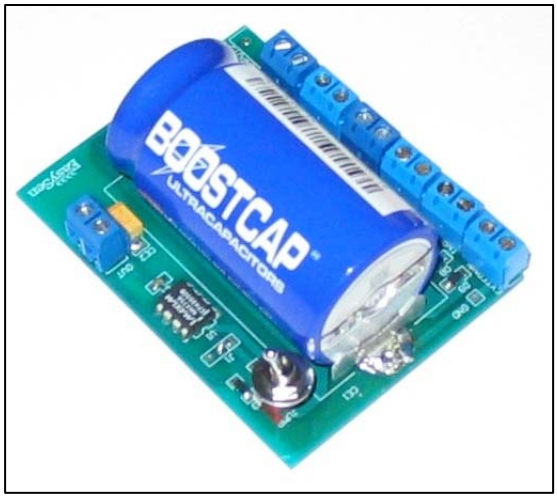
S-Powerizer

Energy harvesting and Storage module for Wireless Sensor Networks

Energy Harvesting and Storage Module for Achieving Extended Lifetime and Eliminating the Need for Battery replacement in Wireless Sensor Networks

Product Description

S-Powerizer is a versatile energy harvesting solution for wireless sensor networks located in remote, hard to reach environments. It can connect to multiple inputs including solar cells and micro wind turbines to scavenge energy from the environment and store this energy in efficient ultracapacitors or rechargeable batteries.



The S-Powerizer comes with a wide number of accessories and options. This provides user the flexibility of customizing the module configuration based on the energy needs and system cost constraints. It can store energy through the use of ultracapacitors and / or a battery with the option of adding additional storage devices. The board can exploit input voltages as low as 1V by converting it to 3V or 5V at the output. Hence it can support a variety of sensor node platforms, including the Imote[1] (5V), Tmote[2] (3V), EpicMote[3] (3V), etc. and many other custom sensors requiring extra external power supplies. A total of 6 different sources can be connected at a time through the input terminals.

Key Features

- Five regular input with diodes for connecting various energy sources including solar cells and micro-wind turbines
- Optional on-board or externally connected ultracapacitor (Electrochemical Double Layer Capacitor - EDLC). Compared to batteries, this ultracapacitor offers extremely long lifetime, high efficiency in energy storage (over 95%), extremely low internal resistance, extremely low heating levels, high output power, and improved safety. It can act as a charge conditioner, storing energy from other energy sources and also serving load balancing purposes.
- One dedicated input/output terminal without a diode for the connection of an external rechargeable battery that can be charged via the module.

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[1] CrossBow Inc, **Imote2** (IPR2400) Product Datasheet, http://www.xbow.com/Products/Product_pdf_files/Wireless_pdf/Imote2_Datasheet.pdf
[2] CrossBow Inc, TelosB (TPR2400CA) Product Datasheet, http://www.xbow.com/Products/Product_pdf_files/Wireless_pdf/TelosB_Datasheet.pdf
[3] ArchRock Inc, EPIC Mote Product Description, http://store.archrock.com/ProductDetails.asp?ProductCode=RMB%2D1010S

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1. Description

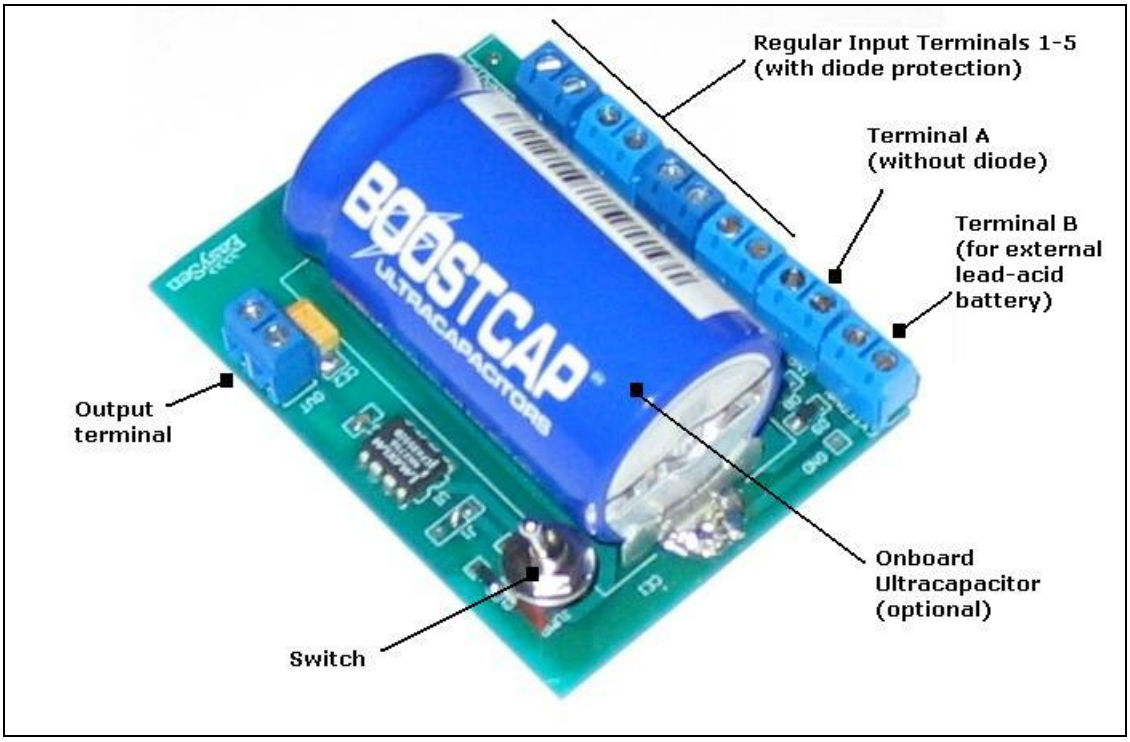

Figure 1. Top view of S-Powerizer
(Shown with optional onboard Ultracapacitor)

Figure 1 shows the top view of the S-Powerizer module.

1.1 Regular input Terminals (input 1 - input 5): The five regular inputs (with diode protection) can be connected to various energy sources. Examples of the energy sources that can be connected to these include

- Solar panel
- Micro wind turbine
- Micro Hydro power turbine

The electrical specifications of these input energy sources must not exceed the values shown in Table 1 at any given time. Further recommendations on input energy sources are given in Section 2.0

Parameter	Min	Typical	Max	Unit
Voltage (open)	1.5	3	6	V
Current (continuous and short circuit)	0.0	100	400	mA
Current (Peak and short circuit)		300	600	mA
NOTE: For micro wind generators, a bridge rectifier should be used before connecting to any of the inputs and generated power should stay well under 1 Watt				

Table 1. Electrical Specifications of Energy Sources connected to input 1 - input 5

1.2 Terminal A : Terminal A (without diode) can be used to connect either

- an additional energy source (in addition to the five sources connected to regular terminals described in 1.1) (**input configuration**)
- an external storage device such as an external ultracapacitor. (**storage configuration**)

When Terminal A is used in the input configuration, the electrical specifications of the input energy source must not exceed the values shown in Table 1 at any given time. When Terminal A is used in the storage configuration, the electrical specifications of the input energy source must not exceed the values shown in Table 2 below at any given time.

Parameter	Min	Typical	Max	Unit
Voltage (open)	1.5	3-4	6	V
Current (continuous and short circuit)	0.0	100	400	mA
Current (Peak and short circuit)		300	600	mA
NOTE: For micro wind generators, a bridge rectifier should be used before connecting to any of the inputs and generated power should stay well under 1 Watt				

Table 2. Electrical Specifications of Energy Sources connected to Terminal A

1.3 Terminal B :

When Terminal B is used to connect an energy source such as an external lead-acid rechargeable battery, its electrical specifications must not exceed the values shown in Table 2 at any given time.

Parameter	Min	Typical	Max	Unit
Voltage (open)	1.5	1.9	2.1	V
Current (continuous)	0	100	300	mA
Current (Peak)		-	5000	mA

Table 2. Electrical Specifications of Storage Devices Connected to Terminal B

2. Operating Conditions

2.1 Operation without a battery

If the energy harvesting board is operated without the recommended 2V sealed lead-acid rechargeable battery at Terminal B, care has to taken that the voltage across the Ultracapacitor never exceeds 2.6V. Therefore, it is recommended to use a Zener diode that stabilizes the voltage to less than 2.6 Volts.

The Zener diode should be matched to the power sources used, i.e. it should be able to handle the maximum input current at 2.6 V and also the Zener diode should not pass a current higher than 10μA if the voltage is lower than 2V.

2.2 Low power operation

The energy harvesting circuit allows the battery or ultracapacitor voltage to fall under 1V for a short amount of time (less than 1 second) and very light load condition (stand by mode). This assumes that before the occurrence of this voltage fall, the ultracapacitor voltage was charged above the critical voltage of 1.4V.

2.3 Energy storage and uptime

The recommended battery allows operating a TelosB/Tmote with typical continuous power demands for approximately 2 full days. The on-board ultracapacitor allows for about 1 hour of continuous operation, while the combination of internal and external ultracapacitors (3300F) allows continuous operation of approximately 10 hours.

2.4 Critical parameters:

(a) Charge capacity of battery and ultracapacitors determines maximum uptime without any harvested energy, i.e. night time operation with solar cells.

(b) Input power/current of energy harvesting devices determines recharge time of energy storage devices under various operating conditions.

(c) Both parameters of (a) and (b) determine the achievable duty cycles of a sensor node.

2.5 Duty Cycle characterization of sensor nodes (output device):

(a) High and continuous (50% duty cycle)

(b) High in on/off mode: once per minute for at least 5 seconds (8% duty cycle)

(c) Medium: approximately once per hour for about 1 minute or equivalent (2% duty cycle)

(d) Low: 4 times a day for about 1 minute. (0.25% duty cycle)

(e) Ultra-low: once per day for several seconds or less (0.02% duty cycle)

3. Available Configurations

3.1 Configuration A - High energy, high duty cycle and high longevity:

This option requires the use of a 2V sealed lead-acid rechargeable battery plus a 300F ultracapacitor mounted on the board. This combination allows to operate the board for long term unattended applications. Typical life time is on the order of years. The ultracapacitor is designed to increase battery longevity by absorbing much of the charge/discharge load changes.

Typical usage data	Min	Typical	Max	Unit
Voltage (across ultracapacitor)	1.0	1.5	2.7	V
Average Current (total input)	5	100	500	mA
Storage device 1 - Lead-acid cell: capacity	-	5	-	Ah
Storage device 2 - ultracapacitor: capacity	-	0.2	-	Ah
Uptime (cont. high duty cycle- no charging conditions)	36	50	100	h

Table 3. Typical Usage Data for Configuration A

3.2 Configuration B - Low energy, low to medium duty cycle, ultra-high longevity (No battery):

This option uses the onboard ultracapacitor plus possibly an external ultracapacitor for medium duty cycle operation. Typical uses include one way missions (space, volcano) that last for more than 10 years. Board operation is expected for over 100 years.

Typical usage data	Min	Typical	Max	Unit
Voltage (across ultracapacitor)	1.0	1.5	2.7	V
Average Current (total input)	1.0	10	500	mA
Storage device 1 Onboard ultracapacitor: capacity	-	0.2	-	Ah
Storage device 2 - External ultracapacitor: capacity	-	2.0	-	Ahs
Uptime (medium duty cycle, no charging conditions)	72	100	1000	h

Table 4. Typical Usage Data for Configuration B

3.3 Configuration C - Low cost version (No onboard ultracapacitor, No external ultracapacitor):

This option uses a 2V 5Ah sealed lead-acid rechargeable battery for energy storage and provides adequate energy storage for many medium to high (on/off) duty cycle applications.

Typical usage data	Min	Typical	Max	Unit
Voltage (lead acid cell)	1.5	1.9	2.1	V
Average Current (total input)	1.0	100	500	mA
Storage device 1 - Lead acid cell : capacity	-	5	-	Ah
Uptime (high cont. duty cycle – no charging cond.)	36	50	100	h

Table 5. Typical Usage Data for Configuration C

4. Available Accessories

4.1 Onboard Ultracapacitor

- Maxwell Boostcap Ultracapacitor (Electric Double Layer Capacitor - EDLC)

Capacitance	350 F	
Rated Voltage	2.5 V DC	
Equivalent series resistance - ESR (DC)	3.2 milliohms	
Equivalent series resistance - ESR (at 1kHz)	1.6 milliohms	
Leakage current (Ic) after 72 hours, 25˚C	1.0 mA	
short circuit current I_{SC} (maximum peak current)	1500 A	
Dimensions (Length x outer diameter)	60.0mm x 33.0mm;	
Operating Temperature Range	-40 °C to +65 °C	
Temperature Characteristics	Capacitance Change	Within ± 5% of initial measured value at 25 °C (at -40 °C)
	Internal Resistance	Within 150% of initial measured value at 25 °C (at -40 °C)
Endurance	After 1000 hours application of rated voltage at 65 °C	
	Capacitance Change	Within 20% of initial specified value
	Internal Resistance	Within 25% of initial specified value
Life Test	After 10 years at rated voltage and 25 °C	
	Capacitance Change	Within 20% of initial specified value
	Internal Resistance	Within 100% of initial specified value
Cycle Test	Capacitors cycled between specified voltage and half rated voltage under constant current at 25 °C (500,000 Cycles)	
	Capacitance Change	Within 20% of initial specified value
	Internal Resistance	Within 100% of initial specified value

- Complete datasheet available at
  http://www.easysen.com/support/Datasheets/ Maxwell_ultracapacitor_BCAP0350-E250.pdf

4.2 External Ultracapacitor

Capacitance	3000 F
Rated Voltage	2.5 V DC
Equivalent series resistance - ESR (DC)	3.2 milliohms
Equivalent series resistance - ESR (at 1kHz)	1.6 milliohms
Leakage current (Ic) after 72 hours, 25˚C	5.0 mA
short circuit current I_{SC} (maximum peak current)	1500 A
Dimensions (Length x outer diameter)	60.0mm x 33.0mm;
Operating Temperature Range	-40 °C to +65 °C

4.3 Solar Cells

- High Efficiency Miniature Monocrystalline Solar Cell
- Can be combined in series or parallel arrangements for increased voltage or current

Efficiency	15.0 %
Peak Voltage (V_{mp})	3.5V
Open Circuit Voltage (V_{oc})	4.0V
Peak Current (I_{mp})	45mA
Short Circuit Current (I_{sc})	48.5mA
Color	Blue
Dimensions (LxWxD)	54mm x 33mm x 3.0mm

4.4 Rechargeable Battery

- Hawker Cyclone sealed lead rechargeable battery

Voltage	2.5 V
Capacity	5 Ah
Internal Resistance (fully charged at 25°C)	3.5 milliohms
Short Circuit Current (I_{sc})	570 A
Cycle Life	700 at 60% Depth of Discharge
	5000 at 10% Depth of Discharge
Operating Temperature Range	-65°C to +80°C
Dimensions (Height x Diameter)	73mm x 45mm

- Complete datasheet available at http://www.easysen.com/support/Datasheets/Hawker_Cyclone_battery_2.5V_5A.pdf

5. General Information

5.1 Document History

Revision	Date	Notes
1.0	02/17/2009	Initial Release

5.2 Disclaimer

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