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**United States Patent** [19]

Redl

[11] **Patent Number:** **5,680,034**[45] **Date of Patent:** **Oct. 21, 1997**[54] **PWM CONTROLLER FOR RESONANT CONVERTERS**[75] Inventor: **Richard Redl**, Onnens, Switzerland[73] Assignee: **Toko, Inc.**, Japan[21] Appl. No.: **532,476**[22] Filed: **Sep. 22, 1995**[51] Int. Cl.<sup>6</sup> ..... **H02M 3/335**[52] U.S. Cl. .... **323/21; 363/79; 363/97; 323/235**[58] Field of Search ..... **363/16, 21, 79, 363/80, 97, 131; 323/235**[56] **References Cited****U.S. PATENT DOCUMENTS**

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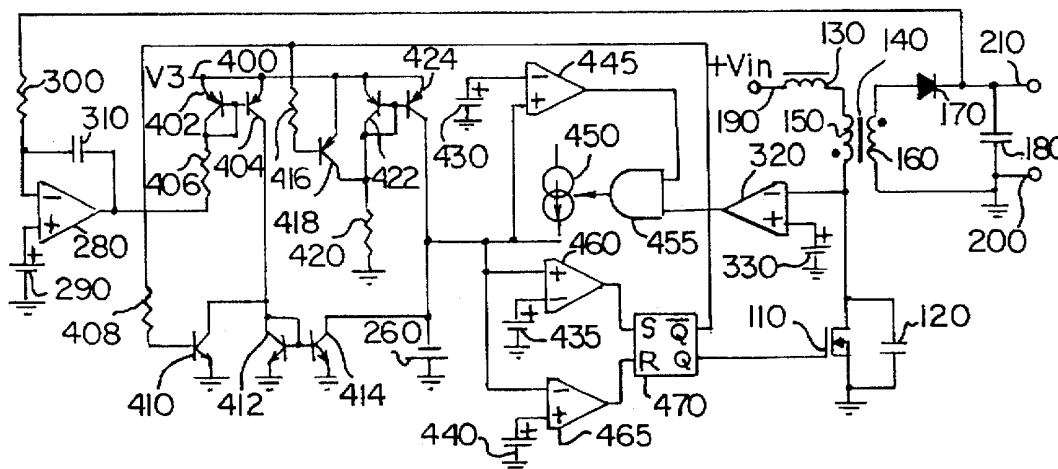
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*Primary Examiner*—Peter S. Wong*Assistant Examiner*—Shawn Riley*Attorney, Agent, or Firm*—William E. Hein[57] **ABSTRACT**

A pulse width modulated controller controls a zero-voltage switching resonant power converter or inverter. The on time of the power switch (110) of the converter or inverter is varied by an error amplifier (280) such that the output voltage of the converter or inverter maintains proportionality to a reference voltage (290). The off time is terminated by a switch-voltage detector (320) when the voltage across the power switch (110) drops below a threshold voltage (330) due to the natural resonance of the external resonating capacitor (120) and inductors (130 and 150). In the first two embodiments of the invention, a single timing capacitor (260) is employed both for determining the on time and the off time. In two other embodiments, two timing capacitors (262 and 264) are employed for separately determining the maximum allowed off time and the variable on time. A cycle-by-cycle current limit circuit comprising a current sensor (605), a comparator (610), and an R-S latch (620) may be added to the circuits representing each of the embodiments. By incorporating a soft start subcircuit (775) and an overlap detector (710, 715, 20, 725), protection against overdissipation of the power switch caused by loss of zero-voltage switching can also be implemented. The soft start subcircuit can also be triggered by a voltage detector (740, 745), which monitors the output voltage of the power converter or some other voltage within the system, such as the peak voltage across the power switch (110), to effectively implement overvoltage protection.

**9 Claims, 7 Drawing Sheets**

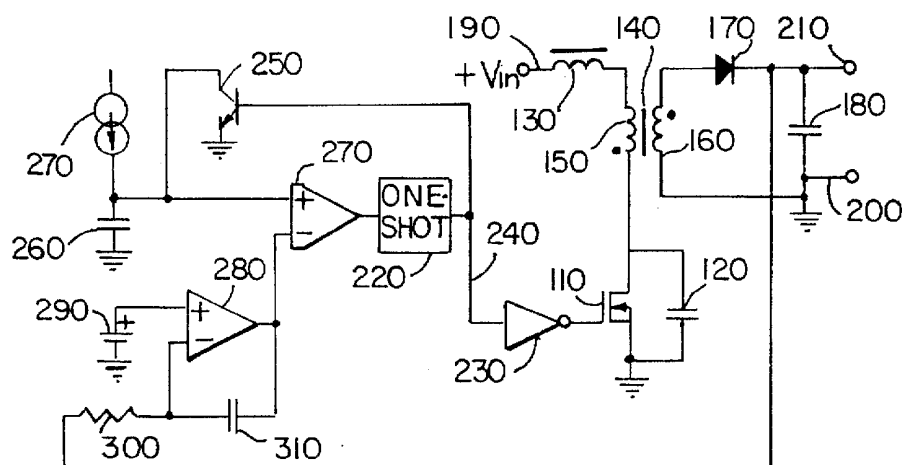


FIG. 1  
(PRIOR ART)

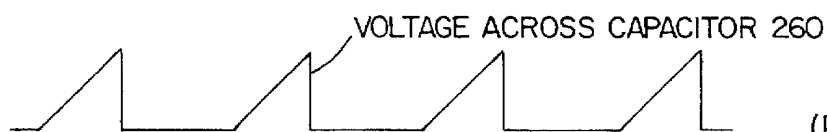


FIG. 2 A  
(PRIOR ART)

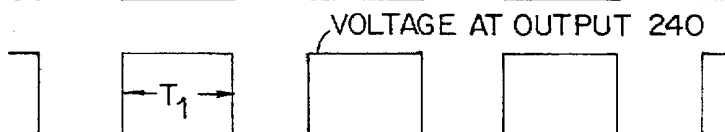


FIG.2B  
(PRIOR ART)

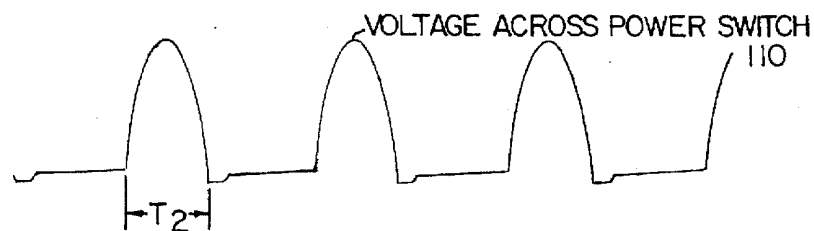


FIG. 2C  
(PRIOR ART)

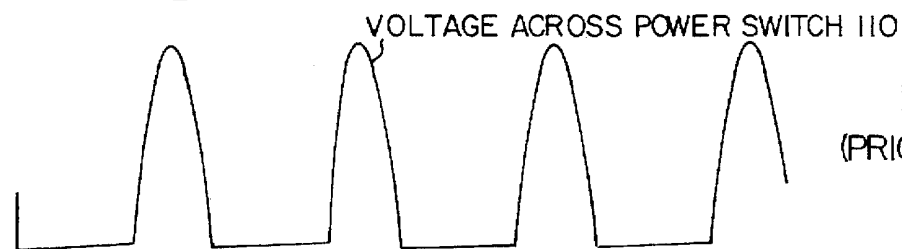


FIG.3A  
(PRIOR ART)

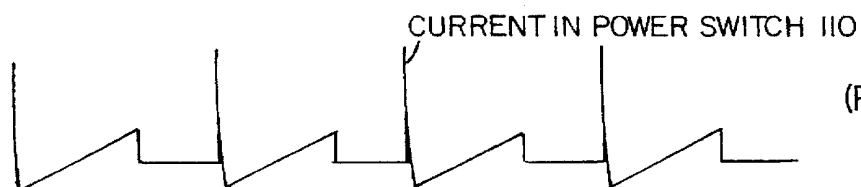


FIG. 3B  
(PRIOR ART)

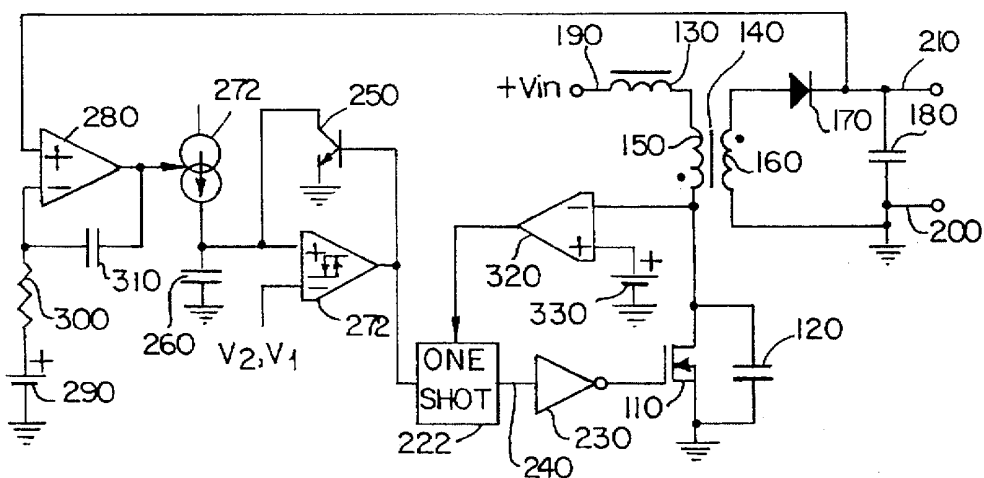
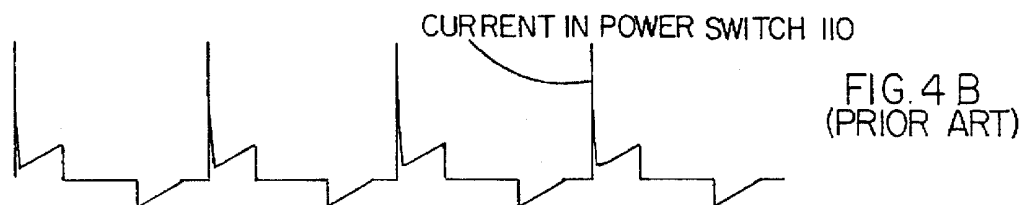
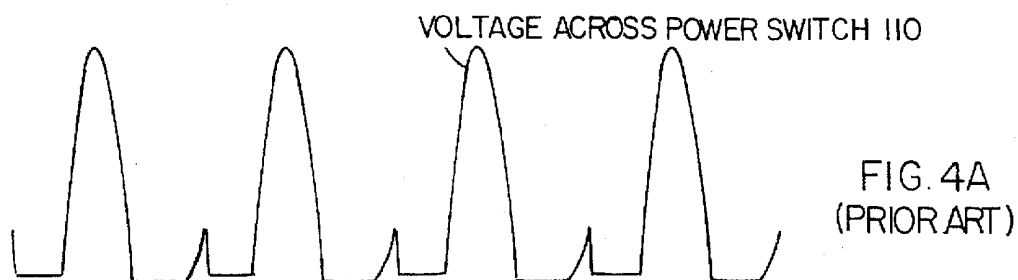
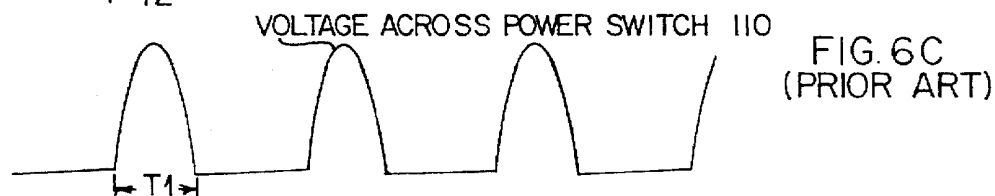
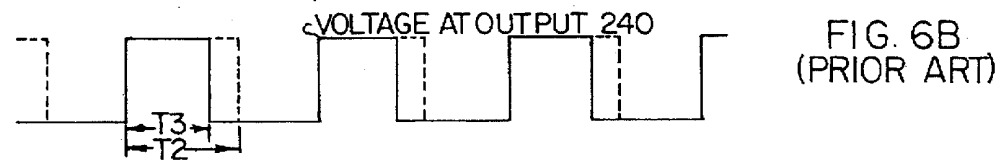
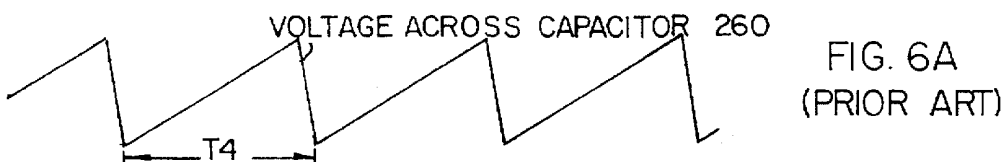


FIG. 5  
(PRIOR ART)



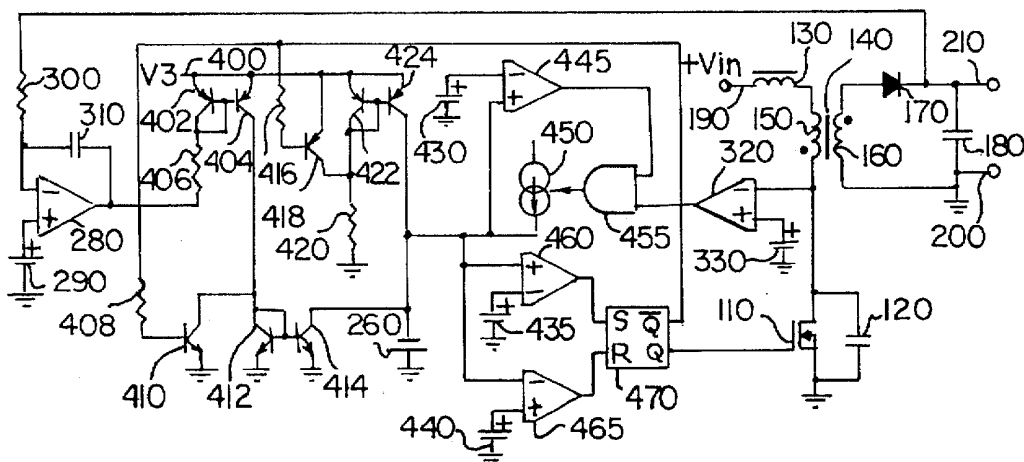


FIG. 7

VOLTAGE ACROSS CAPACITOR 260



FIG. 8A

VOLTAGE AT Q OUTPUT OF R-S LATCH 470



FIG. 8B

VOLTAGE ACROSS POWER SWITCH 110



FIG. 8C

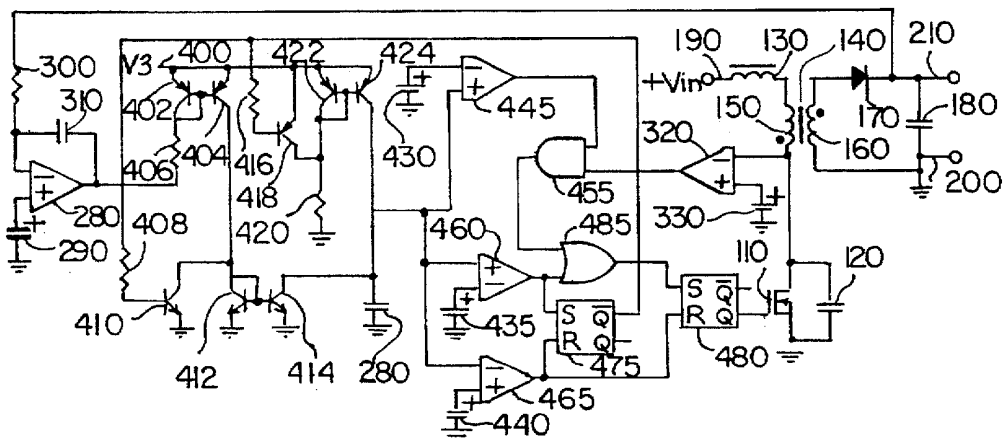
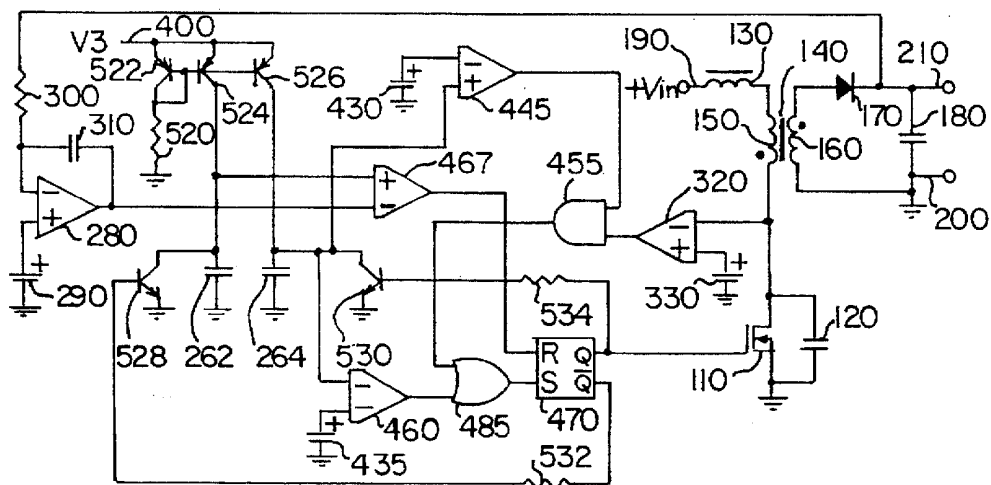
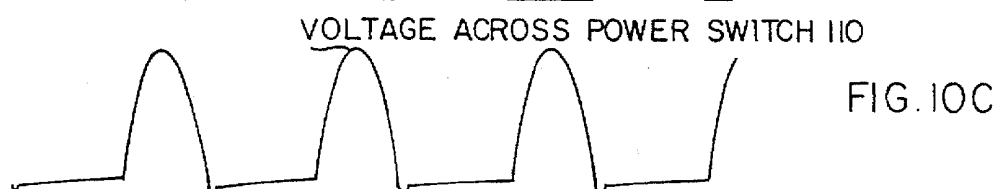
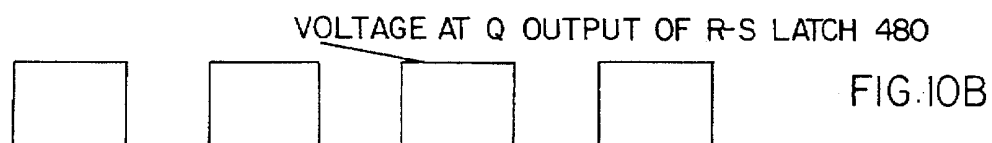


FIG. 9



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