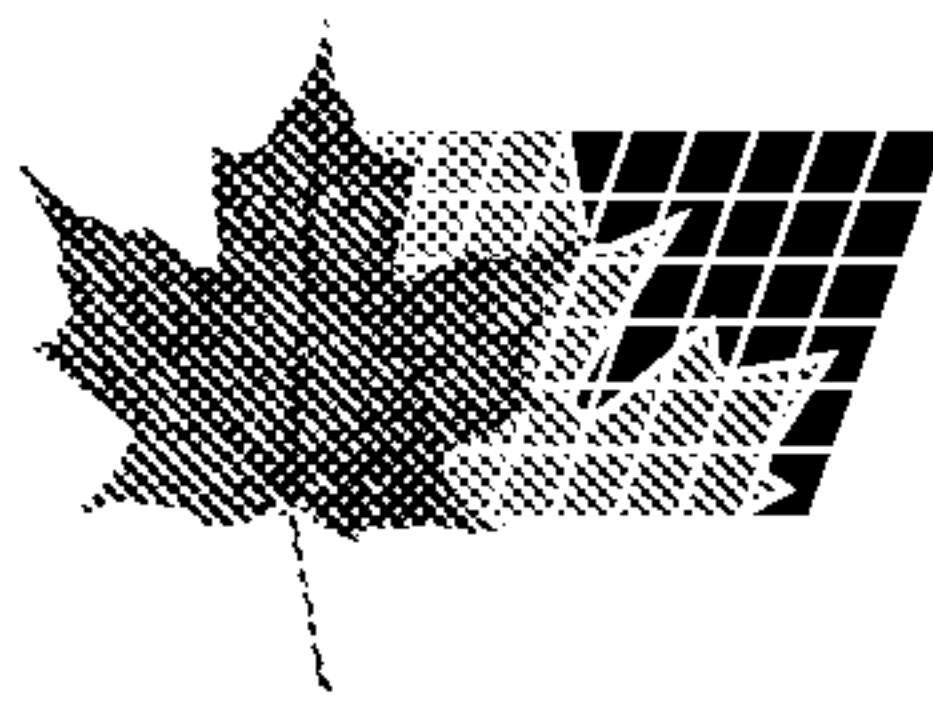




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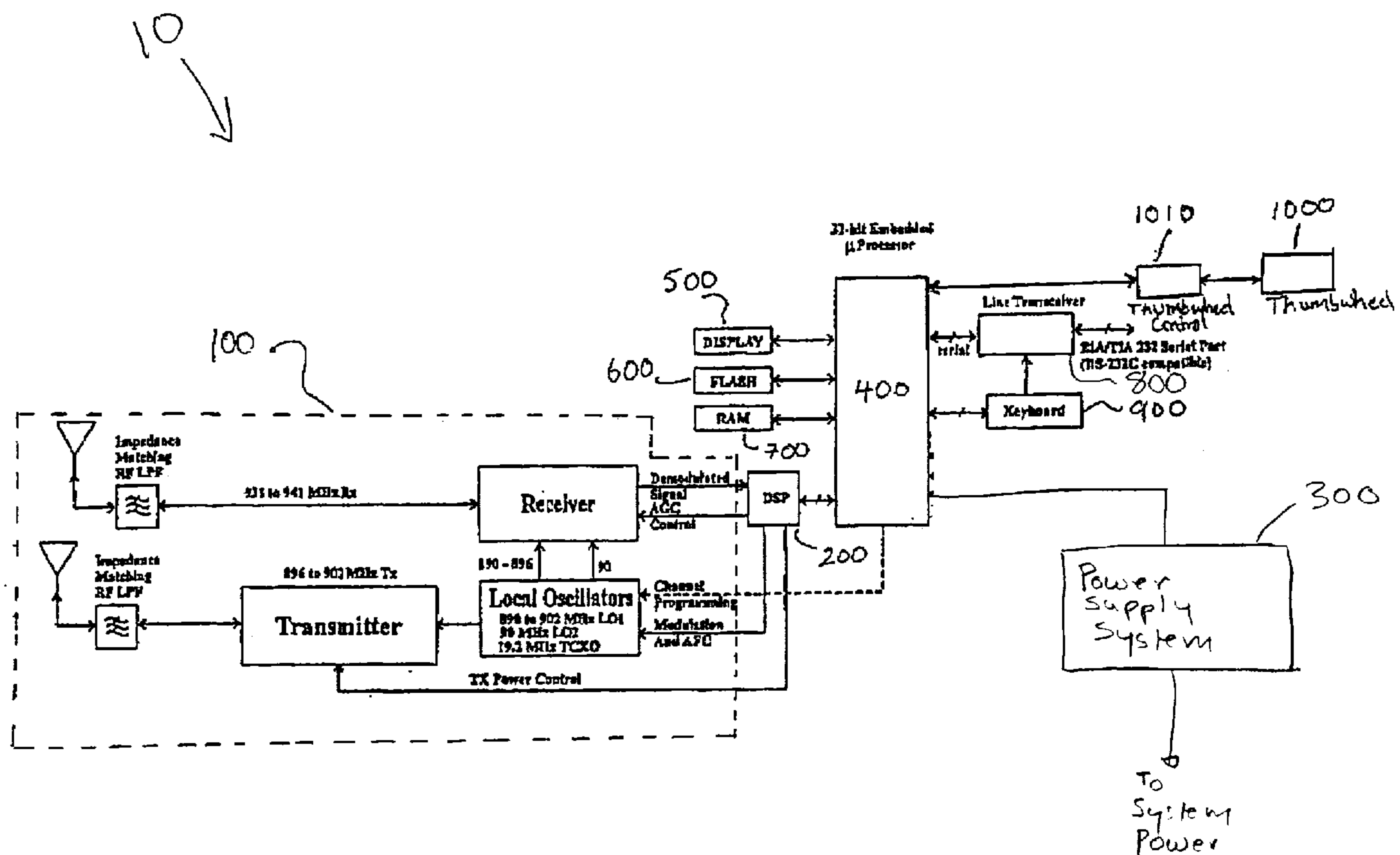
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(54) **SYSTEME D'OPTIMISATION DE LA DUREE DE VIE D'UNE BATTERIE**

(54) **SYSTEM FOR OPTIMIZING THE LIFE OF A BATTERY**



(57) An electronic device, such as a two-way messaging device, includes a primary power source that is configured to perform a charging operation on a secondary power source in a plurality of energy transfer modes, which are selected by a controller, to optimize the life of the primary power source. Powering of the electronic device is performed by the secondary power source. In one embodiment, during an idle state of the electronic device, the secondary power source is charged in an optimized energy transfer mode. In another state, such as during an information transfer state, the controller switches the charging operation from an optimal charge mode to a fast charge mode to quickly charge the secondary power source such that multiple messages can be sent and received without delays. In still another embodiment, the controller switches between an off state, a slow charge mode, and a fast charge mode.



Abstract

An electronic device, such as a two-way messaging device, includes a primary power source that is configured to perform a charging operation on a secondary power source in a plurality of energy transfer modes, which are selected by a controller, to optimize the life of the primary power source. Powering of the electronic device is performed by the secondary power source. In one embodiment, during an idle state of the electronic device, the secondary power source is charged in an optimized energy transfer mode. In another state, such as during an information transfer state, the controller switches the charging operation from an optimal charge mode to a fast charge mode to quickly charge the secondary power source such that multiple messages can be sent and received without delays. In still another embodiment, the controller switches between an off state, a slow charge mode, and a fast charge mode.

System for Optimizing the Life of a Battery

BACKGROUND OF THE INVENTION

Field of the Invention

5 This invention relates to extending the life of batteries. In particular, extending the life of a primary power source in a multiple power source electronic device.

Description of the Prior Art

10 In the art where an electronic device has two power sources (or energy storage devices), namely a removable primary power source/cell (such as a single use AA alkaline-type battery) and a fixed secondary power source, traditionally the power supply system would be optimized to achieve the maximum efficiency of the dc-dc converter between the two energy storage devices. Figs. 1
15 and 2 illustrates a typical power supply system for the current state of the art. These approaches have several disadvantages. First, the time required to charge the secondary energy storage device is fixed. Unfortunately, this time could be too fast or too slow and, as a result, could degrade the user's perception of the portable device. For instance, in traditional systems, when a fresh AA battery is inserted into
20 the electronic device, the device is not operational right away – instead a relatively undesirable period of time elapses for the secondary power source to charge. The prior art also teaches to optimize the efficiency of the dc-dc converter while the current from the primary cell is fixed. This is not suitable for optimizing or extending the life of the primary cell. In addition, in the prior art, a separate dc-dc converter

is used for each voltage rail, but this undesirably impacts the product size and cost of the electronic device that encapsulates such a power supply system. Moreover the dc-dc converter is undesirably always on.

The present invention is directed to an application wherein the electronic device requires a high duty cycle between sleep mode versus active mode time. Such an application would be in wireless two-way communications devices such as an integrated email device or a personal digital assistant (PDA).

In such an application, a removable and disposable AA alkaline battery may be the primary source and an internally fixed all, such as rechargeable lithium-ion battery

would act as the secondary source.

SUMMARY OF THE INVENTION

It is an object of the invention to overcome some of the drawbacks of traditional power supply systems.

It is another object of the invention to extend the life of a primary power source in a multiple-power source power supply system.

It is another object of the invention to make available sufficient power to operate the device employing the present invention in any operating condition.

In the invention there is provided a system to optimize energy transfer from a primary power source to a secondary power source. In another aspect of the present invention, there is provided the ability to switch from the optimized energy transfer mode to a fast charge mode.

In the invention, an electronic device includes a primary power source

that is configured to perform a charging operation on a secondary power source in a plurality of energy transfer modes, which are selected by a controller, to optimize the life of the primary power source. Powering of the electronic device, such as a two-way messaging device, is performed by the secondary power source. In one
5 embodiment, during an idle state of the electronic device, the secondary power source is charged in an optimized energy transfer mode. In another state, such as during an information transfer state, the controller switches the charging operation from an optimal charge mode to a fast charge mode to quickly charge the secondary power source such that multiple messages can be sent and received
10 without delays. In still another preferred embodiment, the controller switches between an off state, a slow charge mode, and a fast charge mode.

Therefore, according to the present invention there is provided a power supply system for an electronic device comprising: a primary and secondary power source operatively coupled to the electronic device and a controller, the
15 controller being configured to control a rate of energy flow from the primary power source to maintain predetermined energy flow rates such that an available capacity of the primary power source is increased.

Further features of the invention will be described or will become apparent in the course of the following detailed description.

20

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more clearly understood, the preferred embodiment thereof will now be described in detail by way of example,

with reference to the accompanying drawings, in which:

Fig. 1 is a power supply system illustrative of the prior art;

Fig. 2 is another power supply system illustrative of the prior art;

Fig. 3 illustrates a graph of the efficiency of a typical dc-dc switcher
5 and a graph of the primary cell capacity based on a duty cycle;

FIG. 4 is a block diagram of a two-way, full-text, messaging device
incorporating the invention;

Fig. 5 is a block diagram illustrating a power supply system
incorporating a preferred embodiment of the invention;

10 Fig. 6 is a block diagram illustrating a power supply system
incorporating an alternative embodiment of the invention suitable for applications
with super capacitors;

Fig. 7 is a circuit diagram of Fig. 5;

Fig. 7a is an alternative circuit diagram of the system of Fig. 5; and,

15 Fig. 8 is a circuit diagram of Fig. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The description of a preferred embodiment of the invention will be
described with reference to Figures 1-8.

20 Figs. 1 and 2 are illustrative of the prior art.

As can be seen in Fig. 3, as the current is decreased, the efficiency
of the dc-dc converter 28 (see Figures 7-7a) decreases and the available energy
from a primary cell 12 (see Figure 5) increases. This phenomena is utilized in the

present invention. To make the maximum power available to the system 10 (see Figure 4) from the primary battery 12 it is therefore desirable to operate the energy extraction circuitry 300 (see Fig 4) at the optimal range where the dc-dc converter 28 efficiency is high and the energy available for extraction from the primary battery 12 is also high. This range occurs in the preferred embodiment of the present invention 10 from about 15 to 50mA range. In alternative configurations, other systems with other dc-dc converters or primary batteries will result in a different optimized range. At high energy extraction rates the efficiency of the dc-dc converter 28 remains nearly constant while the energy available from the primary battery 12 decreases, therefore the total system power will decrease. However, this decrease in total power can be partially recovered if the system 10 is only operated in high-extraction rate mode for short periods of time. The graph in Figure 3 shows the improvement by comparing the Total System Power with a continuous load and with a 15:1 duty cycle load. The end-of-life for the primary cell 12 is determined by the no load voltage minus the voltage drop due to the equivalent series resistance (ESR). By adjusting the energy extraction rate, the voltage drop due to the ESR can be minimized thereby extending the battery life.

Fig. 4 is a block diagram of the major subsystems and elements comprising a palm-sized, mobile, two-way messaging device that preferably incorporates the invention. In its broadest terms, the messaging device 10 includes a transmitter/receiver subsystem 100 connected to a digital signal processor (DSP) 200 for digital signal processing of the incoming and outgoing data transmissions, power supply and management subsystem 300, which supplies and manages

power to the overall messaging device components, microprocessor 400, which is preferably an X86 architecture processor, that controls the operation of the messaging device, display 500, which is preferably a full graphic LCD, FLASH memory 600, RAM 700, serial output and output 800, keyboard 900, thumbwheel 1000 and thumbwheel control logic 1010. In its intended use, a message comes via a wireless data network, such as the Mobitex network, into subsystem 100, where it is demodulated via DSP 200 and decoded and presented to microprocessor 400 for display on display 500. To access the display of the message, the user may choose from functions listed under a menu presented as a result of user interaction with thumbwheel 1000. If the message is an email message, the user may chose to respond to the email by selecting "Reply" from a menu presented on the display through interaction via thumbwheel 1000 or via menu selection from keyboard 900. When the microprocessor 400 receives an indication that the message is to be sent, it processes the message for transport and, by directing and communicating with transmitter/receiver subsystem 100, enables the reply message to be sent via the wireless communications data network to the intended recipient. Similar interaction through I/O devices keyboard 900 and thumbwheel 1000 can be used to initiate full-text messages or to forward messages to another party. The present invention is directed to the power supply management subsystem 300.

In Fig. 5, there is shown a power supply system 300 whereby two power sources (or energy storage devices), a primary power source 12 and a secondary power source 34, are utilized. In one aspect of the present invention,

there is provided a system to optimize energy transfer from a primary power source to a secondary power source. In another aspect of the present invention, there is provided the ability to switch from the optimized energy transfer mode to a fast charge mode. This latter aspect addresses the concern of a user undesirably waiting too long for the secondary cell to recharge. The invention is preferably implemented into a portable device as described in Fig. 4 having the following characteristics: a high ratio of sleep current versus active current mode (the "pulsed load ratio") and the nominal voltage level of the secondary power source is marginally greater than the regulated voltage source. With reference to Fig. 5, the power supply system 300 includes a primary power source 12, an on/off switch 16, a step-up switcher 14 coupled to a current limit 15, which in turn is controlled by a high/low controller 18. The power supply system 300 also includes a secondary power source 34 and a voltage regulator 31. The first energy storage device 12 is preferably a single use AA battery and the secondary cell 34 is a rechargeable or renewable energy storage device such as a lithium-ion battery. In the first aspect of the invention, the rate that the energy is extracted from the primary cell 12 is minimized so as to increase the available capacity from the primary cell. The extracted energy from the primary cell is transferred and stored in the secondary cell 34. The energy stored in the secondary cell 34 is then used to power the device 10. In another aspect of the invention, three energy extraction rate modes, namely: high, low and off. In other alternative configurations, there can be any number of extraction rates. Indeed, over a selected range of energy extraction rates, there can be a continuous range of extraction rates. The "off" extraction rate

mode is utilized in the system when the secondary cell is either fully charged or when the primary cell is depleted. The "low" extraction rate mode, which is related to the optimized extraction rate region of Fig. 3, is utilized when the present invention is using the optimizing energy transfer from the primary cell 12 to the
5 secondary power source 34. The "high" extraction rate mode is utilized when it is desired to charge the secondary cell 34 rapidly as would be the case when the device 10 continuously transmits a communication over the wireless network and the secondary cell 34 has depleted its energy store. In this manner, the secondary cell 34 is quickly ready for another data information transmission or communication.

10 The "high" extraction rate is particularly useful when the user inserts into the device a fresh primary cell 12 and the secondary power source 34 is depleted in power. The "high" extraction rate allows the secondary power source 34 to be rapidly charged in this case.

Fig. 7 is a preferred circuit diagram of the system disclosed in
15 Fig. 5 in a two-way wireless communications device. This circuit includes the primary power source 12, integrated circuit 30, current mirror 32, and secondary power source 34 delivering power to voltage regulators 31 and power amplifier 39. In this circuit, the efficiency of the dc-dc converter 28 (similar to the step-up-switch 14 in Fig. 5) is optimized concurrently with the energy extraction rate of the primary
20 cell 12. The output voltage of integrated circuit 30 is selected to match the technology of the secondary cell 34. In this embodiment the secondary cell 34 is preferably a rechargeable lithium-ion cell battery 34. The output voltage of the integrated circuit 30 is preferably set to 4.2 V. The lithium-ion cell 34 provides

power to an voltage regulators 31 and a power amplifier 39. Power is supplied to the voltage regulators 31 and the power amplifier 39 and this power can be up to 2 A of current from the lithium-ion cell 34 while the current from the primary power source 12 can be limited to optimal energy extraction rate. The peak current drain

5 from the lithium-ion cell 34 does not effect the life of the primary power source 12. The integrated circuit 30 includes a step-up switcher, which increases the input voltage from the primary battery 12 up to a predetermined output voltage, preferably 4.2 V. The voltage output is then used to charge the lithium-ion cell 34 battery. In the current mirror 32, $1/50^{\text{th}}$ of the current through resistor 35 is mirrored through

10 resistor 36. Current mirror 32 generates a voltage across resistor 37. The voltage across resistor 37 is then used to increase the voltage on the feed back pin of integrated circuit 30. As the voltage rises at the feedback pin 29, the output from the integrated circuit 30 is reduced thereby limiting the output current. By defining the value of resistor 37 using ohm law also sets the output current (measured via

15 resistor 35). The current through resistor 37 is $1/50^{\text{th}}$ of the limit and the voltage across resistor 37 is the feedback voltage of integrated circuit 30 plus the forward voltage drop across diode 38. Resistor 33 is used to reduce the effective resistance of resistor 37, providing a second current limit. If resistor 33 is 0 ohms (as an indirect result of a FET located in the integrated circuit 30 and resistor 37), then the

20 effective resistance of resistor 37 is limited by the maximum output current of integrated circuit 30. Resistor 33 is shorted to ground via the FET. This FET is turned on and off via the CHARGE_HIGH_N signal connected to pin 1 of integrated circuit 30.

Fig. 7a is similar to Fig. 7 with the exception of additional circuitry 41 that provides a very accurate secondary power source 34 charge termination. In this alternative embodiment, the switcher 28 output voltage is set to a higher voltage, preferably 4.5 V. When the operational amplifier 42 detects that voltage on the lithium-ion cell 34 battery is a predetermined value, preferably 4.2 V, the charger is turned off. The internal reference of 42 and the precision resistors 43 and 44 provide an accurate voltage termination for the charge cycle. This embodiment also prevents the switcher 28 from consuming a high quiescent current while delivering a relatively small charge current to the lithium-ion cell 34. In this embodiment, if enabled by the software, the charging process is preferably under hardware control, so that a software malfunction cannot result in a overcharged lithium-ion cell 34. In this embodiment, software only has the ability to disable the charging process.

Fig. 6 is a block diagram illustrating a power supply system incorporating an alternative embodiment of the invention suitable for device applications with super capacitors as a secondary power source. This alternative embodiment of the invention is particularly suitable when the nominal voltage of the secondary cell is significantly higher than the regulating voltage. In this system, step-up switcher 21 selects one of two output voltages. In the preferred embodiment, the two output voltages are 3.3V and 4.6V. The voltage regulators 56 are powered by the super capacitors 24 or alternatively by the primary cell 12 via the step-up switcher 21. Likewise, switcher 21 charges super capacitors 24 or them power voltage regulator 56. In most circumstances, the super cap 24 supplies the power to voltage regulator 56. This is efficient since the load current is comparable

to the quiescent current of the switcher 28. When the load current is higher, such as the case when the radio is active or the user is typing a message, the voltage regulators 56 are powered from the switcher 28 operating at 3.3 V. In this case the super caps 24 are disconnected via the FET switch 21 and are able to power the PA 39. In addition the voltage drop across the voltage regulators 31 is much less and hence the system efficiency is much higher. The super capacitors 24 are preferably charged after a data transmission or communication.

Fig. 8 is illustrative of a circuit implementation of the system disclosed in Fig. 6. This particular circuit is utilized for power supply within a two-way wireless communications device that has a predetermined packet size for response messages, such as the case for acknowledgement pagers, which have a fixed packet size for all responses. In this embodiment, the secondary power source cell 24 is composed of two super capacitors 24. The super capacitors 24 provide power to the voltage regulators 56 and power amplifier. The super capacitors 24 supply the large current required by the power amplifier. Any time the load is on, the output voltage of the integrated circuit 51 is set to a predetermined voltage defined by voltage drop of the voltage regulator 56, preferably 3.3 V, which minimizes the voltage drop across the voltage regulators 56. This minimization of the voltage drop is designed to increase efficiency. When the voltage of integrated circuit 51 is set to 3.3 V the super capacitors 24 are disconnected from the circuit via the FET switch 52. When the load is off (or the load current is very low) the output of integrated circuit 51 is set to 4.6 V and the FET switch 52 is closed. This allows the super capacitors 24 to charge. Integrated circuit 54 monitors the voltage of the

super capacitors 24 and turns the step-up switcher (the integrated circuit 51) on and off. It is to be appreciated that this example can be extended to function when a single super capacitor is used.

5 It will be appreciated that the above description relates to the preferred embodiment by way of example only. Many variations on the invention will be appreciated to those knowledgeable in the field, and such variations are within the scope of the invention as described and claimed, whether or not expressly described.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. A power supply system for an electronic device comprising:
5 a primary and secondary power source operatively coupled to the electronic device and a controller, the controller being configured to control a rate of energy flow from the primary power source to maintain predetermined energy flow rates such that an available capacity of the primary power source is increased.
- 10 2. A system according to claim 1 wherein the energy flow rate is configured to flow from the primary to the secondary power source such that the secondary power source is charged and utilized to power the electronic device.
- 15 3. A system according to claim 1 wherein the primary power source is configured to charge the secondary power source via the controller and wherein one of the predetermined energy flow rates is an optimized energy flow rate based on predetermined characteristics of the system.
- 20 4. A system according to claim 1 wherein the primary power source is configured to charge the secondary power source via the controller, which switches an extraction of energy from the primary power source between first and second the predetermined energy flow rates during a charging operation.

5. A system according to claim 4 wherein:
the first predetermined flow rate is an optimized energy transfer flow rate;
and

the second predetermined flow rate is a fast charge flow rate;
5 wherein during periods of information transfer from the electronic device the
controller is configured to switch to the fast charge flow rate such that the secondary
power source is quickly recharged.

6. A system according to claim 1 wherein the electronic device is configured
10 to operate as a wireless two-way communications device.

7. A system according to claim 6 wherein the transceiver is configured to
operate as a integrated email device.

15 8. A system according to claim 1 wherein the secondary power source is
configured to operate as a rechargeable battery.

9. A system according to claim 8 wherein the secondary power source is
configured as a lithium-ion battery.

20

10. A system according to claim 8 wherein the secondary power source is
configured as a NiCa battery.

11. A system according to claim 1 wherein the secondary power source is configured as a super-capacitor device.

12. A system according to claim 1 wherein the primary power source is
5 configured to charge the secondary power source via the controller, which switches an extraction of energy from the primary power source between first, second, and third the predetermined energy flow rates during a charging operation.

13. A system according to claim 12 wherein:
10 the first predetermined flow rate is a fast charge flow rate;
the second predetermined flow rate is a slow charge flow rate; and
the third predetermined flow rate stops the extraction of energy.

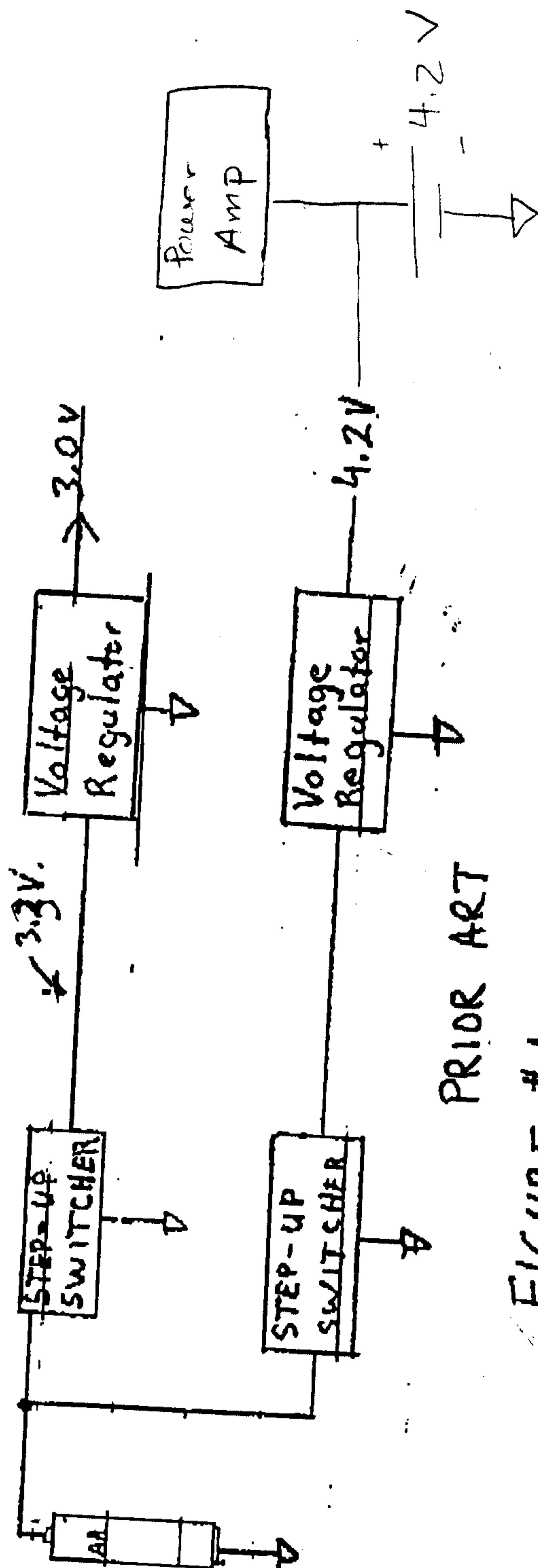


FIGURE #1

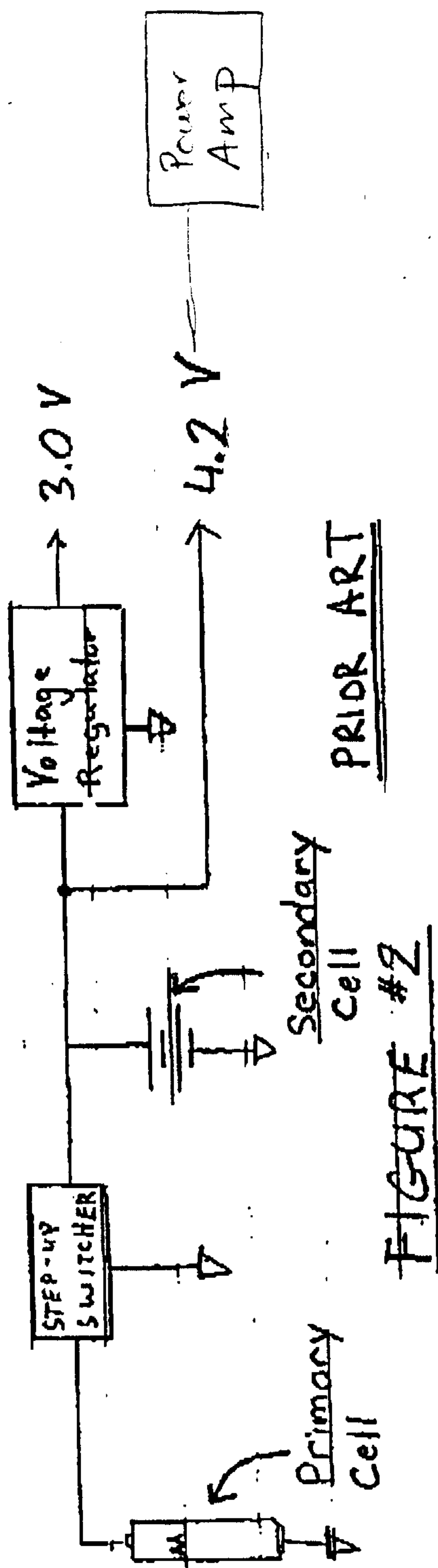
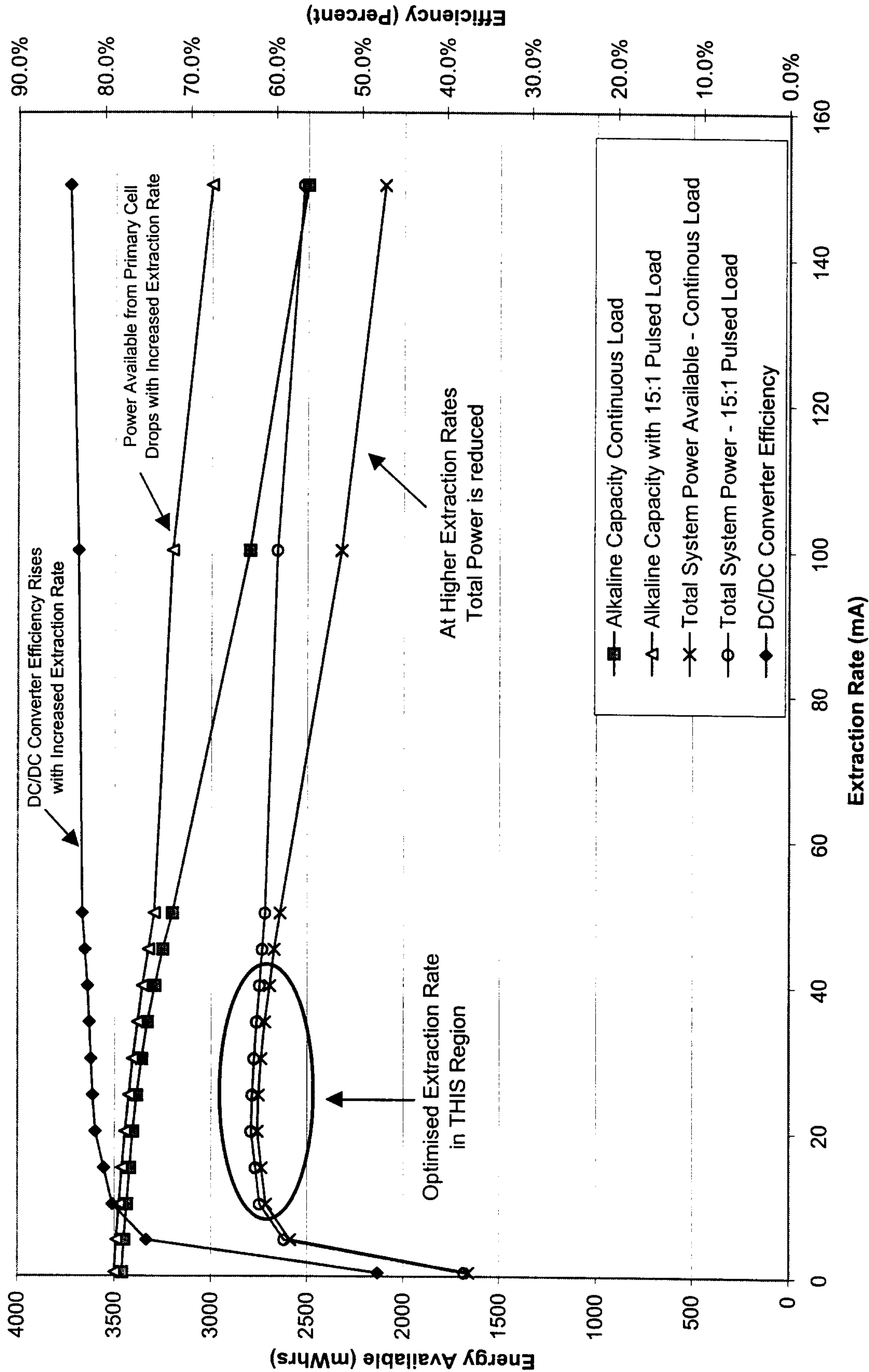
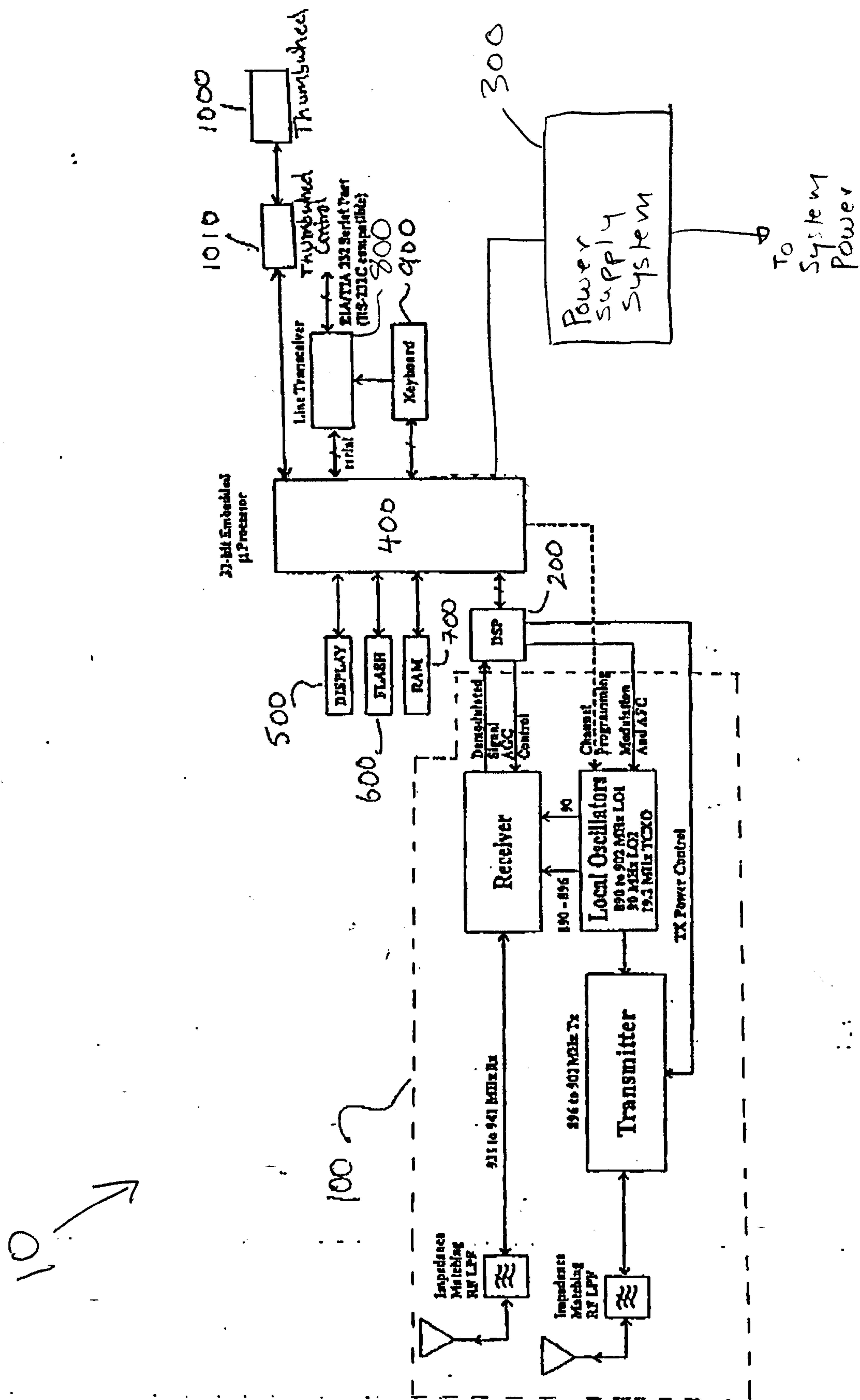


FIGURE #3

Optimum Energy Extraction Rate for AA Alkaline Battery





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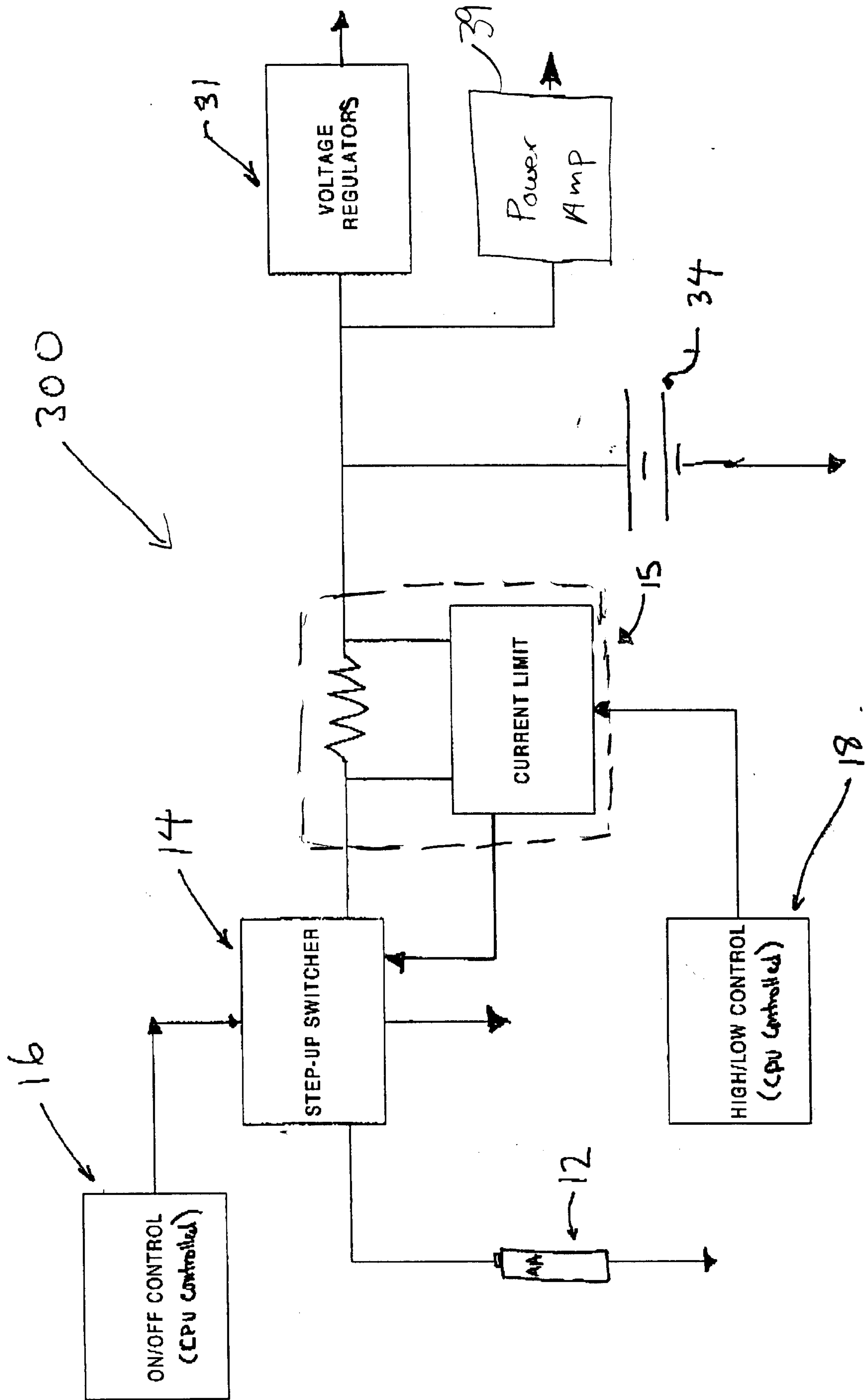


Fig. 5

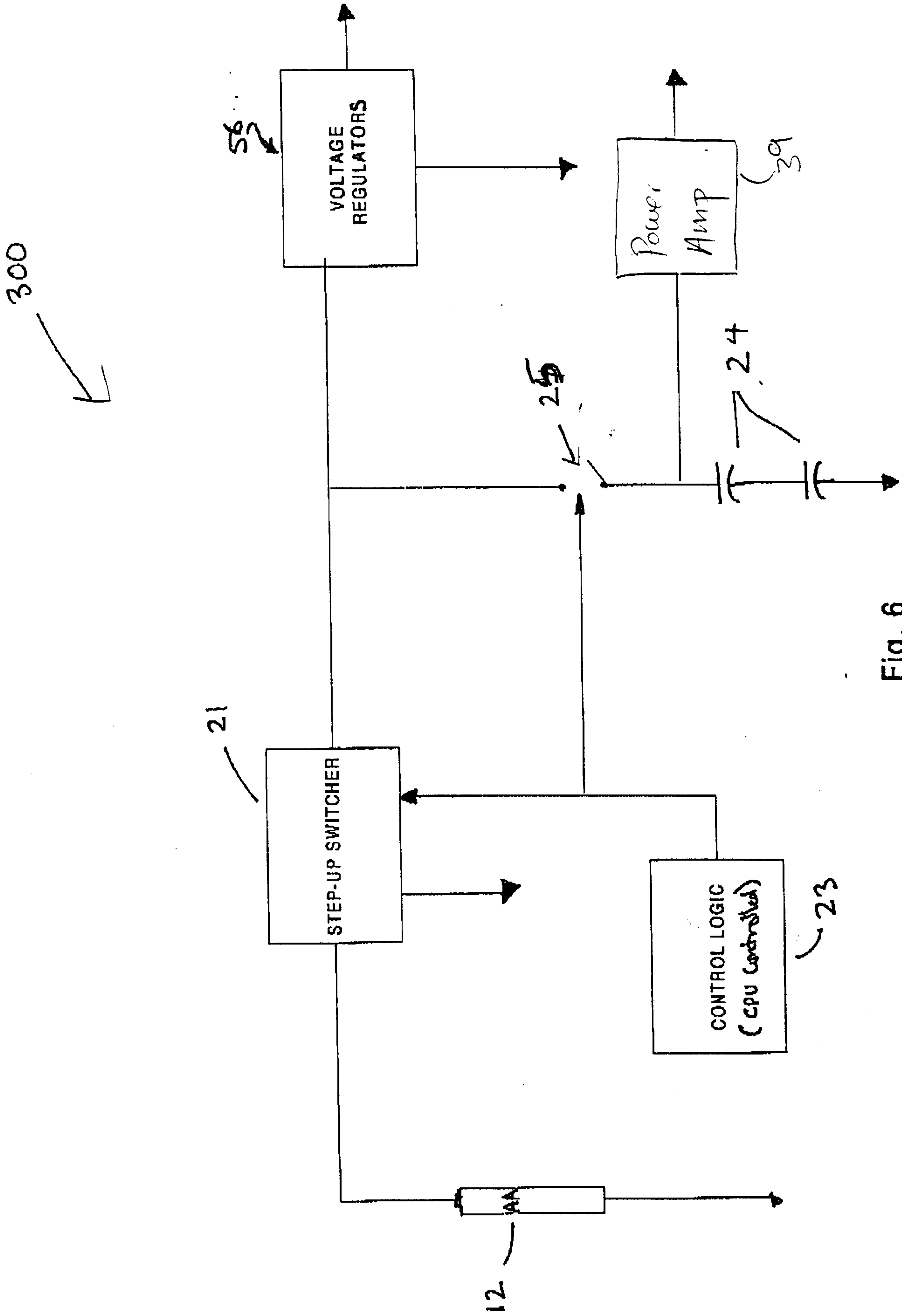


Fig. 6

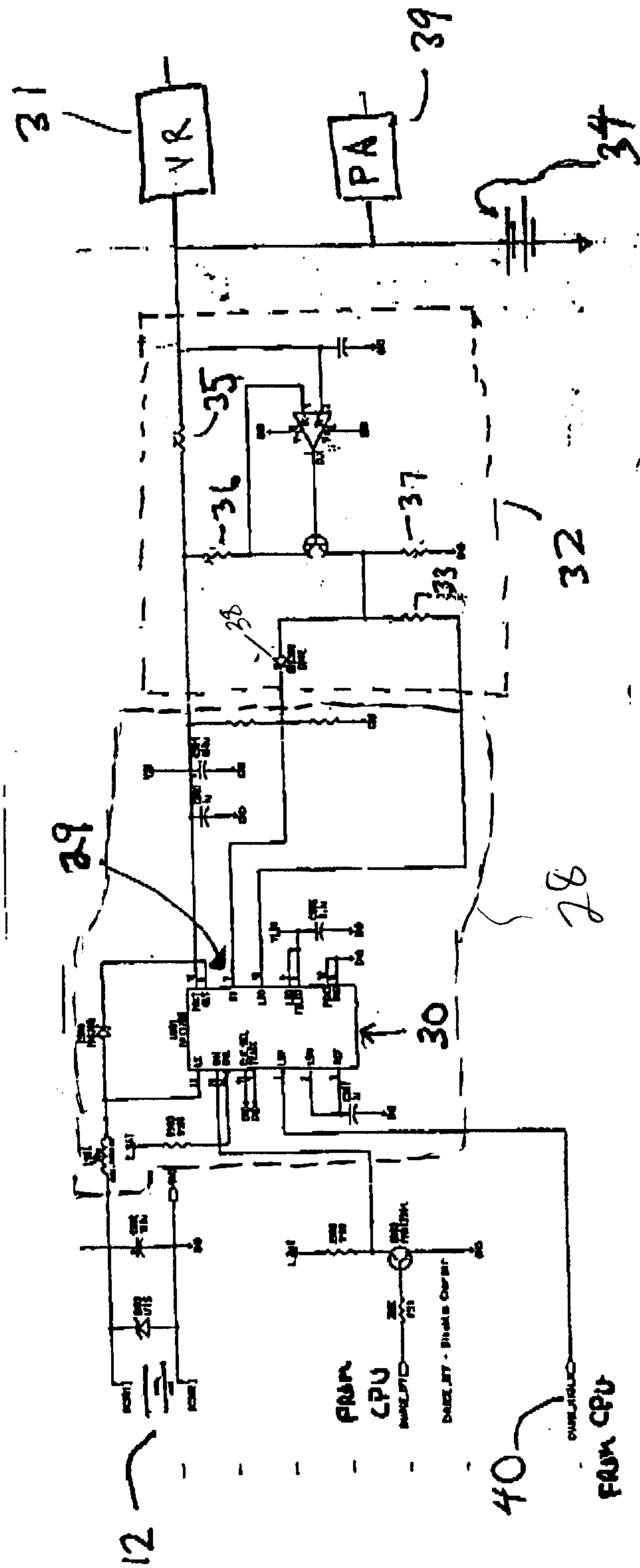


FIGURE 7

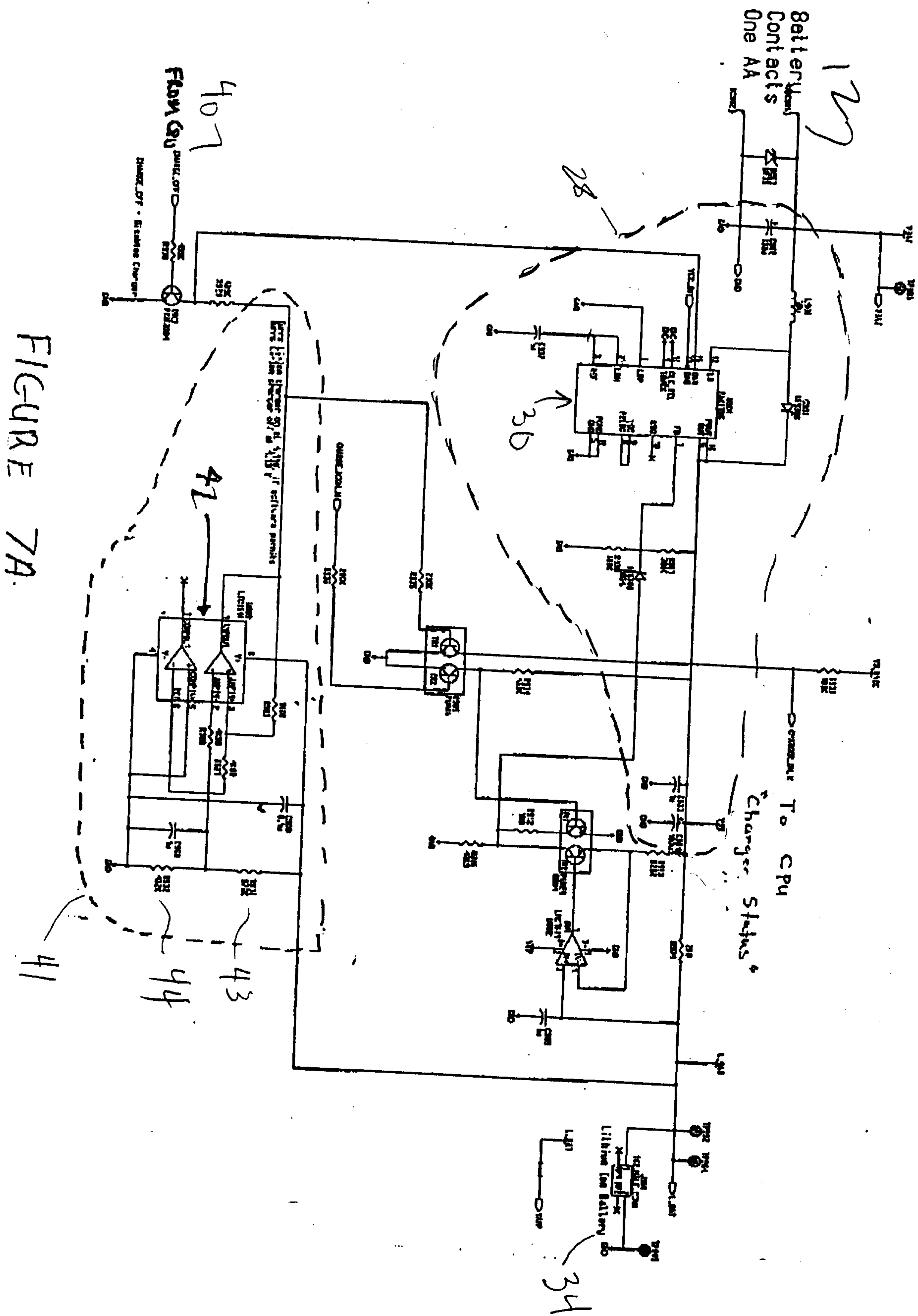


FIGURE 7A.

