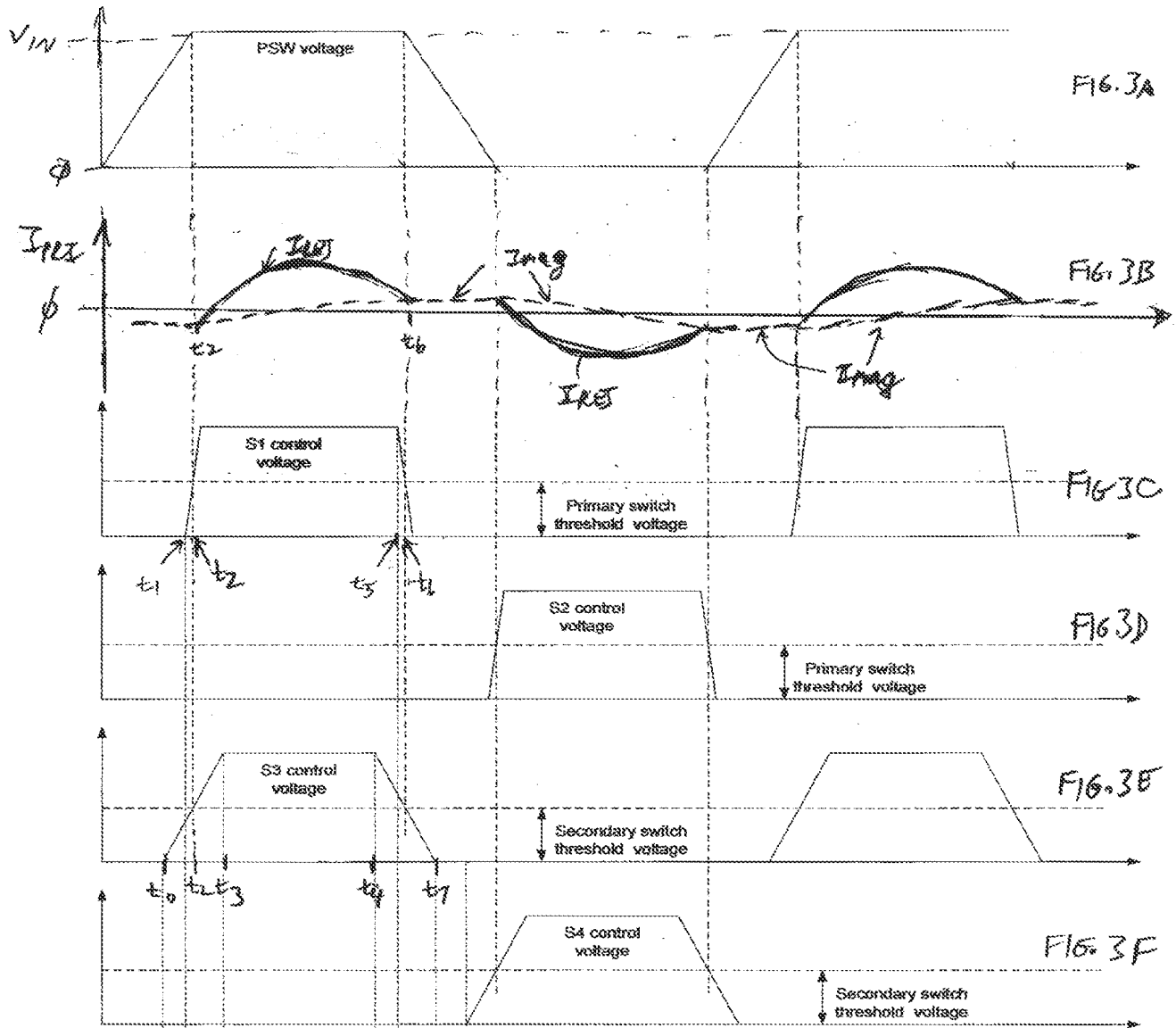


FIG 2



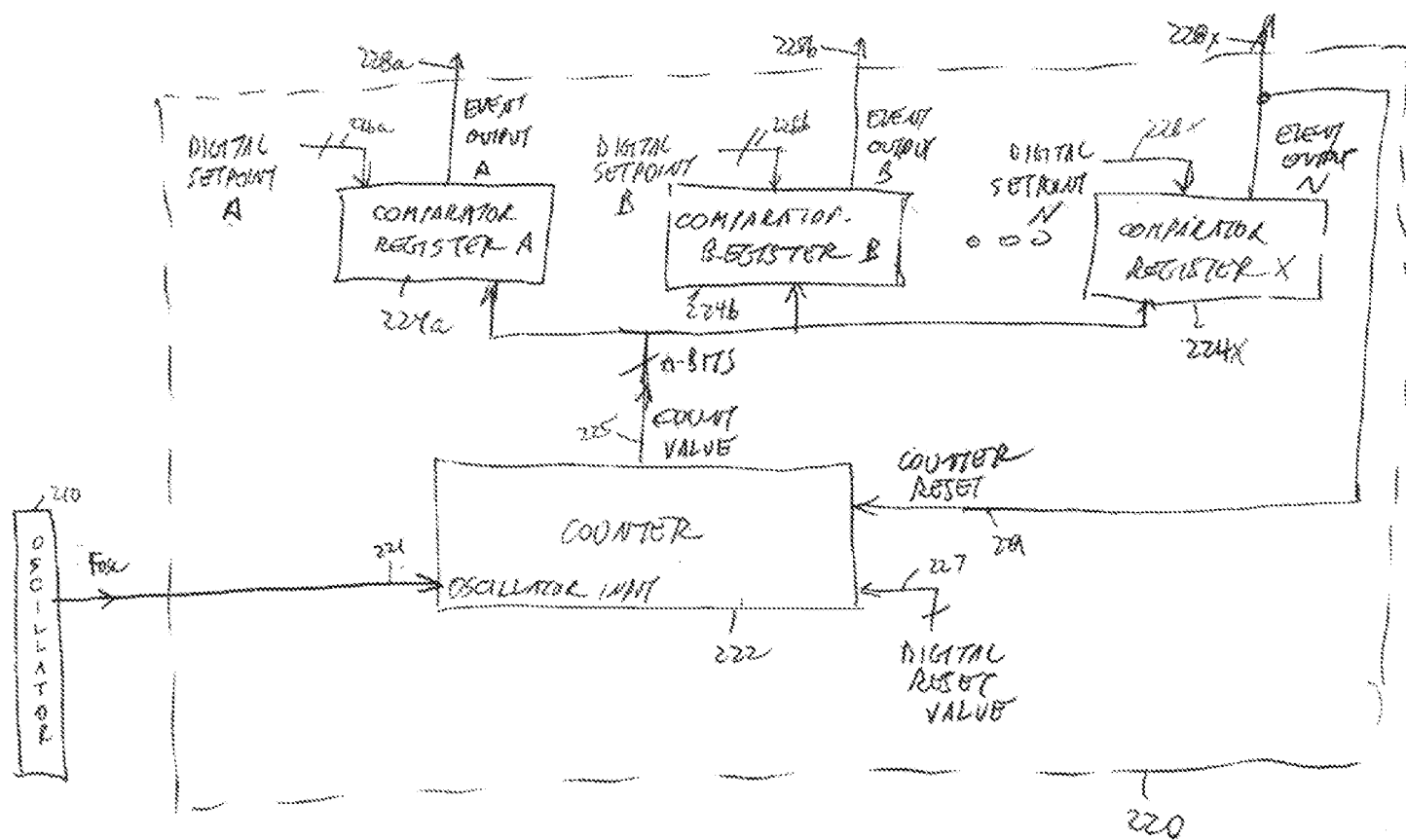
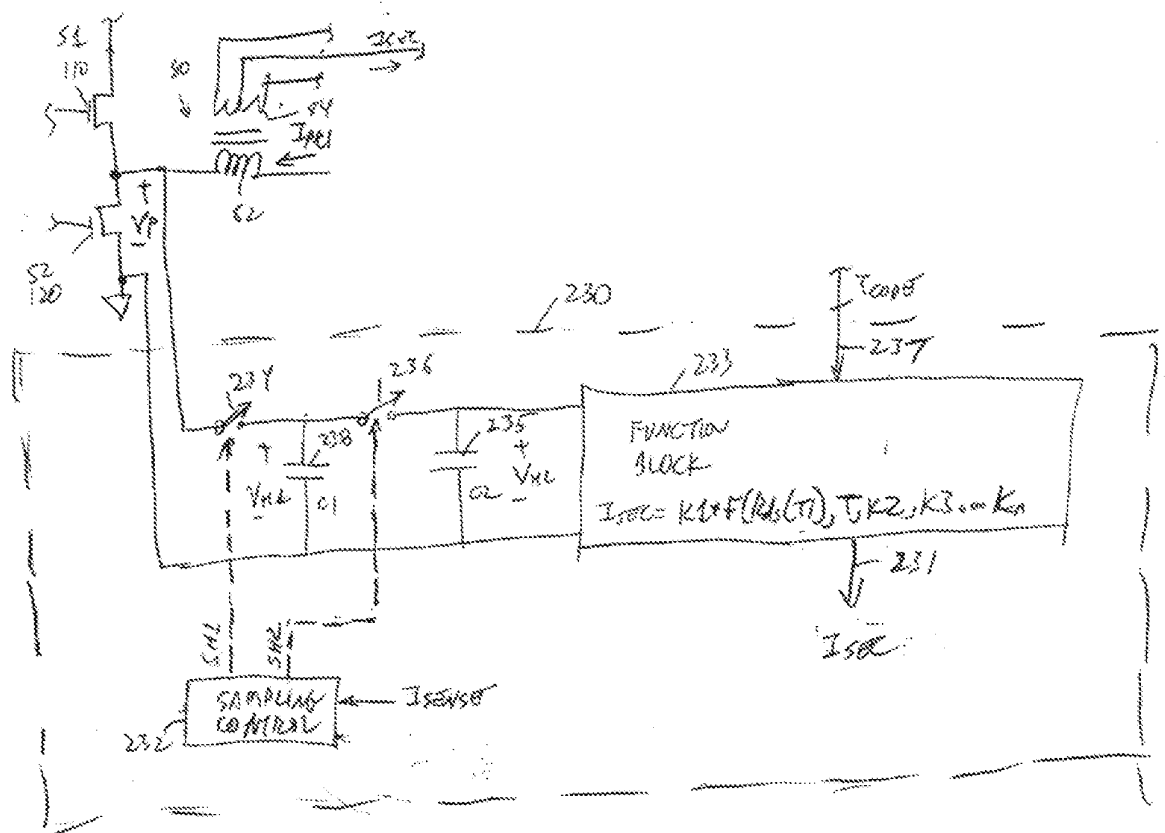


FIG. 4



FILE 5

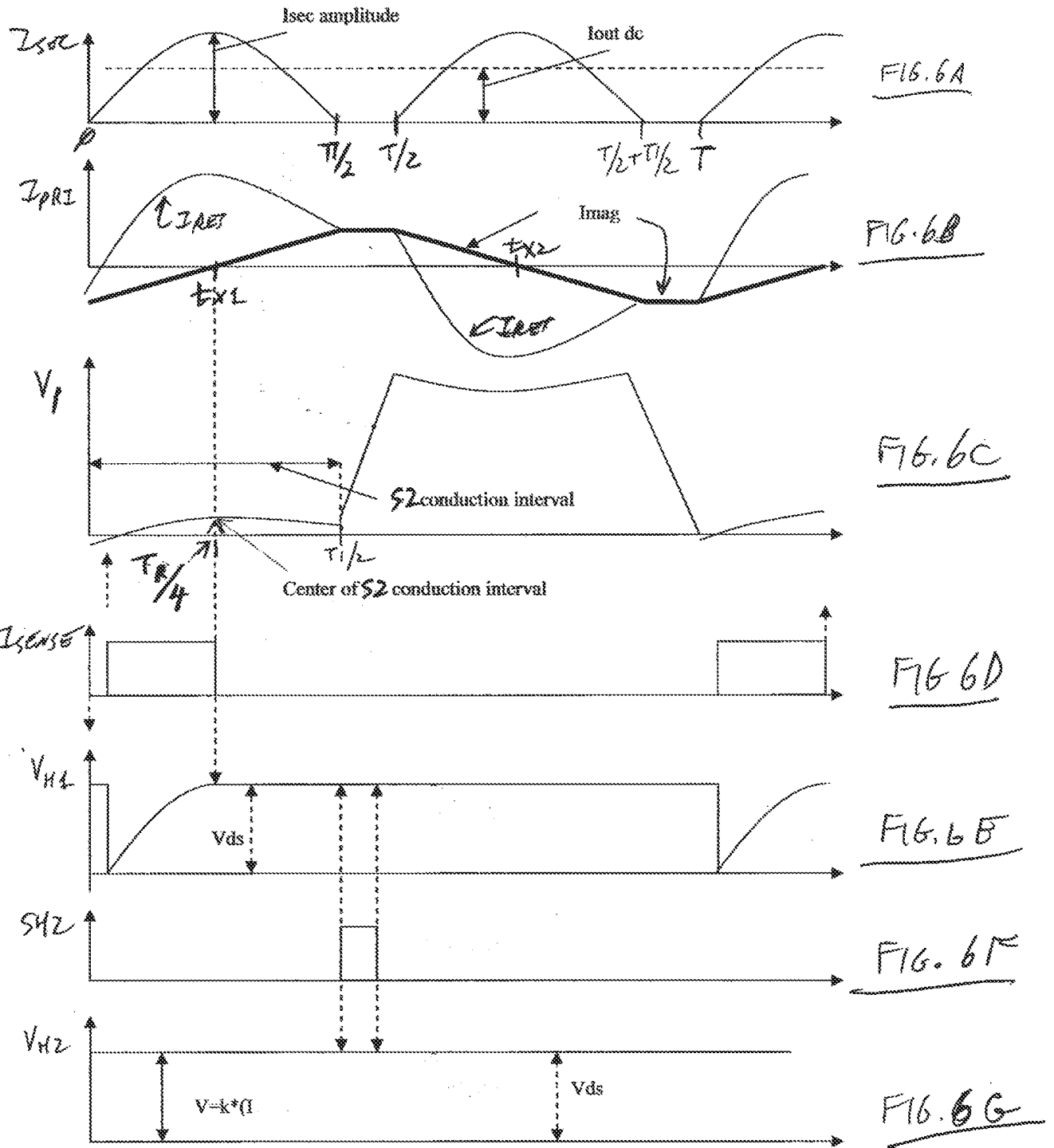
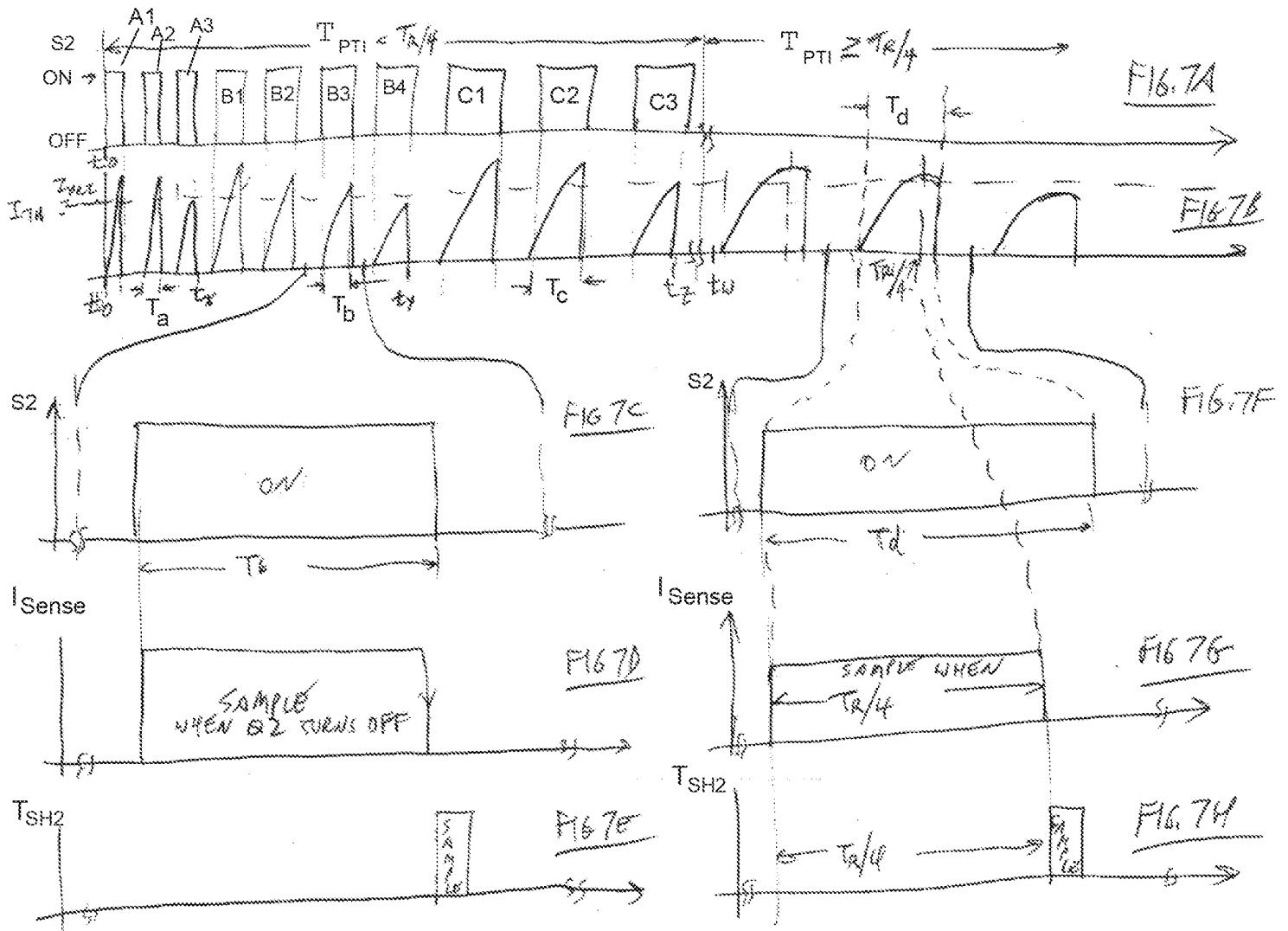


FIG. 6



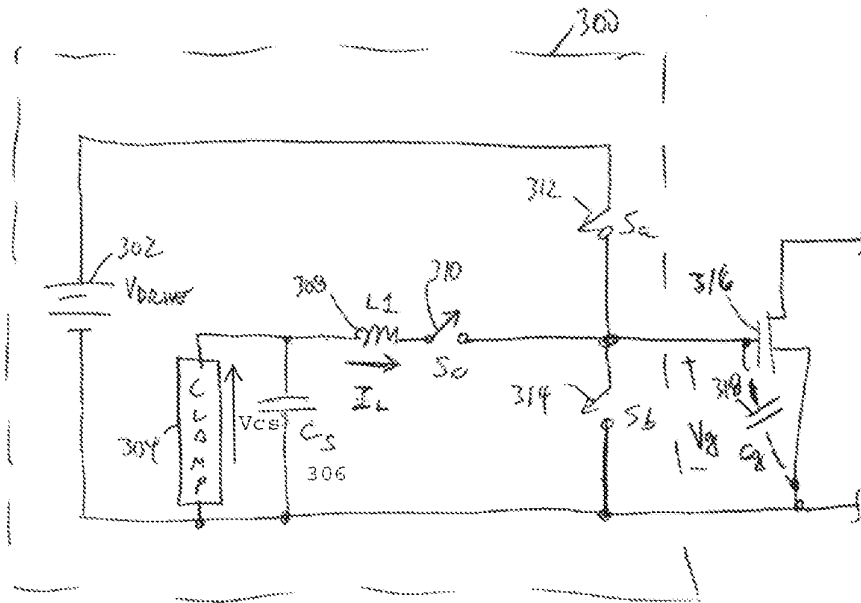
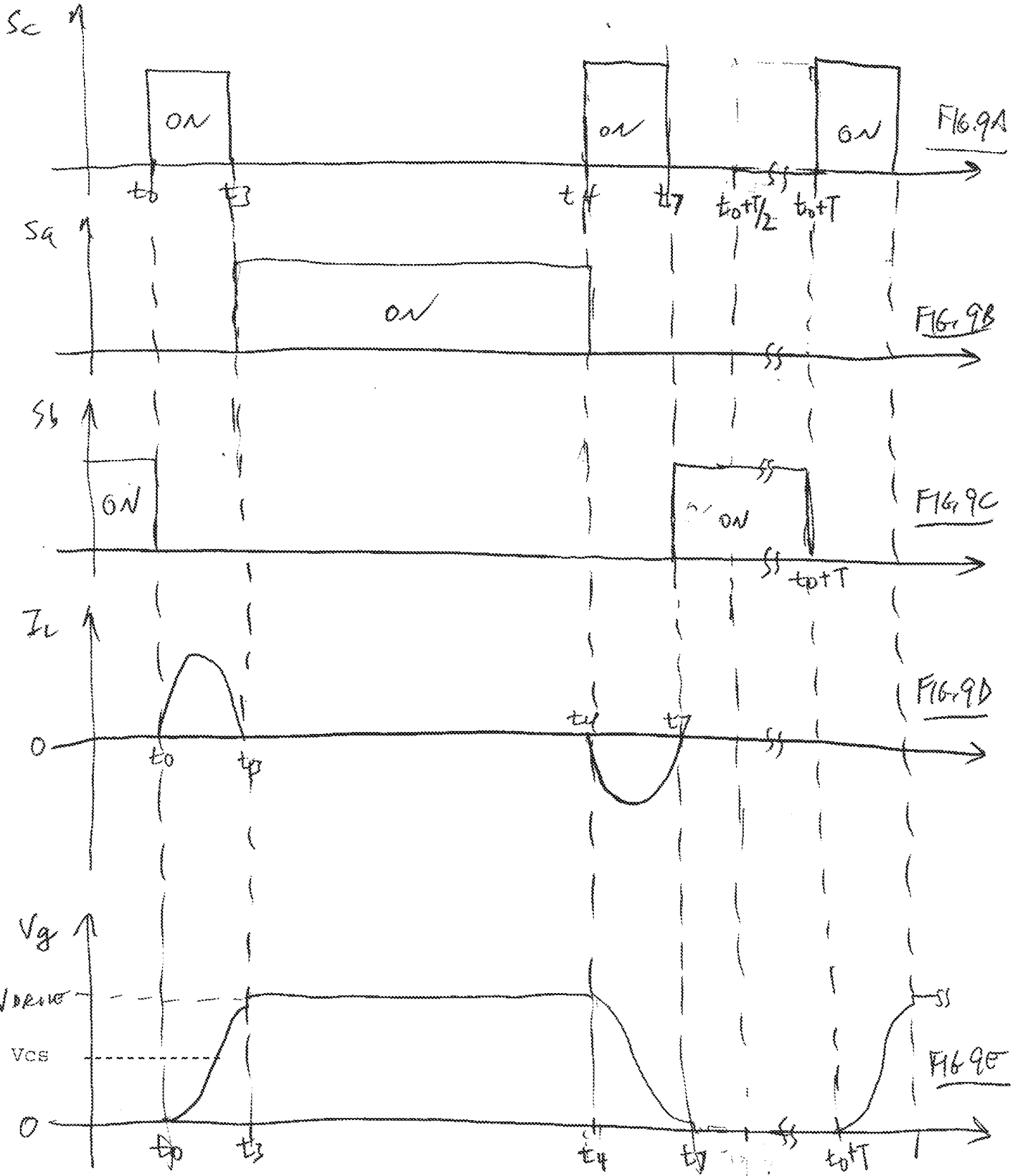


FIG. 8



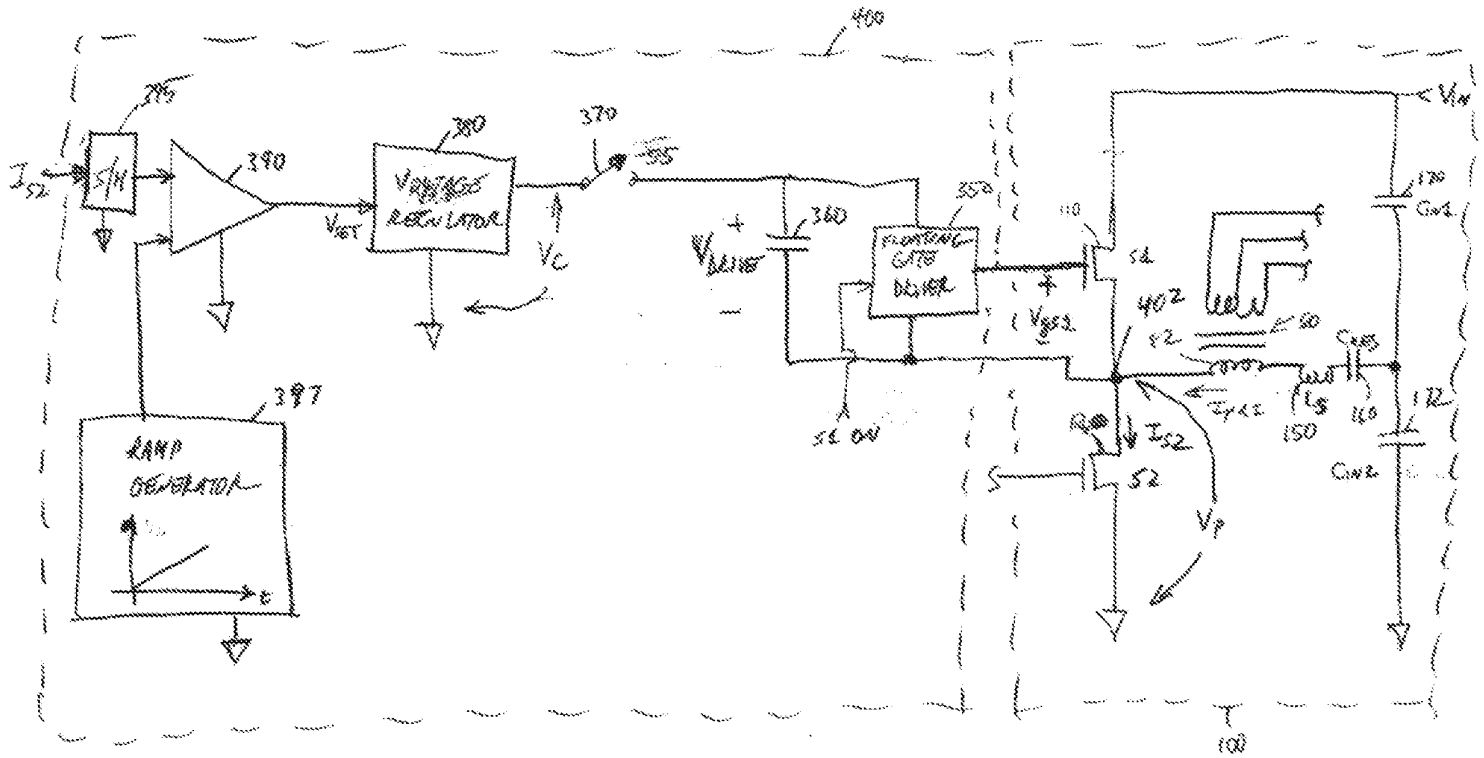
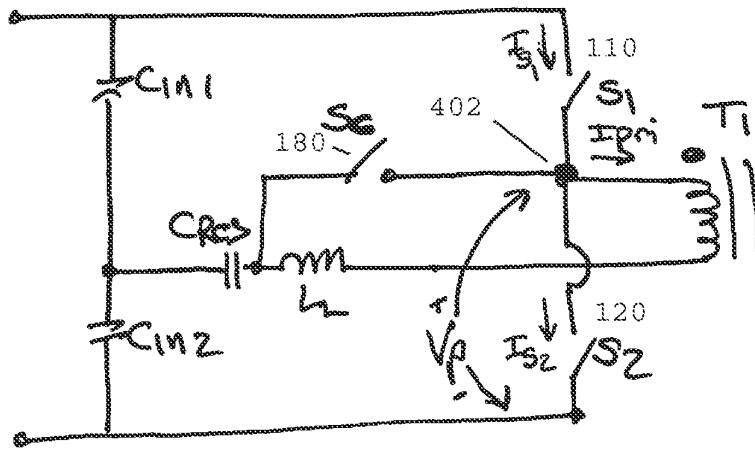
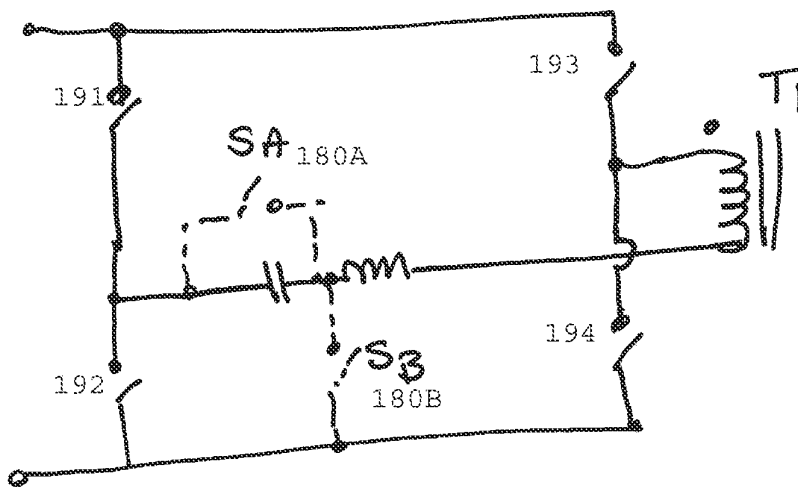


FIG 10



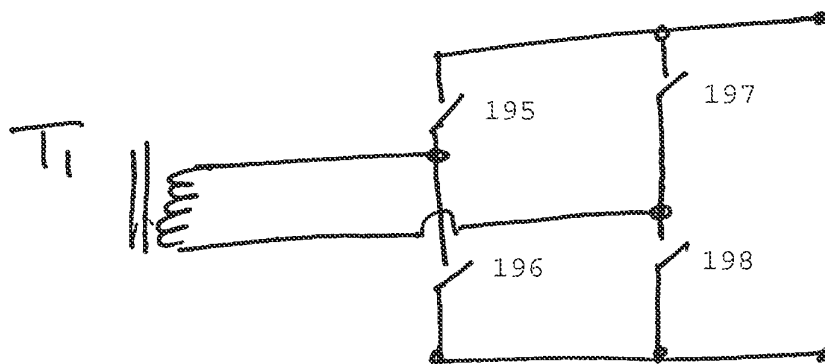
Half Bridge
Primary Clap

Fig. 11



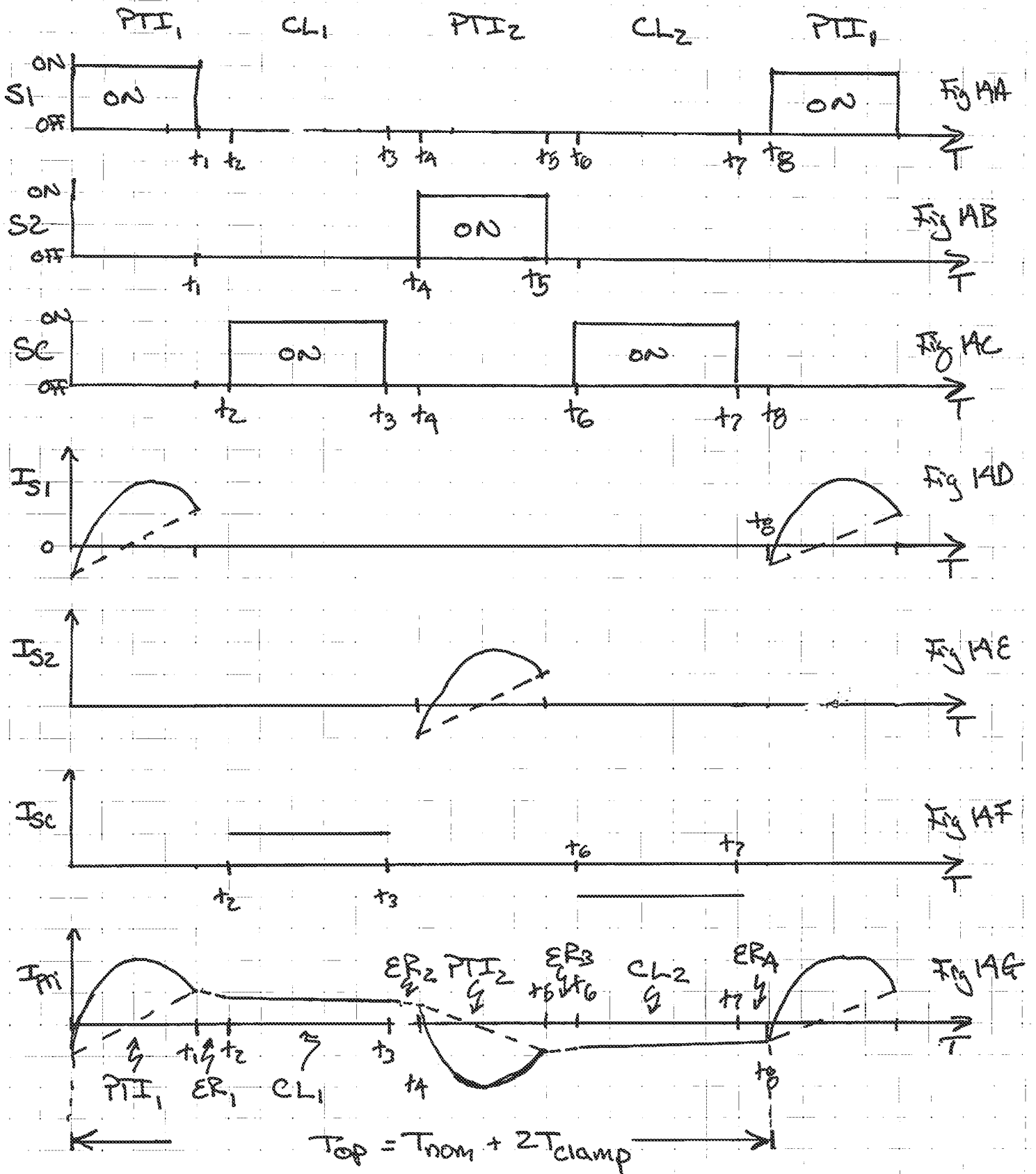
Full Bridge
Primary Clap

Fig. 12



Secondary Clap
Full Bridge

Fig. 13



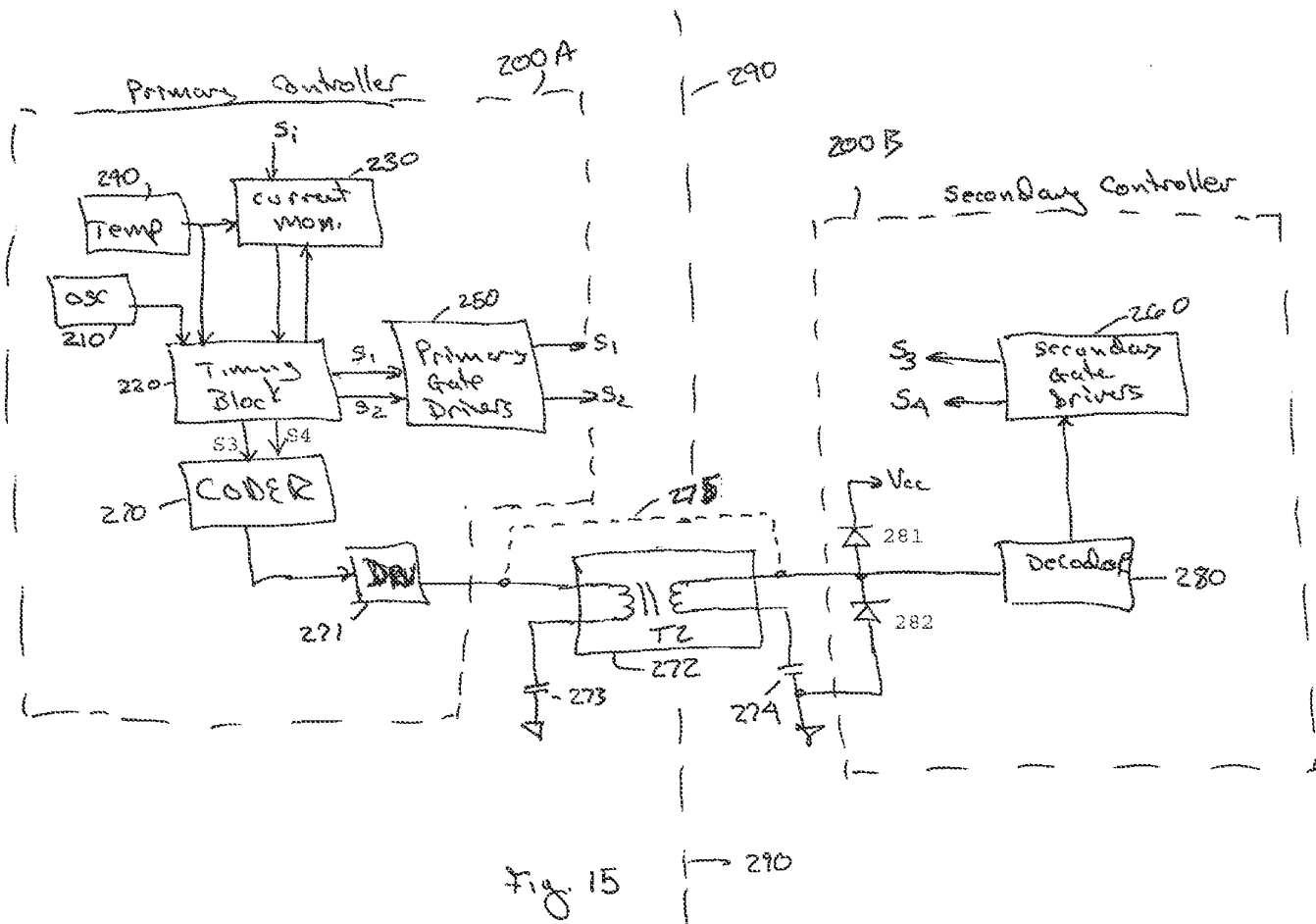
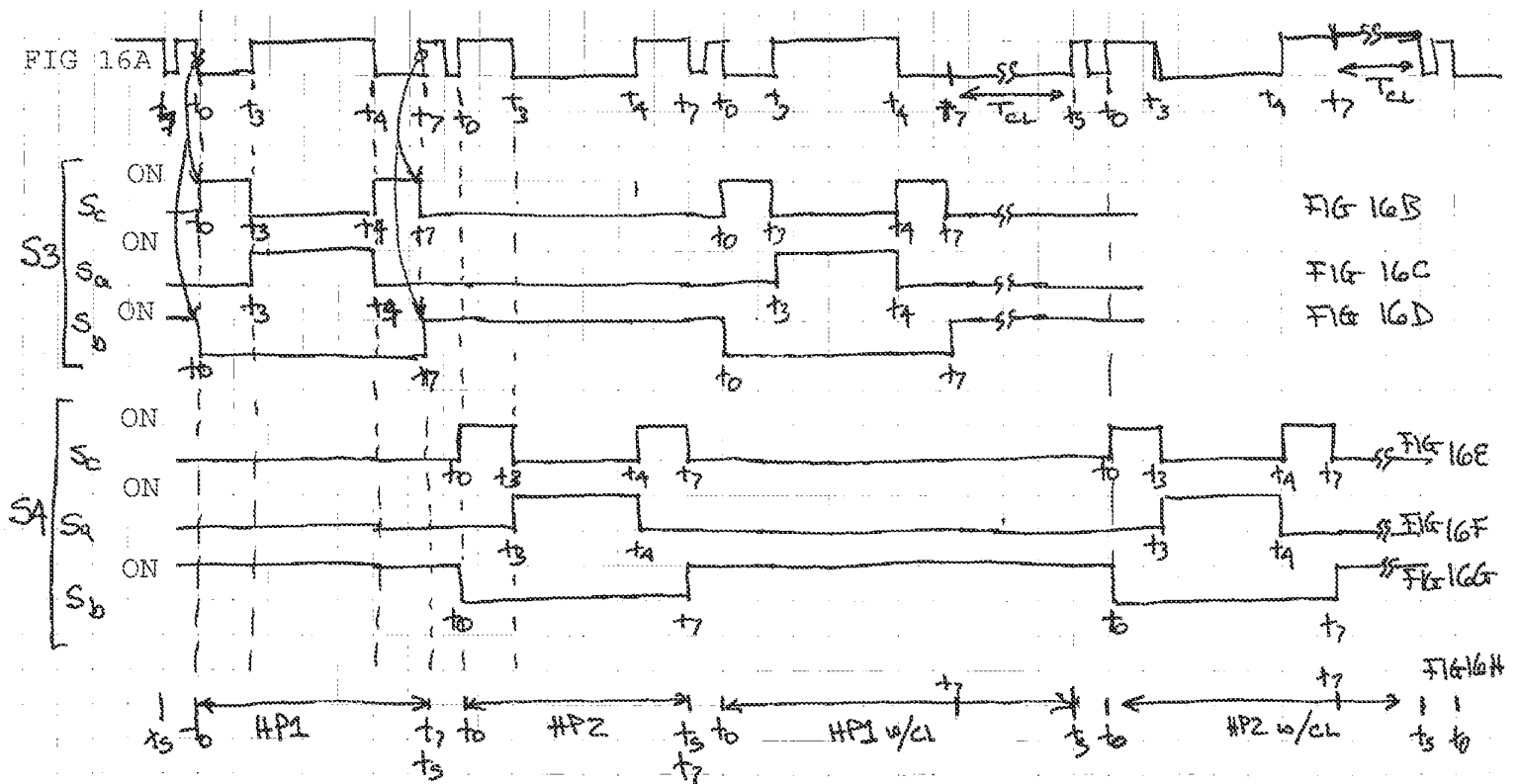


Fig. 15



Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		DIGITAL CONTROL OF RESONANT POWER CONVERTERS		
First Named Inventor/Applicant Name:		Patrizio Vinciarelli		
Filer:		Matthew A. Smith		
Attorney Docket Number:		092377-VND044		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility application filing	1011	1	390	390
Utility Search Fee	1111	1	620	620
Utility Examination Fee	1311	1	250	250
Pages:				
Claims:				
Claims in Excess of 20	1202	15	62	930
Miscellaneous-Filing:				
Late Filing Fee for Oath or Declaration	1051	1	130	130

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				2320

Electronic Acknowledgement Receipt

EFS ID:	15236213
Application Number:	13830262
International Application Number:	
Confirmation Number:	1066
Title of Invention:	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
First Named Inventor/Applicant Name:	Patrizio Vinciarelli
Customer Number:	112754
Filer:	Matthew A. Smith/Katie Newcomb
Filer Authorized By:	Matthew A. Smith
Attorney Docket Number:	092377-VND044
Receipt Date:	14-MAR-2013
Filing Date:	
Time Stamp:	20:04:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$2320
RAM confirmation Number	28516
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
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1	Transmittal of New Application	VND044_Transmittal.pdf	100773	no	4
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Warnings:					
Information:					
2	Application Data Sheet	VND044_ADS.pdf	1001619	no	6
			3969939de17ae40d1cd2903c2094c40fcd6006c		
Warnings:					
Information:					
3	Nonpublication request from applicant.	VND044_nonpub_request.pdf	86232	no	1
			f9d90ec151550288a7a35abf30d9dae028d76561		
Warnings:					
Information:					
4		VND044_Spec.pdf	237532	yes	37
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	Specification		1	30	
	Claims		31	36	
	Abstract		37	37	
Warnings:					
Information:					
5	Drawings-only black and white line drawings	VND044_Figures.pdf	3336030	no	14
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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 13/830,262			
APPLICATION AS FILED - PART I									
(Column 1)		(Column 2)		SMALL ENTITY		OTHER THAN SMALL ENTITY			
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)		
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280		
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	600		
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720		
TOTAL CLAIMS (37 CFR 1.16(i))	35	minus 20 = * 15				x 80 =	1200		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	1	minus 3 = *				x 420 =	0.00		
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00		
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00		
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL		TOTAL	2800		
APPLICATION AS AMENDED - PART II									
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OTHER THAN SMALL ENTITY	
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	x	=
	Application Size Fee (37 CFR 1.16(s))								
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
	TOTAL ADD'L FEE							TOTAL ADD'L FEE	
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	x	=
	Application Size Fee (37 CFR 1.16(s))								
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
	TOTAL ADD'L FEE							TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.									



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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
13/830,262	03/14/2013	2838	2320	092377-0120	35	1

CONFIRMATION NO. 1066

FILING RECEIPT



OC000000060661652

112754
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

Date Mailed: 04/29/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Patrizio VINCIARELLI, Boston, MA;
Sergey LUZANOV, Pelham, NH;

Applicant(s)

VLТ, INC., Sunnyvale, CA

Assignment For Published Patent Application

VLТ, INC., Sunnyvale, CA

Power of Attorney: None

Domestic Applications for which benefit is claimed - None.

A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.

Foreign Applications for which priority is claimed (You may be eligible to benefit from the Patent Prosecution Highway program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

If Required, Foreign Filing License Granted: 04/23/2013

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/830,262**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No

Title

DIGITAL CONTROL OF RESONANT POWER CONVERTERS

Preliminary Class

363

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:**PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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NOT GRANTED

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120

CONFIRMATION NO. 1066

FORMALITIES LETTER



OC000000060661653

112754
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

Date Mailed: 04/29/2013

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Filing Date Granted

An application number and filing date have been accorded to this application. The application is informal since it does not comply with the regulations for the reason(s) indicated below. Applicant is given TWO MONTHS from the date of this Notice within which to correct the informalities indicated below. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
 - The drawings must be reasonably free from erasures and must be free from alterations, overwriting, interlineations, folds, and copy marks. See Figure(s) ALL.
 - Numbers, letters, and reference characters on the drawings must measure at least 0.32 cm (1/8 inch) in height. See Figure(s) 3A-G, 4-6, 7A-H, 8, 10, 15, 16A-H.
 - The drawings must be made on paper that has a white background (see 37 CFR 1.84(e)). For example, drawings on graph paper, lined paper, or paper that has a non-white background are not acceptable. See Figure(s) 14A-G, 16A-H.

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
ALL

Applicant may submit the inventor's oath or declaration at any time before the Notice of Allowance and Fee(s) Due, PTOL-85, is mailed.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

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Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.

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If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/bnguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: VLT, Inc.
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: 13/830,262
Filing Date: 3/14/2013
Examiner: Unassigned
Art Unit: 2838
Confirmation Number: 1066

RESPONSE TO NOTICE TO FILE CORRECTED APPLICATION PAPERS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In response to the Notice to File Corrected Application Papers mailed April 29, 2013 in the above-identified patent application, transmitted herewith are the parts to complete the filing of the subject patent application.

Enclosed are:

[X] Return copy of Notice to File Corrected Application Papers – 2 pages.

[X] Transmittal of Formal Drawings – 1 page.

[X] Replacement Formal Drawings – 14 sheets, Figures 1, 2, 3A-3G, 4, 5, 6A-6G, 7A-7H, 8, 9A-9E, 10, 11, 12, 13, 14A-14G, 15, 16A-16H.

[X] Executed Declaration – 1 page.

[X] Power of Attorney and Accompanying 3.73c statement – 3 pages.

The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 19-0741. Should no proper payment be enclosed herewith, as by the credit card payment instructions in EFS-Web being incorrect or absent, resulting in a rejected or incorrect credit card transaction, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 19-0741.

If any extensions of time are needed for timely acceptance of papers submitted herewith, applicant hereby petitions for such extension under 37 C.F.R. §1.136 and authorizes payment of any such extensions fees to Deposit Account No. 19-0741.

Respectfully submitted,

Date 2013-07-01

FOLEY & LARDNER LLP
Customer Number: 112754
Telephone: (202) 295-4618
Facsimile: (202) 672-5399

(Monday)

By 

Matthew A. Smith
Attorney for Applicant
Registration No. 49,003



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120

CONFIRMATION NO. 1066

FORMALITIES LETTER

112754

Foley & Lardner LLP

3000 K Street N.W.

Suite 600

Washington, DC 20007-5109



OC00000060661653

Date Mailed: 04/29/2013

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Filing Date Granted

An application number and filing date have been accorded to this application. The application is informal since it does not comply with the regulations for the reason(s) indicated below. Applicant is given TWO MONTHS from the date of this Notice within which to correct the informalities indicated below. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
 - The drawings must be reasonably free from erasures and must be free from alterations, overwriting, interlineations, folds, and copy marks. See Figure(s) ALL.
 - Numbers, letters, and reference characters on the drawings must measure at least 0.32 cm (1/8 inch) in height. See Figure(s) 3A-G, 4-6, 7A-H, 8, 10, 15, 16A-H.
 - The drawings must be made on paper that has a white background (see 37 CFR 1.84(e)). For example, drawings on graph paper, lined paper, or paper that has a non-white background are not acceptable. See Figure(s) 14A-G, 16A-H.

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
ALL

Applicant may submit the inventor's oath or declaration at any time before the Notice of Allowance and Fee(s) Due, PTOL-85, is mailed.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.

<https://portal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html>

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at <http://www.uspto.gov/ebc>.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/bnguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: VLT, Inc.
Application No./Patent No.: 13/830,262 Filed/Issue Date: 3/14/2013
Titled: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
VLT, INC., a Corporation
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☒ The assignee of the entire right, title, and interest.
2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):
- ☐ The extent (by percentage) of its ownership interest is ____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.
- ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (e.g., bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

- A. ☒ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 030705, Frame 0230, or for which a copy thereof is attached.
- B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.
2. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

[Page 1 of 2]

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at
 Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at
 Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at
 Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at
 Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☒ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

Signature

Matthew A. Smith, Attorney for Assignee

Printed or Typed Name

Date

49,003

Title or Registration Number

[Page 2 of 2]

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:



Practitioners associated with Customer Number:

112754

OR



Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number

Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignments documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:



The address associated with Customer Number:

112754

OR

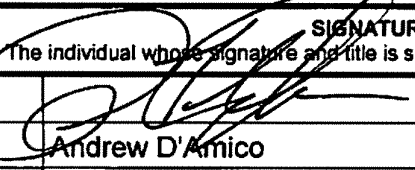
☐	Firm or Individual Name		
	Address		
	City		
	Country		
	Telephone		Email

Assignee Name and Address: VLT, INC.
560 OAKMEAD PARKWAY
SUNNYVALE, CALIFORNIA 94086

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/SB/98 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	4-03-2013
Name	Andrew D'Amico	Telephone	978-749-3230
Title	V.P. Intellectual Property		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: VLT, Inc.
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: 13/830,262
Filing Date: 3/14/2013
Examiner: Unassigned
Art Unit: 2838
Confirmation Number: 1066

TRANSMITTAL OF FORMAL DRAWINGS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

ATTENTION: DRAWING REVIEW BRANCH

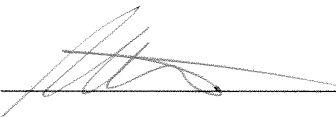
Sir:

Transmitted herewith is a new set of formal drawings (14 sheets, Figures 1, 2, 3A-3G, 4, 5, 6A-6G, 7A-7H, 8, 9A-9E, 10, 11, 12, 13, 14A-14G, 15, 16A-16H) for the above-identified application. The Official Draftsperson is respectfully requested to approve these drawings for entry into the application.

Respectfully submitted,

Date 2013-07-01

FOLEY & LARDNER LLP
Customer Number: 112754
Telephone: (202) 295-4618
Facsimile: (202) 672-5399

By 

Matthew A. Smith
Attorney for Applicant
Registration No. 49,003

Fig. 1

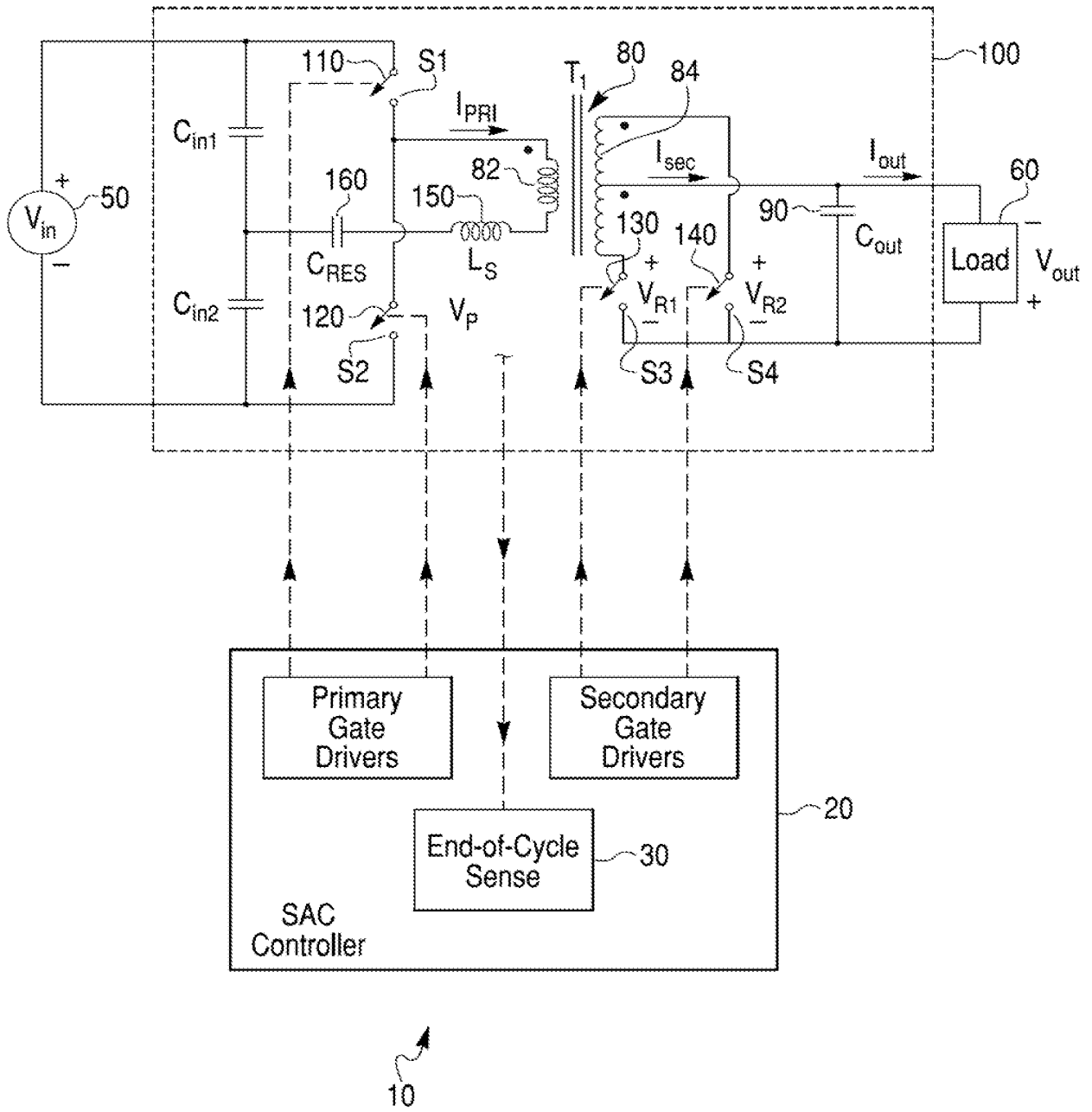


Fig. 2

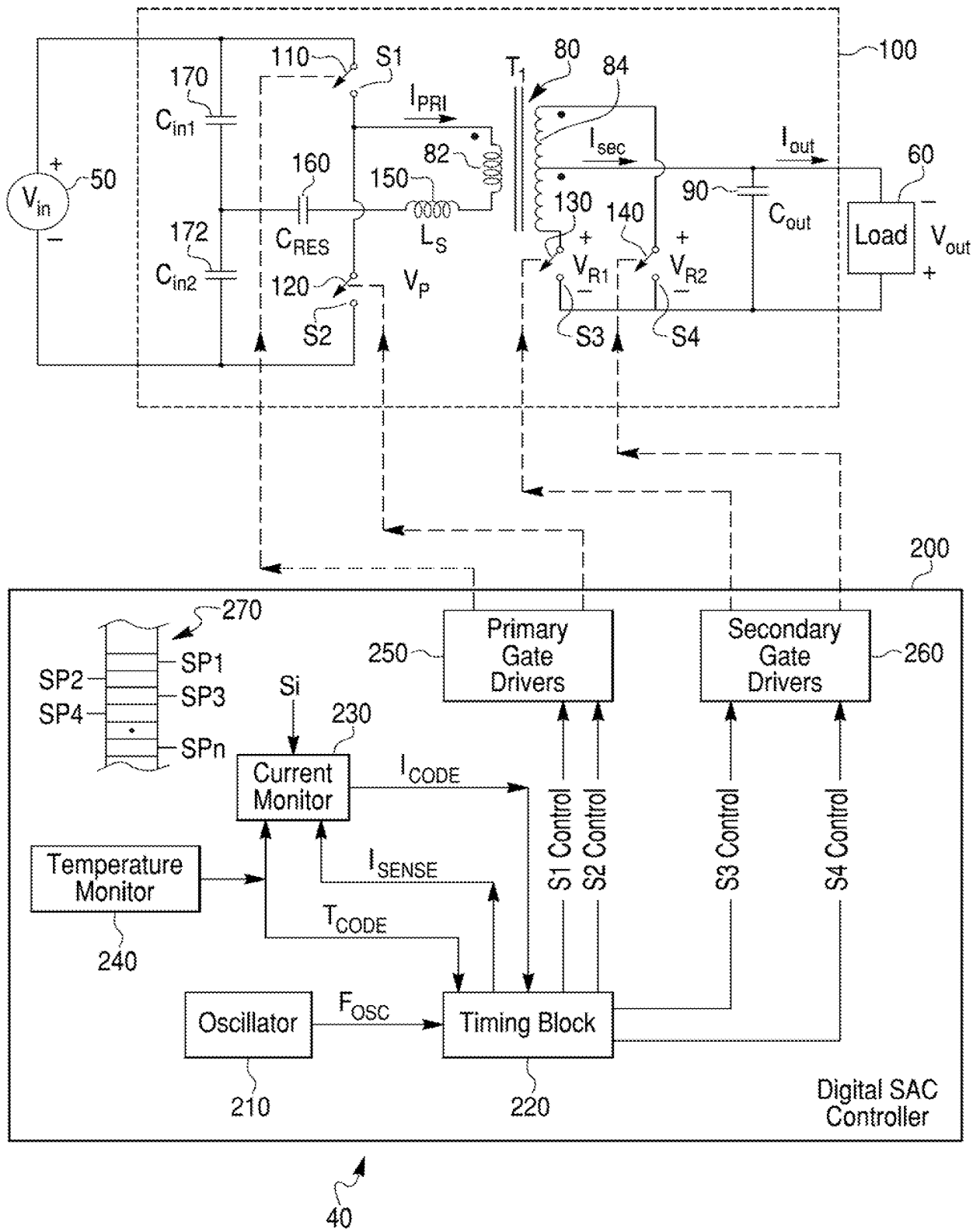


Fig. 3A

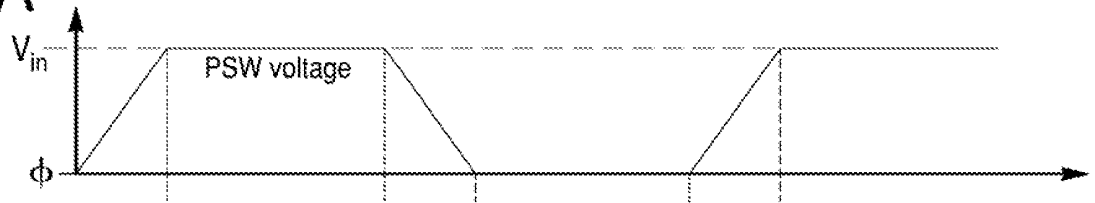


Fig. 3B

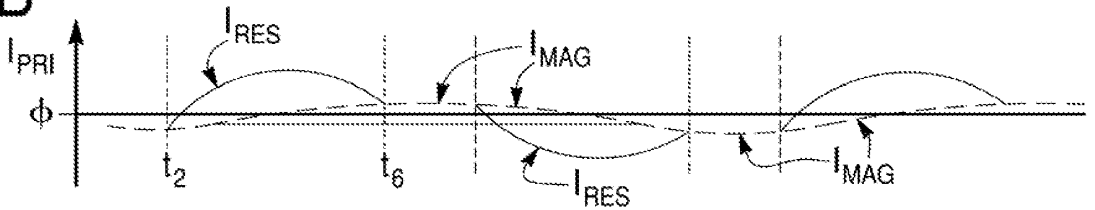


Fig. 3C

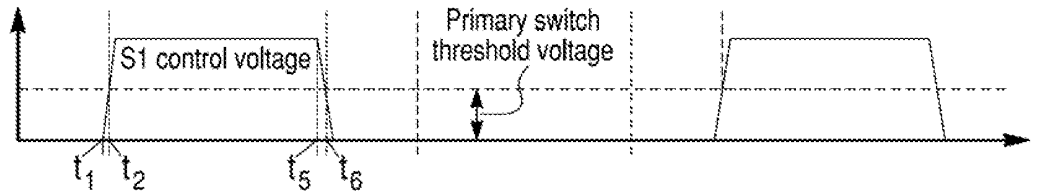


Fig. 3D

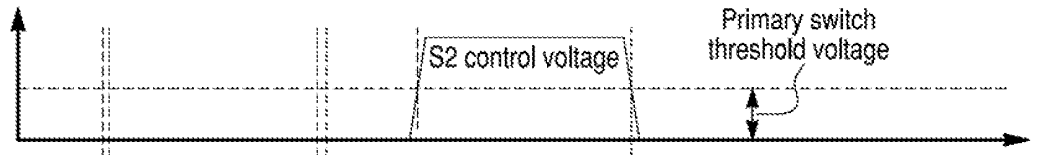


Fig. 3E

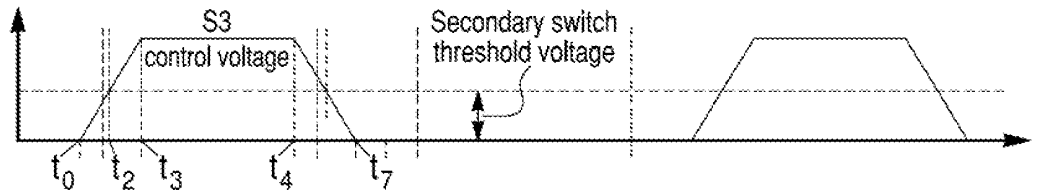


Fig. 3F

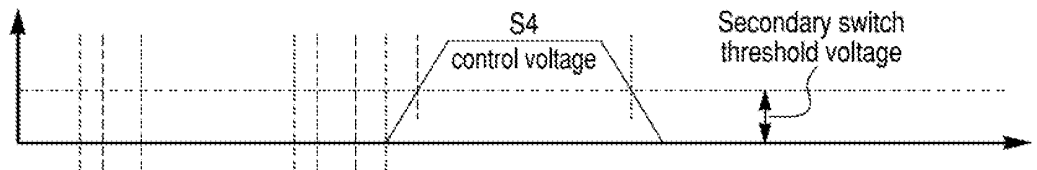


Fig. 3G

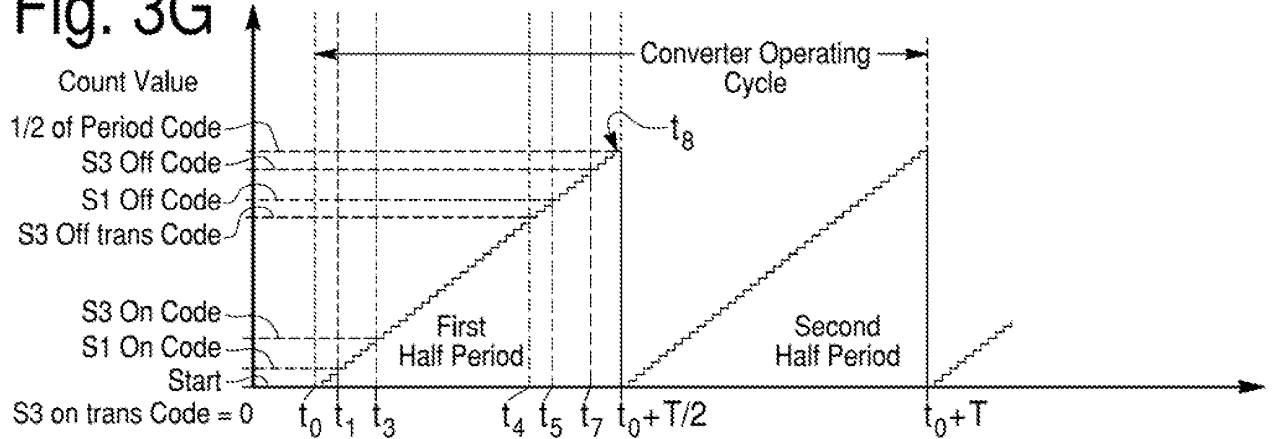


Fig. 4

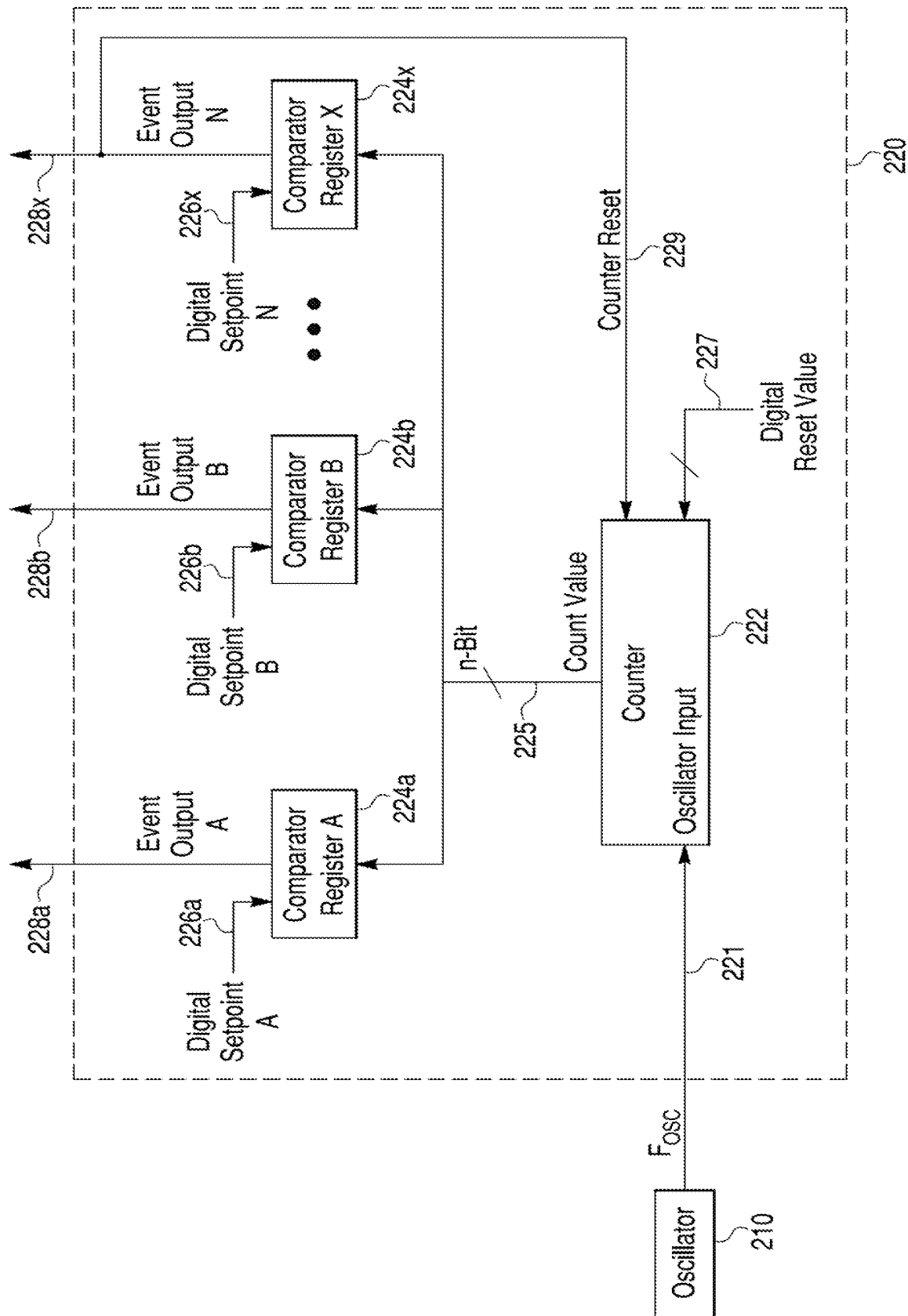
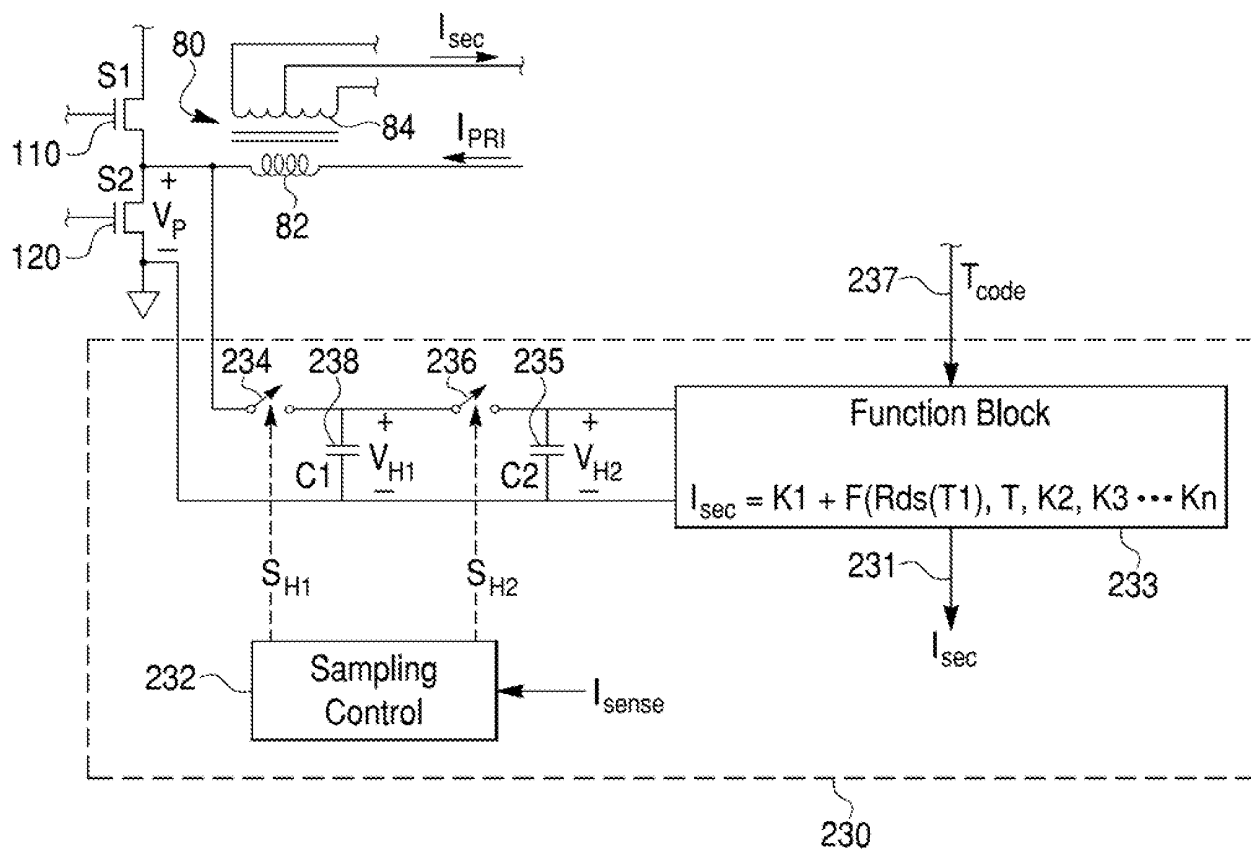


Fig. 5



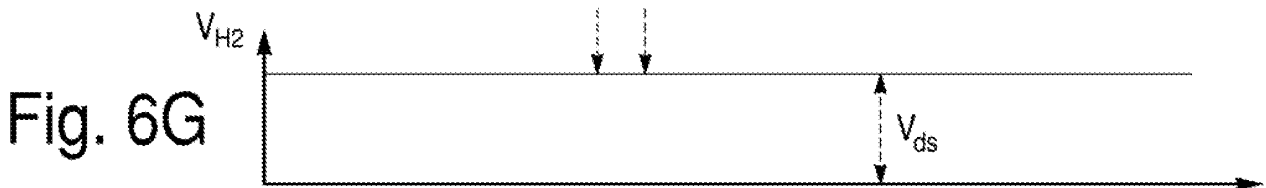
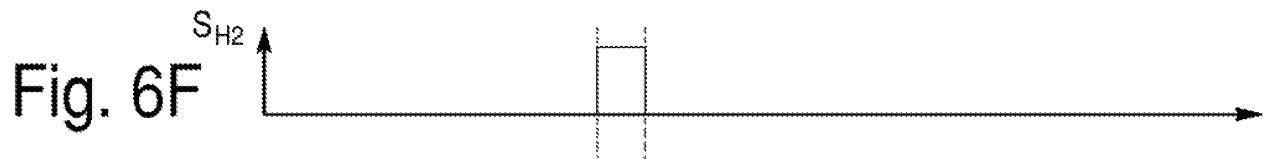
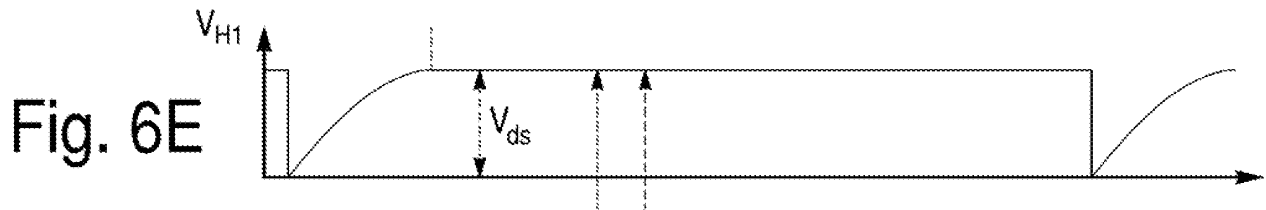
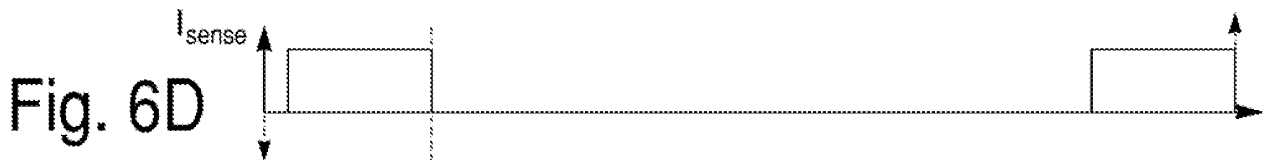
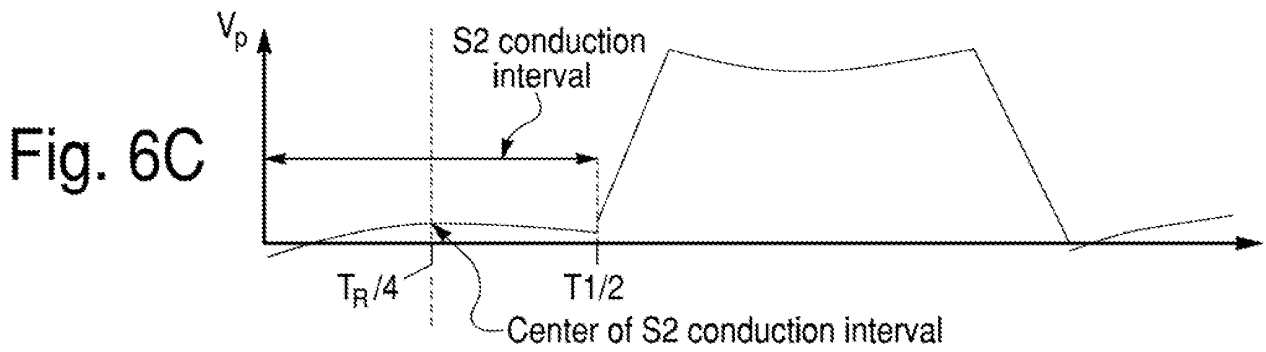
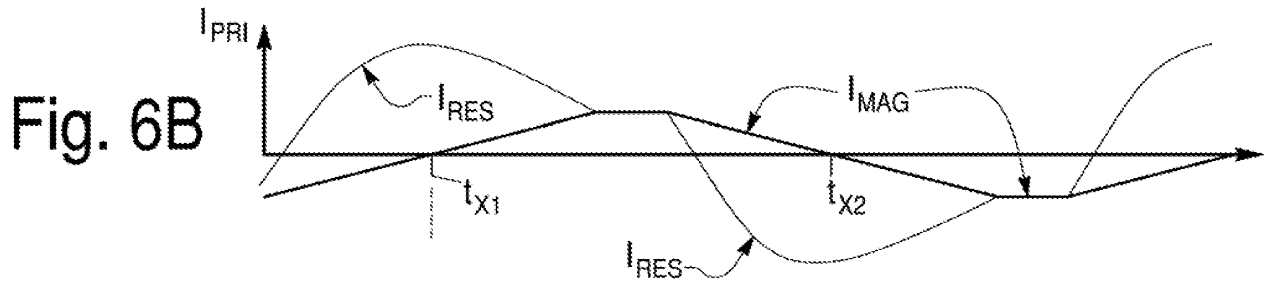
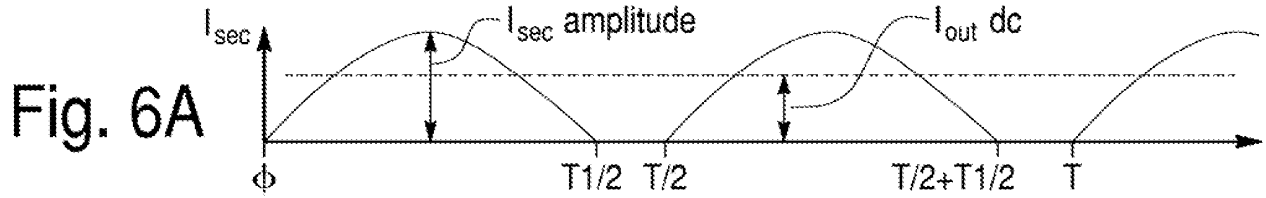


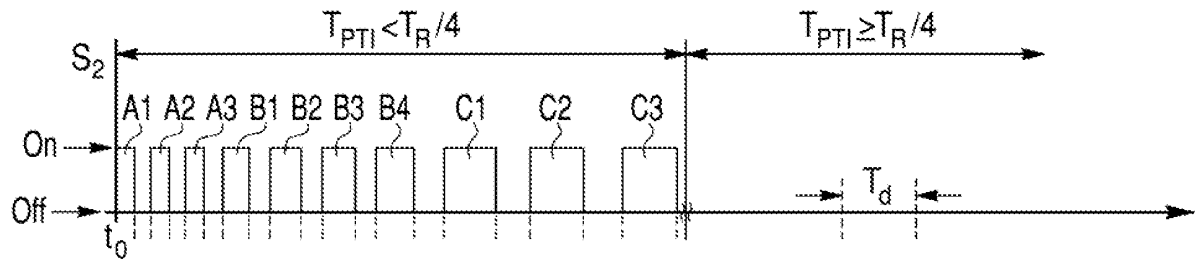
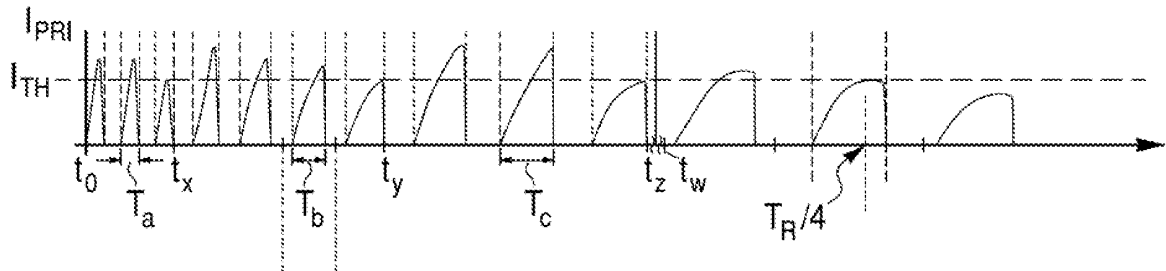
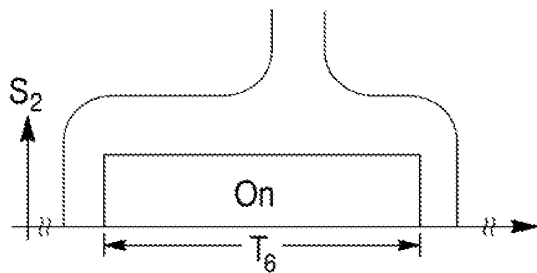
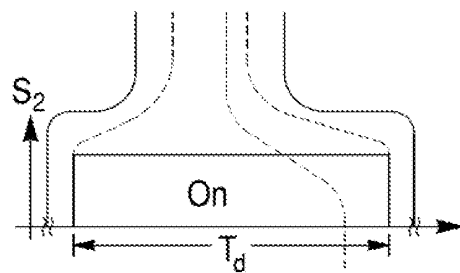
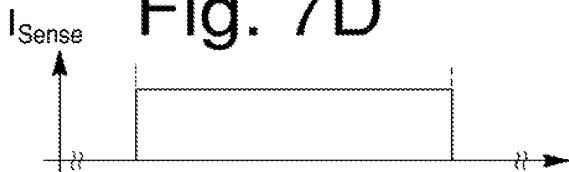
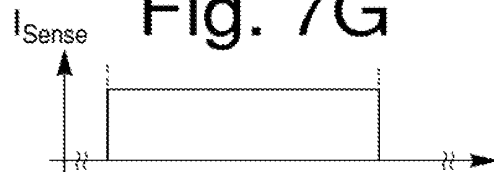
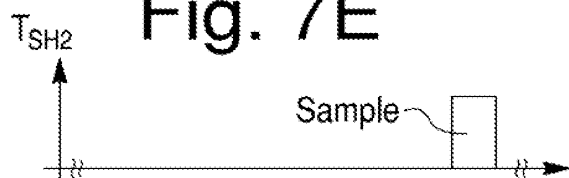
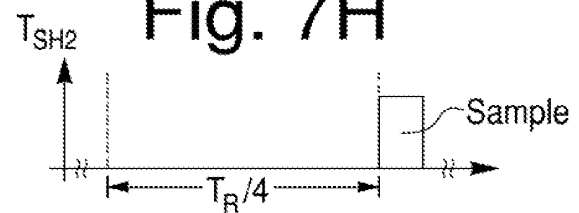
Fig. 7A**Fig. 7B****Fig. 7C****Fig. 7F****Fig. 7D****Fig. 7G****Fig. 7E****Fig. 7H**

Fig. 8

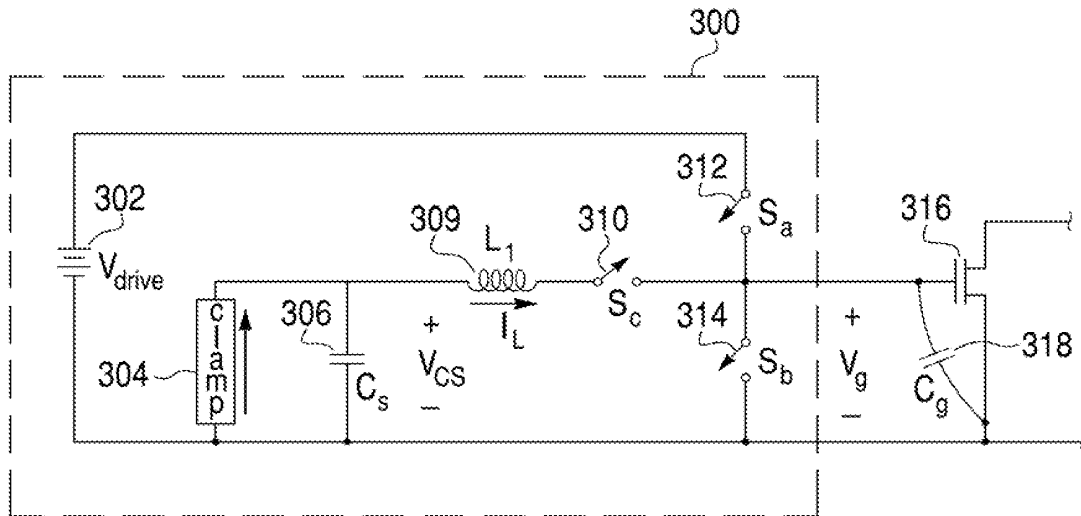


Fig. 9A

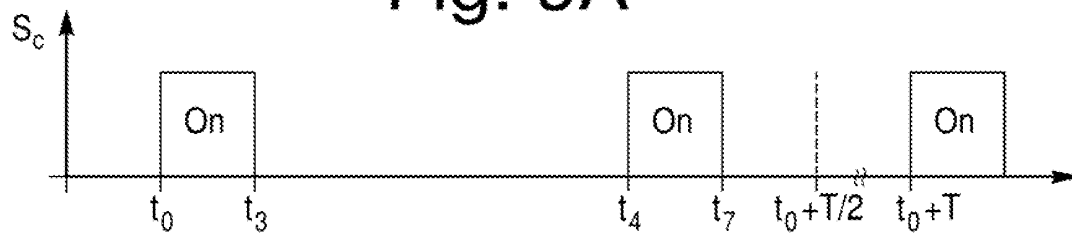


Fig. 9B

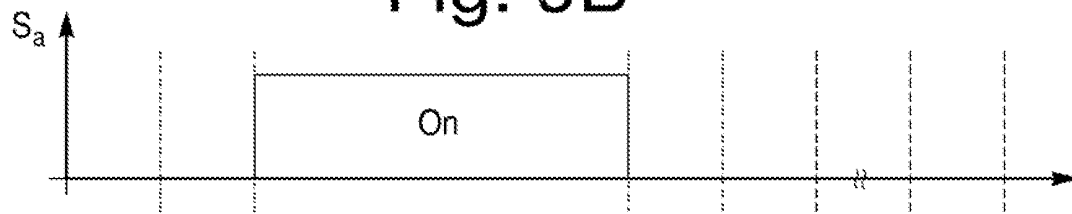


Fig. 9C

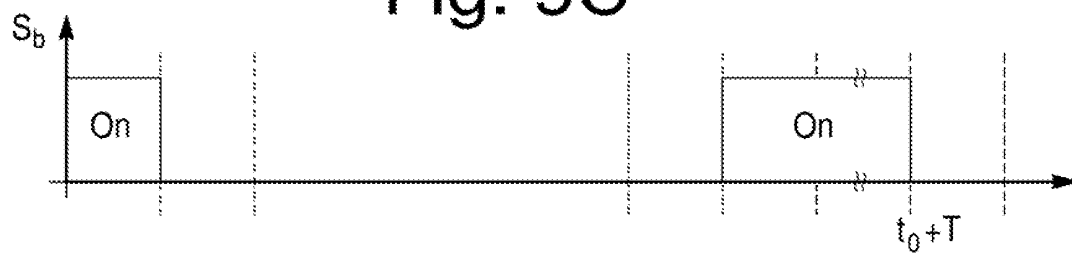


Fig. 9D

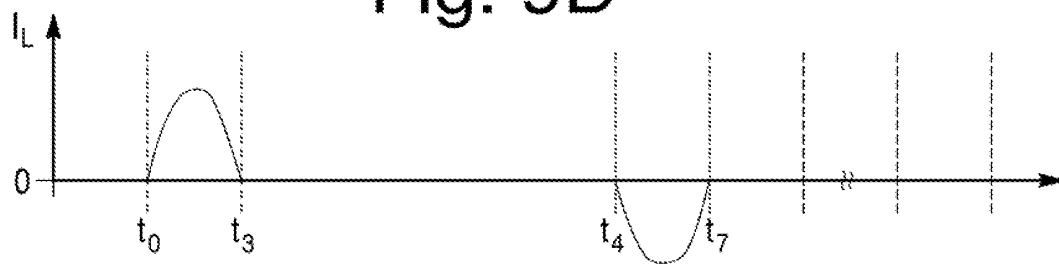


Fig. 9E

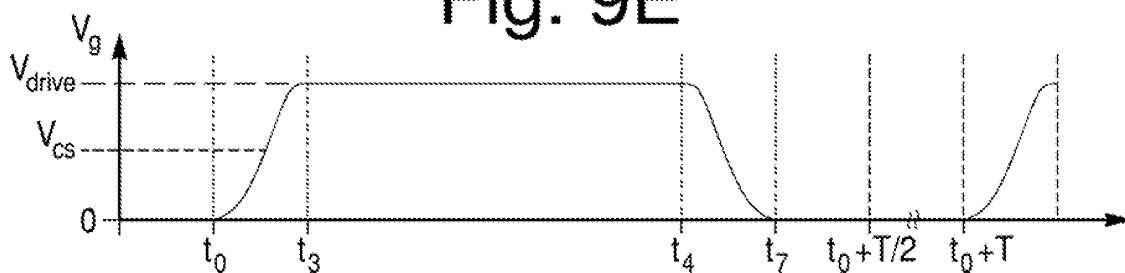


Fig. 10

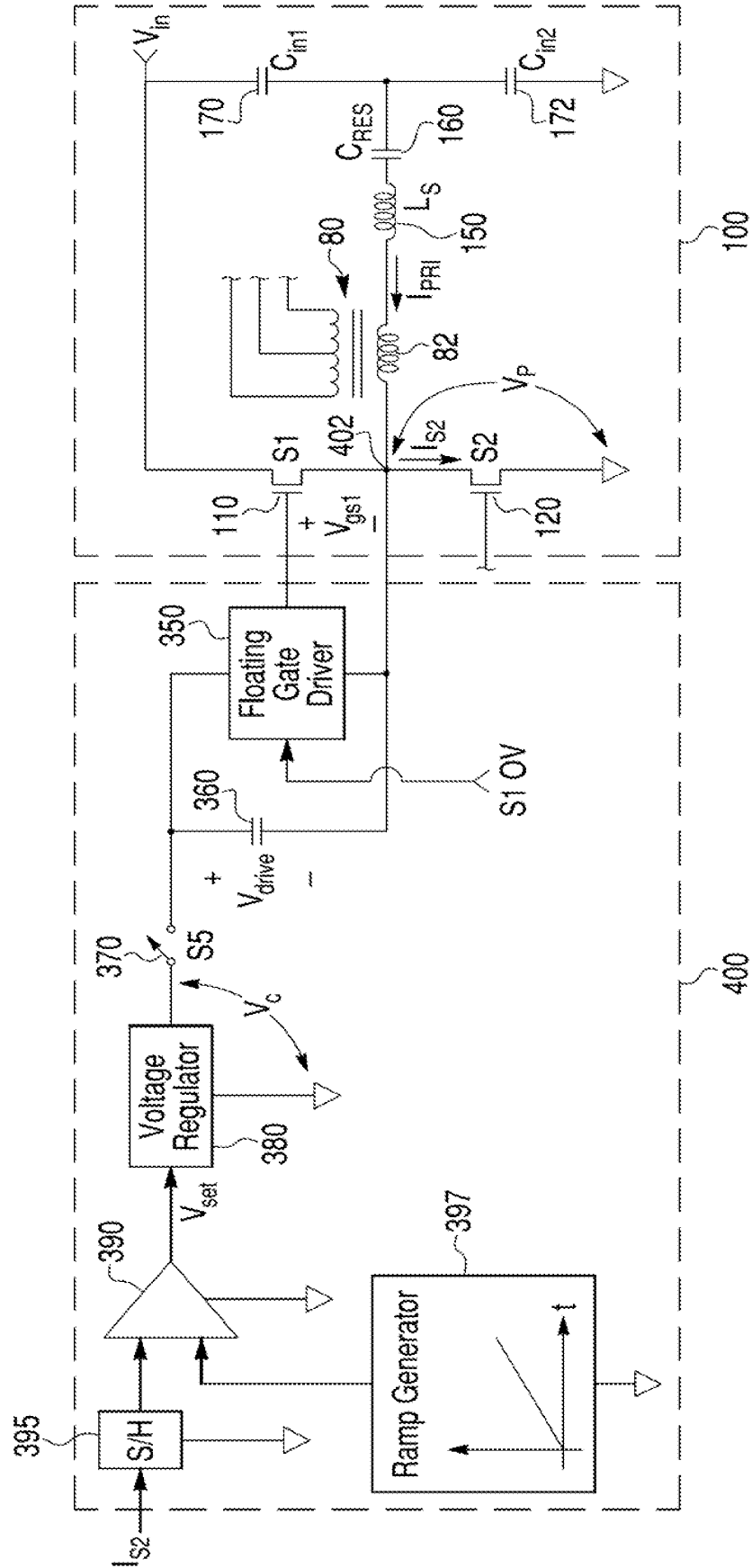


Fig. 11

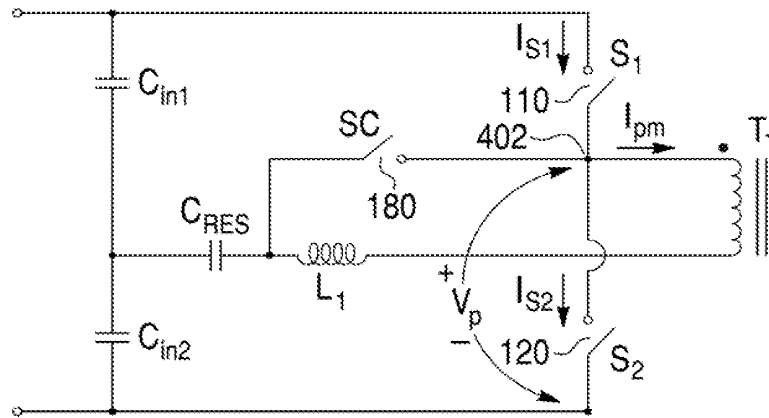


Fig. 12

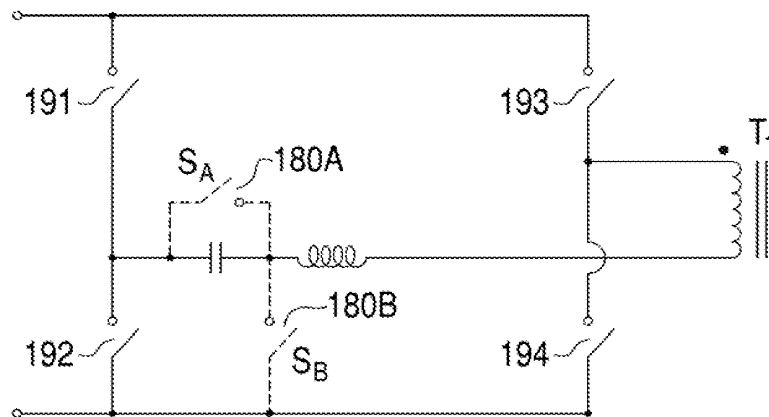


Fig. 13

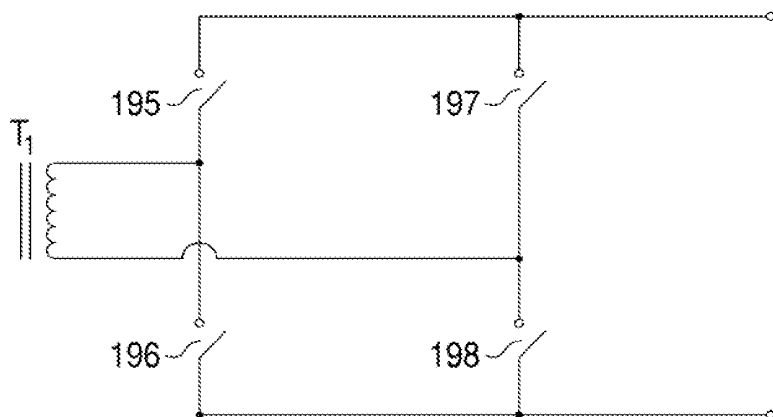


Fig. 14A

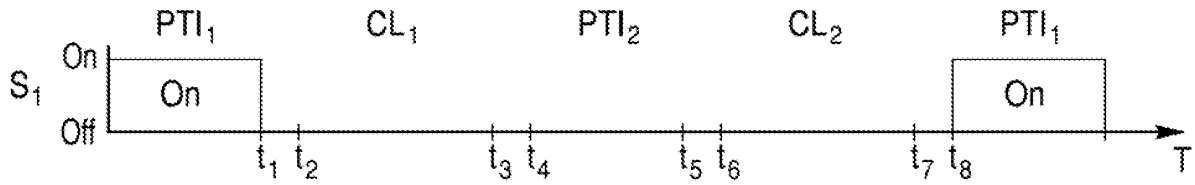


Fig. 14B

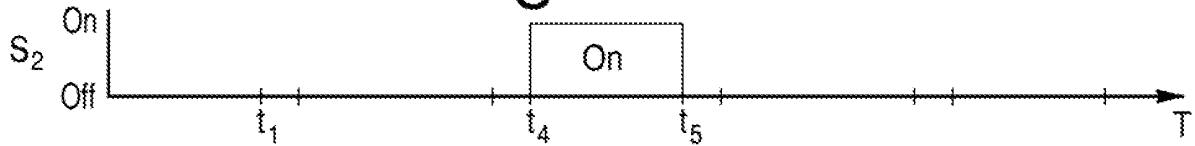


Fig. 14C



Fig. 14D

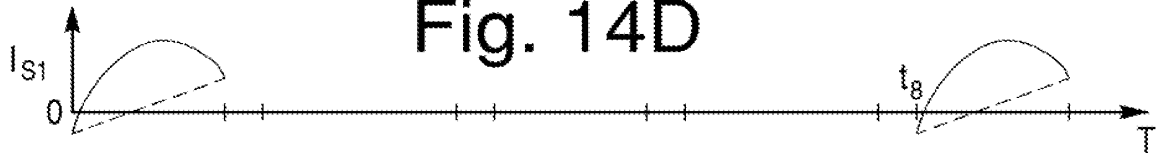


Fig. 14E

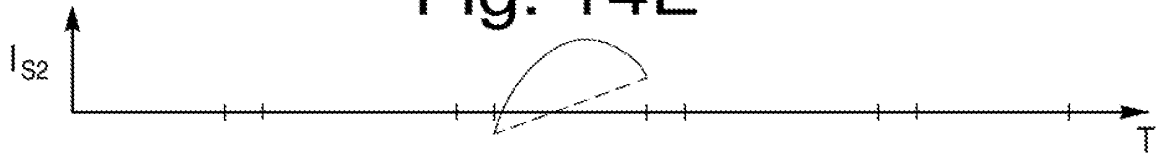


Fig. 14F

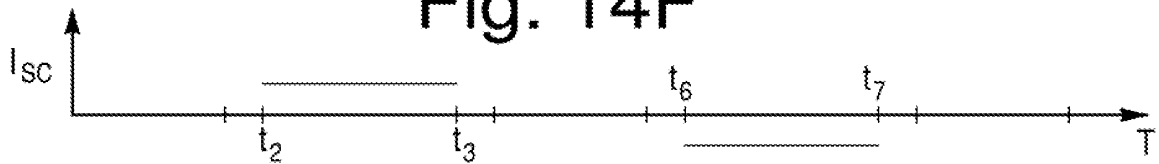


Fig. 14G

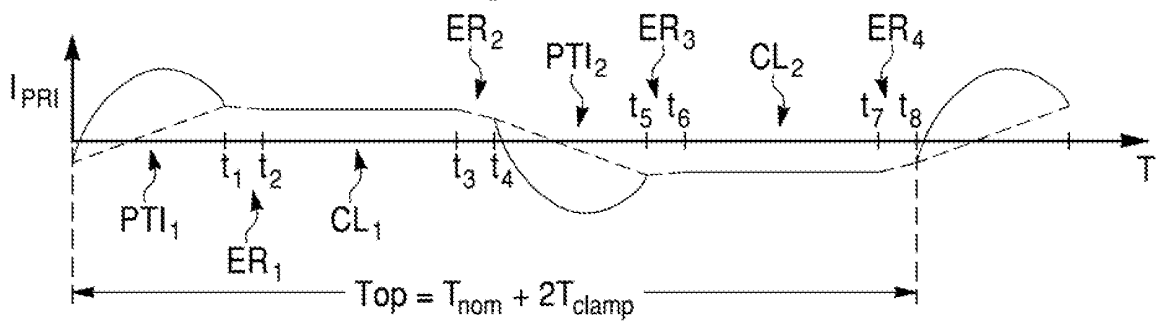
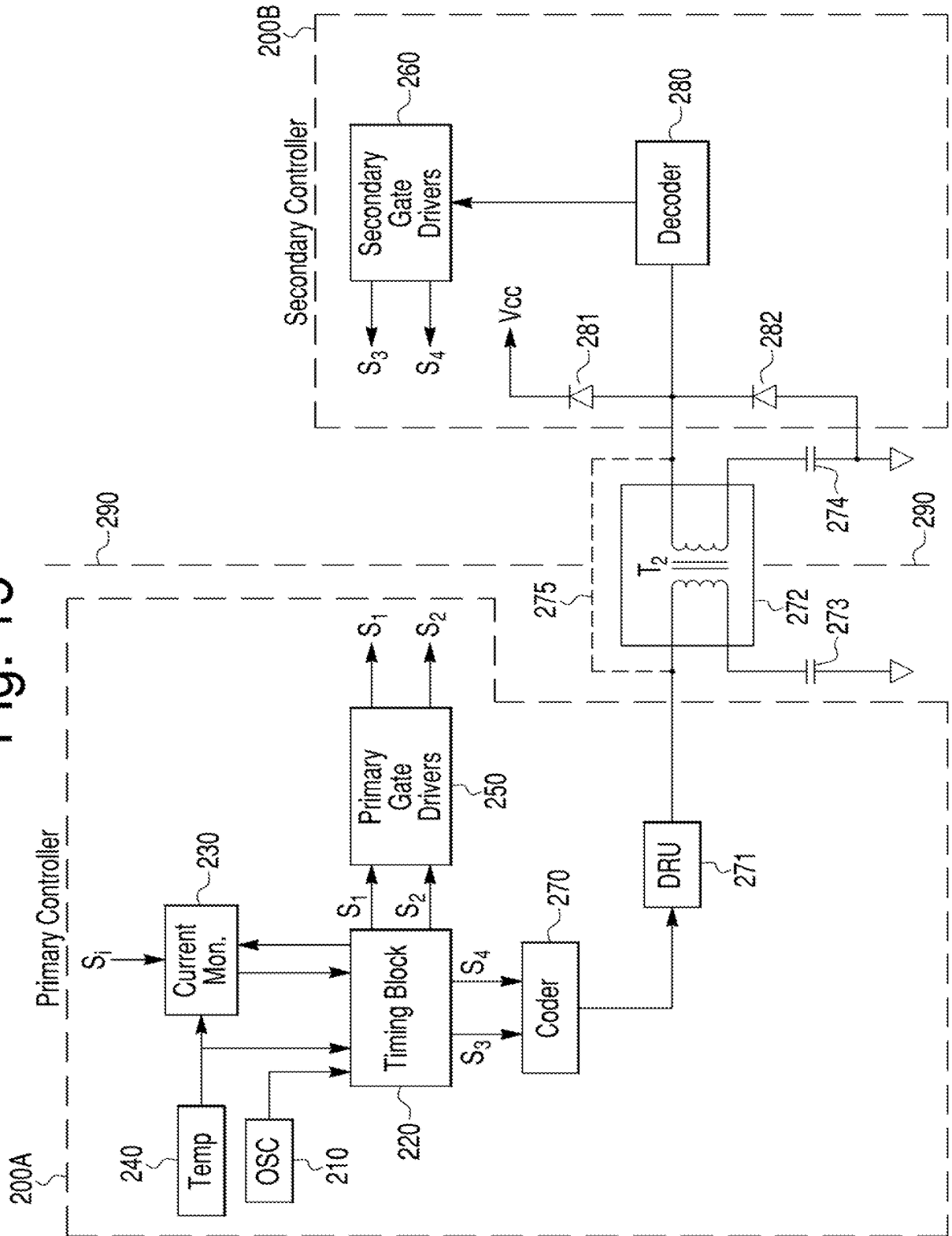
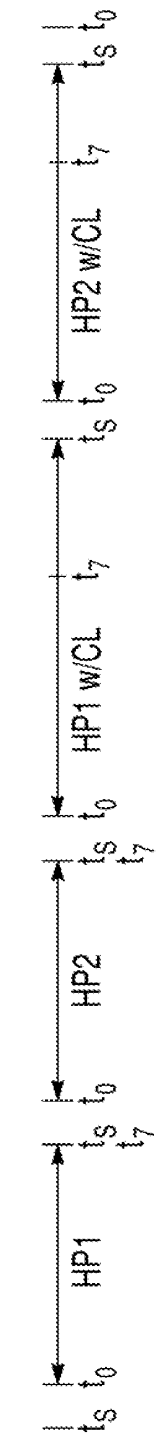
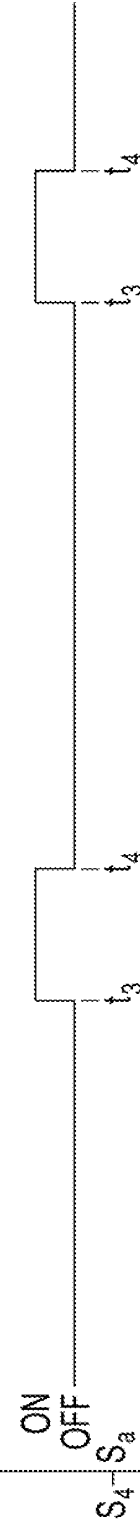
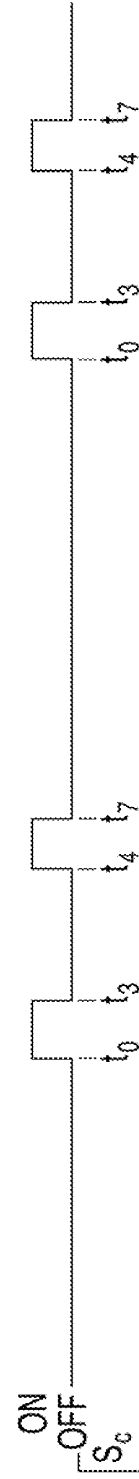
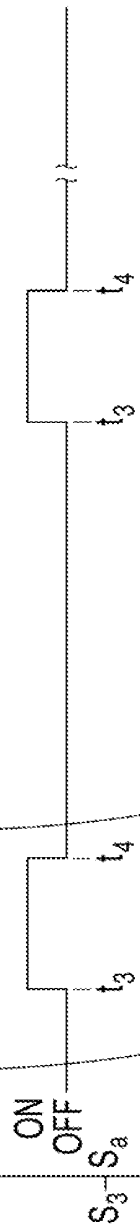
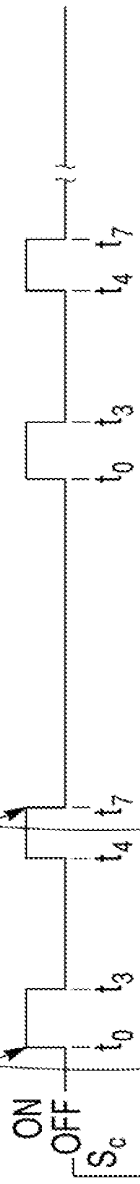
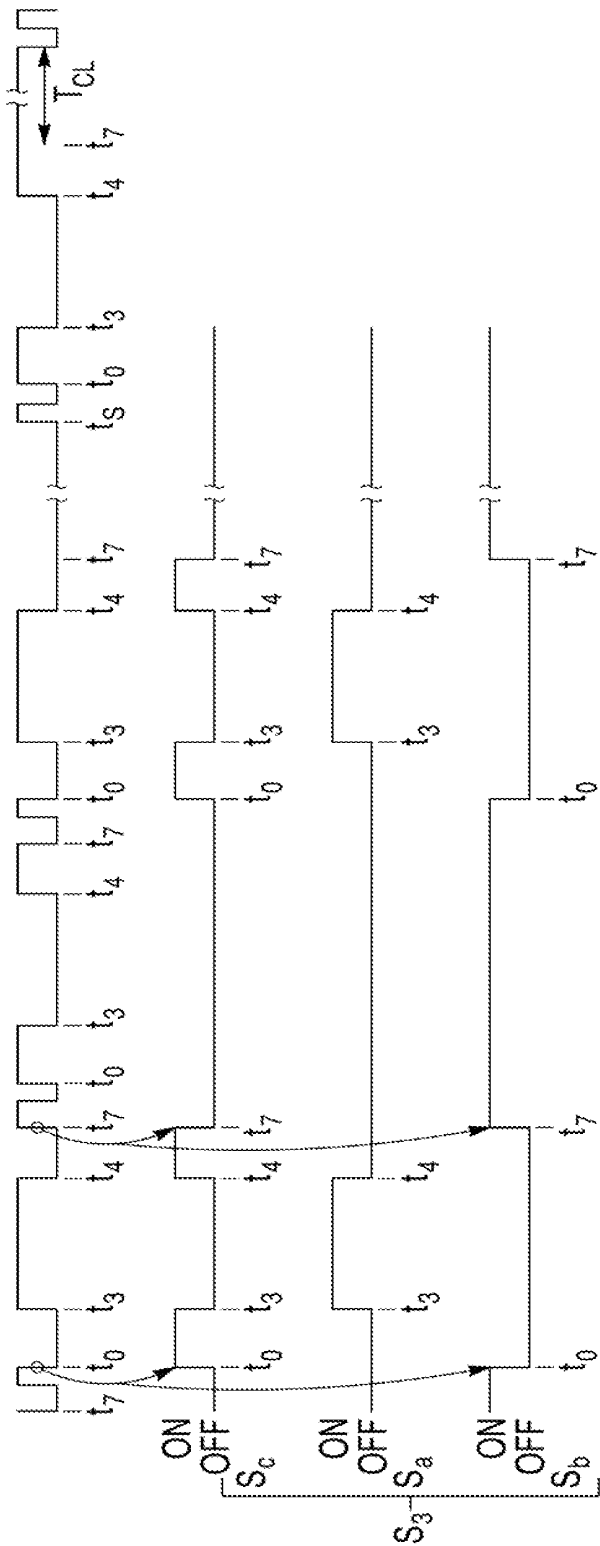


Fig. 15





IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: VLT, Inc.
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: 13/830,262
Filing Date: 3/14/2013
Examiner: Unassigned
Art Unit: 2838
Confirmation Number: 1066

INFORMATION DISCLOSURE STATEMENT
UNDER 37 CFR §1.56

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Applicant submits herewith documents for the Examiner's consideration in accordance with 37 CFR §§1.56, 1.97 and 1.98.

Applicants respectfully request that each listed document be considered by the Examiner and be made of record in the present application and that an initialed copy of Form PTO/SB/08 be returned in accordance with MPEP §609.

The submission of any document herewith is not an admission that such document constitutes prior art against the claims of the present application or that such document is considered material to patentability as defined in 37 CFR §1.56(b). Applicants do not waive any rights to take any action which would be appropriate to antedate or otherwise remove as a competent reference any document submitted herewith.

CONCISE EXPLANATION OF RELEVANCE

The relevance of the listed documents is explained in the present specification.

TIMING OF THE DISCLOSURE

The listed documents are being submitted in compliance with 37 CFR §1.97(b), before the mailing date of the first Office Action on the merits.

Although Applicant believes that no fee is required, the Commissioner is hereby authorized to charge any additional fees which may be due to Deposit Account No. 19-0741.

Respectfully submitted,

Date 2013-07-01

By 

FOLEY & LARDNER LLP
Customer Number: 112754
Telephone: (202) 295-4618
Facsimile: (202) 672-5399

Matthew A. Smith
Attorney for Applicant
Registration No. 49,003

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT Date Submitted: JUL 01 2013 <i>(use as many sheets as necessary)</i>			Complete if Known		
Sheet	1	of	1	Application Number	13/830,262
				Filing Date	03/14/2013
				First Named Inventor	Patrizio VINCIARELLI
				Art Unit	2838
				Examiner Name	Unassigned
				Attorney Docket Number	092377-0120

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Document Number Number-Kind Code ² (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	A1	6,984,965 B2	01-10-2006	Vinciarelli	
	A2	6,107,860	08-22-2000	Vinciarelli	
	A3	5,010,261	04-23-1991	Stiegerwald	
	A4	7,602,229 B2	10-13-2009	Tolle et al.	
	A5	7,091,753 B2	08-15-2006	Inoshita	

UNPUBLISHED U.S. PATENT APPLICATION DOCUMENTS					
Examiner Initials*	Cite No. ¹	U.S. Patent Application Document Serial Number-Kind Code ² (if known)	Filing Date of Cited Document MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No. ¹	Foreign Patent Document Country Code ³ Number ⁴ Kind Code ⁵ (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Documents	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ⁶

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.) date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ⁶

Examiner Signature	Date Considered
-----------------------	--------------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5 Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
---------------------------	---

As the below named inventor(s), I/we declare that:

This declaration is directed to: ☐ The attached application, or ☒ United States application or PCT international application number 13/830,262
 filed on March 14, 2013
☐ As amended on _____ (if applicable);

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought;

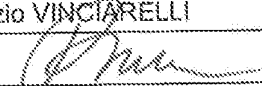
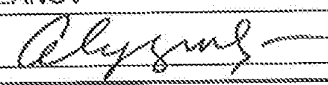
I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above;

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

All statements made herein of my/our own knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR(S)	
Inventor one: <u>Patrizio VINCIARELLI</u>	Date: <u>May 29, 2013</u>
Signature: 	Citizen of: <u>U.S.A.</u>
Inventor two: <u>Sergey LUZANOV</u>	Date: <u>May 29, 2013</u>
Signature: 	Citizen of: <u>USA</u>

☐ Additional inventors or a legal representative are being named on _____ additional form(s) attached hereto.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-8199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	16204133
Application Number:	13830262
International Application Number:	
Confirmation Number:	1066
Title of Invention:	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
First Named Inventor/Applicant Name:	Patrizio VINCIARELLI
Customer Number:	112754
Filer:	Matthew A. Smith/Katie Newcomb
Filer Authorized By:	Matthew A. Smith
Attorney Docket Number:	092377-0120
Receipt Date:	01-JUL-2013
Filing Date:	14-MAR-2013
Time Stamp:	16:29:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		0120_Response.pdf	239076 fbab371b57836d8d0aa357b7eac69d91aa5ce5fc	yes	7

	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Applicant Response to Pre-Exam Formalities Notice		1	2	
	Miscellaneous Incoming Letter		3	4	
	Assignee showing of ownership per 37 CFR 3.73.		5	6	
	Power of Attorney		7	7	
Warnings:					
Information:					
2	Transmittal Letter	0120_Transmittal_Formal_Dwgs.pdf	22228 ee88f99cd56b8de731587d0fbfe99b78321e816c	no	1
Warnings:					
Information:					
3	Drawings-only black and white line drawings	0120_Replacement_Formal_Drawings.pdf	1234470 d7fe65f96d1e276bb651e936f70763ba1893e401	no	14
Warnings:					
Information:					
4		0120_IDS.pdf	99063 35f69043dd6e1fa4fcbeaeaa5061f3491ddb2462	yes	3
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Transmittal Letter		1	2	
	Information Disclosure Statement (IDS) Form (SB08)		3	3	
Warnings:					
Information:					
5	Oath or Declaration filed	0120_Declaration.pdf	2185761 e2b83b300093c7c200a40f50cb7a498a294a9d27	no	1
Warnings:					
Information:					
Total Files Size (in bytes):			3780598		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 13/830,262			
APPLICATION AS FILED - PART I									
(Column 1)		(Column 2)		SMALL ENTITY		OTHER THAN SMALL ENTITY			
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)		
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280		
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	600		
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720		
TOTAL CLAIMS (37 CFR 1.16(i))	35	minus 20 = 15				x 80 =	1200		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	1	minus 3 =				x 420 =	0.00		
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00		
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00		
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL		TOTAL	2800		
APPLICATION AS AMENDED - PART II									
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OTHER THAN SMALL ENTITY	
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	x	=
	Application Size Fee (37 CFR 1.16(s))								
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
TOTAL ADD'L FEE								TOTAL ADD'L FEE	
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=	x	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x	=	x	=
	Application Size Fee (37 CFR 1.16(s))								
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
TOTAL ADD'L FEE								TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.									



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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
13/830,262	03/14/2013	2838	2320	092377-0120	35	1

CONFIRMATION NO. 1066

UPDATED FILING RECEIPT



OC000000062454308

112754
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

Date Mailed: 07/15/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Patrizio VINCIARELLI, Boston, MA;
Sergey LUZANOV, Pelham, NH;

Applicant(s)

VLT, INC., SUNNYVALE, CA

Power of Attorney: The patent practitioners associated with Customer Number 112754

Domestic Applications for which benefit is claimed - None.

A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

If Required, Foreign Filing License Granted: 04/23/2013

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/830,262**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No

Title

DIGITAL CONTROL OF RESONANT POWER CONVERTERS

Preliminary Class

363

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:**PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER
Title 35, United States Code, Section 184
Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit <http://www.SelectUSA.gov> or call +1-202-482-6800.



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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120

CONFIRMATION NO. 1066

112754
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

NOTICE



Date Mailed: 07/15/2013

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

A new inventor's oath or declaration that identifies this application (e.g., by Application Number and filing date) is required. The inventor's oath or declaration does not comply with 37 CFR 1.63 in that it:

- does not state that the above-identified application was made or authorized to be made by the person executing the oath or declaration.

Patrizio VINCIARELLI
Sergey LUZANOV



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120

CONFIRMATION NO. 1066

POA ACCEPTANCE LETTER



112754
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

Date Mailed: 07/15/2013

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 07/01/2013.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/cnguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

DECLARATION

As a below named inventor, I HEREBY DECLARE:

THAT my residence, post office address, and citizenship are as stated below next to my name;

THAT I believe I am the original, first, and sole inventor (if only one inventor is named below) or an original, first, and joint inventor (if plural inventors are named below or in an attached Declaration) of the subject matter which is claimed and for which a patent is sought on the invention entitled

DIGITAL CONTROL OF RESONANT POWER CONVERTERS

(Attorney Docket No. 092377-0120)

the application of which (check one)

 is attached hereto.

 X was filed on 3/14/2013 as United States Application Number or PCT International Application Number 13/830,262 and was amended on (if applicable).

THAT the above-identified application was made or authorized to be made by me.

THAT I do not know and do not believe that the same invention was ever known or used by others in the United States of America, or was patented or described in any printed publication in any country, before I (we) invented it;

THAT I do not know and do not believe that the same invention was patented or described in any printed publication in any country, or in public use or on sale in the United States of America, for more than one year prior to the filing date of this United States application;

THAT I do not know and do not believe that the same invention was first patented or made the subject of an inventor's certificate that issued in any country foreign to the United States of America before the filing date of this United States application if the foreign application was filed by me (us), or by my (our) legal representatives or assigns, more than twelve months (six months for design patents) prior to the filing date of this United States application;

THAT I have reviewed and understand the contents of the above-identified application, including the claim(s), as amended by any amendment specifically referred to above;

THAT I believe that the above-identified application contains a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the invention, and sets forth the best mode contemplated by me of carrying out the invention; and

THAT I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I HEREBY CLAIM foreign priority benefits under Title 35, United States Code §119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number	Country	Foreign Filing Date	Priority Claimed?	Certified Copy Attached?

I HEREBY CLAIM the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

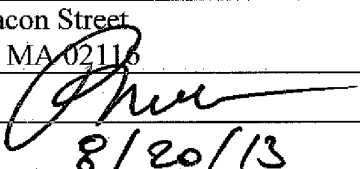
U.S. Provisional Application Number	Filing Date

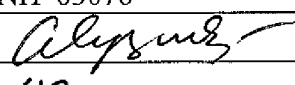
I HEREBY CLAIM the benefit under Title 35, United States Code, §120 of any United States application(s), or § 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of

Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application Number	PCT Parent Application Number	Parent Filing Date	Parent Patent Number

I FURTHER DECLARE THAT all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment of not more than five (5) years, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Name of first inventor Patrizio VINCIARELLI
 Residence Boston, Massachusetts
 Citizenship Country
 Post Office Address 294 Beacon Street
 Boston, MA 02116
 Inventor's signature 
 Date 8/20/13

Name of second inventor Sergey LUZANOV
 Residence Pelham, New Hampshire
 Citizenship Country Russia
 Post Office Address 5 Campbell Rd.
 Pelham, NH 03076
 Inventor's signature 
 Date 8/20/13

Electronic Acknowledgement Receipt

EFS ID:	16731914
Application Number:	13830262
International Application Number:	
Confirmation Number:	1066
Title of Invention:	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
First Named Inventor/Applicant Name:	Patrizio VINCIARELLI
Customer Number:	112754
Filer:	John D. Lanza/Katie Newcomb
Filer Authorized By:	John D. Lanza
Attorney Docket Number:	092377-0120
Receipt Date:	30-AUG-2013
Filing Date:	14-MAR-2013
Time Stamp:	12:53:58
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	0120_Declaration.pdf	97576 af4c079220b6fd2bc672b8bb249b969c436e1cf9	no	3

Warnings:

Information:

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Substitute for form 1449/PTO				Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT Date Submitted: July 29, 2014 <i>(use as many sheets as necessary)</i>				Application Number	13/830,262
				Filing Date	3/14/2013
				First Named Inventor	Patrizio VINCIARELLI
				Art Unit	2838
				Examiner Name	Matthew Van Nguyen
Sheet	1	of	1	Attorney Docket Number	092377-0120

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number-Kind Code ² (if known)			
	A6	6,930,893 B2	08-16-2005	Vinciarelli	
	A7	7,145,786 B2	12-05-2006	Vinciarelli	
	A8	6,911,848 B2	06-28-2005	Vinciarelli	
	A9	6,975,098 B2	12-13-2005	Vinciarelli	
	A10	6,934,166 B2	08-23-2005	Vinciarelli	

UNPUBLISHED U.S. PATENT APPLICATION DOCUMENTS					
Examiner Initials*	Cite No. ¹	U.S. Patent Application Document	Filing Date of Cited Document MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Serial Number-Kind Code ² (if known)			

FOREIGN PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Foreign Patent Document	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Documents	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Country Code ³ Number ⁴ Kind Code ⁵ (if known)			
					T ⁶

NON PATENT LITERATURE DOCUMENTS				
Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.) date, page(s), volume-issue number(s), publisher, city and/or country where published.		

Examiner Signature		Date Considered	
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Electronic Acknowledgement Receipt

EFS ID:	19709731
Application Number:	13830262
International Application Number:	
Confirmation Number:	1066
Title of Invention:	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
First Named Inventor/Applicant Name:	Patrizio VINCIARELLI
Customer Number:	112754
Filer:	John D. Lanza/Katie Newcomb
Filer Authorized By:	John D. Lanza
Attorney Docket Number:	092377-0120
Receipt Date:	29-JUL-2014
Filing Date:	14-MAR-2013
Time Stamp:	12:12:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	0120_IDS_letter.pdf	100138 e851d66df92c202cb50294d504d0cd3554f eb3a9	no	2

Warnings:

Information:

2	Information Disclosure Statement (IDS) Form (SB08)	0120_SB08.pdf	92357	no	1
			3013ec62e4d2395daec73bf4a8715836045 94920		
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
Total Files Size (in bytes):				192495	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

First Inventor Name: Patrizio VINCIARELLI
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: 13/830,262
Filing Date: 3/14/2013
Examiner: Matthew Van Nguyen
Art Unit: 2838
Confirmation Number: 1066

INFORMATION DISCLOSURE STATEMENT
UNDER 37 CFR §1.56

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Applicant submits herewith documents for the Examiner's consideration in accordance with 37 CFR §§1.56, 1.97 and 1.98.

Applicants respectfully request that each listed document be considered by the Examiner and be made of record in the present application and that an initialed copy of Form PTO/SB/08 be returned in accordance with MPEP §609.

The submission of any document herewith is not an admission that such document constitutes prior art against the claims of the present application or that such document is considered material to patentability as defined in 37 CFR §1.56(b). Applicants do not waive any rights to take any action which would be appropriate to antedate or otherwise remove as a competent reference any document submitted herewith.

TIMING OF THE DISCLOSURE

The listed documents are being submitted in compliance with 37 CFR §1.97(b), before the mailing date of the first Office Action on the merits.

Although Applicant believes that no fee is required, the Commissioner is hereby authorized to charge any additional fees which may be due to Deposit Account No. 19-0741.

Respectfully submitted,

Date July 29, 2014

By /John D. Lanza/

FOLEY & LARDNER LLP
Customer Number: 112754
Telephone: (617) 342-4084
Facsimile: (617) 342-4001

John D. Lanza
Attorney for Applicant
Registration No. 40,060



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120	1066
112754	7590	04/23/2015	EXAMINER	
Foley & Lardner LLP			NGUYEN, MATTHEW VAN	
3000 K Street N.W.			ART UNIT	
Suite 600			PAPER NUMBER	
Washington, DC 20007-5109			2838	
			NOTIFICATION DATE	
			DELIVERY MODE	
			04/23/2015	
			ELECTRONIC	

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocketing@foley.com

Office Action Summary	Application No. 13/830,262	Applicant(s) VINCIARELLI ET AL.	
	Examiner MATTHEW NGUYEN	Art Unit 2838	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 2 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 3/14/13.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a) ☐ This action is **FINAL**. 2b) ☐ This action is non-final.

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4) ☒ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☒ Claim(s) 1-35 is/are pending in the application.
5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☒ Claim(s) 1-35 is/are allowed.

7) ☐ Claim(s) _____ is/are rejected.

8) ☐ Claim(s) _____ is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10) ☐ The specification is objected to by the Examiner.

11) ☒ The drawing(s) filed on 7/1/13 is/are: a) ☒ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some** c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. _____.

3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b)
Paper No(s)/Mail Date 7/1/13; 7/29/14.

3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____.

4) ☐ Other: _____.

Art Unit: 2838

1. The present application is being examined under the pre-AIA first to invent provisions.

Quayle Action

2. This application is in condition for allowance except for the following formal matters:

- i) Abstract should be rewritten to reflect subject matter in claims.
- ii) in drawings, Fig. 1 should be labeled as -- Prior Art --.

Prosecution on the merits is closed in accordance with the practice under *Ex parte Quayle*, 25 USPQ 74, 453 O.G. 213, (Comm'r Pat. 1935).

A shortened statutory period for reply to this action is set to expire **TWO MONTHS** from the mailing date of this letter.

Allowable Subject Matter

3. The following is an examiner's statement of reasons for allowance: none of prior art of record taken alone or in combination shows a method of synchronously operating a power converter in a series of converter operating cycles, the converter having at least one primary switch to drive a resonant power train and at least one secondary switch, the resonant power train including a transformer and having a characteristic resonant frequency and period, the method comprising: providing an oscillator for generating clock signals at an oscillator frequency; generating timing control signals for each of a plurality of events based upon the clock signals in a

standard converter operating cycle, having a standard operating period and frequency, to: (i) turn the at least one primary switch ON and OFF at times when essentially zero voltage is impressed across the respective at least one primary switch and essentially zero resonant current is flowing in the respective at least one primary switch; and (ii) turn the at least one secondary switch ON and OFF at times when essentially zero current is flowing in the respective at least one secondary switch and essentially zero voltage is impressed across the respective at least one secondary switch; and wherein the oscillator frequency is preset, and the timing of the timing control signals for one or more selected events may be set independently of other timing control signals and events as recited in claims of the instant application.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Contact Information

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW V. NGUYEN whose telephone number is (571)272-2081. The examiner can normally be reached on 8 HOURS M-F.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, MONICA LEWIS can be reached on (571)272-1838. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MATTHEW V NGUYEN/
Primary Examiner, Art Unit 2838

Notice of References Cited	Application/Control No. 13/830,262		Applicant(s)/Patent Under Reexamination VINCIARELLI ET AL.	
	Examiner MATTHEW NGUYEN		Art Unit 2838	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-5,267,138	11-1993	Shores, Ronald B.	363/98
*	B	US-7,193,866	03-2007	Huang, Ming-Ho	363/22
*	C	US-8,174,851	05-2012	Elferich, Reinhold	363/21.02
*	D	US-2011/0194206	08-2011	Sase et al.	360/75
*	E	US-2013/0314951	11-2013	Harrison, Michael John	363/21.02
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Receipt date: 07/01/2013

13830262 - GAU; 2838

Approved for use through 03/31/2007. OMB 0651-0031

U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO		Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT Date Submitted: JUL 01 2013 <i>(use as many sheets as necessary)</i>		Application Number	13/830,262
		Filing Date	03/14/2013
		First Named Inventor	Patrizio VINCIARELLI
		Art Unit	2838
		Examiner Name	Unassigned
Sheet	1	of	1
		Attorney Docket Number	092377-0120

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Document Number Number-Kind Code ² (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	A1	6,984,965 B2	01-10-2006	Vinciarelli	
	A2	6,107,860	08-22-2000	Vinciarelli	
	A3	5,010,261	04-23-1991	Stiegerwald	
	A4	7,602,229 B2	10-13-2009	Tolle et al.	
	A5	7,091,753 B2	08-15-2006	Inoshita	

UNPUBLISHED U.S. PATENT APPLICATION DOCUMENTS					
Examiner Initials*	Cite No. ¹	U.S. Patent Application Document Serial Number-Kind Code ² (if known)	Filing Date of Cited Document MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Foreign Patent Document Country Code ³ Number ⁴ Kind Code ⁵ (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Documents	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear T ⁶

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.) date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ⁶

Examiner Signature	/Matthew Nguyen/	Date Considered	04/18/2015
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5 Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

4813-6665-2947.1

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.N./

DELTA ELECTRONICS EX. 1002

Page 126

Receipt date: 07/29/2014

13830262 - GAU: 2838
PTO/USB/08 (modified)

Substitute for form 1449/PTO				Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT Date Submitted: July 29, 2014 <i>(use as many sheets as necessary)</i>				Application Number	13/830,262
				Filing Date	3/14/2013
				First Named Inventor	Patrizio VINCIARELLI
				Art Unit	2838
				Examiner Name	Matthew Van Nguyen
Sheet	1	of	1	Attorney Docket Number	092377-0120

U.S. PATENT DOCUMENTS					
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	A7	7,145,786 B2	12-05-2006	Vinciarelli	
	A8	6,911,848 B2	06-28-2005	Vinciarelli	
	A9	6,975,098 B2	12-13-2005	Vinciarelli	
	A10	6,934,166 B2	08-23-2005	Vinciarelli	

UNPUBLISHED U.S. PATENT APPLICATION DOCUMENTS					
Examiner Initials*	Cite No. ¹	U.S. Patent Application Document Serial Number-Kind Code ² (if known)	Filing Date of Cited Document MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Foreign Patent Document Country Code ³ Number ⁴ Kind Code ⁵ (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Documents	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
					T ⁶

NON PATENT LITERATURE DOCUMENTS				
Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.) date, page(s), volume-issue number(s), publisher, city and/or country where published.		
				T ⁶

Examiner Signature	/Matthew Nguyen/	Date Considered	04/18/2015
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4826-7882-9084.1

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.N./

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	9	("6984965" "6107860" "5010261" "7602229" "7091753" "6930893" "7154786" "691184" "6975098" "6934166").pn.	USPAT	OR	ON	2015/04/18: 18:44
L2	476	(vinciarelli near2 patrizio).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:46
L3	4	(luzanov near2 sergey).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:47
L4	478	2 3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:47
L5	269148	synchron\$6 with (switch\$3 rectif\$5 power)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:50
L6	963437	resonan\$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:50
L7	2668678	oscillat\$3 clock	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:51
L8	1850133	timing	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:51
L9	29120	(oscillat\$3 clock) with (preset\$4 "pre-set" "pre-setting")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/04/18: 18:53
L10	3	5 6 8 9	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	SAME	ON	2015/04/18: 18:54

L11	161	5 6 8 7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	SAME	ON	2015/04/18: 18:54
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4/ 18/ 2015 6:55:15 PM

Search Notes 	Application/Control No. 13830262	Applicant(s)/Patent Under Reexamination VINCIARELLI ET AL.
	Examiner MATTHEW NGUYEN	Art Unit 2838

CPC- SEARCHED		
Symbol	Date	Examiner
H02M 3/335; H02M 3/33515; H02M 3/33592	4/18/2015	MN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
363	17, 21.02, 21.03, 21.05, 21.06, 98, 132	4/18/2015	MN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST: see text search history rpintout	4/18/2015	MN
Inventor name search	4/18/2015	MN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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BIB DATA SHEET

CONFIRMATION NO. 1066

SERIAL NUMBER 13/830,262	FILING or 371(c) DATE 03/14/2013 RULE	CLASS 363	GROUP ART UNIT 2838	ATTORNEY DOCKET NO. 092377-0120		
APPLICANTS VLT, INC., SUNNYVALE, CA INVENTORS Patrizio VINCIARELLI, Boston, MA; Sergey LUZANOV, Pelham, NH; ** CONTINUING DATA ***** ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 04/23/2013						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and /MATTHEW VAN NGUYEN/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY MA	SHEETS DRAWINGS 14	TOTAL CLAIMS 35	INDEPENDENT CLAIMS 1
ADDRESS Foley & Lardner LLP 3000 K Street N.W. Suite 600 Washington, DC 20007-5109 UNITED STATES						
TITLE DIGITAL CONTROL OF RESONANT POWER CONVERTERS						
FILING FEE RECEIVED 2320	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			☐ All Fees		
				☐ 1.16 Fees (Filing)		
				☐ 1.17 Fees (Processing Ext. of time)		
				☐ 1.18 Fees (Issue)		
				☐ Other _____		
			☐ Credit			

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 13/830,262		Filing Date 03/14/2013		☐ To be Mailed	
ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO									
APPLICATION AS FILED – PART I									
(Column 1)		(Column 2)							
FOR	NUMBER FILED	NUMBER EXTRA			RATE (\$)	FEE (\$)			
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A			N/A				
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A			N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A			N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*			X \$	=			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*			X \$	=			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).								
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
* If the difference in column 1 is less than zero, enter "0" in column 2.					TOTAL				
APPLICATION AS AMENDED – PART II									
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT	05/01/2015	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 22	Minus	** 22	= 0	X \$80 =		0	
	Independent (37 CFR 1.16(h))	* 5	Minus	*** 5	= 0	X \$420 =		0	
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE		0	
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$		=	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$		=	
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.									
LIE /SHAUNA ZIMMERMAN/									

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

First Inventor Name: Patrizio VINCIARELLI
Title: DIGITAL CONTROL OF RESONANT
POWER CONVERTERS
Appl. No.: 13/830,262
Filing Date: 3/14/2013
Examiner: Matthew Van Nguyen
Art Unit: 2838
Confirmation Number: 1066

**RESPONSE TO EX PARTE QUAYLE OFFICE ACTION
AND AMENDMENT UNDER 37 CFR 1.116**

Mail Stop AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

This communication is responsive to the *Ex Parte Quayle* Action dated April 23, 2015, concerning the above-referenced patent application. A response to this Action is due June 23, 2015. Accordingly, this response is timely filed.

Amendments to the Abstract are presented on page 2 of this document.

Amendments to the Drawings are presented on page 3 of this document.

Remarks/Arguments begin on page 4 of this document.

Amendments to the Abstract:

Please replace the original Abstract with the following Abstract:

A method of synchronously operating a power converter in a series of converter operating cycles includes providing an oscillator for generating clock signals at an oscillator frequency, and generating timing control signals for each of multiple events based upon the clock signals. The method further includes to: (i) turn a primary switch ON and OFF at times when essentially zero voltage is impressed across the primary switch and essentially zero resonant current is flowing in the primary switch; and (ii) turn a secondary switch ON and OFF at times when essentially zero current is flowing in the secondary switch and essentially zero voltage is impressed across the secondary switch. The oscillator frequency is preset, and the timing of the timing control signals for one or more selected events may be set independently of other timing control signals and events.

Amendments to the Drawings:

The appended drawing sheet containing amended Figure 1 is being presented as a new formal drawing sheet to be substituted for the previously submitted drawing sheet. Also appended is an annotated copy of the previous drawing sheet which has been marked to show amendments. The specific amendment is to add the text “Prior Art” to Figure 1A.

REMARKS

Applicant thanks the Examiner for indicating the allowability of claims 1-35. With respect to the reasons for allowance, Applicant agrees that the claims are allowable for at least the stated reasons.

Drawings

The drawings were objected to for informalities. Specifically, it was stated that Fig. 1 should be labeled as 'Prior Art'. A new formal drawing sheet and a Markup Sheet are submitted herewith, as described in the Amendments to the Drawings section, above.

Specification (Abstract)

The Abstract was objected to for informalities. The Abstract has been amended without acquiescence. No new matter is added.

CONCLUSION

The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 19-0741. Should no proper payment be enclosed herewith, as by the credit card payment instructions in EFS-Web being incorrect or absent, resulting in a rejected or incorrect credit card transaction, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 19-0741. If any extensions of time are needed for timely acceptance of papers submitted herewith, Applicant hereby petitions for such extension under 37 C.F.R. §1.136 and authorizes payment of any such extension fees to Deposit Account No. 19-0741.

Respectfully submitted,

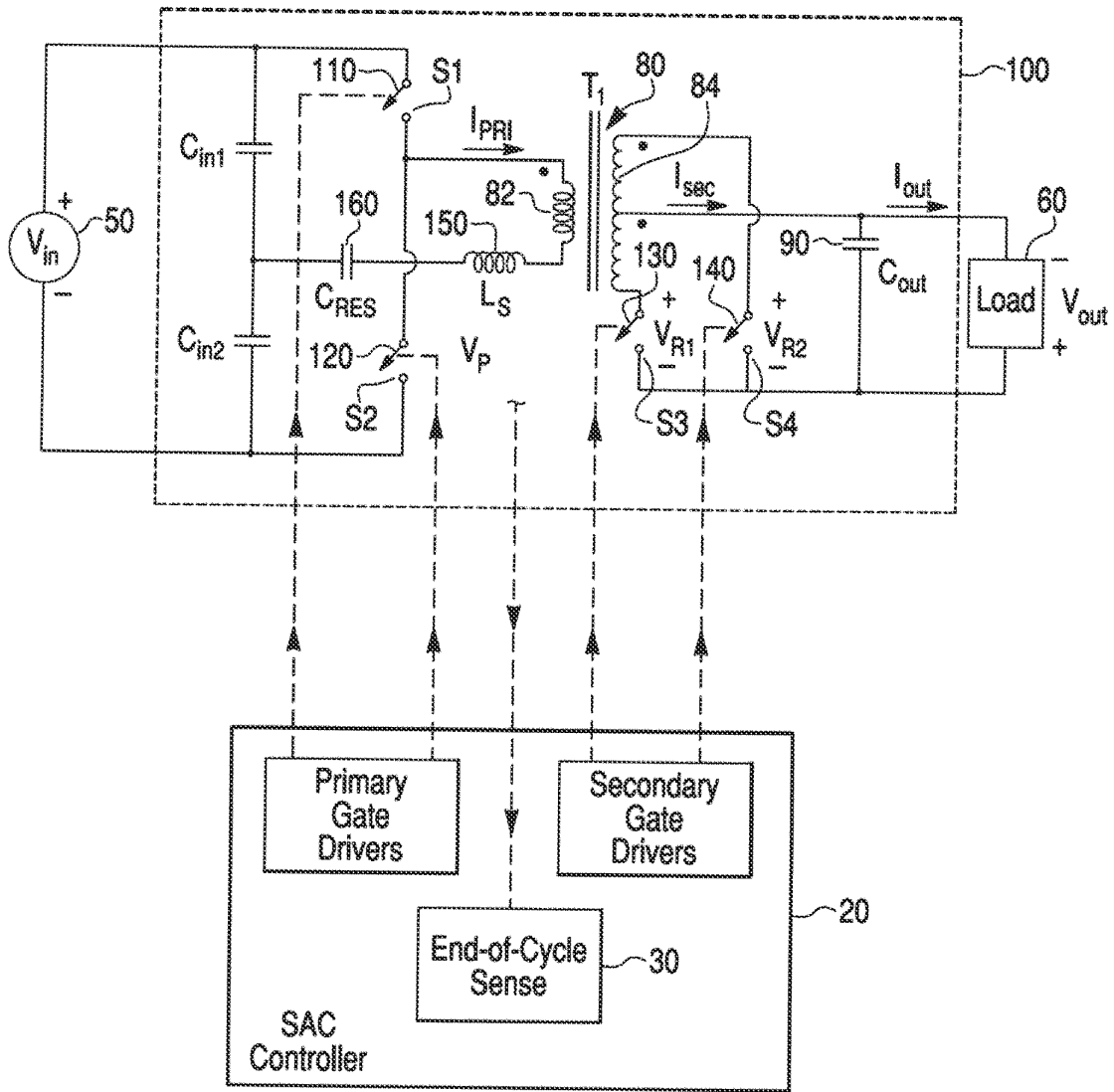
Date June 12, 2015

By /Angela D. Murch/

FOLEY & LARDNER LLP
Customer Number: 112754
Telephone: (650) 251-1105
Facsimile: (650) 856-3710

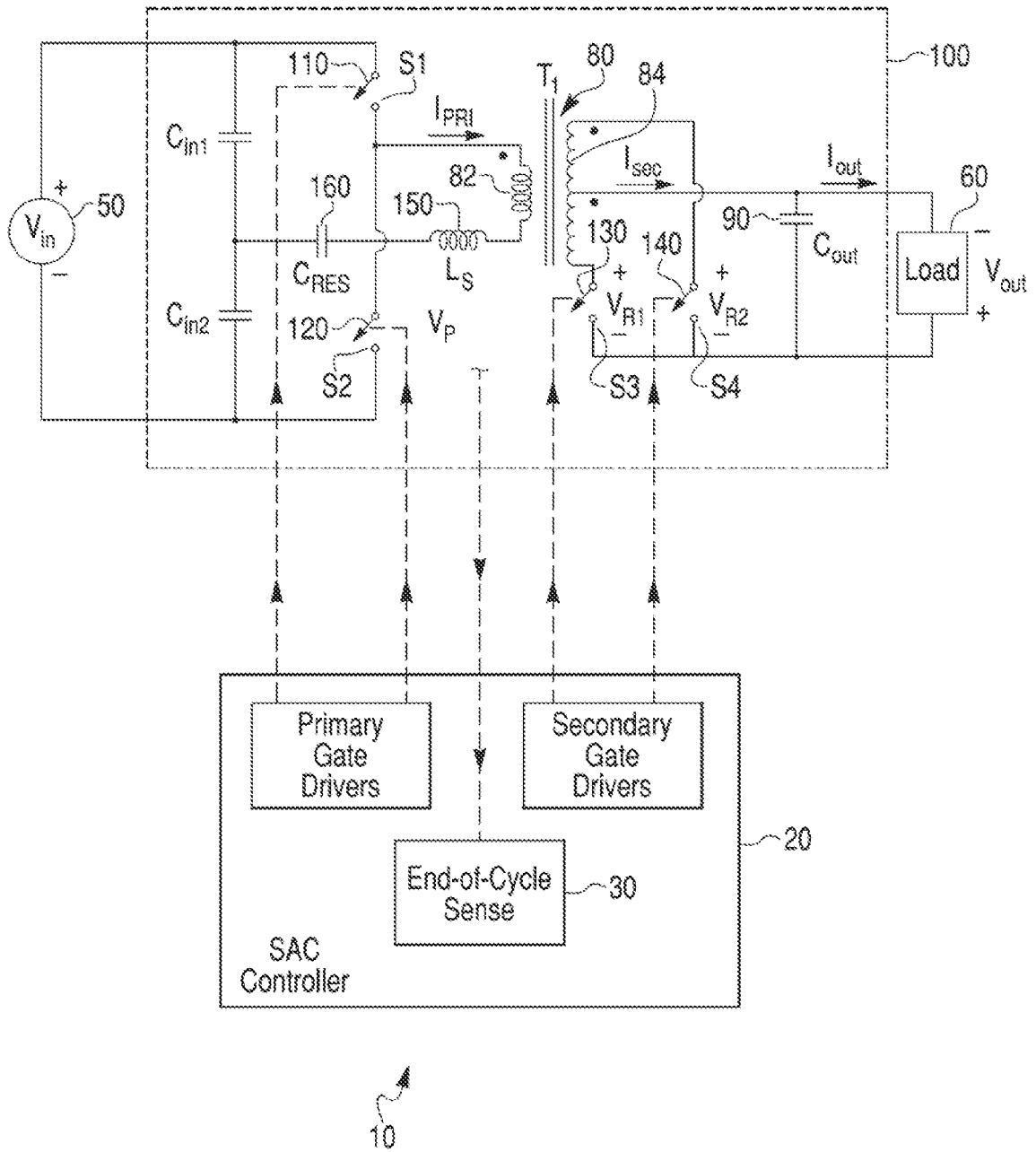
Angela D. Murch
Attorney for Applicant
Registration No. 61,216

Fig. 1



10
Prior Art ← Added

Fig. 1



10

Prior Art

Electronic Acknowledgement Receipt

EFS ID:	22622670
Application Number:	13830262
International Application Number:	
Confirmation Number:	1066
Title of Invention:	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
First Named Inventor/Applicant Name:	Patrizio VINCIARELLI
Customer Number:	112754
Filer:	Angela D. Murch/Karen Kline
Filer Authorized By:	Angela D. Murch
Attorney Docket Number:	092377-0120
Receipt Date:	12-JUN-2015
Filing Date:	14-MAR-2013
Time Stamp:	18:18:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		092377_0120_Amendment_and_Reply.pdf	124855 e06c295f9ba4bd49715a1f46c4ceb930adb9f187	yes	4

	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Response after Ex Parte Quayle Action		1	1	
	Abstract		2	2	
	Drawings-only black and white line drawings		3	3	
	Applicant Arguments/Remarks Made in an Amendment		4	4	
Warnings:					
Information:					
2	Drawings-only black and white line drawings	092377_0120_Annotated_Sheet_Fig_1.pdf	55412	no	1
			830415eb96e301fa5523270c5c958f6140eedb49		
Warnings:					
Information:					
3	Drawings-only black and white line drawings	092377_0120_Replacement_Fig_1.pdf	118237	no	1
			5e0454e6dc5d1006d29d00928bc91194f52df67d		
Warnings:					
Information:					
Total Files Size (in bytes):			298504		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 13/830,262		Filing Date 03/14/2013		☐ To be Mailed		
ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO										
APPLICATION AS FILED – PART I										
(Column 1)		(Column 2)								
FOR	NUMBER FILED	NUMBER EXTRA			RATE (\$)	FEE (\$)				
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A			N/A					
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A			N/A					
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A			N/A					
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*			X \$	=				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*			X \$	=				
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.					TOTAL					
APPLICATION AS AMENDED – PART II										
(Column 1)		(Column 2)		(Column 3)						
AMENDMENT	06/12/2015	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)			
	Total (37 CFR 1.16(i))	* 35	Minus	** 35	= 0	X \$80 =	0			
	Independent (37 CFR 1.16(h))	* 1	Minus	*** 1	= 0	X \$420 =	0			
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
						TOTAL ADD'L FEE 0				
(Column 1)		(Column 2)		(Column 3)						
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)			
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$	=			
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$	=			
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
						TOTAL ADD'L FEE				
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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NOTICE OF ALLOWANCE AND FEE(S) DUE

112754 7590 07/15/2015
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

EXAMINER

NGUYEN, MATTHEW VAN

ART UNIT

PAPER NUMBER

2838

DATE MAILED: 07/15/2015

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
-----------------	-------------	----------------------	---------------------	------------------

13/830,262

03/14/2013

Patrizio VINCIARELLI

092377-0120

1066

TITLE OF INVENTION: DIGITAL CONTROL OF RESONANT POWER CONVERTERS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$960	\$0	\$0	\$960	10/15/2015

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

112754 7590 07/15/2015
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120	1066

TITLE OF INVENTION: DIGITAL CONTROL OF RESONANT POWER CONVERTERS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$960	\$0	\$0	\$960	10/15/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, MATTHEW VAN	2838	363-024000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363). ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached. ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.	2. For printing on the patent front page, list (1) The names of up to 3 registered patent attorneys or agents OR, alternatively, 1 _____ (2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 _____ 3 _____
---	---

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
- ☐ Applicant asserting small entity status. See 37 CFR 1.27
- ☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120	1066
112754	7590	07/15/2015		
Foley & Lardner LLP 3000 K Street N.W. Suite 600 Washington, DC 20007-5109			EXAMINER NGUYEN, MATTHEW VAN	
			ART UNIT 2838	PAPER NUMBER
DATE MAILED: 07/15/2015				

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 13/830,262 Examiner MATTHEW NGUYEN	Applicant(s) VINCIARELLI ET AL. Art Unit 2838 AIA (First Inventor to File) Status No
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-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to Response filed on 6/12/15.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1-35. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some *c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. _____.

3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.

☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892) 2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____ 3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material 4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____	5. ☐ Examiner's Amendment/Comment 6. ☐ Examiner's Statement of Reasons for Allowance 7. ☐ Other _____
--	--

/MATTHEW NGUYEN/ Primary Examiner, Art Unit 2838	
---	--

Issue Classification 	Application/Control No. 13830262	Applicant(s)/Patent Under Reexamination VINCIARELLI ET AL.
	Examiner MATTHEW NGUYEN	Art Unit 2838

CPC						
Symbol				Type	Version	
H02M		3		325	F	2013-01-01

CPC Combination Sets						
Symbol			Type	Set	Ranking	Version

NONE (Assistant Examiner) _____ (Date) _____		Total Claims Allowed: 35	
/MATTHEW NGUYEN/ Primary Examiner.Art Unit 2838 (Primary Examiner) _____ (Date) _____		07/02/2015 O.G. Print Claim(s) 1	O.G. Print Figure 2

Issue Classification 	Application/Control No. 13830262	Applicant(s)/Patent Under Reexamination VINCIARELLI ET AL.
	Examiner MATTHEW NGUYEN	Art Unit 2838

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47															
Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		17		33										
	2		18		34										
	3		19		35										
	4		20												
	5		21												
	6		22												
	7		23												
	8		24												
	9		25												
	10		26												
	11		27												
	12		28												
	13		29												
	14		30												
	15		31												
	16		32												

NONE (Assistant Examiner) (Date)		Total Claims Allowed: 35	
/MATTHEW NGUYEN/ Primary Examiner.Art Unit 2838 (Primary Examiner) (Date)		07/02/2015 O.G. Print Claim(s) 1	O.G. Print Figure 2

Search Notes 	Application/Control No. 13830262	Applicant(s)/Patent Under Reexamination VINCIARELLI ET AL.
	Examiner MATTHEW NGUYEN	Art Unit 2838

CPC- SEARCHED		
Symbol	Date	Examiner
H02M 3/335; H02M 3/33515; H02M 3/33592	4/18/2015	MN
Updated Search all above	7/2/2015	MN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
363	17, 21.02, 21.03, 21.05, 21.06, 98, 132	4/18/2015	MN
	Updated search all above	7/2/2015	MN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST: see text search history rpintout	4/18/2015	MN
Inventor name search	4/18/2015	MN
Updated EAST: see text search history rpintout	7/2/2015	MN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
	see text search history rpintout	7/2/2015	MN

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EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	273277	synchron\$6 with (switch\$3 rectific\$5 power)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/07/02 19:21
L2	978808	resonan\$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/07/02 19:21
L3	2743725	oscillat\$3 clock\$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/07/02 19:22
L4	1879847	timing	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/07/02 19:22
L5	161	1 2 3 4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	SAME	ON	2015/07/02 19:22

7/ 2/ 2015 7:23:36 PM

EAST Search History**EAST Search History (Interference)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L6	136787	synchron\$6 with (switch\$3 rectif\$5 power)	US-PGPUB; USPAT; UPAD	OR	ON	2015/07/02: 19:22
L7	522679	resonan\$2	US-PGPUB; USPAT; UPAD	OR	ON	2015/07/02: 19:22
L8	1268519	oscillat\$3 clock\$3	US-PGPUB; USPAT; UPAD	OR	ON	2015/07/02: 19:22
L9	1225928	timing	US-PGPUB; USPAT; UPAD	OR	ON	2015/07/02: 19:22
L10	55	(6 7 8 9).clm.	US-PGPUB; USPAT; UPAD	AND	ON	2015/07/02: 19:23

7/ 2/ 2015 7:24:02 PM

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax **(571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

112754 7590 07/15/2015
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/830,262	03/14/2013	Patrizio VINCIARELLI	092377-0120	1066

TITLE OF INVENTION: DIGITAL CONTROL OF RESONANT POWER CONVERTERS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$960	\$0	\$0	\$960	10/15/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, MATTHEW VAN	2838	363-024000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

- (1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 **FOLEY & LARDNER LLP**

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

VLT, INC.

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Sunnyvale, California

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☒ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☒ Advance Order - # of Copies **5**

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☒ Payment by credit card. ~~Form PTO 2038 is attached.~~ **Via EFS Web**
☒ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number **19-0741** (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
☐ Applicant asserting small entity status. See 37 CFR 1.27
☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /John D. Lanza /
Typed or printed name John D. Lanza

Date September 15, 2015
Registration No. 40,060

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

First Inventor Name: Patrizio VINCIARELLI
Title: DIGITAL CONTROL OF RESONANT POWER CONVERTERS
Appl. No.: 13/830,262
Filing Date: 3/14/2013
Examiner: Matthew Van Nguyen
Art Unit: 2838
Confirmation Number: 1066

ISSUE FEE TRANSMITTAL

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Enclosed herewith please find Issue Fee Transmittal Form PTOL-85(B).

Fees in the amount of \$975.00 for payment of the Issue Fee and five additional copies of the issued utility patent are being paid by credit card via EFS-Web.

The applicant agrees that the allowed claims are distinguished from the cited prior art. The applicant does not concede that all of the limitations are necessary for patentability of the allowed claims or other claims directed to the disclosed subject matter. The applicant expressly reserves the right to set forth additional and/or alternative reasons for patentability and/or allowance in connection with the present Application or any future proceeding.

The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to

Deposit Account No. 19-0741. Should no proper payment be enclosed herewith, as by the credit card payment instructions in EFS-Web being incorrect or absent, resulting in a rejected or incorrect credit card transaction, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 19-0741.

Respectfully submitted,

Date September 15, 2015

By /John D. Lanza/

FOLEY & LARDNER LLP
Customer Number: 112754
Telephone: (617) 342-4084
Facsimile: (617) 342-4001

John D. Lanza
Attorney for Applicant
Registration No. 40,060

Electronic Patent Application Fee Transmittal				
Application Number:		13830262		
Filing Date:		14-Mar-2013		
Title of Invention:		DIGITAL CONTROL OF RESONANT POWER CONVERTERS		
First Named Inventor/Applicant Name:		Patrizio VINCIARELLI		
Filer:		John D. Lanza/Karen Kline		
Attorney Docket Number:		092377-0120		
Filed as Large Entity				
Filing Fees for Utility under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	1501	1	960	960

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Printed Copy of Patent - No Color	8001	5	3	15
Total in USD (\$)				975

Electronic Acknowledgement Receipt

EFS ID:	23493980
Application Number:	13830262
International Application Number:	
Confirmation Number:	1066
Title of Invention:	DIGITAL CONTROL OF RESONANT POWER CONVERTERS
First Named Inventor/Applicant Name:	Patrizio VINCIARELLI
Customer Number:	112754
Filer:	John D. Lanza/Karen Kline
Filer Authorized By:	John D. Lanza
Attorney Docket Number:	092377-0120
Receipt Date:	15-SEP-2015
Filing Date:	14-MAR-2013
Time Stamp:	17:19:17
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$ 975
RAM confirmation Number	4228
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	092377-0120_PTOL85.pdf	129609 cf1ffae5a336936dc7b96e8750ba988804f3fa71	no	1
Warnings:					
Information:					
2	Transmittal Letter	092377_0120_Issue_Fee_Transmittal.pdf	96354 eafe53a3cdc841c5aae039ce1a910b70bb3de8a53	no	2
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	32174 6836e1cb76c94d8f2dfc53469f19beff64b43a76	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			258137		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/830,262	10/20/2015	9166481	092377-0120	1066

112754 7590 09/30/2015
Foley & Lardner LLP
3000 K Street N.W.
Suite 600
Washington, DC 20007-5109

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 308 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

VLT, INC., SUNNYVALE, CA
Patrizio VINCIARELLI, Boston, MA;
Sergey LUZANOV, Pelham, NH;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.