on, 80% capacity when 4 lights are on, 60% capacity when 3 lights are on, 40% capacity when two lights are on, 20% capacity when one light is on and empty or no charge remaining when no lights are on. In most situations, a user will discard the battery when one or two lights are on in order to avoid a loss of power when the battery becomes completely discharged. As a result, many batteries are discarded with between 20 and 40% of the charge capacity unused. Accordingly, there is a need in the art to more fully utilize the charge remaining on non-rechargeable batteries connected to a power manager.

[0013] The charge remaining on many rechargeable batteries, e.g. lithium sulfur dioxide ($LiSO_2$) and lithium magnesium dioxide ($LiMnO_2$) is not easily detected using conventional terminal voltage measurements, so more sophisticated and more expensive coulomb counting devices are integrated into these rechargeable batteries and are used to predict the charge level remaining on the rechargeable battery. One advantage of coulomb counters is that they have a higher resolution than LED charge level indicators. For example, a coulomb counter may be able to discern 20 levels of charge capacity with only the last 5% remaining uncertain. However, a coulomb counter does not provide a visible indicator of remaining charge level and a user cannot check the charge level of a rechargeable battery that uses a coulomb counter without connecting the battery to a device capable of reading data from the battery. As a result, these batteries are often discarded after one use simply because the user is uncertain about how much charge is remaining on the battery. Accordingly, there is a need in the art to more fully utilize the charge remaining on rechargeable batteries connected to a power manager without an unexpected power interruption even when the charge level on the rechargeable batteries is uncertain. In addition, it is desirable to eliminate a coulomb counter from rechargeable batteries used with portable power manager to reduce the cost and complexity of the batteries.

SUMMARY OF THE INVENTION

[0014] There are disclosed herein~~Various aspects of the invention provide~~ power managers, methods of operating a power manager, and method of operating a power network

[0015] ~~One aspect of the invention provides a power manager including a power bus (410), a plurality of device ports each configured to operably connect with an external power device, a first power channel (1510) comprising a first conductive path disposed between each device port and the power bus, a first controllable switching~~

~~element (C) disposed along the first connective path for selectively connecting and disconnecting each device port to and from the power bus over the first power channel, a second power channel (1320) comprising a second conductive path disposed between each device port and the power bus and a second controllable switching element (D) disposed along the second connective path for selectively connecting and disconnecting each device port to and from the power bus over the second power channel, a data processing device (420) and associated memory in communication with each of the first and second controllable switches (C, D), and energy management schema operating on the power manager for independently operating each of the first and second controllable switches.~~According to an aspect of the present invention, there is disclosed a power manager comprising: a power bus; a plurality of device ports each configured to operably connect with an external power device; for each of the plurality of device ports: a first conductive path disposed between the device port and the power bus; a first controllable switching element disposed along the first conductive path; a second conductive path disposed between each device port and the power bus; a controllable power converter disposed along the second conductive path between the device port and the power bus; a second controllable switching element disposed along the second conductive path between the controllable power converter and the device port; wherein the second conductive path and the controllable power converter can be shared between two or more of the plurality of device ports; a data processing device and associated memory in communication with each of the first and second controllable switches and with each of the controllable power converters; and, energy management schema operating on the power manager for controlling each of the first and second controllable switches and each of the controllable power converters.

[0015a] According to another aspect of the present invention, there is provided a power manager comprising: a power bus; a plurality of device ports each configured to operably connect with an external power device; for each of the plurality of device ports: a first conductive path disposed between the device port and the power bus; and a first controllable switching element disposed along the first conductive path; a second conductive path disposed between the device port and the power bus; a second and a third controllable switching element disposed along each second conductive path; a sensor for sensing a low power condition on the power bus and for generating a low power signal in response thereto; wherein each of the third controllable switching elements is conductively connected to the sensor and operates to close in response the low power signal.

[0016] ~~This aspect of the invention can have a variety of embodiments.~~ The power manager can include a sensor (1315) for sensing a low power condition on the power bus and for generating a low power signal in response thereto and a conductive path (1316) extending between the sensor and one of the first and second controllable switching elements associated with at least a portion of the device ports for connecting at least a portion of the device ports to the power bus in response to the low power signal. The low power signal can causes each of the second controllable switching elements (C) to connect the device port to the power bus over a power channel without interaction with the data processing device.

[0017] The power manager can include a controllable power converter (440) in communication with the data processing device (420) disposed along one or more of the first and second power channels between corresponding first and second controllable switching elements and the power bus and wherein the energy management schema operates to configure the power converter to covert power signals passing between the device port and the power bus.

[0018] The power manager can include a communication channel (655, 665) that includes a communications interface device (650, 660) disposed between each device port and the data processing device (420) for communicating with power devices operably connected with the device ports.

[0019] The power manager can include a sealed enclosure (1100) formed to house the power bus, data processor, associated memory and the first and second power channels, a terminal connector (1150, 1160, 1170, 1180, 1190, 1200) associated with each device port disposed to extend through an external wall of the sealed enclosure for connecting with the external power devices by wire cables, a user input device in

communication with the data processing device and disposed for responding to user inputs from outside the sealed enclosure, and one of a display device and an indicator device in communication with the data and disposed to indicate user feedback.

[0020] The sealed enclosure can include opposing substantially rectangular top and bottom faces, opposing substantially rectangular longitudinal front and back faces, and opposing substantially rectangular transverse side faces. The terminal connectors can be only disposed on the transverse side faces and on one of the longitudinal front and back faces.

[0021] Each of the first and second controllable switching elements can include a semiconductor switch suitable for bidirectional power exchange between the power bus and corresponding device ports. The power bus can be configured for an average operating voltage in the range of 1-50VDC. The controllable power converter (442) can be suitable for bidirectional power exchange and for bidirectional power conversion.

[0022] There is also disclosed~~Another aspect of the invention provides~~ a method for operating a power manager having a plurality of device ports, a power bus, two or more power channels disposed between each device port and the power bus, controllable switches disposed along each power channel for connecting and disconnecting the device port to the power bus over each power channel, a processing device for controlling the controllable switches and a communication channel disposed between each device port and the processing device for communicating with external power devices connected with each device port. The method includes polling device ports to determine if an external power device is connected to the device port, disconnecting the device port from the power bus when no external power device is connected to the device port, accessing information from the external power device when an external power device is connected to the device port, and connecting the external power device to the power bus over one of the two or more power channels.

[0023] ~~This aspect of the invention can have a variety of embodiments.~~ The power manager can include a power converter disposed between the device port and the power bus along one of the power channels and the method can include the steps of determining a power conversion setting that would allow an external power device to be connected to the power bus, setting the power converter to operate at the power conversion setting, and connecting the external power device to the power bus over the power converter.

[0024] The method can include the steps of determining if the external power device is a power source, determining if other external power devices connected to the power manager are power sources, selecting a single power source as a primary power source, and connecting the primary power source to the power bus and disconnecting any non-primary power sources from the power bus.

[0025] The method can include the steps of: sensing a power characteristic of the power bus, generating a low power signal in response to the power bus power characteristic falling below a threshold value, and connecting one or more of the disconnected non-primary power sources to the power bus in response to the low power signal.

[0026] There is also disclosed~~Another aspect of the invention provides~~ a method for operating a power manger having a plurality of device ports for connecting with external power devices and a power bus for connecting with each device port. The method includes the steps of: accessing information from each external power device connected to one of the plurality of device ports, characterizing each external power device as one of a power load, a power or energy source and a rechargeable energy source and if no rechargeable energy sources are connected, associating external devices characterized as power loads with a power allocation interface, associating external devices characterized as power or energy sources with a source allocation interface, calculating a total power available from the source allocation interface, allocating the total power available to the power allocation interface, and connecting as many power loads to the power bus as can be powered by the total power available.

[0027] ~~This aspect of the invention can have a variety of embodiments.~~ One or more rechargeable energy sources can be connected and the method can include the steps of: determining if a power source suitable for recharging the connected rechargeable energy sources is operably connected to the power manager; if a suitable power source is operably connected, characterizing the rechargeable energy sources as power loads for association with the power allocation interface; and if suitable power source is not operably connected, characterizing the rechargeable energy sources as energy sources for association with the source allocation interface.

[0028] Each power load can have a load priority and the step of allocating the total power available to the power allocation interface can be performed in priority order from a highest priority power load to a lowest priority power load. Each power source and each energy source can have a source priority and the method can include

the steps of: selecting the power source or the energy source with the highest source priority for connection to the power bus; connecting the power source or the energy source with the highest source priority to the power bus; disconnecting selected power sources or energy sources from the power bus; and powering all of the power loads connected to the power bus with the power source or the energy source having the highest source priority.

[0029] There is also disclosed~~Another aspect of the invention provides~~ a method for operating a power network including the steps of: connecting a plurality of substantially identical power managers together with a cable extending between device ports of each pair of connected power managers; connecting at least one power load to a first of the plurality of substantially identical power managers; connecting at least one power or energy source to a second of the plurality of substantially identical power managers; and powering the power load by exchanging power between two or more of the connected power managers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The features of the present invention will best be understood from a detailed description of the invention and a preferred embodiment thereof selected for the purposes of illustration and shown in the accompanying drawings in which:

[0031] FIG. 1 illustrates a block diagram representing a power network that includes a power manager according to the present invention.

[0032] FIG. 2 illustrates a schematic representation of a single power manager power network configuration according to the present invention.

[0033] FIG. 3 illustrates a schematic representation of a multiple power manager power network configuration according to the present invention.

[0034] FIG. 4 illustrates a block diagram representing elements of a first example embodiment of a power manager according to the present invention.

[0035] FIG. 5 illustrates a block diagram representing elements of a second multiple power manager power network configuration according to the present invention.

[0036] FIG. 6 illustrates a block diagram representing an example embodiment of a power device connected by a cable to a port of the power manager according to the present invention.

CLAIMS

1. A power manager comprising:

a power bus (410);

a plurality of device ports each configured to operably connect with an external power device;

a first power channel (1510) comprising a first conductive path disposed between each device port and the power bus;

a first controllable switching element (C) disposed along the first connective path for selectively connecting and disconnecting each device port to and from the power bus over the first power channel;

a second power channel (1320) comprising a second conductive path disposed between each device port and the power bus and a second controllable switching element (D) disposed along the second connective path for selectively connecting and disconnecting each device port to and from the power bus over the second power channel;

a data processing device (420) and associated memory in communication with each of the first and second controllable switches (C, D); and,

energy management schema operating on the power manager for independently operating each of the first and second controllable switches.

2. The power manager of claim 1 further comprising:

a sensor (1315) for sensing a low power condition on the power bus and for generating a low power signal in response thereto;

a conductive path (1316) extending between the sensor and one of the first and second controllable switching elements associated with at least a portion of the device ports for connecting at least a portion of the device ports to the power bus in response to the low power signal;

wherein the low power signal causes each of the second controllable switching elements (C) to connect the device port to the power bus over a power channel without interaction with the data processing device.

3. The power manager of claim 1 further comprising a controllable power converter (440) in communication with the data processing device (420) disposed along one or more of the first and second power channels between corresponding first

and second controllable switching elements and the power bus and wherein the energy management schema operates to configure the power converter to covert power signals passing between the device port and the power bus.

4. The power manager of claim 1, further comprising a communication channel (655, 665) that includes a communications interface device (650, 660) disposed between each device port and the data processing device (420) for communicating with power devices operably connected with the device ports.

5. The power manager of claim 1 further comprising:

a sealed enclosure (1100) formed to house the power bus, data processor, associated memory and the first and second power channels;

a terminal connector (1150, 1160, 1170, 1180, 1190, 1200) associated with each device port disposed to extend through an external wall of the sealed enclosure for connecting with the external power devices by wire cables;

a user input device in communication with the data processing device and disposed for responding to user inputs from outside the sealed enclosure; and

one of a display device and an indicator device in communication with the data and disposed to indicate user feedback.

6. The power manager of claim 5, wherein the sealed enclosure comprises opposing substantially rectangular top and bottom faces, opposing substantially rectangular longitudinal front and back faces and opposing substantially rectangular transverse side faces and wherein the terminal connectors are only disposed on the transverse side faces and on one of the longitudinal front and back faces.

7. The power manager of any one of the above claims wherein each of the first and second controllable switching elements comprises a semiconductor switch suitable for bidirectional power exchange between the power bus and corresponding device ports.

8. The power manager of any one of the above claims wherein the power bus is configured for an average operating voltage in the range of 1-50VDC.

9. The power manager of any one of claims 3-8 wherein the controllable power converter (442) is suitable for bidirectional power exchange and for bidirectional power conversion.

10. A method for operating a power manager having a plurality of device ports, a power bus, two or more power channels disposed between each device port and the power bus, controllable switches disposed along each power channel for connecting and disconnecting the device port to the power bus over each power channel, a processing device for controlling the controllable switches and a communication channel disposed between each device port and the processing device for communicating with external power devices connected with each device port comprising the steps of:

polling device ports to determine if an external power device is connected to the device port;

disconnecting the device port from the power bus when no external power device is connected to the device port;

accessing information from the external power device when an external power device is connected to the device port; and

connecting the external power device to the power bus over one of the two or more power channels.

11. The method of claim 10, wherein the power manager includes a power converter disposed between the device port and the power bus along one of the power channels further comprising the steps of:

determining a power conversion setting that would allow an external power device to be connected to the power bus;

setting the power converter to operate at the power conversion setting; and

connecting the external power device to the power bus over the power converter.

12. The method of claim 10 further comprising the steps of:

determining if the external power device is a power source;

determining if other external power devices connected to the power manager are power sources;

selecting a single power source as a primary power source; and

connecting the primary power source to the power bus and disconnecting any non-primary power sources from the power bus.

13. The method of claim 12, further comprising the steps of:

sensing a power characteristic of the power bus;

generating a low power signal in response to the power bus power characteristic falling below a threshold value; and

connecting one or more of the disconnected non-primary power sources to the power bus in response to the low power signal.

14. A method for operating a power manger having a plurality of device ports for connecting with external power devices and a power bus for connecting with each device port comprising the steps of:

accessing information from each external power device connected to one of the plurality of device ports;

characterizing each external power device as one of a power load, a power or energy source and a rechargeable energy source and if no rechargeable energy sources are connected;

associating external devices characterized as power loads with a power allocation interface;

associating external devices characterized as power or energy sources with a source allocation interface;

calculating a total power available from the source allocation interface;

allocating the total power available to the power allocation interface; and

connecting as many power loads to the power bus as can be powered by the total power available.

15. The method of claim 14, wherein one or more rechargeable energy sources are connected, and wherein the method further comprises the steps of:

determining if a power source suitable for recharging the connected rechargeable energy sources is operably connected to the power manager;

if a suitable power source is operably connected, characterizing the rechargeable energy sources as power loads for association with the power allocation interface; and

if suitable power source is not operably connected, characterizing the rechargeable energy sources as energy sources for association with the source allocation interface.

16. The method of claim 15, wherein each power load has a load priority and the step of allocating the total power available to the power allocation interface is performed in priority order from a highest priority power load to a lowest priority power load.

17. The method of claim 17, wherein each power source and each energy source has a source priority and wherein the method further comprises the steps of:

selecting the power source or the energy source with the highest source priority for connection to the power bus;

connecting the power source or the energy source with the highest source priority to the power bus;

disconnecting selected power sources or energy sources from the power bus; and

powering all of the power loads connected to the power bus with the power source or the energy source having the highest source priority.

18. A method for operating a power network comprising the steps of:

connecting a plurality of substantially identical power managers together with a cable extending between device ports of each pair of connected power managers;

connecting at least one power load to a first of the plurality of substantially identical power managers;

connecting at least one power or energy source to a second of the plurality of substantially identical power managers; and

powering the power load by exchanging power between two or more of the connected power managers.

CLAIMS

1. A power manager comprising:

a power bus;

a plurality of device ports each configured to operably connect with an external power device;

for each of the plurality of device ports:

a first conductive path disposed between the device port and the power bus;

a first controllable switching element disposed along the first conductive path;

a second conductive path disposed between each device port and the power bus;

a controllable power converter disposed along the second conductive path between the device port and the power bus;

a second controllable switching element disposed along the second conductive path between the controllable power converter and the device port;

wherein the second conductive path and the controllable power converter can be shared between two or more of the plurality of device ports;

a data processing device and associated memory in communication with each of the first and second controllable switches and with each of the controllable power converters; and,

energy management schema operating on the power manager for controlling each of the first and second controllable switches and each of the controllable power converters.

2. The power manager of claim 1, further comprising a communication channel that includes a communications interface device disposed between each device port and the data processing device.

3. The power manager of claim 2, wherein the communication interface device is configured for communicating with the external power devices using a communication protocol that is common to the power manager and the external power device.

4. The power manager of claim 3, wherein the communication protocol comprises one of the SMBus, the IIC and the USB communication protocols.

5. The power manager of claim 1, wherein the first controllable switching element comprise a semiconductor switch suitable for bidirectional power exchange between the power bus and corresponding device ports.

6. The power manager of claim 1, wherein the controllable power converter is suitable for bidirectional power exchange between the power bus and the external power device.

7. The power manager of claim 1, wherein the controllable power converter is operable to attenuate current amplitude passing through the power converter.

8. The power manager of claim 1, wherein the controllable power converter is operable to increase or decrease the voltage of a DC power signal.

9. The power manager of claim 1, wherein the plurality of device ports comprises six device ports where the power manager includes three controllable power converters and wherein each controllable power converter is disposed along a second different conductive path that is shared between two device ports.

10. The power manager of claim 1, wherein the plurality of device ports comprises two device ports and the second conductive path is shared between the two device ports.

11. The power manager of claim 1, wherein the power bus is configured for an average operating voltage in the range of 1-50VDC.

12. The power manager of claim 1, wherein the power bus is configured for an average operating voltage substantially centered around one of 15VDC and 30VDC.

13. The power manager of claim 11, wherein each of the controllable power converters is configured for DC to DC up and down voltage conversion over an input and output voltage range of 1-50VDC.

14. The power manager of claim 1, further comprising a user interface device in communication with the data processing device.

15. The power manager of claim 14 further comprising a display device in communication with the data processing device.

16. The power manager of claim 1 further comprising:

a sealed enclosure formed to house the power bus, data processor, associated memory and the first and second conductive paths; and,

a terminal connector associated with each device port disposed to extend through an external wall of the sealed enclosure for connecting with the external power devices by wire cables.

17. The power manager of claim 16, further comprising an indicator device associated with each device port and in communication with the data processing device for indicating a status of an external power device connected to the corresponding device port.

18. The power manager of claim 16, wherein the sealed enclosure comprises opposing substantially rectangular top and bottom faces, opposing substantially rectangular longitudinal front and back faces and opposing substantially rectangular transverse side faces and wherein the terminal connectors are only disposed on the transverse side faces and on one of the longitudinal front and back faces.

19. The power manager of claim 18, further comprising a key pad associated with the user interface device disposed along one of the longitudinal front and back faces.

20. The power manager of claim 16, having a weight of less than 500 grams.

21. The power manager of claim 19, further comprising a display device in communication with the data processing device disposed on one of the top and bottom faces.

22. The power manager of claim 20, wherein the enclosure has a longitudinal length, a transverse width and a thickness, and the transverse width is less than 8.0 cm.

23. The power manager of claim 22, wherein the longitudinal length is less than 12.0 cm.

24. The power manager of claim 23, wherein the thickness is less than 4.0 cm.

25. The power manager of claim 1, further comprising:

a sensor in communication with the data processing device for sensing a low power condition on the power bus and for generating a low power signal in response thereto and communicating the low power signal to the data processing device;

a third conductive path disposed between each device port and the power bus;

a third controllable switching element disposed along each third conductive path and in communication with the data processing device;

a fourth controllable switching element disposed along each third conductive path between the third controllable switching element and the power bus, wherein the fourth controllable switching element is in communication with the data processing device;

and further wherein each fourth controllable switching element is conductively connected to the sensor and operates to close in response to the low power signal.

26. A power manager comprising:

a power bus;

a plurality of device ports each configured to operably connect with an external power device;

for each of the plurality of device ports:

a first conductive path disposed between the device port and the power bus; and

a first controllable switching element disposed along the first conductive path;

a second conductive path disposed between the device port and the power bus;

a second and a third controllable switching element disposed along each second conductive path;

a sensor for sensing a low power condition on the power bus and for generating a low power signal in response thereto;

wherein each of the third controllable switching elements is conductively connected to the sensor and operates to close in response the low power signal.

27. The power manager of claim 26, wherein each of the third controllable switching elements closes less than 10 msec after the sensor generates the low power signal.

28. The power manager of claim 26, further comprising a data processing device and associated memory in communication with each first, second, and third controllable switching element and with the sensor.

29. The power manager of claim 28, wherein each third controllable switching element closes in response to the low power signal without interaction with the data processing device.

30. The power manager of claim 28, further comprising energy management schema operating on the power manager wherein the energy management schema operates to determine a device type for each external power device.

31. The power manager of claim 30, wherein the energy management schema operates to open each first, second, and third controllable switching element associated with a device port that is not connected with an external power device.

32. The power manager of claim 31, wherein the energy management schema operates to close each second controllable switching element associated with a device port that is operably connected to a power source.

33. The power manager of claim 32, wherein the energy management schema operates to connect selected external power devices to the power bus over the first power channel.

34. The power manager of claim 26 further comprising a controllable power converter disposed along the first power channel between the power bus and the first controllable switching element.