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Lanni

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(54) **TIP HAVING ACTIVE CIRCUITRY**

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(52) **U.S. Cl.** **323/274; 323/284; 323/221**

(58) **Field of Classification Search** **323/273, 323/274, 283, 284, 221, 282**

See application file for complete search history.

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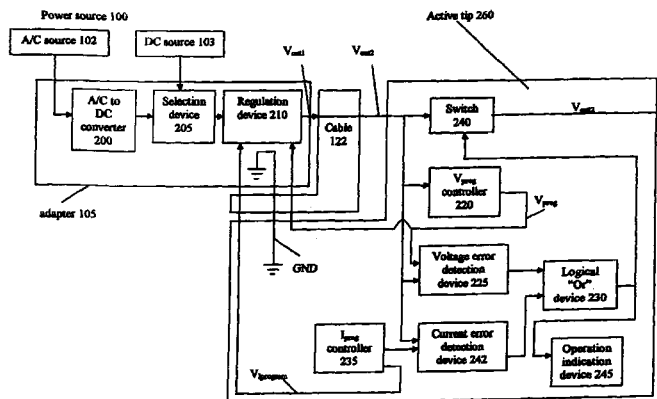
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(57) **ABSTRACT**

A power supply system includes an adapter to receive power from a power source, and output a regulated output voltage (V_{out}). A tip receives V_{out} from the adapter, and output V_{out} to an electronic device. The tip includes active circuitry to adjust a programming voltage (V_{prog}). V_{prog} is fed back to the adapter to control a magnitude of V_{out} .

15 Claims, 7 Drawing Sheets



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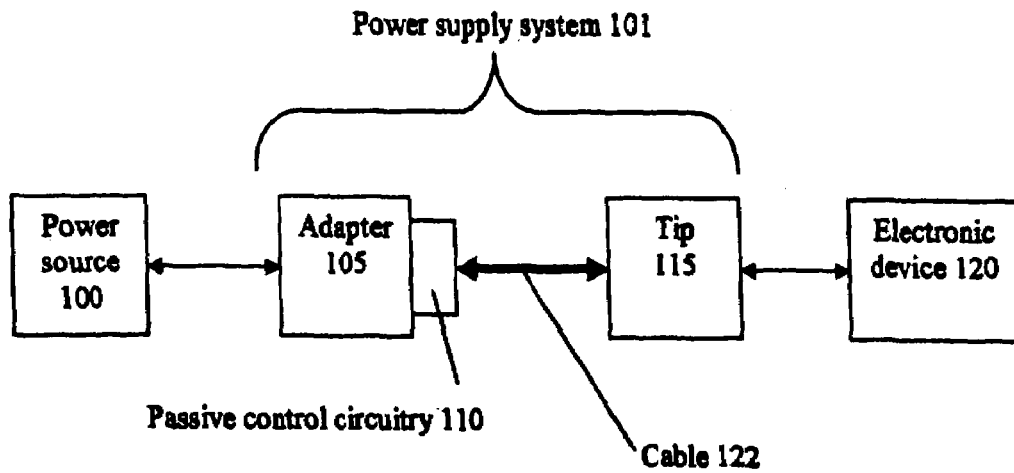
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PRIOR ART

FIG. 1A

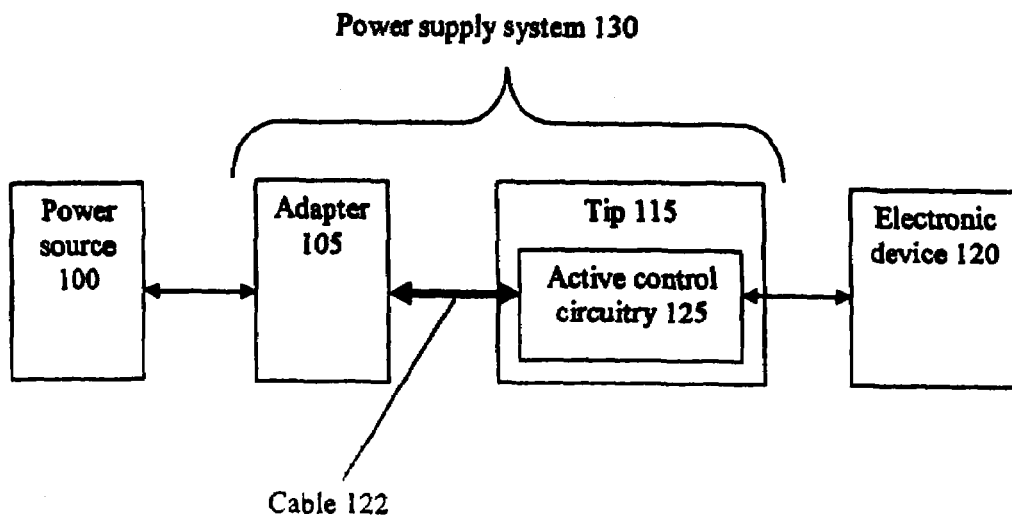


FIG. 1B

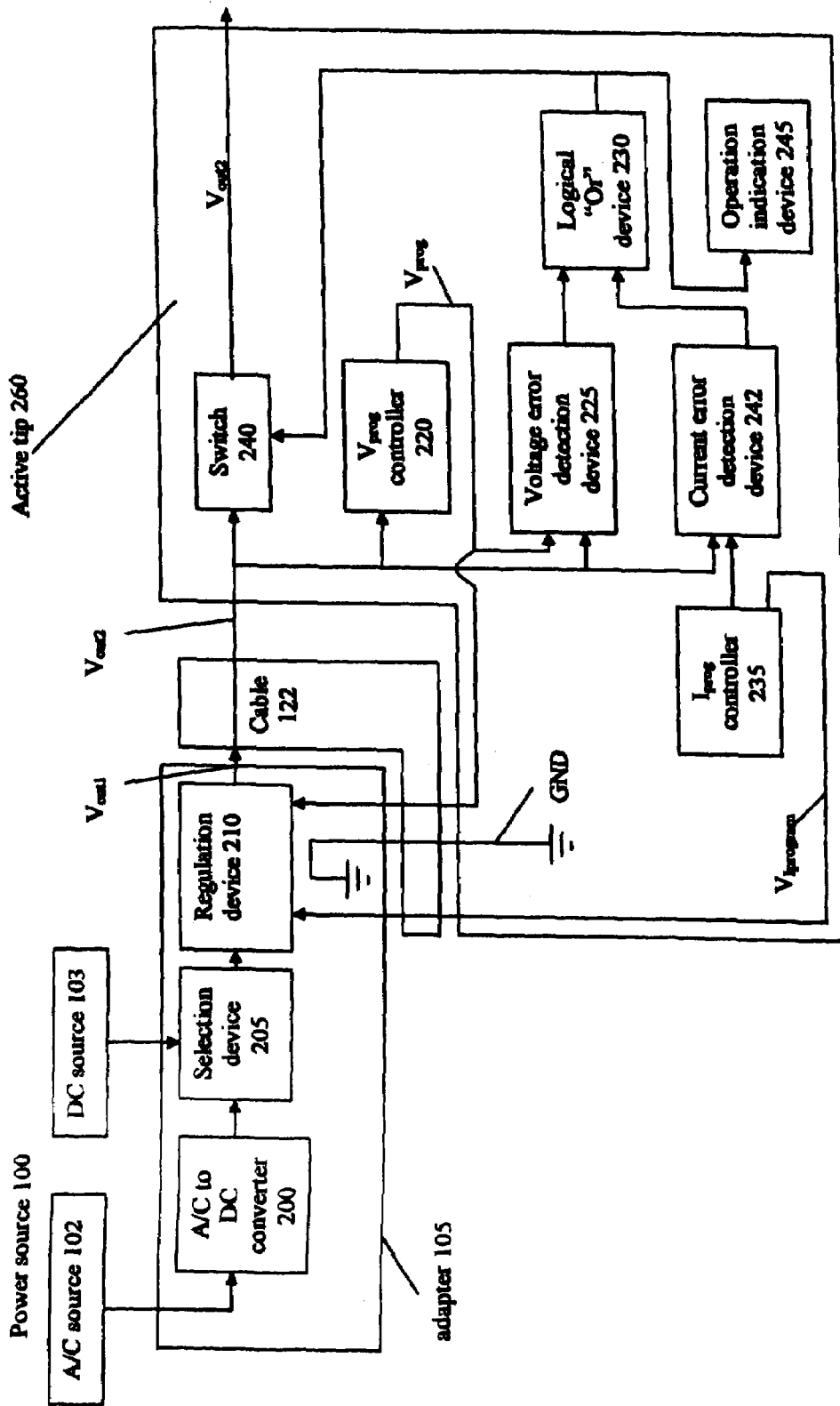


FIG. 2

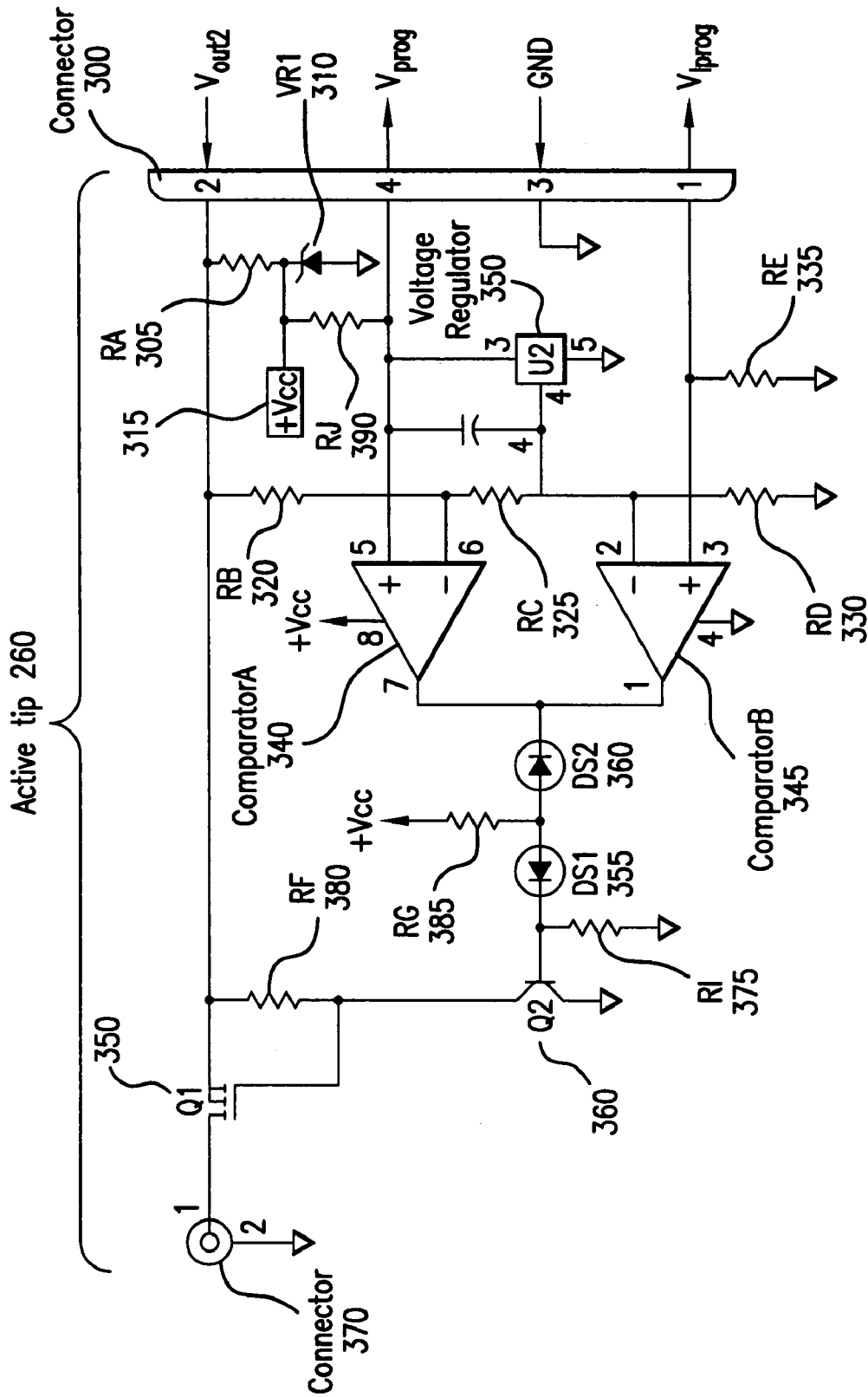


FIG.3

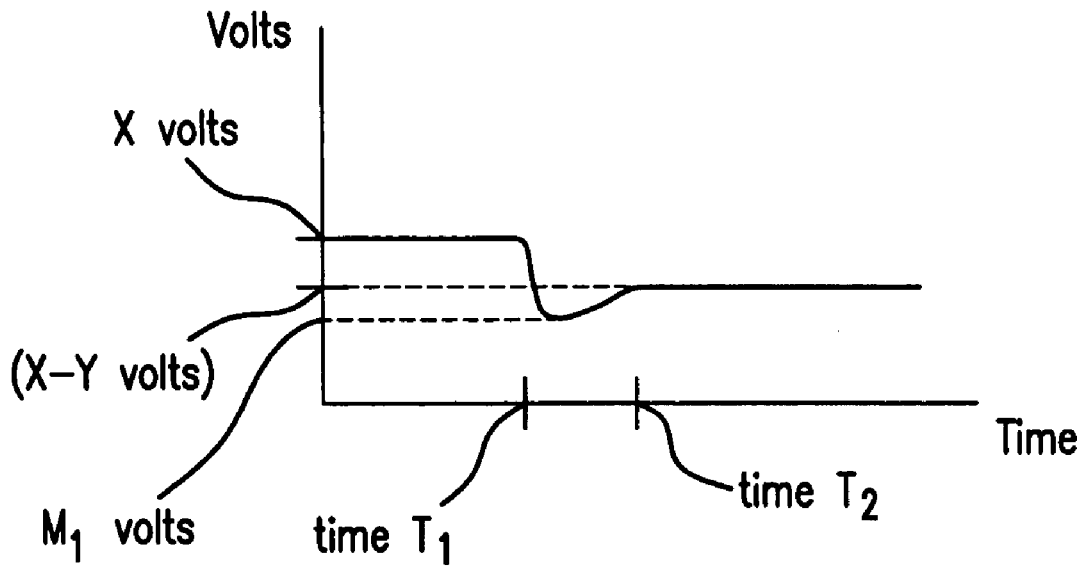


FIG.4A
PRIOR ART

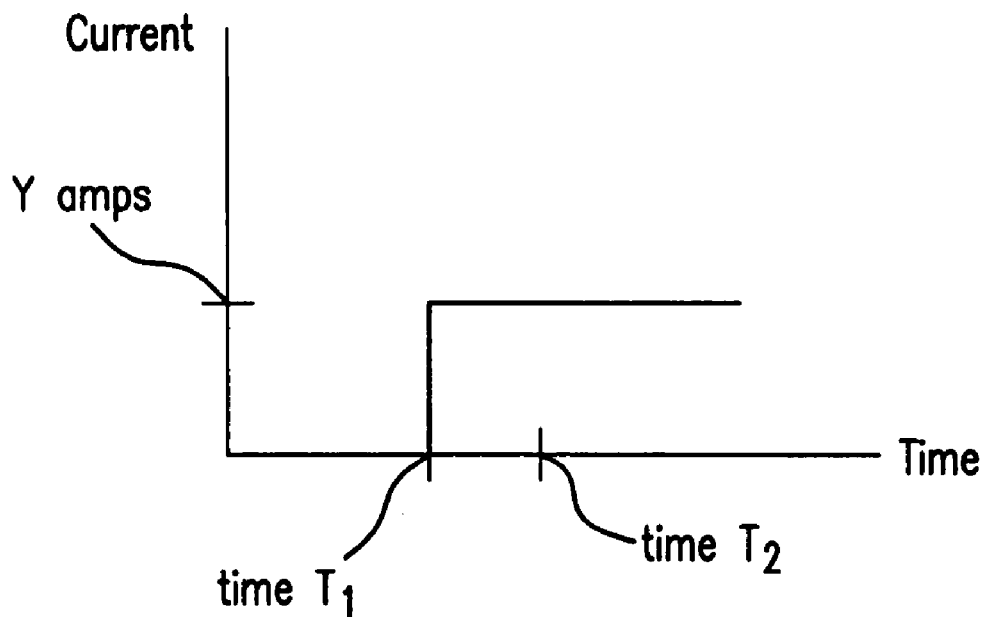
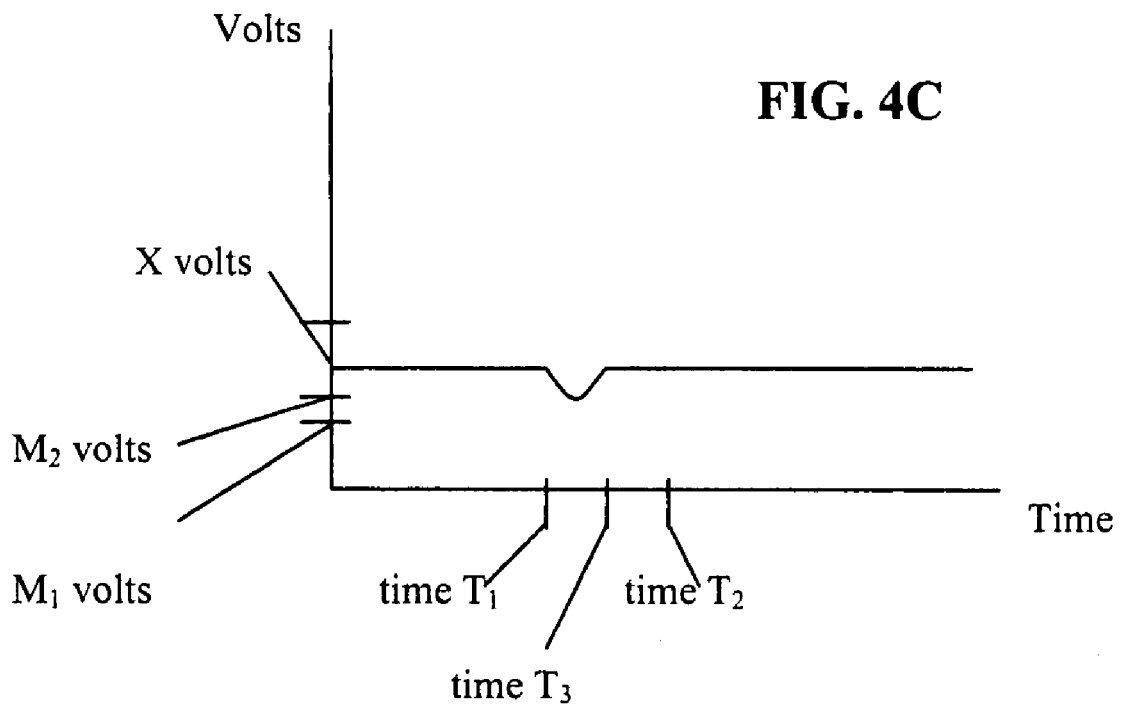


FIG.4B



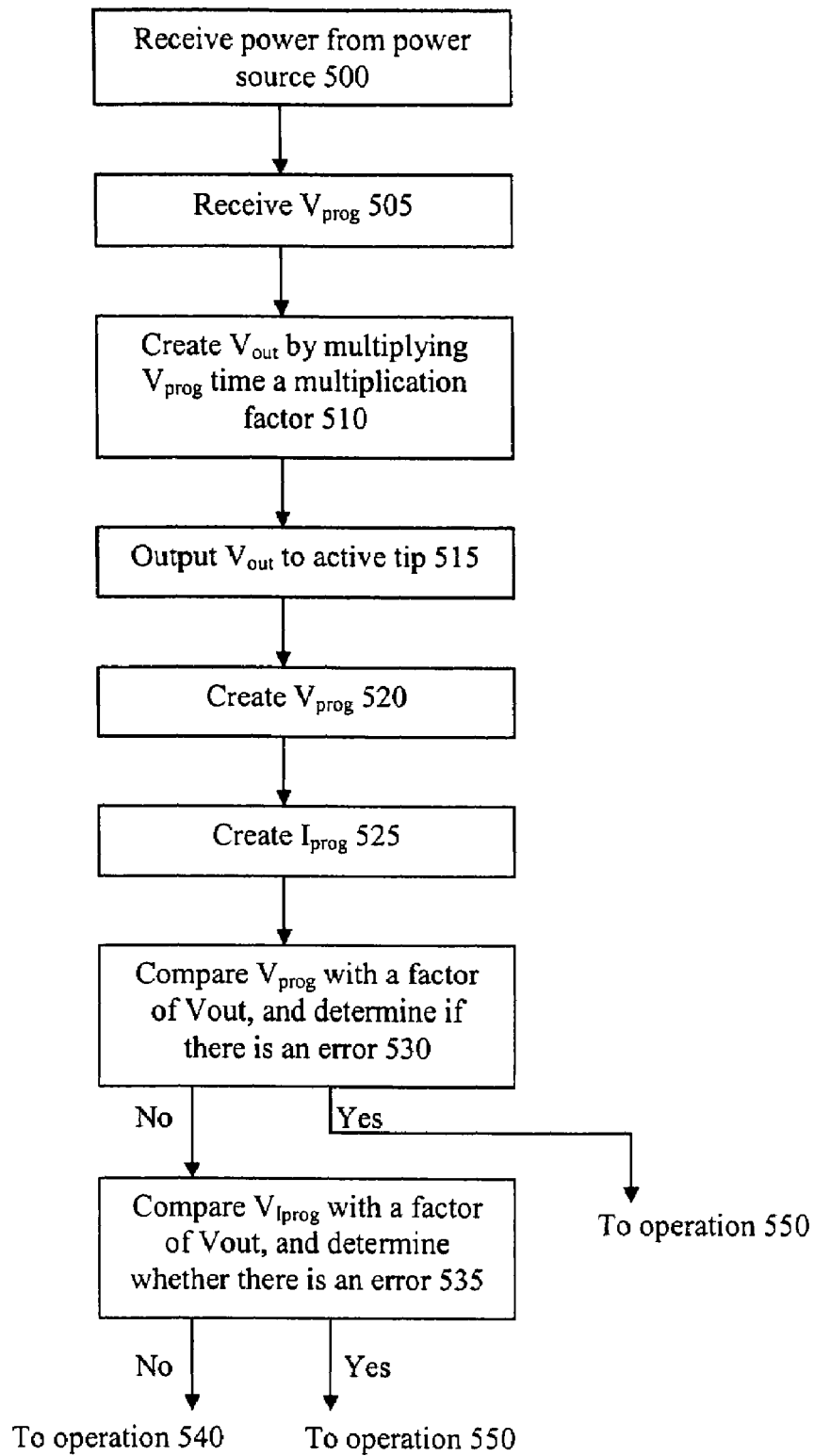


FIG. 5A

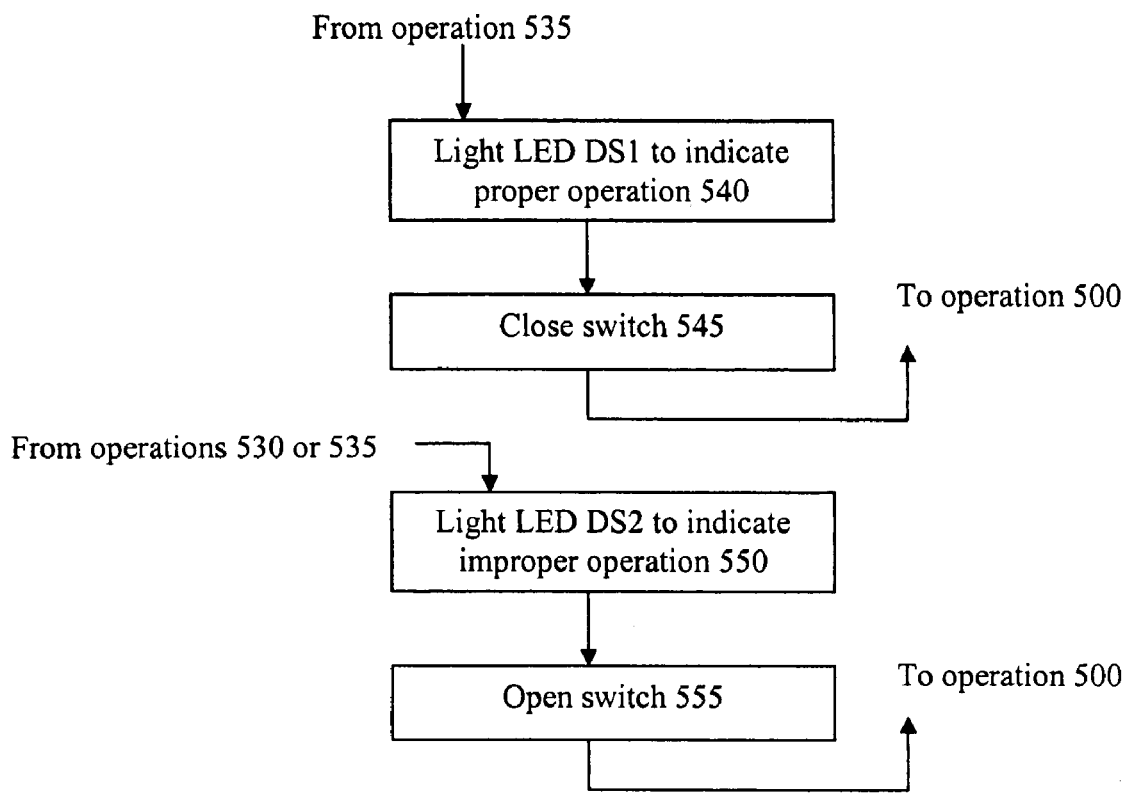


FIG. 5B

TIP HAVING ACTIVE CIRCUITRY

RELATED APPLICATIONS

This application is a continuation application of application Ser. No. 10/927,619, filed Aug. 26, 2004, now U.S. Pat. No. 7,139,398, which is a continuation application of application Ser. No. 10/313,662, filed Dec. 5, 2002, now U.S. Pat. No. 6,836,101, entitled "Tip Having Active Circuitry."

BACKGROUND OF THE INVENTION

1. Technical Field

This invention relates to power adapters, and more specifically, to a system, method, and apparatus housed within a power adapter tip to control a supply voltage for use by an electronic device coupled to the tip.

2. Description of the Related Arts

There are power systems in the art which provide an interface between a power adapter and an electronic device to regulate the amount of power supplied to the electronic device. Such power systems include the power adapter, a cable coupled to the power adapter, the electronic device, and a "tip" to interface between the cable and the electronic device. The cable or tip can include resistors which passively control the amount of voltage output by the power adapter.

There is a power system which has a power adapter which utilizes the following signals: (a) a programming voltage (V_{prog}), (b) ground (GND), and (c) an output voltage (V_{out}) to supply to the electronic device. V_{out} is produced by the power adapter and can be controlled by coupling a resistor of a set value between V_{prog} and GND. The V_{out} produced depends upon the resistor value. Accordingly, the resistor is used to "passively program" V_{out} .

Such a power system produces at the output of the power adapter the V_{out} determined by the resistor value. V_{out} from the power adapter is applied to a first end of a cable, the second end of which is coupled to the electronic device. The cable as an internal resistance. As a result of this internal resistance, there is a voltage drop across the cable. For example, if 1 Amp of current is supplied by the power adapter, and the cable has an internal resistance of 0.5 Ohms, there will be a 0.5 Volt voltage drop across the cable. Therefore, if the resistor sets V_{out} supplied by the power adapter at 12 volts, only 11.5 volts will actually be available to the electronic device. Alternatively, if 0.5 Amps of current is supplied, then the voltage drop would be 0.25 Volts ((0.5 Amp) \times (0.5 Ohms)). The internal resistance of cables may be dependent upon the materials from which the cable is formed, the length of the cable, etc. Accordingly, even if V_{out} of the power adapter is passively programmed to be 12 Volts, for example, current systems do not ensure that 12 Volts are actually supplied to the electronic device, due to the internal resistance of the cable.

Also, systems which passively program the voltage are slow to compensate for fluctuations in the output voltage amount. For example, if the electronic device being powered is a DVD player, when the motor starts spinning, the DVD player will draw more current than had been drawn before its motor started spinning. Accordingly, the load will substantially increase, resulting in a lower V_{out} which must then be corrected. Typically, the power adapter is a regulated power supply which includes a feedback path from its output to control the regulation. Thus, the power adapter will compensate for the decrease in V_{out} by supplying more current, thereby raising V_{out} (at the output of the power

adapter) to the correct voltage level. The power adapter itself detects the change in the load and compensates for the increased load. Since the power adapter detects the load change at its output, rather than at the input to the electronic device (the cable being therebetween), there is a lag time between when the load changes and when the V_{out} is changed.

Current systems also do not protect the electronic device if the adapter operates improperly and supplies too much power to the electronic device. This excess power can result in damage to the electronic device. Moreover, a user has no way to quickly determine whether the adapter is malfunctioning.

Accordingly, prior systems would be improved if the actual amount of voltage supplied to the electronic device would be regulated at the input to the electronic device rather than at the output of the power adapter, eliminating the effect of the voltage drop across the cable. It is also desirable to decrease the response time (i.e., increase the loop gain) between when the load of the electronic device changes and when V_{out} is compensated to the correct level, as compared to current systems. It is further desirable to interrupt the supply of power to the electronic device if a malfunction of the system is detected and to provide the user with an indication of such malfunction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A illustrates a power supply system according to the prior art;

FIG. 1B illustrates a power supply system according to an embodiment of the invention;

FIG. 2 illustrates a system overview of a power supply system according to an embodiment of the invention;

FIG. 3 illustrates a schematic diagram of an active tip according to an embodiment of the invention;

FIG. 4A illustrates a response time (not drawn to scale) of an adapter after a fluctuation in voltage according to the prior art;

FIG. 4B illustrates the magnitude of current flowing out of the adapter to the electronic device according to an embodiment of the invention;

FIG. 4C illustrates a response time (not drawn to scale) of the adapter coupled to the active tip according to an embodiment of the invention;

FIG. 5A illustrates a first portion of a method of supplying power to an electronic device via an adapter and active tip according to an embodiment of the invention; and

FIG. 5B illustrates a second portion of the method of supplying power to an electronic device via an adapter and active tip according to an embodiment of the invention.

DETAILED DESCRIPTION

An embodiment of the present invention is directed to a power supply system to power an electronic device. The power supply system may include a power adapter to provide an output voltage (V_{out}) to the electronic device. The power adapter may also provide a ground reference voltage (GND) and receive (a) a voltage programming voltage (V_{prog}), and (b) a current programming voltage (V_{Iprog}). A cable may be used to couple the power adapter to an active tip which contains circuitry to control V_{out} . The active tip is coupled to the electronic device. The active tip may have an outlet jack having a physical size dependent upon the electronic device being powered. For example, a laptop computer may receive a tip jack having a different

size than a tip jack which can be coupled to a personal digital assistant (PDA). Also, the active tip may include active programming circuitry to regulate the V_{out} supplied to the electronic device. Since the programming circuitry is active and in the active tip, the V_{out} supplied to the electronic device may be precisely controlled, and the effect of a voltage drop across the cable is effectively eliminated. Also, because the active circuitry is contained within the tip, V_{out} may more quickly compensate when the effective load of the electronic device changes (i.e., the power supply system may have a greater "system loop gain"). Moreover, the active tip may include circuitry to detect an error in the amount of power supplied by the adapter, and prevent power from reaching the electronic device. The active tip may further include circuitry to indicate to a user whether the adapter is functioning properly or improperly.

FIG. 1A illustrates a power supply system **101** according to the prior art. As illustrated, a power source **100** is coupled to an adapter **105**. The adapter **105** can be used to provide a regulated DC voltage. The adapter **105** can be coupled to a cable **122**, and the cable **122** can be coupled to a tip **110**. The tip **110** can be utilized to provide the regulated DC voltage to an electronic device **120**. The tip **110** can contain passive control circuitry (e.g., $R_{V_{program}}$ and $R_{I_{program}}$) which is utilized to set the output voltage and limit the output current. The adapter **105** can provide the following outputs: (a) V_{out} (i.e., the output voltage), and (b) a ground reference voltage (GND). The tip **110** provides a feedback $V_{V_{program}}$ to set V_{out} . The tip **110** also provides a feedback $V_{I_{program}}$ to the adapter **105** to limit the current of the regulated DC output.

Resistor $R_{V_{program}}$ is located in the tip **110** and forms a voltage divider circuit with $R_{adapter1}$ of the adapter **105**. Based on the value of resistor $R_{V_{program}}$, V_{out} can be controlled. Resistor $R_{I_{program}}$ is also located in the tip **110** and forms a voltage divider circuit with $R_{adapter2}$. Based on the value of $R_{I_{program}}$, the maximum current output can be limited.

FIG. 1B illustrates a power supply system **130** according to an embodiment of the invention. As illustrated, a power source **100** is coupled to an adapter **105**. The power source **100** may be an A/C power source such as a household electric outlet. Alternatively, the power source may be a DC source such as an airplane electric outlet, or a cigarette lighter outlet in an automobile, for example. The adapter **105** may be utilized to provide a regulated DC output voltage, V_{out} . Accordingly, if the power source **100** is an A/C source, the adapter **105** may include circuitry to convert the A/C voltage to DC. The adapter **105** may also produce a GND signal. The adapter **105** may be coupled to a tip **115** via a cable **122**. The tip **115** may include active control circuitry **125** to control V_{out} produced by the adapter **105**. The tip **115** may also provide an interface to the electronic device **120**. The physical size and shape of the tip **115** may be dependent upon the electronic device **120** being powered. For example, if the electronic device **120** is a laptop computer, the tip **115** may have a different size and shape than it would if the electronic device **120** were a PDA.

FIG. 2 illustrates a system overview of a supply system according to an embodiment of the invention. As shown, an A/C source **102** may supply A/C power to an adapter **105**. Alternatively, a DC source **103** may supply DC power to the adapter **105**. An example of a power source and an adapter **105** is shown in U.S. Pat. No. 6,172,884, the disclosure of which is herein incorporated by reference. The adapter **105** may include an A/C to DC converter **200** to convert an A/C input into a DC output. The adapter **105** may also include a selection device **205**. The selection device **205** may be

utilized to select a (a) DC input from a DC source **103**, or (b) a DC output of the A/C to DC converter **200** when the input is A/C power from an A/C source **102**. The selection device **205** may output the selected DC voltage to a regulation device **210**. Accordingly, the selection device **205** may provide a DC voltage to the regulation device **210**, regardless of whether an A/C source **102** or a DC source **103** is provided to the adapter **105**. The regulation device **210** may receive the selected DC voltage and provide an output voltage, V_{out1} . V_{out1} may be sent via a cable **122** to an active tip **260**. The cable **122** may include an internal resistance. Accordingly, there may be a voltage drop (e.g., V_{cable}) across the cable **122**. Accordingly, when V_{out1} is output from the adapter **105** to the cable **122**, the cable **122** provides a voltage V_{out2} to the active tip **260**. However, due to the voltage drop across the cable, V_{out2} will not equal V_{out1} . Instead, V_{out2} equals $V_{out1} - V_{cable}$. Whereas current systems only control the voltage output from the adapter **105** (i.e., V_{out1}), the active tip **260** may be utilized to control the actual voltage received by the active tip **260** (i.e., V_{out2}), and provided to the electronic device **120** without further voltage drops. The active tip **260** may include active control circuitry to control the V_{out2} received. Accordingly, the active tip **260** may correct for a voltage drop across the cable **122** so that V_{out2} can be controlled.

The adapter **105** may provide V_{out1} and GND to the cable **122**. The adapter **105** may receive the following outputs from the active tip **260** via the cable **122**: (a) a programming voltage (V_{prog}) to program V_{out1} , and (b) a programming current voltage ($V_{I_{prog}}$) to limit the current from the adapter **105**. The active tip **260** may alter the V_{prog} in order to control V_{out2} , for example. V_{out2} may enter the active tip **260**, and may flow through a switch **240** and out of the active tip **260** to power an external electronic device **120**. The switch **240** may be utilized to protect the electronic device **120**. For example, if the active tip **260** changes V_{prog} in order to decrease V_{out2} , but V_{out2} does not decrease, the active tip **260** may detect an error and open the switch **240** so that V_{out2} does not flow through the switch **240** to the electronic device **120**. The switch **240** may also be opened when V_{prog} is changed in order to increase V_{out2} , but V_{out2} does not correspondingly increase. The switch **240** may also be opened if the active tip detects excess current. Accordingly, the switch **240** may be utilized to protect the electronic device **120** from becoming oversupplied, for example.

The active tip **260** may include a V_{prog} controller **220** to set V_{prog} . For example, in a scenario where lowering V_{prog} causes V_{out2} to be lowered, the V_{prog} controller may compare V_{out2} with a predetermined reference voltage to determine whether V_{out2} needs to be lowered, raised, or remain constant. The V_{prog} controller **220** may also divide V_{out2} by a certain amount before comparing with the reference voltage (e.g., one-half of V_{out2} may be compared with the reference voltage). If V_{out2} needs to be lowered, the V_{prog} controller **220** may lower V_{prog} to a level so V_{out2} is correctly set. The V_{prog} output of the V_{prog} controller **220** may be output to the regulation device **210** in the adapter **105**. The regulation device **210** may determine and output V_{out1} based upon the value of V_{prog} . For example, V_{out1} may be equal to the product of V_{prog} multiplied by a factor. For example, the regulation device **210** may output a V_{out1} that is 3 times V_{prog} . Therefore, if V_{prog} is 3 volts, V_{out1} would be 9 volts, and V_{out2} would be 9 volts minus the V_{cable} .

The active tip **260** may also include circuitry to detect when the adapter **105** is functioning improperly. For example, a voltage error detection device **225** may determine when the relationship between V_{prog} and V_{out2} is

incorrect. If the regulation device **210** is set to output a V_{out1} that is 3 times V_{prog} , and, for example, if V_{out2} is detected as being equal to only 1.5 times V_{prog} , then the voltage error detection device **225** may determine that the adapter **105** is functioning improperly. Accordingly, to protect the electronic device **120**, if the voltage error detection device **225** detects an error in the relationship between V_{prog} and V_{out2} , a signal indicative of the error may be output by the voltage error detection device **225**.

The active tip **260** may also include a current error detection device **242** to detect an error between current output by the regulation device **210** and I_{prog} . The active tip **260** may include an I_{prog} controller **235** to set V_{Iprog} . The I_{prog} controller **235** may be a passive device such as a resistor. The voltage drop across the I_{prog} controller **235** (i.e., V_{Iprog}) and V_{out2} may be inputs to the current error detection device **242**. When the relationship between I_{prog} and the adapter output current is beyond an acceptable range, the current error detection device **242** may determine an error in the functioning of the adapter **105** and may output a signal indicative of the error.

The outputs of the voltage error detection device **225** and the current error detection device **242** may be received by a logical "or" device **230**, which may logically "or" its inputs. If either the voltage error detection device **225** or the current error detection device **242** output a signal indicative of an error, then the logical "or" device **230** may output a signal to open the switch **240**. Accordingly, if the adapter **105** is functioning improperly, the active tip **260** may detect the error and open the switch **240**, preventing the electronic device **120** from being damaged.

The output of the logical "or" device **230** may also be sent to an operation indication device **245**. The operation indication device **245** may include Light Emitting Diodes (LEDs) to indicate whether the adapter **105** is properly functioning. For example, if a signal indicative of an error is output by the logical "or" device **230**, the operation indication device **245** may include a red LED which is lit up to indicate the error. However, if no such error signal is output by the logical "or" device **230**, a green LED in the operation indication device **245** may be lit, to indicate the correct operation. In other embodiments, devices other than LEDs may be utilized to indicate whether the adapter **105** is functioning properly.

FIG. 3 illustrates a schematic diagram of an active tip **260** according to an embodiment of the invention. As shown on the right side of the active tip **260**, a connector **300** may be utilized to couple the active tip **260** to the cable **122**. V_{out2} may flow into the active tip **260** via pin **2** of the connector **300**, and pin **3** may be coupled to GND. Pin **4** may be utilized to allow V_{prog} to be sent to the cable **122**, and to the regulation device **210** of the adapter **105**. Pin **1** may allow V_{Iprog} to be applied to the cable **122** and to the regulation device **210** to limit the current.

V_{out2} may be utilized to power circuitry in the active tip **260**. Specifically, Resistor RA **305** and a Zener diode VR1 **310** lie between V_{out2} and GND. The Zener diode **310** may be utilized to set the V_{cc} **315** of the active circuitry in the active tip **260**. In other embodiments, the active tip may receive its V_{cc} directly from the adapter **105**. Zener diode **310** may be utilized to set a maximum voltage of V_{cc} **315**, such as 10 Volts, for example. The Zener diode **310** may be utilized to protect circuitry in the active tip by limiting the voltage. Resistors RB **320**, RC **325**, RD **330**, are connected between V_{out2} and GND. Resistors RB **320**, RC **325**, and RD **330** may be utilized to set the inputs to comparator A **340** and comparator B **345**.

Resistance values of resistors RB **320**, RC **325**, and RD **330** in the active tip **260** are selected based on the power requirements of the electronic device **120** being powered. For example, an electronic device requiring 9 volts DC would include different resistance values of resistors RB **320**, RC **325**, and RD **330** than would be used to provide 12 volts DC to a different electronic device. Accordingly, electronic devices **120** having different DC power requirements require active tips **260** having different resistance values. Resistors RB **320**, RC **325**, and RD **330** form a voltage divider. The voltage divider is utilized to control the voltage received at pin **4** of a voltage regulator **350**. The voltage regulator **350** is utilized to set V_{prog} , based on a comparison between the voltage received at pin **4** and an internal reference voltage of the voltage regulator **250** (e.g., 2.5 volts). Because RB **320**, RC **325**, and RD **330** form a voltage divider, their resistance values may be utilized to control the percentage of V_{out2} received at pin **4** of the voltage regulator **350**. Since V_{prog} is set based on a comparison between the voltage regulator's internal voltage and the voltage at pin **4** of the voltage regulator **350**, the resistance values of RB **320**, RC **325**, and RD **330** therefore indirectly control V_{out2} .

The voltage regulator **350** may, via its pin **4**, receive a voltage equal to $V_{out2} \cdot (RD) / (RB + RC + RD)$. The voltage regulator **350** may compare $[V_{out2} \cdot (RD) / (RB + RC + RD)]$ with an internal reference voltage, such as 2.5 Volts, and output V_{prog} via pin **3**. If $[V_{out2} \cdot (RD) / (RB + RC + RD)]$ is greater than the internal reference voltage, then V_{prog} may be lowered. Accordingly, in an embodiment where the regulation device **210** outputs V_{out1} (and the active tip receives V_{out2}) that is equal to 3 times V_{prog} , V_{prog} may be increased when V_{out2} is too low. V_{prog} may also be decreased in order to lower V_{out1} (and correspondingly lower V_{out2}) when V_{out2} is too high. Accordingly, the voltage regulator **350** may serve to control the V_{out1} produced by the regulation device **210** of the adapter **105**. The voltage regulator **350** therefore sets V_{prog} based on comparison of its internal reference voltage and $[V_{out2} \cdot (RD) / (RB + RC + RD)]$. V_{prog} is output back to the regulation device **210** to change V_{out1} (and correspondingly, V_{out2}). Accordingly, the regulation device **210** provides feedback to the adapter **105** so that V_{out1} (and correspondingly, V_{out2}) can be quickly changed as necessary. Due to this feedback, the response time for changing V_{out1} (and correspondingly, V_{out2}) may be decreased over what it would be if there were no feedback from active circuitry.

The voltage regulator **350** not only acts to set the magnitude of V_{out2} , it also provides additional gain in the feedback loop which compensates for variations in the load of the electronic device **120**. The regulation device **210** of the adapter **105** has its own response time for changing V_{out1} (and correspondingly, V_{out2}) in response to a load variation. Accordingly, the regulation device **210** of the adapter **105** provides its own gain. However, unlike regulation devices **210** of adapters in the prior art, the regulation device **210** of the adapter **105** according to an embodiment of the invention also receives feedback (i.e., V_{prog}) from the voltage regulator **305**. The voltage regulator is an active device which provides additional gain to the regulation device **210** of the adapter **105**. Thus, the regulation device has greater gain and a quicker response time because the regulation device **210** receives feedback from itself as well as the voltage regulator **305**. As discussed above, such combination also does not suffer from any voltage drop (i.e., V_{cable}) due to the resistance of the cable **122** connecting the adapter **105** to the active tip **260** since V_{out2} is monitored at the point of

application to the device, i.e., at the active tip 260, rather than at the output of the adapter as in prior configurations.

Comparators A 340 and B 345 may be used to control whether transistor Q1 350 is on (normal operation) or off (failure condition) and whether green LED DS1 355 (normal operation) or red LED DS2 360 (failure condition) is illuminated. Comparator A 340 may be utilized as a voltage error detection device 225. When the input to the noninverting input (i.e., V_{prog}) exceeds the input to the inverting input (i.e., $[V_{out2} * (RC+RD)/(RB+RC+RD)]$), as it should during normal operation, comparator A 340 is "off." If, however, $[V_{out2} * (RC+RD)/(RB+RC+RD)]$ exceeds V_{prog} , comparator A 340 is said to be "on," and outputs a low voltage such as GND. The low voltage may indicate that the adapter 105 is operating improperly.

Resistor RE 335 may be utilized as a current programming device (i.e., I_{prog} controller 235 of FIG. 2). The voltage across resistor RE 335 may be input into the noninverting input of comparator B 345. The input to the inverting input of comparator B 345 may be $[V_{out2} * (RD)/(RB+RC+RD)]$. Comparator B 345 may be utilized as a current error detection device 240. When the input to the noninverting input (i.e., V_{Iprog} , which is $[I_{prog} * RE]$) exceeds the input to the inverting input (i.e., $[V_{out2} * (RD)/(RB+RC+RD)]$), as it should during normal operation, comparator B 345 is off. If, however, $[V_{out2} * (RD)/(RB+RC+RD)]$ exceeds V_{Iprog} , comparator B 345 is said to be "on," and outputs a low voltage such as GND. The low voltage may indicate that the adapter 105 is operating improperly.

If either or both of comparators A 340 and B 345 output a low voltage indicative of an error state, LED DS2 360 may be lit. Red LED DS2 360 may be lit to indicate that an error condition has occurred. If no errors are detected, the green LED DS1 355 may be lit.

When both comparators A 340 and B 345 detect correct operation, VCC through RG 385 pulls up the base of Q2 365, and there is sufficient current to turn on transistor Q2 365, thereby pulling low the gate voltage of P-channel FET Q1 350 to turn it on, and allowing V_{out2} to be passed through to pin 1 of the connector 370 going to the electronic device 120 being powered.

When one, or both, of comparators A 340 and B 345 detect an improper operation, the low voltage output by them turns off transistor Q2 360, thereby turning off FET Q1 350 to prevent V_{out2} from being passed to the electronic device 120.

If either comparator A 340 or comparator B 345 is on (e.g., either one outputs GND), then current may flow from Vcc through red LED DS2 360, and then to GND. Accordingly, if either comparator A 340 or comparator B 345 is on, the current will cause red LED DS2 360 to become lit, but not green LED DS1 355.

However, if neither comparator A 340 nor B 345 is on, then both will be off, having no effect on Q2 365. Accordingly, the current will flow from Vcc through resistor RG 385, through green LED DS1 355, and to GND via RI 375. The current will also provide a voltage at the base of transistor Q2 360, activating Q2 360. Once Q2 360 is activated, current may flow through resistor RF 380, and then down to Q2 360 and to GND to turn on, i.e., close, transistor Q1 350. When Q1 350 is closed, V_{out2} may flow out of the active tip 260 via pin 1 of the connector 370, and on into the electronic device 120 being powered.

Resistors RB 320, RC 325, and RD 330 may be different values, depending upon the type of electronic device 120 being powered by the active tip 260. Resistors RB 320, RC 325, and RD 330 are utilized for voltage division. Accord-

ingly, resistors RB 320, RC 325, and RD 330 vary from active tip 260 to active tip 260, depending upon the amount of V_{out2} to be supplied to the electronic device 120. A specific active tip 260 may be utilized to supply power to an electronic device 120 having specified power requirements. Accordingly, when a device having different power requirements is to be utilized, the active tip 260 may be replaced with a different active tip 260 having different resistor values RB 320, RC 325, RD 330, and RJ 390.

The voltage regulator 350 may be a TL431 or TLV431 shunt regulator produced by Texas Instruments, for example. Comparators A 340 and B 345 may be dual differential comparators such as the following models produced by Texas Instruments: LM193, LM293, LM293A, LM393, LM393A, LM2903, or LM2903Q, for example.

FIG. 4A illustrates a response time (not drawn to scale) of an adapter 105 after a fluctuation in voltage according to the prior art. The vertical axis represents voltage, and the horizontal axis represents time. The adapter 105 may output X volts. The cable 122 may have an internal resistance, resulting in a voltage drop (e.g., Y volts) when current is being drawn by the device. Accordingly, voltage reaching the electronic device 120 may equal X-Y volts. If no current is being drawn by the device, the voltage supplied to the device (i.e., the open circuit voltage) is X volts, which case is shown in FIG. 4A. If at time T_1 , the load increases, the voltage may suddenly drop, eventually down to a low of M_1 volts, until the adapter 105 responds by increasing the voltage back up, so that the output of the cable 122 is X-Y volts. As shown, the voltage does not recover until time T_2 .

FIG. 4B illustrates the magnitude of current flowing out of the adapter to the electronic device according to an embodiment of the invention. As shown, at time "0", no current flows from the adapter 105 through the cable 122 and on into the electronic device 120. Accordingly, there is substantially no voltage drop across the cable 122 at this time. However, at time T_1 , the current increases to Y amps. The increase in the current results in a voltage drop across the cable 122, as shown in FIG. 4A. The current increases, and a voltage drop across the cable 122 is realized before the power source 100 has a chance to compensate (due its delayed response time). Once the power source 100 compensates, the voltage supplied to the electronic device 120 increases to X-Y volts, where Y is the voltage drop across the cable 122.

FIG. 4C illustrates a response time (not drawn to scale) of the system having the adapter 105 coupled to the active tip 260 according to an embodiment of the invention. As shown, the output of the cable 122 is X volts. The output of the cable 122 may be precisely set due to the active circuitry in the active tip 260. At time T_1 , the load may increase (as shown in FIG. 4B), pulling down the voltage. The active tip 260 may sense the decrease in the voltage, and may increase V_{prog} accordingly, raising the output voltage back up to X volts. As shown, the trough of the voltage is M_2 volts. The trough M_2 is higher than the trough M_1 of the prior art. Also, the time period during which the voltage dips below the correct amount is shorter than that of the prior art. As shown, the prior art has a response time equal to (T_2-T_1) , but the response time of the system having the active tip 260 is shorter, (T_3-T_1) . The active tip system has a lower response time due to greater loop gain than adapters 105 of the prior art. Because of the gain in the tip (due to the voltage regulator 350), the regulation device 210 of the adapter 105 has a faster response time and, after compensation, raises the voltage at the tip back up to X volts.

FIG. 5A illustrates a first portion of a method of supplying power to an electronic device 120 via an adapter 105 and active tip 260 according to an embodiment of the invention. First, the adapter may receive 500 power from a power source 100. Next, the adapter 105 may receive 505 V_{prog} . The adapter 105 may then create V_{out} by multiplying 510 V_{prog} times a multiplication factor. Next, V_{out} may be outputted 515 to the active tip 260. Based on V_{out} , the active tip 260 may create 520 V_{prog} . The active tip 260 may then create 525 I_{prog} . Next, V_{prog} is compared with V_{out} or a factor of V_{out} to determine 530 whether there is an error. If “yes,” processing proceeds to operation 550. If “no,” the voltage drop across the I_{prog} controller 235 (i.e., V_{Iprog}) is compared with V_{out} or a factor of V_{out} to determine 535 whether there is an error. If “yes,” processing proceeds to operation 550. If “no,” processing proceeds to operation 540.

FIG. 5B illustrates a second portion of the method of supplying power to an electronic device 120 via an adapter 105 and active tip 260 according to an embodiment of the invention. At operation 540, LED DS1 355 is lit 540 to indicate proper operation. At operation 545, transistor Q1 350 (i.e., switch 240) is closed, and then processing reverts to operation 500. At operation 550, LED DS2 360 is lit to indicate improper operation. At operation 555, transistor Q1 350 (i.e., switch 240) is opened to protect the electronic device 120. Finally, processing reverts to operation 500.

While the description above refers to particular embodiments of the present invention, it will be understood that many modifications may be made without departing from the spirit thereof. The accompanying claims are intended to cover such modifications as would fall within the true scope and spirit of the present invention. The presently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims, rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A power supply system, comprising:
 - a power adapter to receive power from a power source and to output a first regulated output voltage (V_{out}), the power adapter including a regulation device;
 - a cable coupled to the power adapter, the cable having an associated resistance; and
 - a tip to receive a second regulated output voltage from the power adapter through the cable through a first connector and provide the second regulated output voltage to the power adapter through a second connector, the second regulated output voltage being based upon the first regulated output voltage but subject to a voltage loss in the cable, the tip including circuitry to provide a fraction of the second regulated output voltage to a voltage regulator to set a programming voltage (V_{prog}) based on comparing the fraction of the second regulated output voltage to a reference voltage, the programming voltage being output through the first connector and the cable to control a magnitude of the first output voltage output by the power adapter.
2. The power supply system according to claim 1, wherein the power adapter has a quicker response time in providing the first regulated output voltage (V_{out}) due to feedback of the programming voltage (V_{prog}).
3. The power supply according to claim 1, wherein the voltage regulator is selected based upon its predetermined regulation characteristics.

4. The power supply system of claim 1, where the power supply system does not suffer any voltage drop due to the associated resistance of the cable between the power adapter and the tip.

5. A power supply system, comprising:

- a power adapter to receive power from a power source and to output a first regulated output voltage (V_{out}), the power adapter including a regulation device;
- a cable coupled to the power adapter, the cable having an associated resistance;

a tip to receive a second regulated output voltage from the power adapter through the cable through a first connector and provide the second regulated output voltage to the power adapter through a second connector, the second regulated output voltage being based upon the first regulated output voltage but subject to a voltage loss in the cable, the tip including circuitry to provide a fraction of the second regulated output voltage to a voltage regulator to set a programming voltage (V_{prog}) based on comparing the fraction of the second regulated output voltage to a reference voltage, the programming voltage being output through the first connector and the cable to control a magnitude of the first output voltage output by the power adapter, and

a comparator to detect an error in a relationship between a first regulated output voltage (V_{out}) and the programming voltage (V_{prog}).

6. The power supply system of claim 5, wherein the tip further includes a first lighting device to light when the error is detected.

7. The power supply system of claim 5, the tip further including a switch to open, to prevent the second regulated output voltage from reaching the electronic device, when the error is detected.

8. The power supply system of claim 5, wherein the tip includes a second lighting device to light when no error is detected.

9. The power supply system of claim 5, further including a switch to close, to allow the second regulated output voltage to reach the electronic device, when no error is detected.

10. The power supply system of claim 5, where the power supply system does not suffer any voltage drop due to the associated resistance of the cable between the power adapter and the tip.

11. A method of supplying power to an electronic device, the method comprising:

receiving a compensated output voltage at a tip, the compensated output voltage being the difference being a regulated output voltage provided from an adapter and voltage loss across a cable coupling the adapter to the tip;

setting, at a tip, a programming voltage (V_{prog}) based on comparison of a predetermined fraction of the compensated output voltage received at the tip and a reference voltage utilizing a regulator, the predetermined fraction defined by resistors within the tip;

feeding back the programming voltage (V_{prog}) to a regulator in the adapter to control a magnitude of the regulated output voltage provided by the adapter; and outputting, via the tip, the compensated output voltage to the electronic device.

12. The method of claim 11, further including detecting an error in a relationship between the predetermined fraction of the compensated output voltage and the programming voltage.

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13. The method of claim **12**, further including lighting a lighting device, located within the tip, when the error is detected.

14. The method of claim **12**, further including opening a switch located in the tip, to prevent Vout from reaching the electronic device, when the error is detected. 5

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15. The method of claim **12**, further including lighting a lighting device, located within the tip, when the error is not detected.

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