⊜Silvertel

Ag105

Miniature Lithium-ion Charge Controller with Solar MPPT

Features

➢ Solar panel or fixed DC source charge controller for lithium-ion battery packs

➢ Maximum Power Point Tracking (MPPT)

➢ JEITA Compatible lithium-ion battery charger

➢ Integrated Buck-Boost converter

➢ Adjustable charge voltage and current

➢ Fully integrated module, minimal external components

➢ Wide DC input voltage range

➢ I^{2}C interface

➢ High Efficiency

➢ Low heat output

➢ Overload, short-circuit, and thermal protection

➢ Silvertel "design-in" assistance

Description

The Ag105 is a solar charge controller for protected Lithium-ion (Li-ion) and Lithium Polymer (Li-Po) batteries that can also be used with a fixed DC supply in standalone applications. The module design means that very few supporting components are required to configure the charger to any application.

With a wide operating input range of 11V$_{DC}$ to 36V$_{DC}$ and using intelligent charging techniques, such as maximum power point tracking (MPPT), the Ag105 will adjust the charge rate to optimise the power produced by a solar panel.

The Ag105 can be configured for 1, 2 or 3 series cell Li-ion batteries, with 4 voltage-per-cell options to balance servicable battery lifetime and usable capacity.

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1 Product Overview

1.1 Ag105 Product Selector

Part Number[1]	Input Voltage	Battery Capacity	Marking	Package	Marking[2]
Ag105	11-36V	0.5-12Ah	Ag105	DIL	aaa

Note 1: Complies with the European Directive 2011/65/EU for the Restriction of use of certain Hazardous Substances (RoHS) including Directive 2015/863 published in 2015, amending Annex II of Directive 2011/65/EU. Moisture Sensitive Level 1 and HBM 1.

Note 2: The first two letters are the date code, and the final letter is a Silvertel reference.

Table 1: Ordering Information
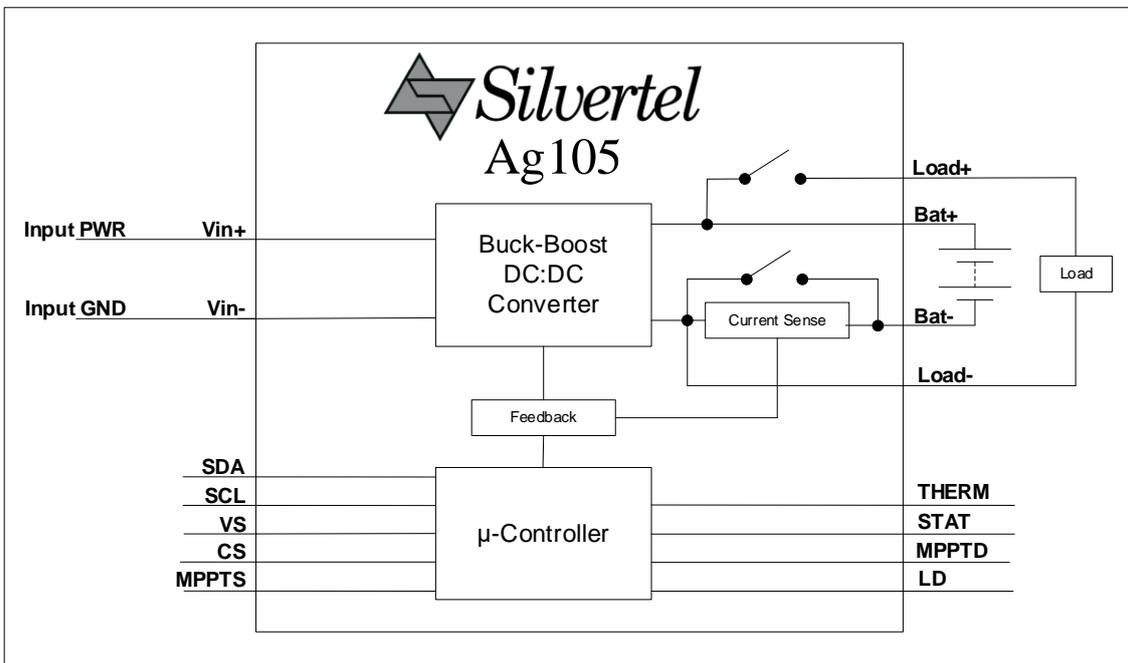
Figure 1: Block Diagram

1.2 Package Format

Figure 2: Ag105 Package Format

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1.3 Pin Description

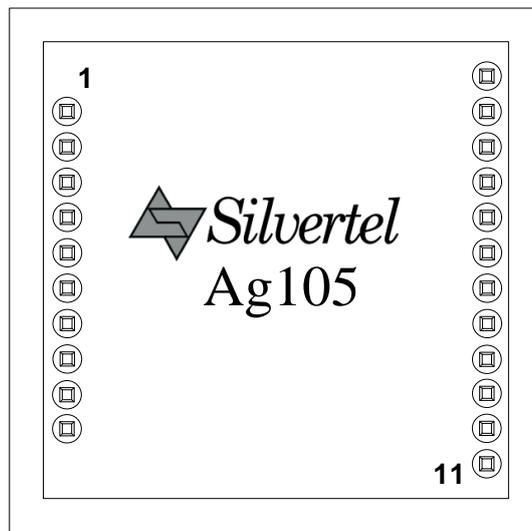| Pin #	Name	Description
1	VS	**Cell Charge Voltage Select**. This pin connects to an external resistor to set the charge voltage.
2	CS	**Charge Current Select**. This pin connects to an external resistor to set the charge current.
3	STAT	**Charge Status (Output).** This output pin is used to indicate the system status.
4	V_{in}-	**Negative Supply (Input).** This pin connects to the negative DC supply (11V to 36V).
5	IC	**Internal Connection.** Do not connect to this pin.
6	IC	**Internal Connection.** Do not connect to this pin.
7	SCL	**Serial Clock Input** This high impedance input pin connects to the I^{2}C bus clock.
8	SDA	**Serial Data Analogue Input** This high impedance input pin is used in conjunction with the SCL pin to for the I^{2}C bus.
9	IC	**Internal Connection.** Do not connect to this pin.
10	V_{in}+	**Positive Supply (Input).** This pin connects to the positive DC supply (11V to 36V).
11	MPPTD	**MPPT Disable.** Pull this pin to V_{in}- to disable MPPT
12	MPPTS	**MPPT Voltage Select**. This pin connects to an external resistor to set the threshold voltage for the max power point tracking.
13	THERM	**Thermistor (Input).** This pin can be connected to an external thermistor to enable JIETA temperature profile (if required).
14	V_{Bat}-	**Battery Negative (Output).** This output pin connects to the battery negative terminal. Must NOT be connected directly to the GND pin.
15		
16	V_{Load}-	**Load Negative (Output).** This Load output pin connects the battery negative terminal to the users load. Internally connected to V_{in}-.
17		
18	V_{Bat}+	**Battery Positive (Output).** This output pin connects to the battery positive terminal.
19		
20	LD	**Load Disable.** Pull this pin to V_{in}- to disable the load output.
21	V_{Load}+	**Load Positive (Output).** This Load output pin connects the battery positive terminal to the users load.
22		

Table 2: Pin Description

2 Functional Description

2.1 Operation

The Ag105 has a two stage charging process. The first stage is constant current mode, set by either the CS Pin or I^{2}C; see section 2.6: Charge Current for more details. This will continue until the cell voltage reaches the configured charge voltage, set by either the VS pin or I^{2}C; see section 2.5: Charge Voltage for more details. After which the Ag105 will switch to the second stage, constant voltage mode, where the charging continues as the current draw by the battery decays. When the current draw has reduced to 10% of the constant current configured for the first stage, the charging is ceased and the battery is flagged as fully charged.

Once a Cell is flagged as fully charged the Ag105 will not attempt to charge the battery again until the battery voltage has reduced to lower than 0.2V/cell of the configured charge voltage.

There is an additional third stage, "Pre-Charge"; this is for over discharged batteries. If the battery voltage is less than 2.7V per cell when charging commences, the "Pre-Charge" profile will be applied. This profile is calculated to be 10% of the configured constant current, this will continue until the cell voltage exceeds 3.0V per cell or a fixed 30 minute timer has elapsed.
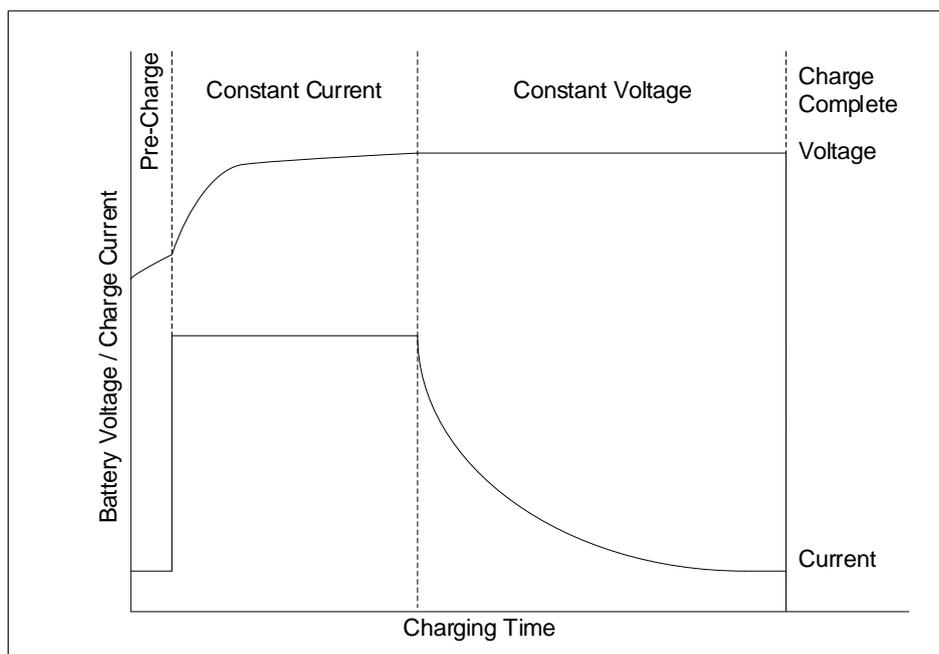
Figure 3: Basic Ag105 Charge Profile

2.2 **Battery Detection**

The Ag105 measures the battery voltage to detect the presence of a battery. If the battery presents 0V it performs a "Bring-Up" Charge, in which the output is gradually ramped while the Ag105 monitors the current draw and voltage across the battery output.

- If there is no current draw during the "Bring-Up" Charge, the Ag105 will trigger a battery disconnect status, and repeat the detection cycle.

- If the battery voltage is below 2V while 10% of the charge current is drawn, the Ag105 will trigger the Major Battery Fault status.

- If the battery voltage is below 2.7V/cell while 10% of the charge current is drawn, the Ag105 will trigger enter "Pre-Charge", this will provide the battery with 10% of the set charge current until either a 30 minute fixed timer has elapsed, triggering the Major Battery Fault status, or the battery has reached 3.0V/Cell, at which the Ag105 will continue to charge the battery as per the configured settings.

- If the voltage across the battery is above 2.7V/cell when the current draw reaches 10% of the charge current setting, the Ag105 will continue to charge the battery as per the configured settings.

- If the battery voltage reaches within 0.2V/cell of the configured charge voltage, the Ag105 will trigger a battery fully charged status.

While in a status that prevents charging, the Ag105 will continue to measure the battery voltage or perform the "Bring-Up" charge in order to detect a battery disconnect.

2.3 **Supply**

The Ag105 is designed to be operated with a wide DC input range from $11V_{DC}$ to $36V_{DC}$ either from a fixed DC supply, or a variable DC source, such as a solar panel. If long leads between the power source and the module are to be used, for stable operation it may be required to fit a 470µF capacitor across the input pins, as close to the module pins as possible.

2.4 **Typical Connections**

The Ag105 requires few external components to operate correctly, Figure 4: Typical System Diagram shows a simple battery backup circuit for a 12V system, such as a PoE camera.

R_{VS} configures the battery charge voltage, R_{CS} configures the charge current. Q1 is used to disable the load output of the Ag105 while the input supply is above the threshold configured by R1 and R2. A capacitor may be required across the load to maintain power during the transition from input supply to battery supply.

D1 and the Fuse provide over-current and polarity reversal protection. TH1 should be in physical contact with the battery for the Ag105 to adjust the charge profile for the temperature of the battery.
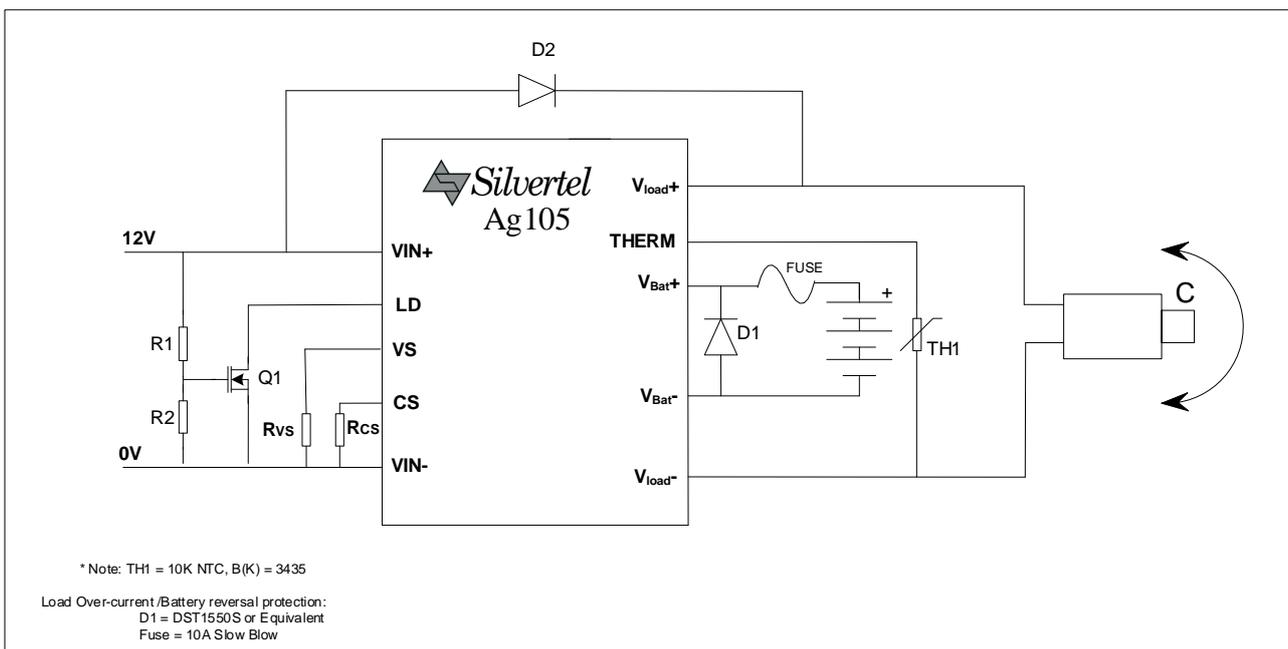

Figure 4: Typical System Diagram

2.5 **Charge Voltage**

The stresses are induced into a cell in the final stages of charging to 100%, causing ageing and reducing the cells available capacity over time. Lowering the charge voltage across a cell can reduce this aging effect, by easing the stresses caused during charging.

The Ag105 gives four options for charge voltage per cell, and the option of up to three cells in series, giving a total of 12 charge voltage options, This can set either by connecting a resistor, R_{VS}, between the VS pin and V_{in}- pins, or via I^2C. If no resistor is fitted then the Ag105 will default to 4.2V charge voltage.

Qty Series Cells	Charge Voltage (V)	Usable Capacity (%)	R_{VS}	I^2C field Value
1	3.9	≈ 75	200kΩ	1
	4.0	≈ 80	100kΩ	2
	4.1	≈ 90	62kΩ	3
	4.2	100	39kΩ	4
2	7.8	≈ 75	24kΩ	5
	8.0	≈ 80	20kΩ	6
	8.2	≈ 90	15kΩ	7
	8.4	100	10kΩ	8
3	11.7	≈ 75	6.8kΩ	9
	12.0	≈ 80	3.9kΩ	10
	12.3	≈ 90	1.8kΩ	11
	12.6	100	0Ω	12

Table 3: Charge Voltage Select

2.6 **Charge Current**

When charging a Lithium-ion battery, it is recommended that a constant current charge of between 0.5C and 1C, where C is the capacity value in Ah, for a timely charge. Dedicated battery chemistries can be charged at higher or lower charge currents.

The Ag105 provides 12 options for the constant current charge rate. This can set either by connecting a resistor, R_{CS}, between the CS pin and V_{in}- pins, or via I^2C. If no resistor is fitted then the Ag105 will default to 1000mA charge Current.

Charge Current (mA)	Charge Cutoff Current (mA)	R_{CS}	I^2C field Value
100	10	0Ω	12
150	15	1.8kΩ	11
200	20	3.9kΩ	10
250	25	6.8kΩ	9
500	50	10kΩ	8
750	75	15kΩ	7
1000	100	20kΩ	6
1250	125	24kΩ	5
1500	150	39kΩ	4
1750	175	62kΩ	3
2000	200	100kΩ	2
2500	250	200kΩ	1

Table 4: Charge Current Select

2.7 **Load Disable**

By default, the Ag105 directly presents the battery potential across the V_{load} output at all times that the battery is not being charged, such as fully charged or an input voltage below the MPPT threshold.

It is recommended that the LD pin is actively controlled in applications so that the battery voltage is only presented across V_{load} when required, preventing unnecessary charge-discharge cycles. See Section 3: Typical applications for more details.

The Ag105 will never present the battery potential on the V_{load} output when charging is in process. If a load is to be powered while the battery is charging, see section 3.2: Battery backup and storage.

2.8 **JEITA Profile**

Care should be taken when charging Lithium-ion batteries at extreme temperatures. When charging at low temperatures and high charge rates, metallic lithium plating is more likely to occur; while charging at high temperatures may cause increased gas generation within the cell.

The Ag105 adheres to the JEITA specifications for the safe charging of Lithium-Ion batteries by reducing the charge rate and then terminating charge if the battery is detected to be beyond the safe charging limits.

With a thermistor, connected between THERM and V_{in}- pins, the Ag105 will limit the charge current to 50% of the set charge current if the battery temperature is between 0˚C and 10˚C.and cease charge if the battery temperature is below 0˚C.

By default the Ag105 will cease charging if it detects a battery temperature is above 45˚C, with the Extended JEITA profile enabled, see section 2.11.3: I^{2}C Parameters, the Ag105 will charge up to battery temperatures of 60˚C at a reduced charge voltage, as per Figure 5.

For correct operation a 10k @25˚C NTC with a Beta curve of 3435K should be used, and should be in direct contact with the battery.
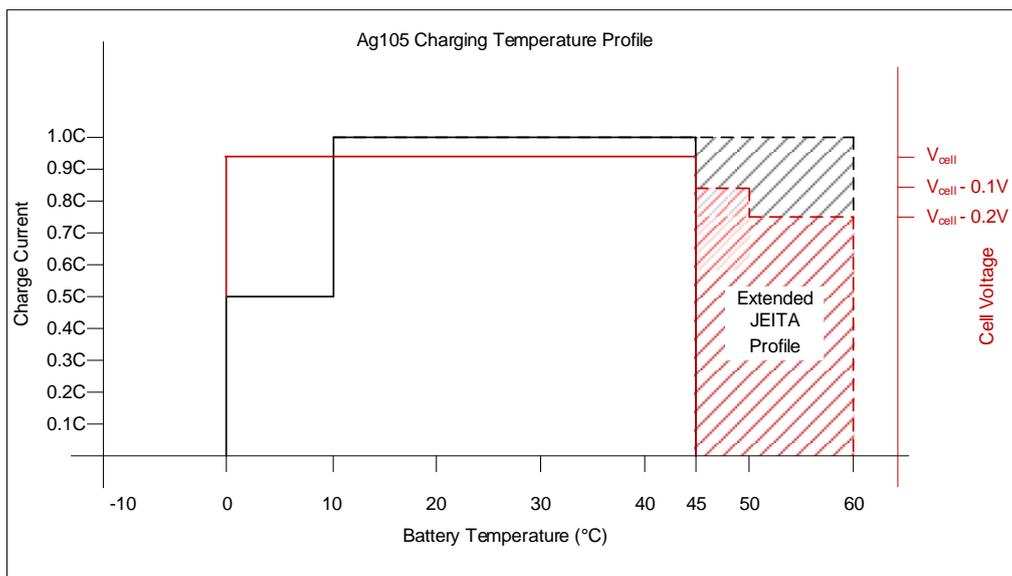

Figure 5: Temperature Compensation

2.9 Maximum Power Point Tracking (MPPT)

The Ag105 features max power point tracking for use with renewable energy generation sources, such as a solar panel. When this feature is enabled the Ag105 will monitor the input voltage and adjust the charge profile in order to maximise the energy harvested from the generation source to charge the battery.

The MPPT voltage setting configures the threshold voltage of between 11V and 33V that must be present across the input of the Ag105 before charging will commence. This can be set either by connecting a resistor between the MPPTS and V_{IN}- pins, or via I^{2}C. If left open circuit the default threshold voltage will be 18V, the typical peak power point of a 21V Photovoltaic panel.

This setting may not be needed in all applications, and some applications may require that the tracking is disabled in certain conditions; as such the max power point tracking can be disabled by pulling the MPPTD pin to V_{IN}-.

The MPPT can be enabled or disabled without restarting the module or terminating charge.

The approximate resistance to set the MPPT voltage between 11 and 33V is given by the below equation.

$$R_{MPPT} = 20 \times 10^3 \left(\frac{36}{47 - V_{MPPT}} + 1 \right)$$

2.10 Status

The Ag105 has a status indication output pin 'STAT'; that can be connected to a µ-controller input for full status monitoring or can be used with an LED as an indicator (as shown in Figure 6: Status Pin output Configurations).
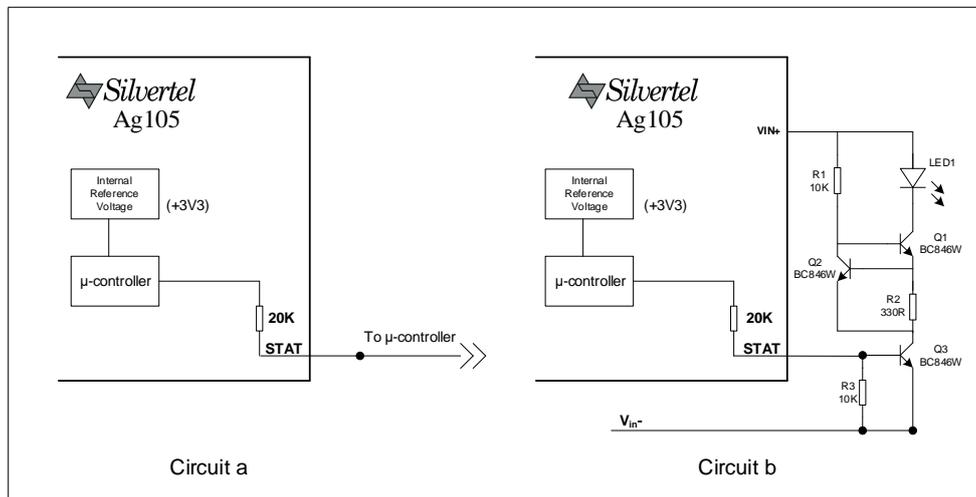
Figure 6: Status Pin output Configurations

Figure 6b shows a simple constant current circuit to drive the LED when the Ag105 is connected to a variable voltage source, if a fixed voltage source is to be used, a resistor in series with the LED would be sufficient.
The constant current circuit consists of R1, R2, Q1 and Q2 driving LED1 while the STAT pin is logic 1. The drive current is set by R2, in the example above would drive LED1 with approximately 2.1mA, assuming a V_{BE} of 700mV.

Table 5, shows the different Status modes of the Ag105:

Mode	Status Mode	STAT Output
0	Charging	Steady State 'Logic 1'
1	Fully Charged	50% 'Logic 1', period:2s
2	Disconnected Battery Error	1 Pulse
3	Battery Temperature Error	2 Pulses
4	OC/Regulation Error	3 Pulses
5	Timeout Error	4 Pulses
6	Major Battery Fault	5 Pulses
7	Input Voltage Removed	Steady State 'Logic 0'

All pulses are 200ms 'Logic 1' followed by a 200ms 'logic 0'.

With a period, dependant on the configuration and error state, of ≥1.2 seconds between sets of pulses.

Table 5: Status Output

2.10.1 Charging

The Ag105 is charging the battery in one of the three charging phases detailed in section 2.1: Operation.

2.10.2 Fully charged

The Ag105 has either completed the charge process as per section 2.1: Operation or the battery voltage during the "Bring-Up" charge is within 0.2V/cell of the charge setting. The battery is allowed to drop to 0.2V/cell below the set voltage before restarting a charge cycle to prevent excess charge cycles.

2.10.3 Battery Disconnected

The Ag105 does not detect a battery connected during the "Bring-Up" charge.

2.10.4 Battery temperature Error

The battery temperature error can be caused by one of two conditions, the module has exceeded the thermal protection built into the device, or has detected through the THERM pin that the battery temperature has gone outside the safe charging region as per the selected JEITA profile. See Section 2.8: JEITA Profile for more details.

2.10.5 Over Current/Regulation error

If the Ag105 detects a voltage or current behaviour that is not expected from a battery, charging will be terminated, and the Ag105 will return to the battery detect cycle.

2.10.6 Timeout condition

The timeout condition halts charging and the battery detection cycle until either a power cycle or the recovery timer has elapsed. See section 2.11.4: Timeout and Recovery timers for more details.

2.10.7 Major Battery Fault

Major Battery Fault status can be triggered in one of three events, the "Pre-Charge" stage of the battery exceeds the 30 minute timeout, the battery voltage does not rise above 2V during the "Bring-Up" charge or a short circuit has been detected on the output.

The battery detection cycle continues in this state, a battery potential of greater than 2.7V/cell, a power cycle or a battery disconnect is required to resume charging.

2.11 I²C Interface

The Ag105 contains an I²C interface in order to allow for the control and monitoring of the charge controller.

The Ag105 is a slave device using two pins to connect to the I²C interface SCL (serial clock) and SDA (serial data). The interface connection should be referenced to the negative input supply V_{in}-, and is compatible with a 3V and 5V bus.

The interface signals are unbuffered prior to the microcontroller on the Ag105. If a long cable is to be used to carry the I²C signals, buffering should be added in order to protect the Ag105 from damage. It is advisable to include 10kΩ pullup resistors on the SCL and SDA lines.

2.11.1 I²C Protocol

To write to a field on the slave the data should be sent as per Figure 7.
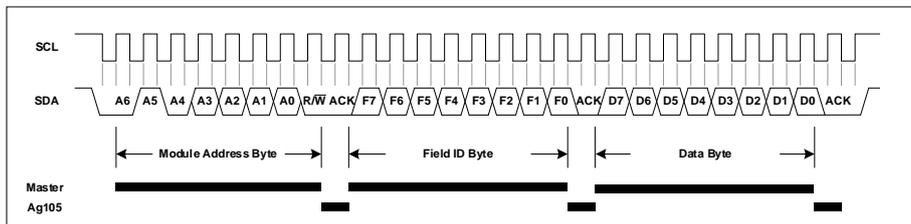
Figure 7: Writing to a Register

To read a field from the slave the following should be sent.

Figure 8: Reading a Register

2.11.2 Status Byte

The Ag105 will always return the status byte prior to any requested field value upon a read request; this can be interpreted as per Table 6.
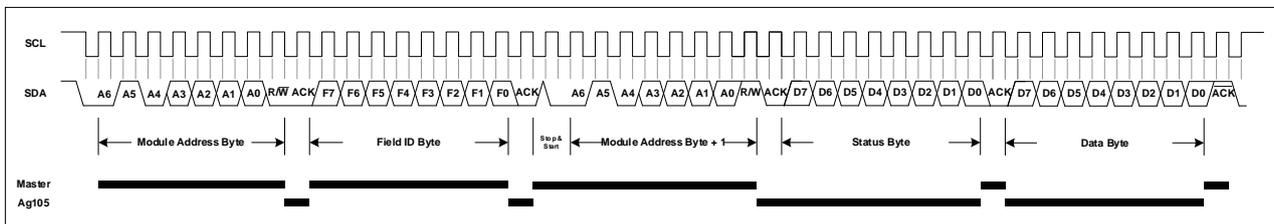
Bit	Description	function decription			
		B2	B1	B0	Decription
0-2	GENSTAT	0	0	0	Battery Dissconnect
		0	0	1	Low Power
		0	1	0	Charging
		0	1	1	Fully Charged
		1	0	0	Bring-Up Charge
		1	0	1	OC/regulation error
		1	1	v	Thermal Shutdown
		1	1	1	Timeout Error
3	MMPT EN/DIS	Max power point tracking enabled			
4	Power Tracking	Charge profile is tracking the input power			
5	Constant Voltage	Ag105 is in constant voltage mode			
6	Constant Current	Ag105 is in constant current mode			
7	Thermal Limting	Charge profile is limited due to battery temperature			

Table 6: I^{2}C Status Byte

2.11.3 I^{2}C Parameters

Field ID	Description	Read/Write	Default Value	Range	Function Description	Approximate Scaling factor	stored in eprom
0x00	Charge Current Setting	Read+Write	0x00	0 - 0x0C	0: external resistor setting 1 - 12: charge current profile (2.5A - 0.1A)	-	yes
0x01	Battery Voltage Setting	Read+Write	0x00	0 - 0x0C	0: external resistor setting 1 - 12: selects the charge voltage (3.9 - 12.6)	-	yes
0x02	MPPT Voltage	Read+Write	0xFF	0-0xFF	0-250: sets the MPPT voltage between 11-33V >=251: external resistor	0.088	yes
0x03	Timeout	Read+Write	0x00	0-0xFF	0: No timeout 1-254: sets the timeout time in 3 minute increments	-	yes
0x04	Recovery Time	Read+Write	0x00	0-0xFF	0: No error recovery 1-254: sets the major error recovery time in 3 minute increments	-	yes
0x05	Measured Battery Voltage	read	N/A	0-0xFF	Measured battery voltage (fixed multiplier can be used to convert to real Value)	0.064	-
0x06	Measured Charge Current	read	N/A	0-0xFF	Measured charge current (fixed multiplier can be used to convert to real Value)	0.011	-
0x07	Measured Input Voltage	read	N/A	0-0xFF	Measured of supply voltage (fixed multiplier can be used to convert to real Value)	0.141	-
0x0A	Extended JEITA Profile	Read+Write	0x00	0 - 0x01	Enables charging up to 60˚C battery tempertures	-	yes
0xFD	Major Firmware Version	read	N/A	0-0xFF	Returns a char that represents the major firmware version of the ag105	-	fixed
0xFE	Minor Firmware Version	read	N/A	0-0xFF	Returns a char that represents the minor firmware version of the ag105	-	fixed
0xE5	Change I^{2}C Address	Read+Write	0x30	0x01-0x7F	Can be used to change the Ag105 I2C address	-	yes
0xE6	Reset Memory	Write	N/A	-	Writing to this field resets all settings to default.	-	-

Table 7: I^{2}C Parameters

2.11.4 **Timeout and Recovery timers**

The Ag105 has two user configurable counters, Timeout and Recovery Time.

Timeout is the maximum period of time a battery is allowed to be in a state of ongoing charge before charging is locked out for the period of the recovery time.

Recovery time is the maximum time that the timeout flag is active before it is automatically reset and charging can be resumed.

The timeout counter begins incrementing when the module switches to a charging state, and will continue counting even when the charge is ceased. The counter will only be reset when either the fully charged flag is set or the module has been through a power cycle.

The recovery time counter will only begin incrementing when the timeout flag has been set, this counter is reset when the module is power cycled or the counter has elapsed.

Both counters can be set in increments of approximately 3 minutes. For Example a 12 hour maximum charge time can be configured by setting the timeout field to 0xF0.

2.11.5 **Measurements**

All measurements transmitted over the I^{2}C interface are stored and transmitted as an 8 bit unsigned integer; as such, there is a level of quantization error that should be expected.

If the input voltage is below 9 volts or the Ag105 reports an error state, for example dropping below MPPT threshold voltage, all measures transmitted will be 0xFF.

2.11.6 **Out of Range Values**

There are three fields that can have a data byte written that may fall outside of the range of values for that field. Table 8: Out of range Behaviour details the behaviour of each field if a byte that is out of range is written to it.

Field	Range	Out of range Behaviour
Charge Current Setting	0 - 0x0C	Ag105 wil default to 1000mA charge setting
Battery Voltage Setting	0 - 0x0C	Ag105 wil default to 4.2V barttery setting
Extended JEITA Profile	0-1	Any non-zero byte will result in 0x01 stored

Table 8: Out of range Behaviour

2.11.7 **I^{2}C Module Address**

The Ag105 can be addressed using the addresses set in field 0xE5, by default this is set to 0x30, but can be changed to any value between 0x01 and 0x7F.

3 Typical applications

3.1 Solar powered Light

Figure 9 shows a simple circuit that would enable a solar panel to charge a battery during the day, and automatically power an LED light when the ambient light detected by the photodiode drops below the threshold. If the photodiode was not present the light would be enabled as soon as the battery was charged, or the voltage produced from the panel dropped below the set MPPT voltage.

D1 and the fuse provide over-current and polarity reversal protection. TH1 should be in physical contact with the battery for the Ag105 to adjust the charge profile for the temperature of the battery.
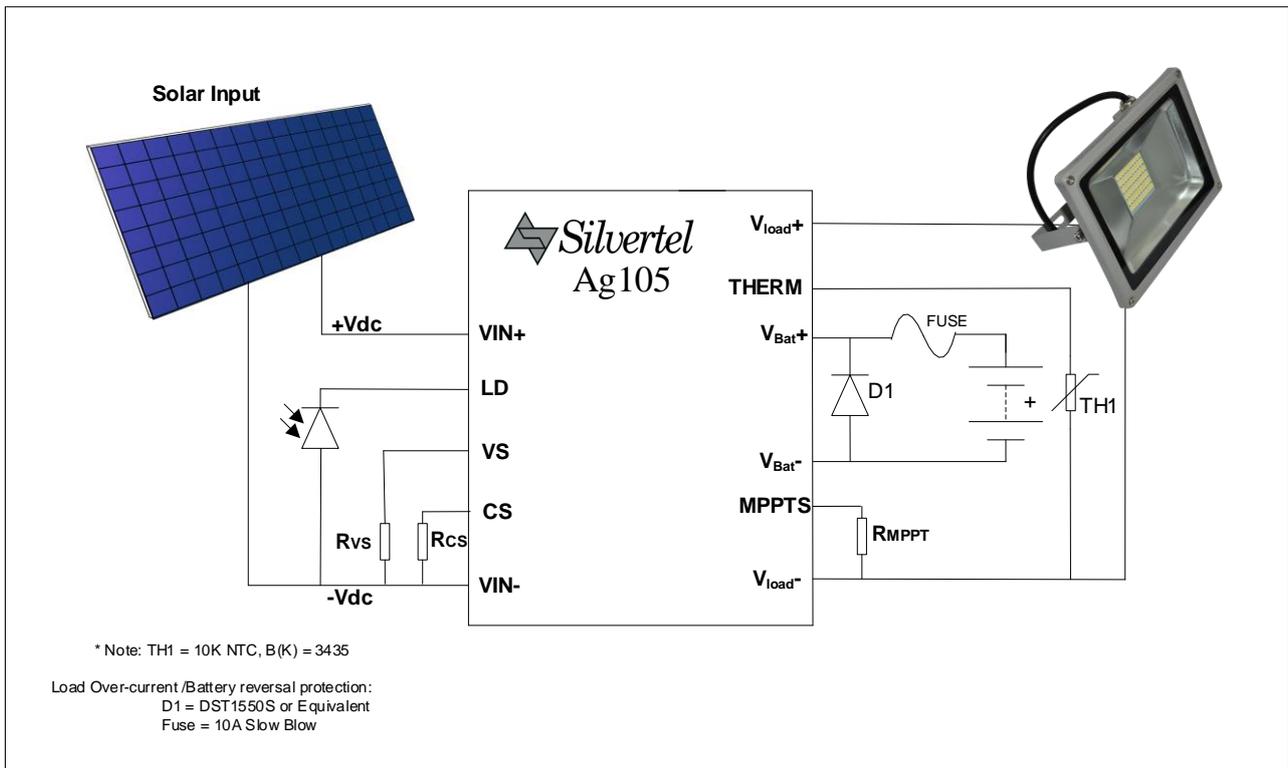

Figure 9: Solar Powered Light

3.2 Battery backup and storage

The circuit in Figure 10 shows a simple circuit where the Ag105 is configured as a battery backup storage for a solar powered terminal. In this circuit the wide input DC/DC converter will power the terminal off of solar while the battery is being charged by the solar panel. Once the output of the solar panel drops below a configured level, the battery will automatically switch in to power the DC/DC converter. It is recommended to set the MPPT voltage above the threshold configured by R1 and R2 in order to prevent the Ag105 switching to a charging state while it is still supplying the output.

If the input supply can go above 30V then protection should be added to the $V_{Load}+$ output to prevent back feed voltage causing damage to the module.

In this example all the charge parameters are set via the I^{2}C interface, allowing the charge settings to be configured for best operation depending on the use case of each individual application.

D1 and the fuse provide over-current and polarity reversal protection. TH1 should be in physical contact with the battery for the Ag105 to adjust the charge profile for the temperature of the battery.
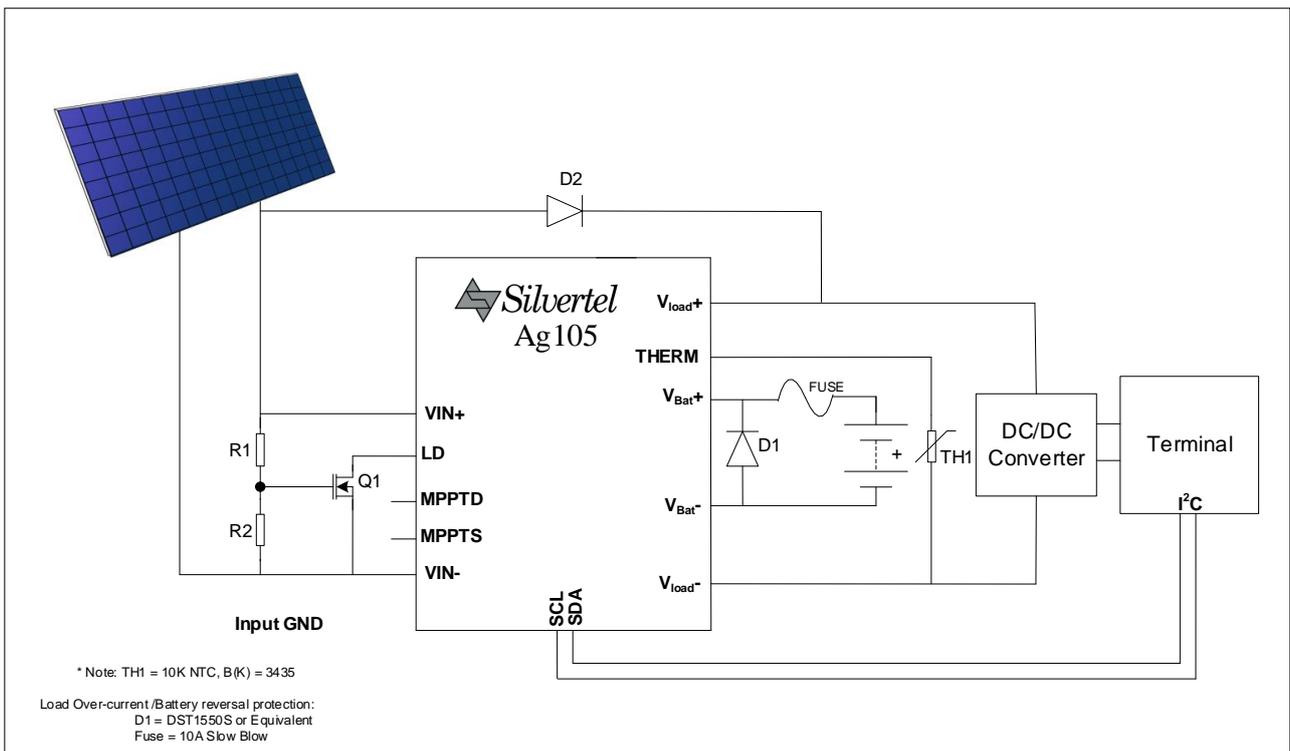

Figure 10: Battery backup

4 Operating Temperature Range

While the Ag105 can operate up to a maximum of 70˚C ambient, and a minimum of -40˚C ambient, charging should be limited to a battery temperature of 0˚C to 45 ˚C, or 60˚C using the Extended JEITA profile provided the lithium battery chemistry permits higher temperature charging.

The core of the Ag105 is a Buck-Boost DC/DC converter. While this has been designed to be one of the highest efficiency modules on the market, is still a power device and thus will generate heat, so it is important that this is taken into consideration at the design stage. The amount of heat generated by the module will depend on the cell configuration and the charge current.

The Ag105 is capable of utilising the full array of settings across an operating temperature range of -40°C to +45°C. If the module is expected to operate in ambient temperatures above this, the charge current may have to be reduced as per Table 9.

The table below was calculated under continuous load conditions recorded in a Temperature Applied Sciences ECO MT135 Environmental chamber, with circulating air at a rate of approximately 0.5m/s over the module. Operation in a sealed enclosure or with limited airflow will result in further de-rating of the operating temperature profile.

Cell count	Ambient temperature (˚C)		
	≤ 45	≤ 60	≤ 70
1	All settings	All settings	≤2.0A
2	All settings	≤2.0A	≤1.75A
3	All settings	≤2.0A	≤1.5A

Table 9: Ag105 operating temperature profile

5 Protection

5.1 Protected Cells

The Ag105 is designed for charging protected battery packs or cells. Use of the Ag105 with unprotected (bare) cells or battery packs is not supported by Silvertel.

It is also very important to remember, the cell's under-voltage protection circuit is the last line of defence. The Ag105 will apply a "Pre-Charge" to restore a battery that has entered a protected state, showing 0V across its terminals, If this fails to return the battery from its protected state, the Ag105 will not continue attempting to recover the battery further.

Battery manufacturers do not recommend that you allow a cell to go into an under-voltage condition.

5.2 Input Protection

The Ag105 may be damaged by input voltages greater than 36V. It is recommended that an over-voltage clamping device is fitted across the V_{IN}+ and V_{IN}- input pins if it is possible that the supply voltage could exceed 36V.

5.3 Over current Protection

The Ag105 output has over current and short circuit protection. This is triggered when the output current exceeds 200mA above the set charge current. If an over current fault is detected, the Ag105 will shut-down the DC-DC converter and the STAT output will report an over current error.

5.4 Deep Discharge Protection

If the voltage on a battery does not raise above 2V while drawing current in the "Bring-Up" charge, the battery will be labelled as over discharged and the status pin will generate 5 pulses which will only be cleared in the event of a power cycle or a battery disconnect.

In the event a battery voltage does not rise above 2.7V per cell during the "Bring-Up" charge, the Ag105 will enter "Pre-Charge" where it will supply 10% of the charge current to the battery until the voltage per cell increases to 3.0V. If this takes more than 30 minutes, charging will cease and the Major Battery Fault status will flag, which will only be cleared in the event of a power cycle or a battery disconnect.

5.5 Battery Reversal

The Ag105 does not provide battery reversal protection, however Figure 9 and Figure 10 shows a simple method of providing this safety feature. This also provides protection for an over-current or short circuit on the Load Output pin.

5.6 **Output Short Circuit Protection**

5.6.1 **Battery**

The Ag105 will only output up to the configured charge current if a partial short circuit is applied to the output. If the voltage across the battery is below what would be expected from a cell configuration, the Ag105 will cease output and trigger a regulation error. After this the Ag105 will continue to test the output with a "Bring-Up" until a valid cell voltage is detected.

If a dead short is applied to the output, an overcurrent status will initially be flagged, terminating charging. The Ag105 will continue to test the battery output for a short and flag the Major Battery Fault status.

5.6.2 **V$_{Load}$ output Protection**

The Ag105 provides no overcurrent protection between the battery and the load output.

5.7 **Thermal Protection**

In addition to the battery thermal profile detailed in section 2.8: JEITA Profile, The Ag105 contains built in thermal protection to prevent the module becoming damaged in the event that it is operated beyond its temperature specification. When the Ag105 has detected it is over temperature, the output will be disabled until the module has cooled sufficiently.

6 **Electrical Characteristics**

6.1 **Absolute Maximum Ratings**

	Parameter	Symbol	Min	Max	Units
1	DC Supply Voltage	V$_{CC}$	-0.3	36	V
2	Storage Temperature	T$_S$	-40	+100	°C

Note: Exceeding the above ratings may cause permanent damage to the product. Functional operation under these conditions is not implied. Maximum ratings assume free airflow.

6.2 **Recommended Operating Conditions**

	Parameter	Symbol	Min	Typ	Max	Units
1	Input Supply Voltage	V$_{IN}$	11		36	V
2	Input Under Voltage Lockout	V$_{LOCK}$		11		V
3	Operating Temperature[1]	T$_{OP}$	-40	25	70	Ta / °C

Note 1: See sections 2.8: JEITA Profile and 4: Operating Temperature Range

6.3 DC Electrical Characteristics

	DC Characteristic		Sym	Min	Typ[1]	Max	Units	Comments
1	Charge Efficiency[2]		EFF		88		%	
2	Pre-Charge timeout		T_{RT}		30		Min	
3	Maximum voltage across V_{load} pins		V_{load}	0		30	V	
4	Input Current - Idle		I_{IN}			18	mA	
6	Maximum Continuous Discharge Current		I_{DIS}			4	A	
7	Battery Standby Current		I_{BAT}	120		420	μA	No Input Voltage
8	STAT output	Logic 0	V_{OL}			0.5	V	
		Logic 1	V_{OH}	3.3				
9	Output Ripple (at the battery terminal)		V_{RN}		100		mV_{p-p}	
10	Short-Circuit Duration		T_{SC}			∞	sec	
11	Line Regulation		I_{LINE1}		0.15		%	
12	Load Regulation[3]		V_{LOAD}		0.4		%	@ $24V_{in}$
13	Ripple and Noise		I_{RN}			300	mA_{p-p}	@ 2.5A charge

Note 1: Typical figures are at 25°C with a nominal output voltage with 24V supply and are for design aid only. Not Guaranteed.

Note 2: Typical figures are at 25°C, $12V_{in}$ 3 series cell configuration.

Note 3: Constant Voltage Mode.

7 Package
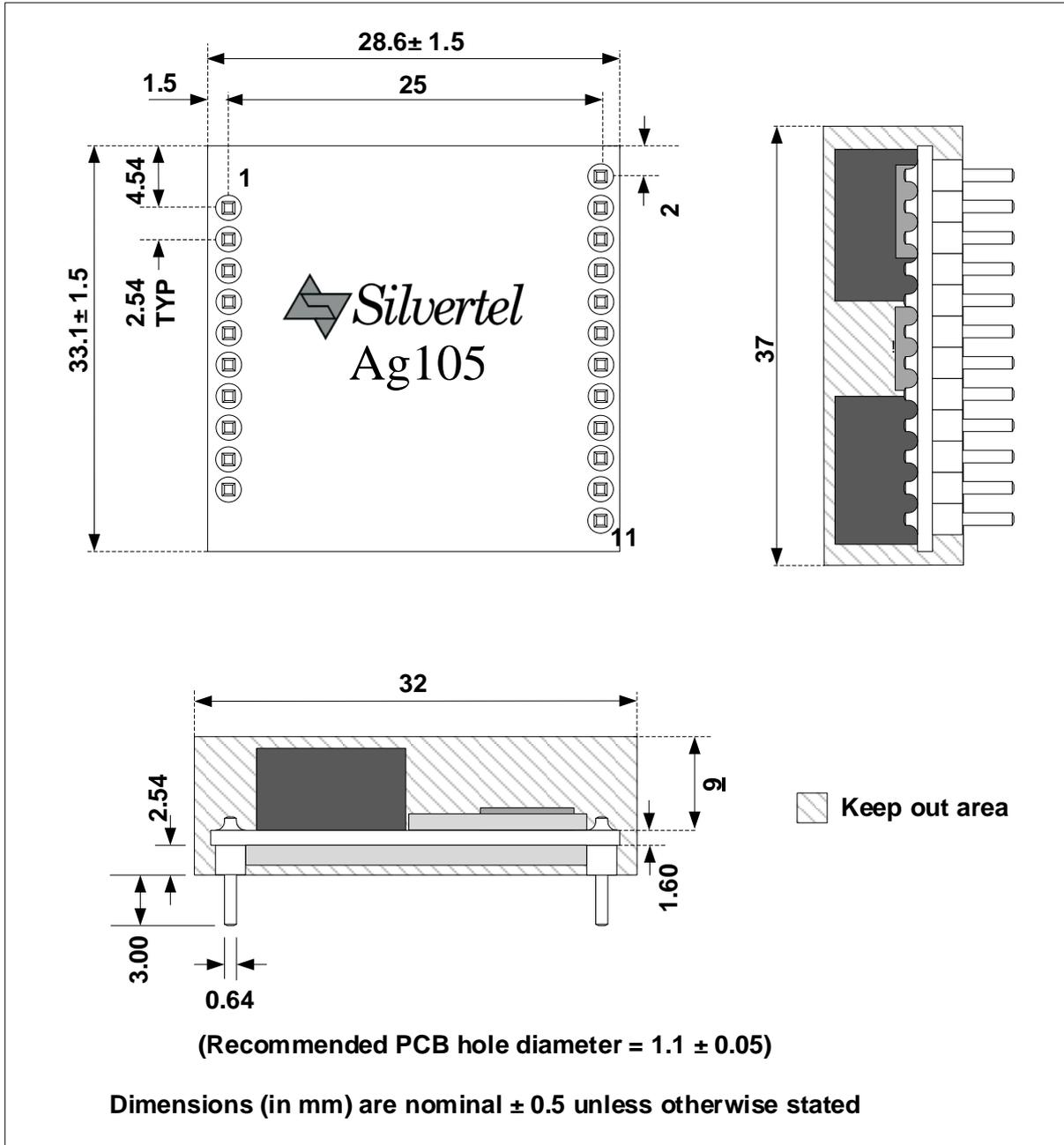
Figure 11: Package Dimensions

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