EH01

Solar Energy Harvesting IC with 5V output power port and Li-Ion Battery Charger Circuit

Features

- Complete all-in-one management of energy-harvesting process
- Works with both solar panels or conventional wall adapters
- Regulated 5V output power port withstanding currents up to 1.2A (see 1.2A Solar/Wall USB Charger application);
- Operation mode consumption below 5mW
- Total conversion efficiency above 90%
- Stand-by consumption less than 500µW
- Battery Monitoring via Led or Serial Interface

Applications

- Solar Battery Chargers
- Mobile devices powered by solar energy
- Solar powered wireless sensor nodes

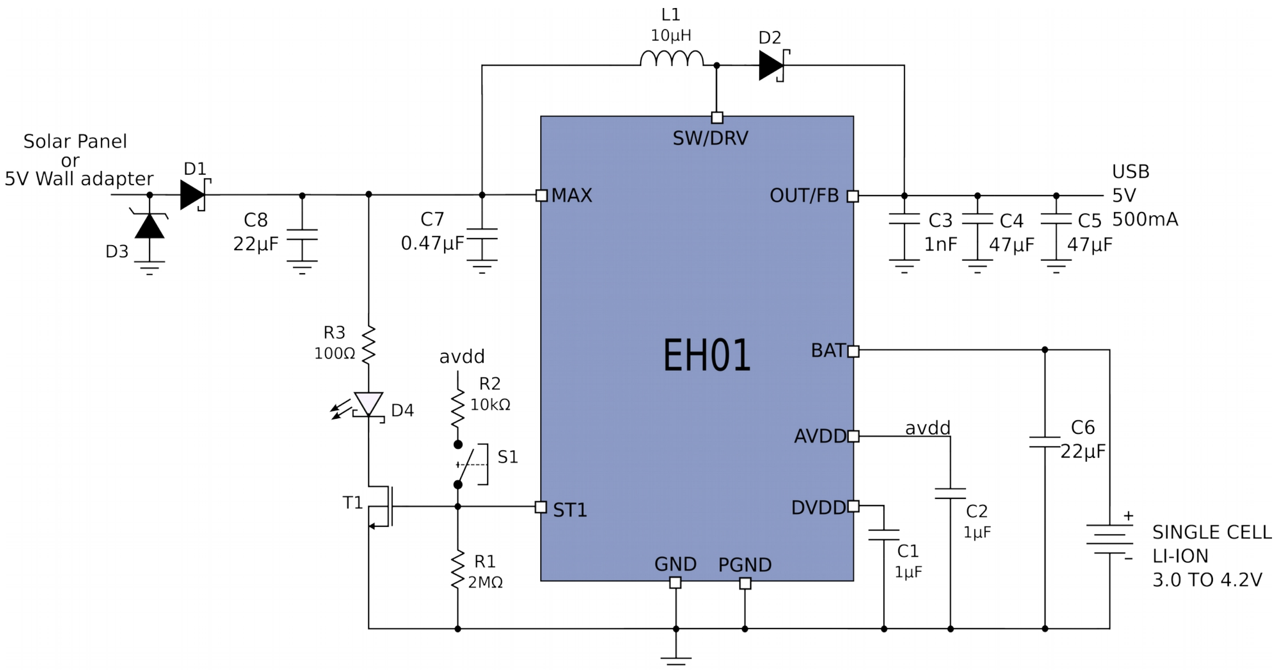
Description

The EH01 is a complete power management solution for a variety of energy-harvesting applications, providing a small and simple solution combining power from different sources: a DC wall adapter, photovoltaic cells and a Li-Ion battery. This device enables a simple implementation of a 5V supply, like a USB charger compatible with the ITU standard for the Universal Charging Solution (L.1000).

Using a high efficiency DC/DC converter the EH01 converts the voltage from the panel to a stable 5V output. In addition a Li-Ion Battery Charger (with numerous protection features) stores the excess energy from the panel in an external battery. This battery then complements the energy to the DC/DC converter when needed.

The EH01 also provides an interface for battery status monitoring. This can be done via a simple button making a LED pulse or via a microcontroller based serial communication.

Typical Application



Absolute Maximum Ratings

Parameter	Range
MAX, SW/DRV, OUT/FB and BAT Voltages	-0.3V to 7V
AVDD and DVDD	-0.3V to 2V
Junction Temperature	+125°C
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-65°C to +125°C

Electrical Characteristics

Parameter	Min	Typ	Max	Units
MAX voltage	3.6	5	5.5	V
MAX pin current			1.2	A
Battery regulated voltage	4.1	4.2	4.25	V
Battery voltage	3	3.7	4.24	V
Fast Charge Current Limit	400	500	600	mA
Slow Charge Current Limit	100	150	200	mA
Slow/Fast charge Threshold	3.4	3.5	3.6	V
End of Charge Trigger	4.05	4.1	4.15	V
End of Charge Trigger Hysteresis	50	100	150	mV
End of Charge Current	10	50	100	mA
End of charge Timeout	100	120	140	min
Under-Voltage Lockout Voltage	2.9	3.0	3.15	V
Under-Voltage Lockout Voltage Hysteresis	400	500	600	mV
Discharge current			1.2	A
BAT Pin Quiescent Current Shutdown		70		µA
OUT/FB Pin regulated Voltage	4.75	5	5.25	V
OUT/FB Pin Ripple Voltage		2		%
OUT/FB Pin Current			500	mA
Output Enable Trigger[1]	3.4	3.5	3.6	V
Inductor peak current			1.2	A
NMOS Switch resistance	250	300	350	mΩ
NMOS Switch DC current			1	A
PMOS Switch resistance	250	300	350	mΩ
PMOS Switch DC current			1	A
Maximum Duty Cycle		50	60	%
Minimum Duty Cycle	15	16		%
Switching frequency	0.8	1	1.1	MHz

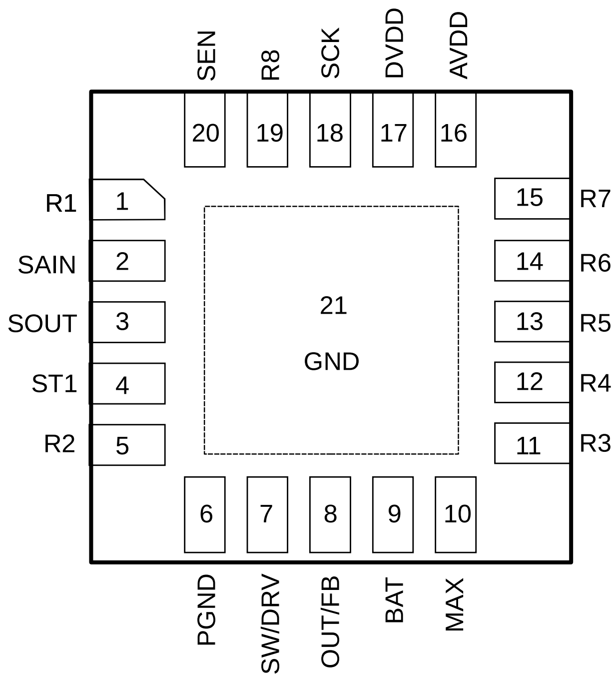
1. The Output Enable Trigger activates the output regulation feature of the system. However, it does not monitor the OUT/FB pin, but the BAT pin instead.

Pin Functions

Pin	Function	Notes and Additional Requirements
R1	Reserved	**Tie to ground**
SAIN	Serial Address In	Serial Address In, tie to ground if not used.
SOUT	Serial Out	Serial Out, leave unconnected if not used.
ST1	Battery level indicator	Connect to an SPST push-button (without retention) and then to the gate of an NMOS transistor between the LED negative terminal and the circuit ground, see typical application schematic.
R2	Non-connected	**Leave unconnected**
PGND	Power ground	Connect to PCB ground plane.
SW/DRV	Switching node / Low side driver	Connect 10µH inductor between this pin and MAX pin.
OUT/FB	5V regulated output / Feedback signal line	This pin is current limited at 500mA and its behavior is compliant with the Micro-USB Charging Port. Above this current voltage will drop below 5V.
BAT	Battery pin	Connect a 4.2 Li-Ion battery at this pin.
MAX	Solar Cell or Wall adapter input	Connect a 22µF capacitor from this pin to ground as close to EH01 as possible.
R3	Non-connected	**Leave Unconnected**
R4	Reserved	**Tie to ground**
R5	Non-connected	**Leave Unconnected**
R6	Reserved	**Tie to ground**
R7	Reserved	**Tie to ground**
AVDD	Analog Power Voltage	Used to compensate internal LDO. Connect an external compensation capacitor (≈1 µF). This is not a power supply pin.
DVDD	Digital Power Voltage	Used to compensate internal LDO. Connect an external compensation capacitor (≈1 µF). This is not a power supply pin.
SCK	Serial Clock	Serial Interface Clock, tie to ground if not used
SEN	Serial Enable	Serial Interface Enable, tie to ground if not used. Must be low when powering up the device.
R8	Reserved	**Tie to ground**
GND	Ground pin	**Connect to PCB ground plane.**

Pin Configuration

Number	Name	Description	Type	Direction	Max. Voltage	Max. Current
1	R1	Reserved, tie to ground				
2	SAIN	Serial Address In	Digital	I	5V	
3	SOUT	Serial Out	Digital	O	5V.	
4	ST1	Status output	Signal	O	5V	200µA
5	R2	Non-connected pin				
6	PGND	Power ground to Output DC DC Boost Converter	Power	–	0V	–
7	SW/DRV	Output Boost DC DC Converter switching node	Power	–	5V	1.2A
8	OUT/FB	USB power output for charging external devices and feedback line	Power	O	5V	500mA
9	BAT	Battery connection pin	Power	I/O	4.2V	1.2A
10	MAX	Central node connection pin	Power	I/O	5V	1.2A
11	R3	Non-connected pin				
12	R4	Reserved, tie to ground				
13	R5	Non-connected pin				
14	R6	Reserved, tie to ground				
15	R7	Reserved, tie to ground				
16	AVDD	1.8 V analog internal voltage source	Power	O	1.8V	
17	DVDD	1.8 V digital internal voltage source	Power	O	1.8V	
18	SCK	Serial Interface Clock	Digital	I	5V	
19	R8	Reserved, tie to ground				
20	SEN	Serial Interface Enabled (keep low when not using)	Digital	I	5V	
21	GND	Analog and digital ground. Also used as thermal pad.	Signal	–	0V	–



Principle of Operation

The EH01 is a complete solution for power management of energy-harvesting systems that require an internal battery and a regulated output voltage. It provides one DC/DC converter, a fully-featured Battery Management circuit, and a regulated USB charger output. The system also has a battery monitoring mechanism via a status pin that indicates the battery charge level.

The design can be divided into two major blocks: the battery-charger and the output switcher. The two blocks are powered by a single main power line (MAX), which can be connected to a wall adapter or a Photo-voltaic Cell (PV). In addition the device has protection circuits and battery monitoring features. The following sections describe the device's operation to illustrate its behavior under different scenarios.

Features

The design possesses numerous protection circuits, such as:

- » Under-Voltage Lock-Out: disables the whole system if MAX pin voltage is under 2.3V;
- » Peak inductor current limit control: it senses NMOS current and limit it's peak to 1.2A;
- » Battery over charge protection I: it prevents battery overcharge by interrupting the energy transfer if charge current goes bellow 100mA.
- » Battery over charge protection II: it prevents battery overcharge by interrupting the energy transfer two hours after battery voltage have reached 4.1V level.
- » Battery deep discharge protection: it prevents battery from being discharged below 3V.

Battery-Management System

This block is responsible to manage both charge and discharge processes. When charging the battery from a wall adapter connected to MAX pin, the energy is transferred from MAX to BAT pin following a two steps constant current phase (CC phase) and a constant voltage phase (CV phase), as depicted in Figure 1.

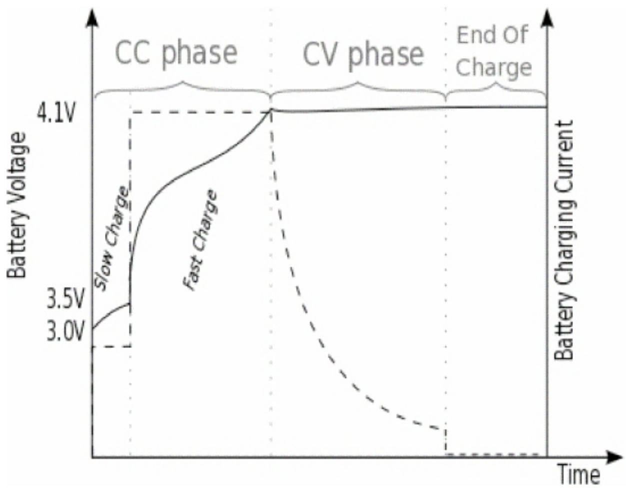


Figure 1: Battery charging profile. Solid line represents battery voltage, while the dashed one depicts battery current during all charge process.

If the battery is deeply discharged (below 3.0V), EH01's battery management system will act as constant current source, providing a slow charge current, between 100mA and 200mA, to BAT pin (first step of CC phase). When battery voltage reaches 3.5V level, the current is increased to the *fast charge current* level (second step of CC phase), between 400mA and 600mA. The system will be held at this state until battery voltage reaches 4.1V, moment in which charging profile is changed from constant current to constant voltage. At this point, EH01 triggers a 2 hours timer counter, regulates BAT pin voltage at 4.2V and monitors charging current behavior (CV phase). Battery end of charge phase is detected by the drop of charging current bellow the 100mA level. In order to prevent over charge conditions the charging process is also interrupted two hours after battery has reached 4.1V. When removing the MAX supply (PV cell or wall-adapter) the EH01 starts to transfer the previously charged battery energy back to MAX pin, which in turns delivers it to a load connected at OUT/FB pin. During the discharging process, battery voltage is allowed to decreases down to the Under-Voltage Lockout level (3.0V), where discharge is interrupted and BAT pin is isolated from MAX pin, preventing battery from being deeply discharged, as depicted in Figure 2. Battery discharge current is defined by the OUT/FB pin attached load, nevertheless EH01 defines an upper discharge current limit (1.2A).

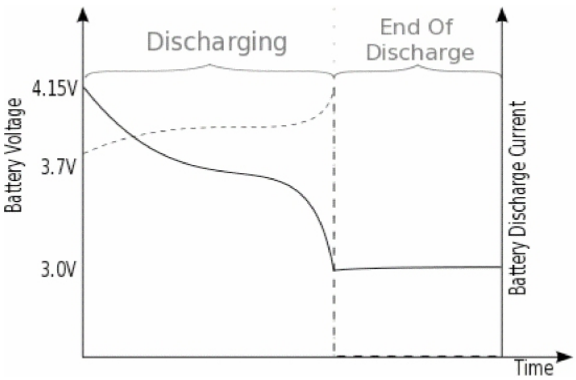


Figure 2: Battery discharging profile when supplying 5 volts to a resistive load attached at OUT/FB pin. Solid line represents the battery voltage, while the dashed one depicts battery current.

Output Converter System

EH01 integrates a monolithic DC/DC boost converter to transfer energy from MAX to OUT/FB pin. When enabled it can keep output voltage regulated at 5V with MAX pin voltage inside the range of 3V to 5V. The converter is enabled/disabled by the battery management system in order to provides an output regulated voltage regardless illumination conditions. So, during battery discharge phase the output converter will be enabled while the battery voltage remains above 3V (fully discharged).

However, if the battery had been fully discharged, output converter will be disabled until the battery has charged up to at least 20% of its total capacity, which is equivalent to 2 blinks of ST1 pin's LED (see STATUS CONTROLLER functional description).

Operating Scenario: Battery-Charging through Photovoltaic cell only

As an example, consider the following situation: no light is hitting the photovoltaic panel, no wall-adapter plugged-in, half-discharged battery and no load at the output. Initially, since the photovoltaic panel has no available energy, the main power line will be held at the battery voltage (minus a small PMOS VT voltage drop). When sunlight starts to hit the photovoltaic cell, the system is enabled and starts to transfer energy from the PV cell to the power line. The voltage at the power line will start to increase and battery charging will take place. Once the battery surpasses its 50% charge capacity, the output converter will be enabled and both functions will take place simultaneously, the OUT/FB pin voltage regulation and the battery charging. In this scenario, the application connected to the OUT/FB pin will have power priority and battery charge progress can decrease depending on available power at PV cell. When the battery is fully charged, it will be disconnected from main power line, allowing the whole PV cell power to be transferred exclusively to OUT/FB pin.

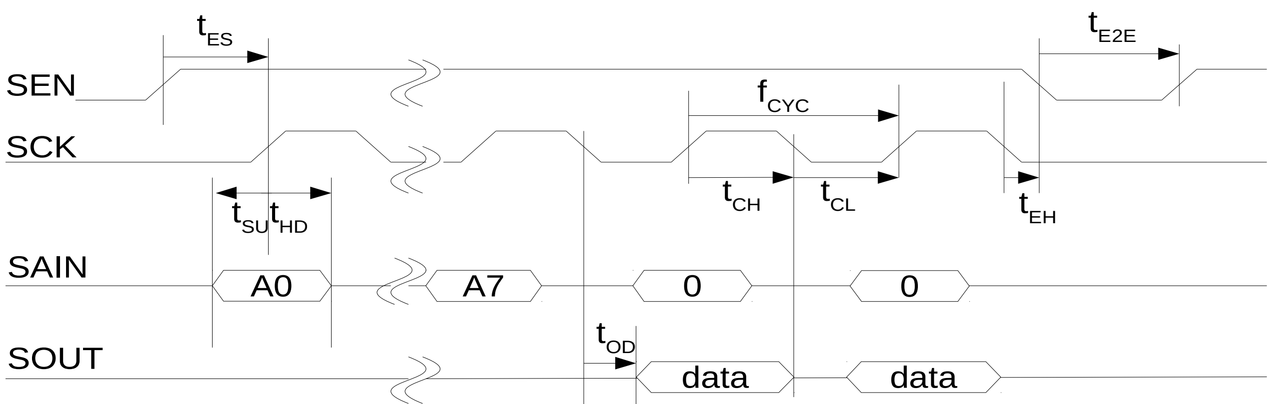


Figure 3: Serial Interface Timing Diagram

Serial Interface

The EH01 comes with a 4 wire serial interface for monitoring the device. It can be used to check the battery level and the charger state. If this interface is not used, the SEN pin should be tied low. Both the clock as well as SEN must be parked low.

Each command begins by raising the SEN pin. Then the 8 bit address must be given, starting with the LSB (A0 in graph). The address on pin SAIN will be sampled on the rising edge of the clock.

Sym	Name	Min	Max	Un
f_{CYC}	Clock Frequency		25	kHz
t_{CL}	Clock High Time	20		µs
t_{CH}	Clock Low Time	20		µs
t_{ES}	Enable Setup Time	10		µs
t_{EH}	Enable Hold Time	4		µs
t_{E2E}	Enable to Enable Time	10		µs
t_{SU}	SAIN Setup Time	5		µs
t_{HD}	SAIN Hold Time	5		µs
t_{OD}	SOUT Delay Time		19	µs

After the 8th address bit is given data is returned on the SOUT pin on the following fall of the clock. The LSB will be returned first followed by the remaining 7 bits, one per cycle. SAIN should be kept low. Clocking out more than 8 bits returns undefined data. After the 8th bit is returned, the interface must be disabled and SEN can only rise again at least t_{E2E} later.

The parameters available are listed in the following table. All other addresses are reserved and should not be accessed as they influence the functionality of the device.

Addr	Value
6Eh	VBAT Level
69h	CHARGER STATUS[15:8]
68h	CHARGER STATUS[7:0]

The VBAT Level is a 8 bit register that reports the battery voltage level following the equation:

$$V_{BAT} = Register_{value} \times 0.03\,V$$

The CHARGER STATUS register contains 16 bits that report the current charger operation.

Bit	NAME	Battery Charger Status Bit
15-9		Reserved
8	EOC	High on end of charge
7	BFAST	When Low Fast Charge Phase
6	DIS	Discharging Battery
5-3		Reserved
2	TIMER	Charger timer running
1	CDB	H = Charging, L = Discharging
0	UVLO	When low indicates battery critically low and disables discharging to prevent damage.

Performance Characteristics

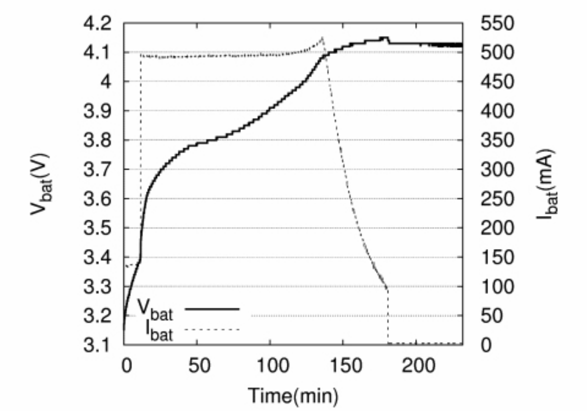


Figure 4: Battery-Charging profile result for a 1250mAh Li-Ion battery.

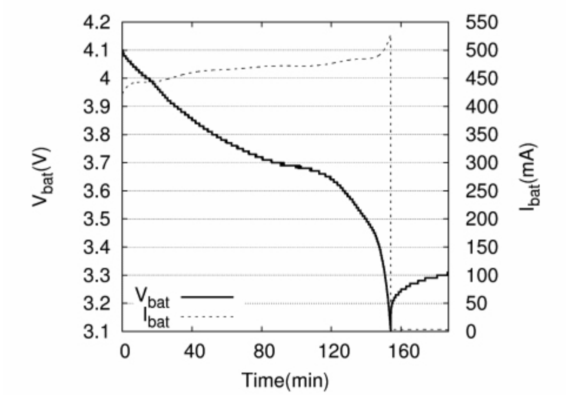


Figure 5: Battery-Discharging profile for a 1250mAh Li-Ion battery using a 16 Ω resistor (5V@312mA) attached to OUT/FB pin.

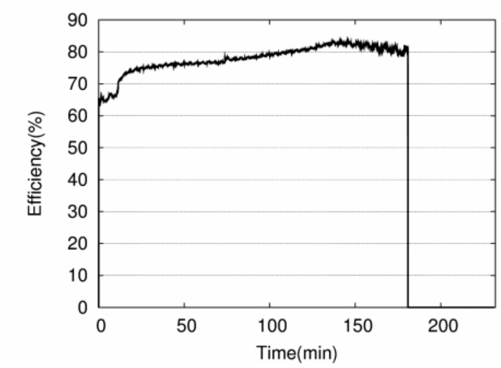


Figure 6: Charging efficiency. From solar panel node (see typical application) to 1250mAh Li-Ion battery.

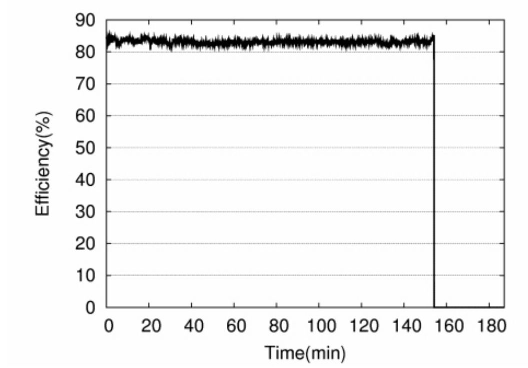


Figure 7: Discharging efficiency. From 1250mAh Li-Ion battery to a 16 Ω resistor (5V@312mA) attached to OUT/FB pin (see typical application).

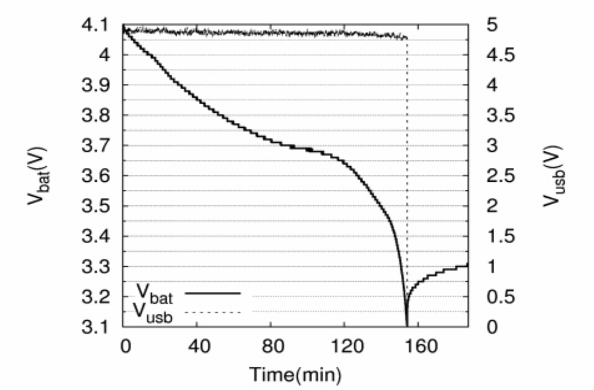


Figure 8: OUT/FB voltage regulation during battery discharge process with 1250mAh Li-Ion battery and 16 ohm resistor (5V@312mA) attached to OUT/FB pin.

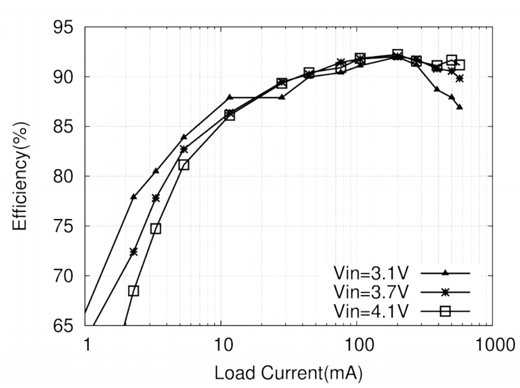


Figure 9: Output converter efficiency versus output current. Results were obtained for output voltage being regulated at 5V.

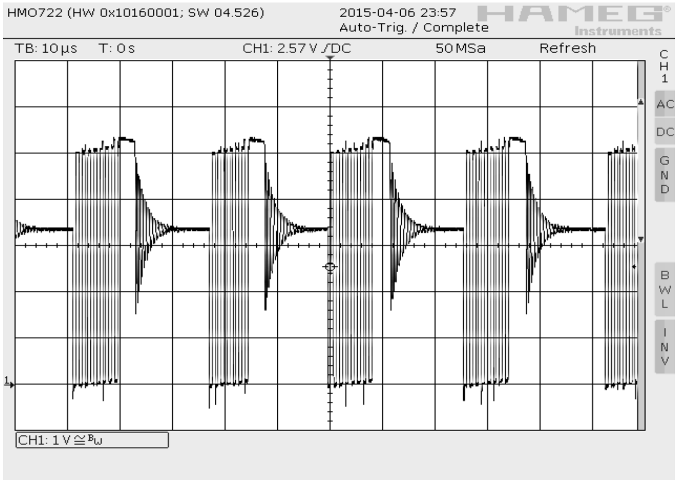


Figure 10: Output converter switching node. BAT pin at 3.5V and 47Ω resistor (5V@106mA) attached to OUT/FB pin (see typical application).

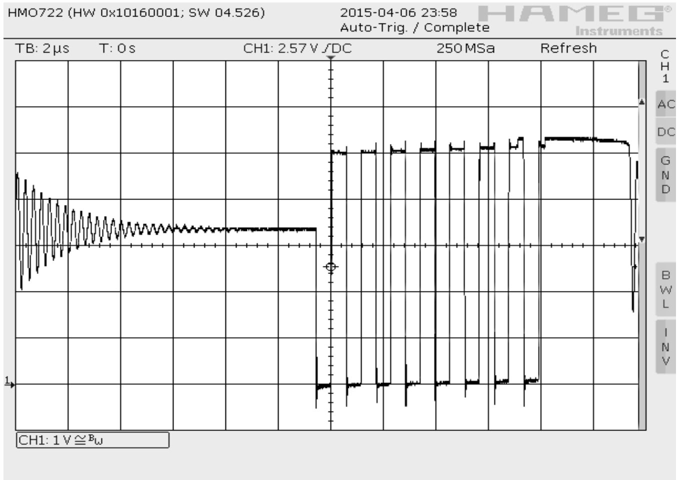


Figure 11:Output converter switching node. BAT pin at 3.5V and 47Ω resistor (5V@106mA) attached to OUT/FB pin (see typical application).

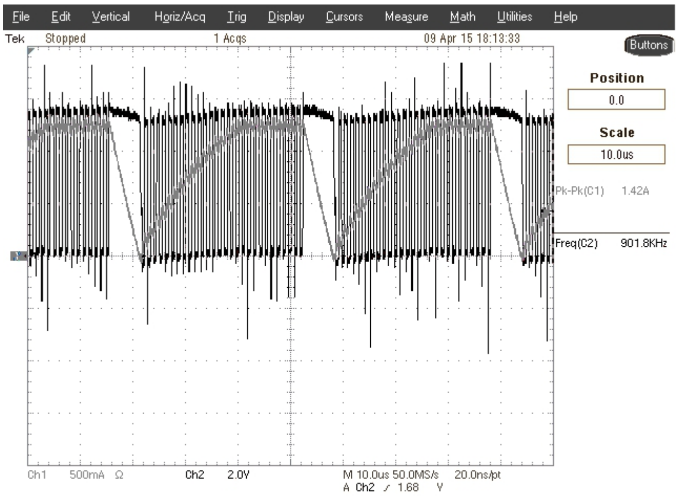


Figure 12: Output converter switching node (red) and inductor current (blue). BAT pin at 3.5V and 10Ω resistor(5V@500mA) attached to OUT/FB pin (see typical application).

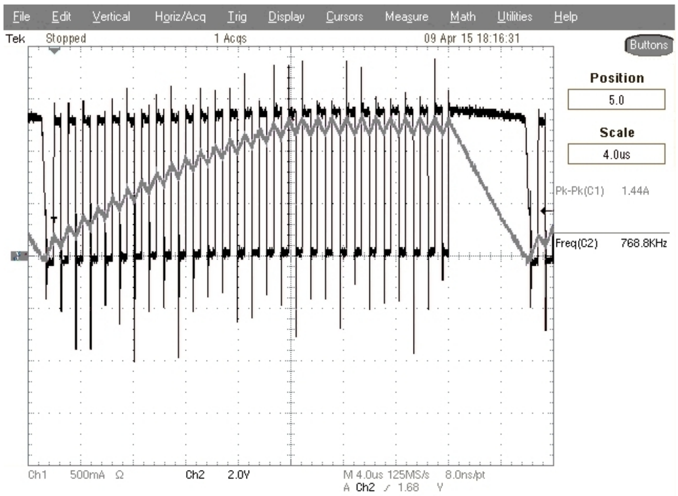
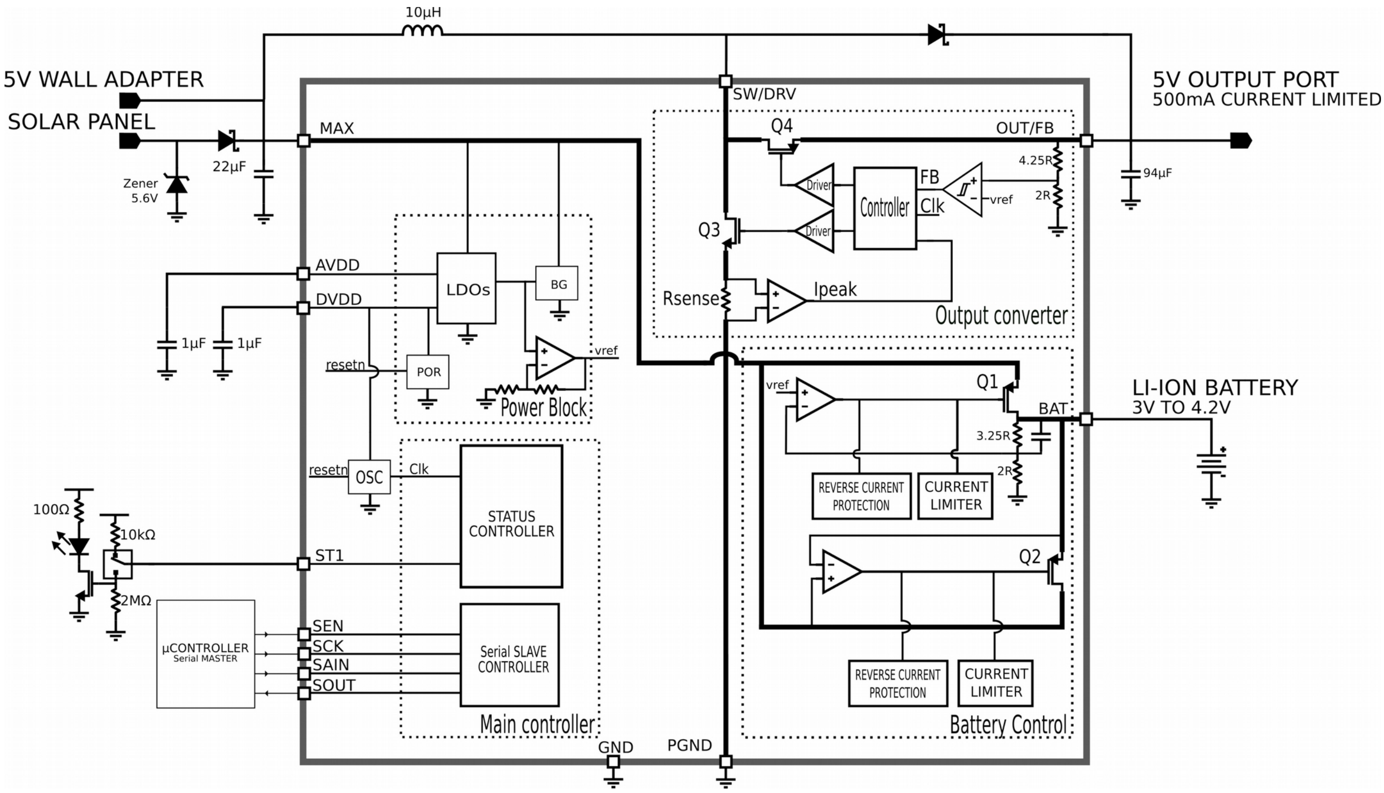


Figure 13:Output converter switching node (red) and inductor current (blue). BAT pin at 3.5V and 10Ω resistor(5V@500mA) attached to OUT/FB pin (see typical application).

Simplified Block Diagram



Functional Description

OUTPUT CONVERTER: is a boost DC/DC converter which operates in pulse skipping mode and implements a peak inductor current limit control. Start-up procedure guarantee that switching operation only occurs when output voltage (OUT/FB pin) is a couple hundreds of mV bellow input voltage level (MAX pin). From then on, the converter will turn boost operation on and toggle internal switches at a constant frequency of 1MHz. At this condition, switches are controlled by a non-overlapping protection circuit that both prevents shoot-through currents from input to ground, and interrupts the inductor charging cycle if an Ipeak detection signal is received from the NMOS current sensor.

Boost operation is turned off when the internal feedback signal, from the resistor divider attached to OUT/FB pin (see above figure), reaches the reference level. In contrast, it will be turned back on when said feedback signal drops 18mV bellow the same reference level. While turned off switching is fully interrupted, thus achieving a better efficiency under light load conditions.

POWER BLOCK: generates a *Power On Reset* signal so that no external reset pin is needed to switch on the device. This block is also responsible for generating multiple internal supplies and references for the design. It is supplied by the main power line, so it can be powered by any of the three input sources.

STATUS CONTROLLER: controls the status output. This pin can be connected to a LED, as shown in the diagram. This pin is also bidirectional: by placing a SPST (Single-Pole Single-Throw) push-button as shown in the diagram, the user can press it and this will trigger a Battery Level readout. The readout will then be sent via the ST1 pin; this one will be pulled-down for 300ms from 1 to 5 times, indicating the percentage of battery energy (see chart). In addition, the table defines a half-blink. This handles very low battery levels and perhaps might never occur in practice. However unlikely, the system will be able to notify the user if the circumstances should arise. In this case ST1 will be pulled down for just 100ms. The pulsing on ST1 will be repeated every second as long as the button is pressed.

# of ST1 pulses	Battery Level
half	very low
1	under 20%
2	under 40%
3	under 60%
4	under 80%
5	over 80%

The battery state of charge is based on battery's voltage readings. So, readouts can be affected whenever battery is being charged or discharged. Therefore, battery status reading should not be considered at these above mentioned conditions.

BATTERY CONTROL: used in EH01 Li-Ion battery charging and discharging control system. When charging, it will apply a constant current until a voltage threshold is reached, where it then switches to a constant-voltage mode. Once the battery is fully charged, it is automatically disconnected from the main power line. In case there is no other supply driving the system, the battery will be used to power the main power line and then the output USB port.

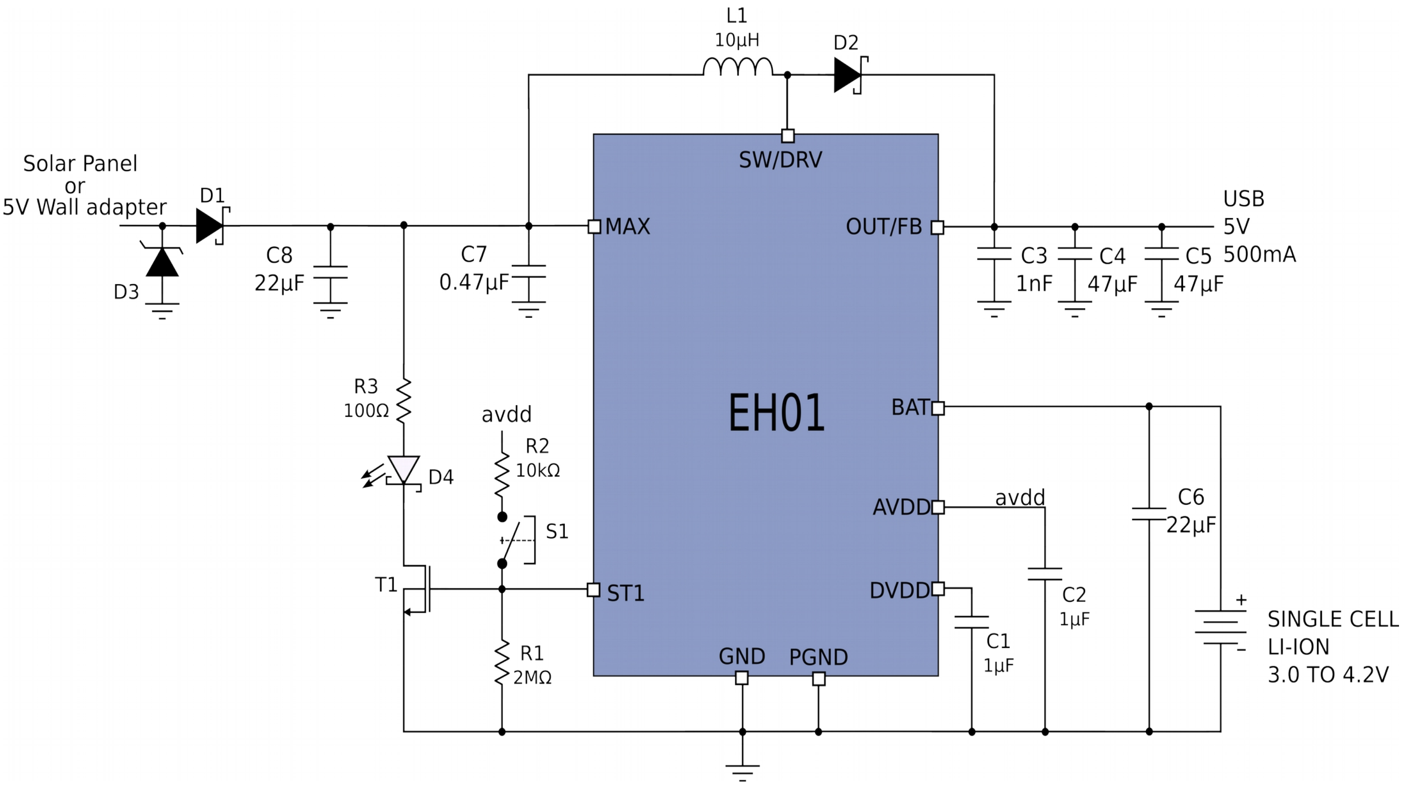
REVERSE CURRENT PROTECTION: prevents current to return from the battery when voltage input is lower than battery voltage and the battery is in charging mode. It also prevents current from going to the battery while it is in discharge mode (powering the system).

CURRENT LIMITER: limits the maximum current either to charge or discharge the battery. It operates in two modes: low charge and fast charge. In low charge mode, battery voltage is lower than 3.5V. In this region it should not be charged so that risk of damage is avoided. In fast charge mode, battery voltage is greater than 3.5V. Thus, it can be charged with a higher current without damaging the battery.

CLOCK AND RESET: generates the internal clock and reset signals so that no external crystal or oscillator is needed. An internal clock divider also produces (slower) lower frequencies where possible to save power.

Application Information

500mA Solar/Wall USB Battery Charger



The following external components are recommended for maximum performance and efficiency.

#	Part	Manufacturer Part Number	Description	Vendor
1	L1	SRN6045-100M	10µH inductor 2.5A 58 mΩ smd	Bourns
2	C1 and C2	C1206C105M4RACTU	1µF ceramic cap 16V X7R 1206	Kemet
3	C3	12065A102JAT2A	1nF ceramic cap 50V C0G 1206	AVX
4	C4 and C5	C1206C476M8PACTU	47µF ceramic cap 10V X5R 1206	Kemet
5	C7	MC1206B474K160CT	0.47µF ceramic cap 10V X7R 1206	Multicomp
6	C6 and C8	EMK316BBJ226MLHT	22µF ceramic cap 16V X5R 1206	Taiyo Yuden
7	R1	ERJ-8GEYJ205V	2MΩ resistor, 5%, 1/4W 1206	Panasonic
8	R2	LTR18EZPJ103	10kΩ resistor, 5%, 1/4W 1206	Rohm Semiconductor
9	R3	LTR18EZPJ101	100Ω resistor, 5%, 1/8W 1206	Rohm Semiconductor
10	D1 and D2	B340A-13-F	Schottky Diode 3A 40V DO214AC	Vishay Semiconductor
11	D3	3SMAJ5919B-TP	5.6V zener diode 3W DO214AC	Micro Commercial
12	D4	SML-LX1206GC-TR	Led 565nm wtr green 1206 smd	Lumex-Opto
13	S1	MJTP1230	Switch tactile spst-no 0.05A 12V	Apem
14	T1	NTR4003NT1G	MOSFET N-CH 30V 500mA sot-23	ON Semiconductor

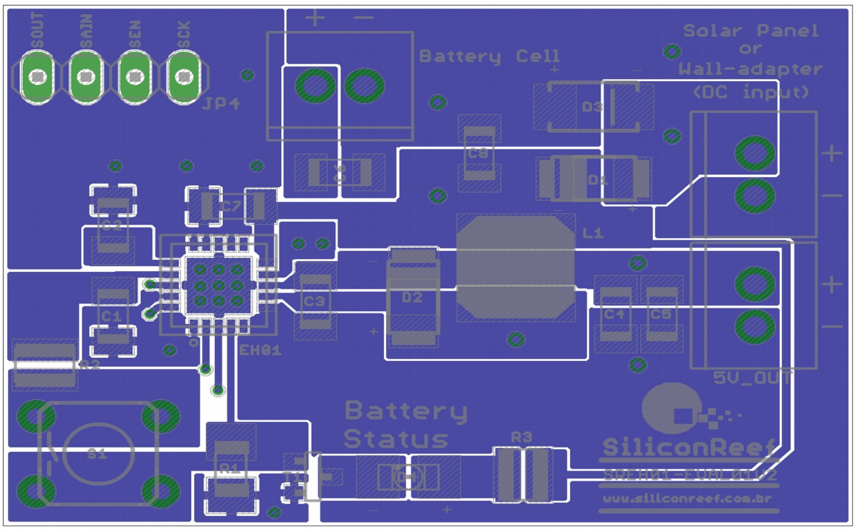


Figure 14:Typical application Top layer.

PCB Layout recommendations and Component Selection

Printed circuit board layout is a critical process for switching circuit applications. Due to the inherent current-loop variations associated with inductor charge and discharge phases, voltages variations on ground path/plane (ground-bounce) may occur causing system operation malfunction. In order to avoid these problems, caution must be taken during passive components placement, such as output capacitor, compensation capacitors, rectify diode, power inductor and filter capacitors.

For typical boost converters, output capacitor placement is one of most important and should be placed going from rectify diode's cathode to the bottom of low side switch in order to reduce the change in the loop area, thus reducing ground-bounce. The EH01 has an internal synchronous PMOS switch (acting as the rectify diode), NMOS switch (low side switch) and internal feedback loop (directly connected to OUT/FB pin), so output high frequencies capacitor should be placed between OUT/FB and PGND pins, and, as close to EH01 IC as possible, using wide, short and at same layer traces, like capacitor C3 on Figure 14. This capacitor is the critical one and should possesses high quality dielectric material such as C0G/NP0.

The suggested value for total output capacitance is around 100uF, and the recommended type of capacitor is ceramic, with X7R and X5R dielectric material. This capacitance can be conformed by one or several capacitors, as is the case of the suggested PCB layout, since ceramic capacitors of high capacitance are expensive and hard to find. However, if another type of capacitor were chosen, make sure it possesses low ESR (<60mΩ). Furthermore, the capacitors should be able to withstand at least twice the value of the output voltage. Higher capacitance values will work as well and will provide better filtering and higher ripple attenuation.

Similar recommendations are given for the power inductor. It should be placed as close as possible to the IC and its traces should be kept short, direct and wide. The suggested device is a 10μH shielded inductor with low ESR (<60mΩ), which has proven to yield the best switching node stability to output voltage ripple tradeoff performance. Moreover, its saturation current must be higher than the peak current it will experiment during operation. Finally, the resonance frequency of the inductor should be at least one decade higher than the switching frequency (>10MHz).

Likewise, the same directives are given for the power diode. It should be placed as close as possible to the switching nodes and routed with wide, short and direct traces. The power diode should have low forward bias voltage and fast recovery time, hence the suggested component is a schottky diode. The diode should be able to withstand the peak current of the system during operation and a reversed bias voltage higher than the output voltage (>5V).

Besides power components placement recommendations, filtering capacitors near sensitive nodes, like BAT and MAX also requires close proximity with EH01 in order to better attenuate noise and spikes from switching converter. LDO's compensation capacitors at AVDD and DVDD pins should follow the same recommendation as well.

EH01's pin 21 has a double function of GND electrical contact and thermal PAD. So, to improve thermal dissipation, use ground planes at top and bottom layers and connect them, as depicted by PCB Layout recommendations figures.

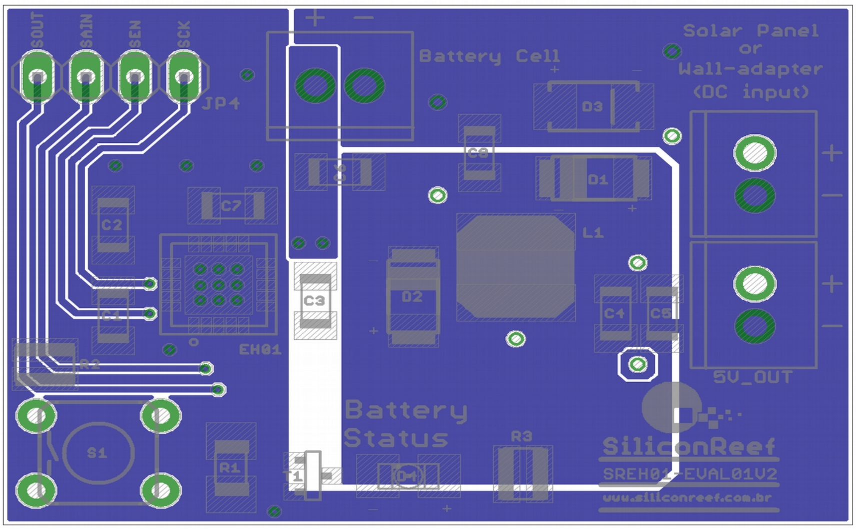
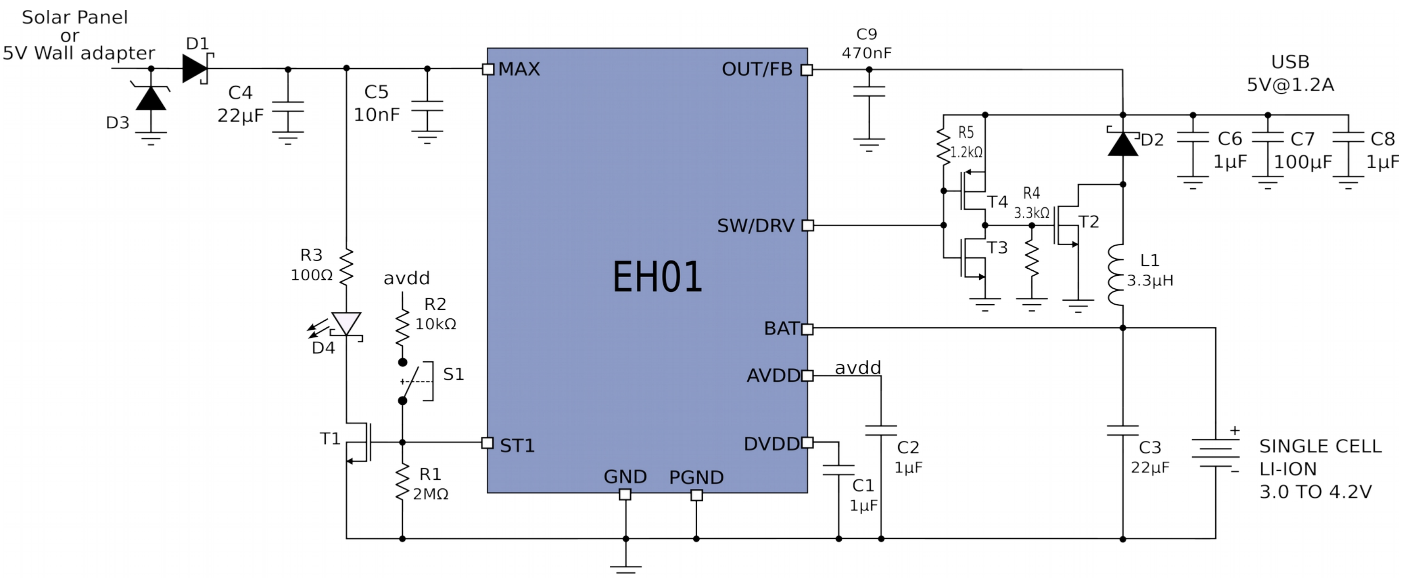


Figure 15: Typical application Bottom layer.

1.2A Solar/Wall USB Charger

This sample application is for a 1.2A charger, but can also be adapted to higher current levels by replacing the external components: L1, T2, D2, C6, C7 and C8. In this application the EH01 drives an external power transistor to regulate the output voltage.

It is important to note that in this case the battery is connected directly to the converter input. in this application the battery is directly connected to the DC/DC converter's input, so that more current can be supplied. This bypasses the internal battery discharge limit. In this application the board can provide up to 1.2A at 5V.



The following components are recommended for maximum performance and efficiency.

#	Part	Manufacturer Part Number	Description	Vendor
1	L1	SDR1307-3R3ML	3.3µH inductor 7.5A 8.7mΩ smd	Bourns
2	C1, C2, C6 and C8	C3216X5R1H105K160AA	1µF ceramic cap 50V X5R 1206	TDK
3	C3 and C4	EMK316BBJ226MLHT	22µF ceramic cap 16V X5R 1206	TDK
4	C5	1206YC103KAT2A	10nF ceramic cap 16V X7R 1206	AVX
5	C7	T520D107M010ATE055	100µF tantalum cap 10V 2917	Kemet
3	C9	MC1206B474K160CT	0.47µF ceramic cap 10V X7R 1206	Multicomp
4	D1 and D2	B340A-13-F	Diode Schottky 40V 3A DO214-AC	Diodes Inc.
5	D3	3SMAJ5919B-TP	5.6V zener diode 3W DO214AC	Micro Commercial
6	D4	LTST-S115KGJRKT	Led 565nm wtr green 1206 smd	Lumex-Opto
7	R1	ERJ-8GEYJ205V	2MΩ resistor, 5%, 1/4W 1206	Panasonic
8	R2	LTR18EZPJ103	10kΩ resistor, 5%, 1/4W 1206	Rohm Semiconductor
9	R3	MC0063W06031100R	100Ω resistor, 1%, 63mW 0603	Multicomp
10	R4	MCR01MRTF3301	3.3kΩ resistor, 5%, 63mW 0402	Rohm Semiconductor
11	R5	MCR01MRTJ122	1.2kΩ resistor, 5%, 63mW 0402	Rohm Semiconductor
12	S1	MJTP1230	Switch tactile spst-no 0.05A 12V	Apem
13	T1 and T3	NTR4003NT1G	MOSFET N-CH 30V 500mA sot-23	ON Semiconductor
14	T2	SI2312BDS-T1-E3	MOSFET N-CH 20V 3.9A sot-23	Vishay Semiconductor
15	T4	NTR0202PLT1G	MOSFET P-CH -20V 400mA sot-23	ON Semiconductor

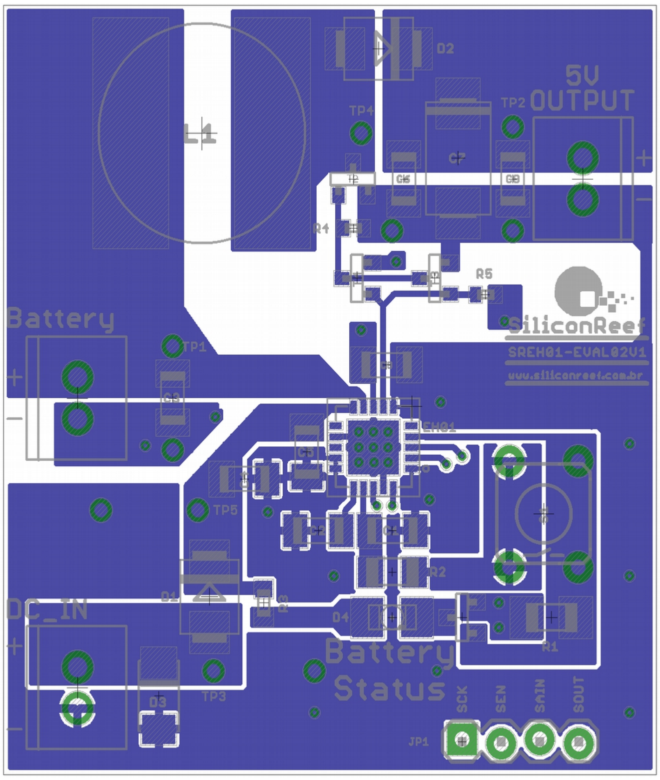


Figure 16: High output current application top view. 43mm x 47mm

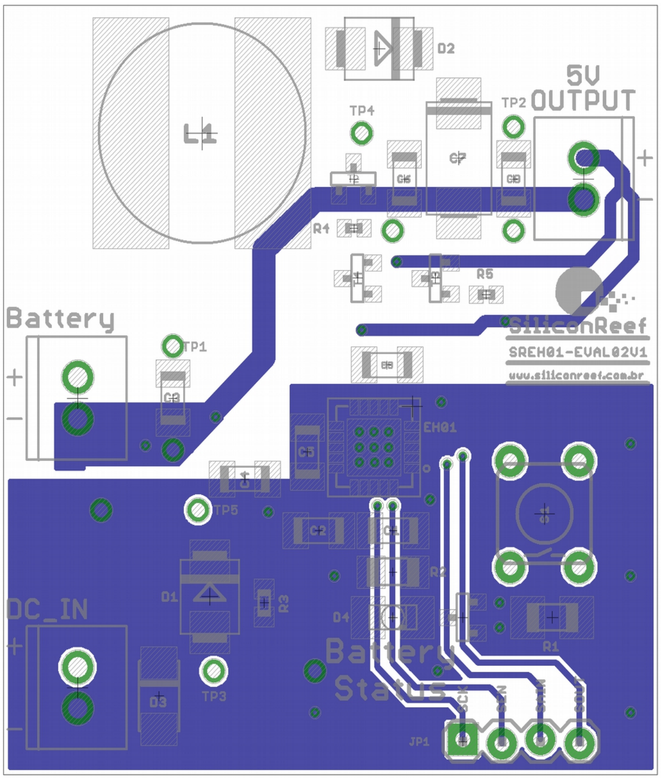


Figure 17: High output current application bottom view.

Special considerations for high current applications

For 500mA applications, the EH01 monitors the discharge process to extend the battery life. This protection includes making sure the battery never goes below 3V and never gets drained faster than 1.2A[2]. On applications over 500mA we bypass the over discharge protection. Therefore special considerations apply:

- The maximum discharge current for the battery is based on the output load condition and the converter efficiency. To calculate the maximum discharge current then we need to consider the worst case. So the battery voltage (V_{BAT}) should be at 3V and the efficiency should be at 90%.

2 This 1.2A refers to the discharge current for the battery, not the circuit's output current.

We then multiply this level to take in account the 90% efficiency but also to give a small extra margin. Then we use the equation:

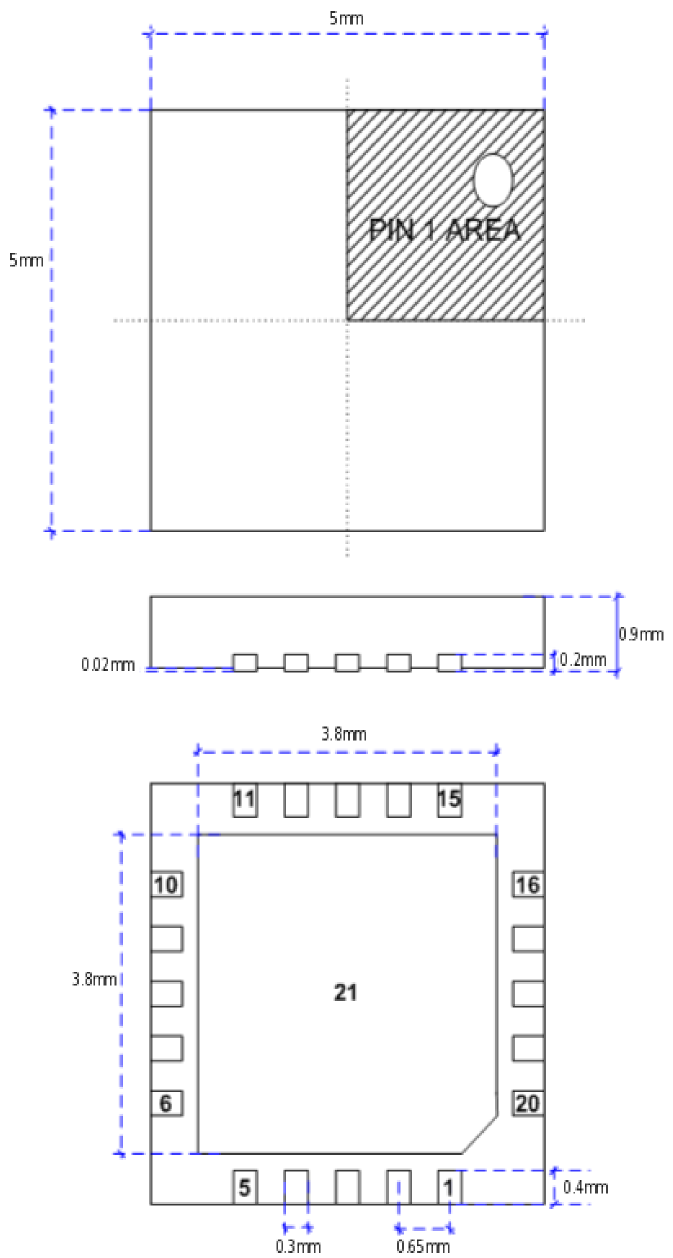
$$I_{DISCH}=\frac{V_O \cdot I_O}{0.85 \cdot V_{BAT}}$$

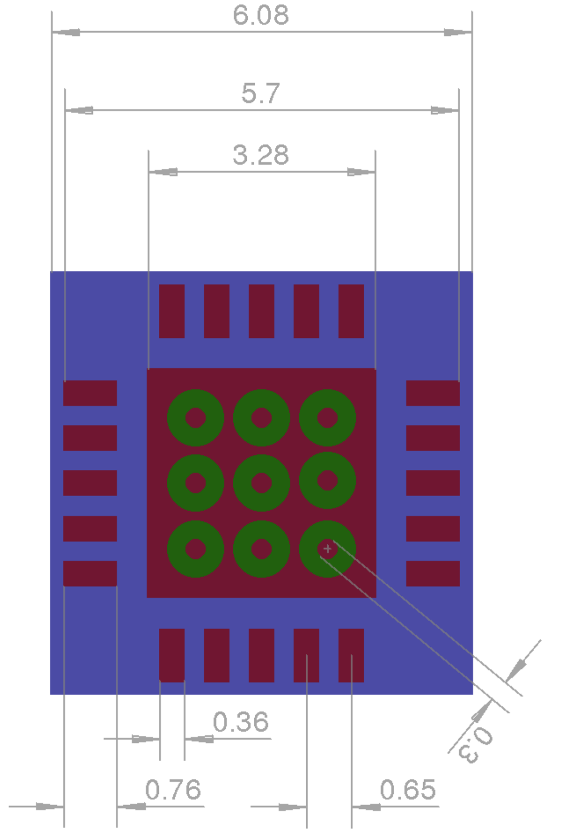
E.g.: the output voltage (V_O) is regulated to 5V and considering the battery at the lowest level of 3V, and if the output load consumes up to 1.2A, the battery discharge current (I_{DISCH}) will reach approximately 2.5A. Therefore, in this particular case, the battery should have a capacity of at least 2500mAh, so that the battery will be discharged at a rate always bellow 1C and extend its lifetime;

- The DC/DC controller uses a fixed 50% duty cycle and regulates the output voltage through pulse skipping modulation. Although the average input current can reach approximately 2.5A, external inductor L1, transistor T2 and diode D2 can have current peaks up to tree times higher. Therefore these components must be capable of withstanding this.
- When the battery voltage drops below 3.0V the DC/DC converter will be disabled making the output voltage drop to the battery voltage level. If one is using a passive load, such as resistors, the battery will continue being drained even though the level is below the voltage limit. Therefore, for high current applications, it is recommended the use of activate loads, which recognize when voltage is outside regulated limits and interrupt the power consumption.

Package Description

QFN-20 5x5mm (JEDEC MO-220-VHHC-2) – Quad Flat No-leads package with 20 pins[3]





Recommended solder pad pitch and dimensions. Bottom layer (blue), top layer (red) and vias (green).

3 Dimensions in millimeters