

Photovoltaic Beacon User Guide

Revision History

Date	Version	Description
March 9, 2021	0.60	Initial version created.
June 30, 2021	0.61	Updates for Beacon with sensors.
July 21, 2021	0.62	Format change; updated sections 5 Sensor Beacon Payload , 7 Changing PV Beacon Parameters ; removed Atmosic App. information in section 3 Sensor Beacons , removed Configure the Parameters via Atmosic App section, information to be included in separate app user guide.

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1 Overview

This document details the use of Photovoltaic (PV) Bluetooth LE beacons created by Atmosic to demonstrate how the energy harvesting capabilities of the Atmosic ATM3 device can be used to either extend the battery life or implement a completely battery free beacon. This document will describe the features, usage, and over the air (OTA) configuration of the PV Beacon.

The PV beacon is designed to operate at indoor light levels without the need for batteries. In general, the required light level for beacon operation will depend on the beacon rate and size of the PV cell. The 10.9 cm² PV cell on the beacon can support a default once per second beacon interval at low (~200 lux) indoor light levels. The PV Beacons optionally support sensors for Temperature/Humidity and accelerometer.

NOTE: Operating the beacon battery free requires that the internal storage capacitor have sufficient stored energy to start beacon operation. See section [6 Beacon Operation](#) for details.

These beacons are provided for demonstration and evaluation purposes only with no guarantee of performance. These beacons are not to be used for commercial purposes.

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2 PV Beacon Features

The Atmosic PV beacon is shown in [Figure 1](#). The beacon incorporates a Panasonic AM-1454 Amorphous Silicon PV cell to harvest ambient light and a 33 mF supercapacitor for storage of any excess energy. An optional coin cell battery can be used to power the device when ambient light is unavailable and the supercapacitor is depleted. There is no rechargeable battery option for the beacon.



Figure 1 - PV Beacon Unit

The mini beacon's internals can be viewed by sliding off the rear cover of the unit. [Figure 2](#) shows the exposed circuit board with the battery holder and supercapacitor. The Bluetooth LE module attached to the opposite side of the board is partially exposed at the top of the figure.

A single CR1616 battery may be installed in the battery holder to power the beacon during extended periods of use when a light source is not available. The 33 mF supercapacitor is permanently installed and should not be removed.

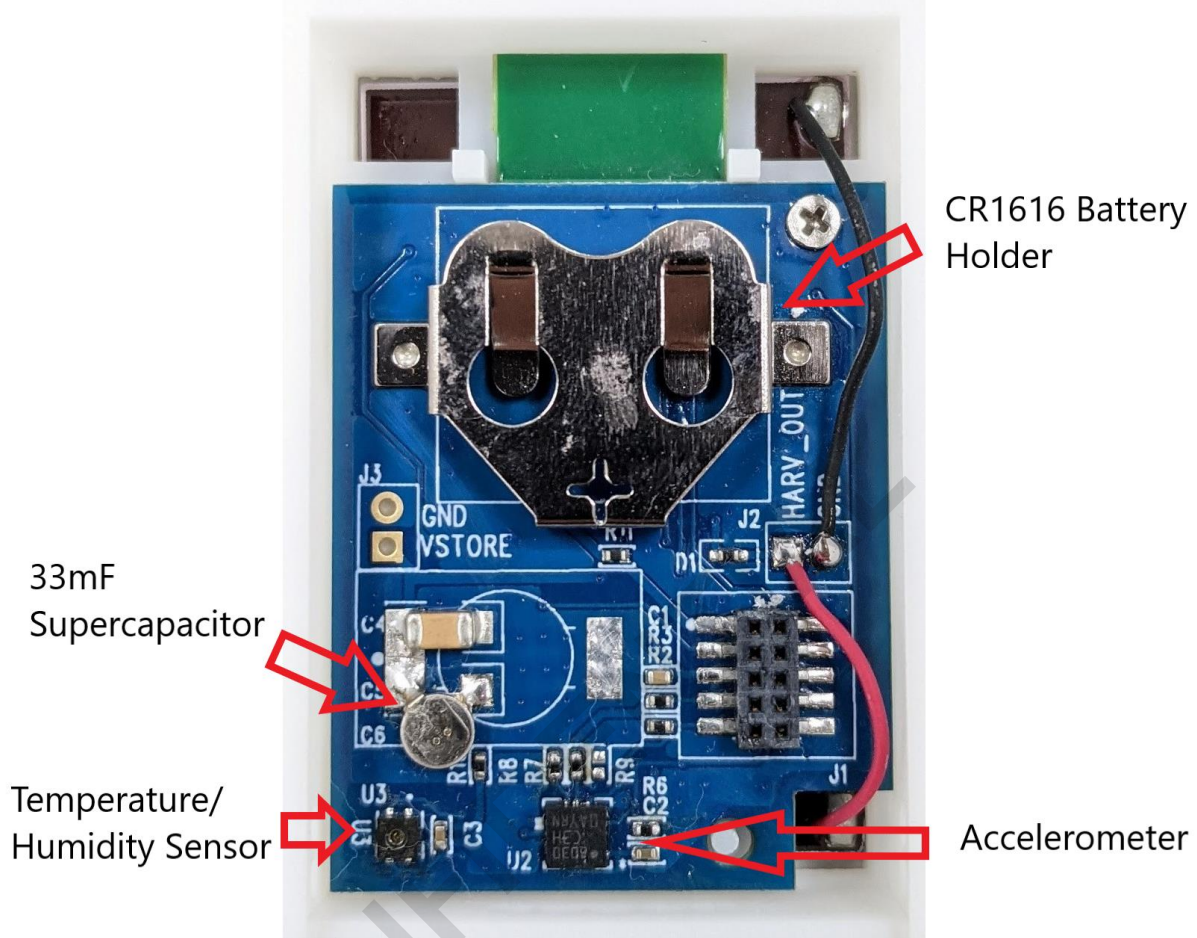


Figure 2 - Inside of the PV Beacon

The mini beacon measures 47mm x 33mm x 12mm. The beacon size is primarily dictated by the size of the PV cell.

More information about Panasonic Amorphous Silicon products can be found at <https://panasonic.co.jp/ls/psam/en/products/>

3 Sensor Beacons

The PV beacon is available with an optional temperature/humidity sensor and an accelerometer sensor. The temp/humidity sensor is an AMS ENS210 and the accelerometer is an ST LIS3DH. PV Beacons with sensors are indicated with a circular yellow sticker on the outside of the beacon. You can also check for the presence of the sensors by checking the inside of the beacon as shown in [Figure 2](#).

4 Default Beacon Configuration

The details of the default beacon configuration are shown in [Table 1](#). Section [7 Changing PV Beacon Parameters](#) of this document outlines the commands and procedure for changing some of the beacon’s parameters using a Bluetooth LE connection.

Configuration Parameter	Value
Device Name	Name: Atmosic BCNxxxxxx xxxxxx: last 6 digits of BD address
Beacon Advertising Interval	1 per second
Output Power	~ 0 dBm (uncalibrated)
Advertisement Type	Legacy
# of advertising Channels	3
Connectable	Yes
Payload content	28 Bytes
Type	Eddystone

Table 1 - PV Beacon Configuration

5 Sensor Beacon Payload

PV Beacons with temperature/humidity and accelerometer sensors send a separate beacon with sensor data. The format of this data is detailed in [Table 2](#).

A separate phone-based application to read the sensor data is available from Atmosic. Contact Atmosic support for additional information.

Offset	Length	Type	Data
0	1	Data Length	0x16
1	1	manufacturer_flag	0xFF
2	2	company_id	0x240A
4	1	type	0x00
5	2	temperature	Read from ens210

7	2	humidity	Read from ens210
9	2	X axis	Read from lis3dh
11	2	Y axis	Read from lis3dh
13	2	Z axis	Read from lis3dh
15	4	Vstore value	Vstore channel
19	4	Vbatt value	Vbatt channel

Table 2 - Sensor Beacon Payload

6 Beacon Operation

The PV beacon can be used without a battery to demonstrate how energy harvesting can enable operation from only ambient light or with a battery to demonstrate how harvesting ambient light can be used to extend the battery life of a beacon.

The light level required to operate the beacon will depend on the beacon interval, output power, and size of the advertising data. In general, the beacon can maintain its default once per second beacon even at relatively low indoor light levels around 200 lux. Higher indoor light levels above 500 lux are sufficient for even the fastest 250 ms beacon interval.

6.1 Battery Free

Long term operation without a battery is possible because the beacon will store any harvested energy not immediately used for normal operation to the 33 mF capacitor to power the beacon when sufficient light for beacon operation is not available. Depending on the duration and level of light available where the beacon is operating, a larger or smaller capacitor may be required to meet the operational goal for the beacon in a specific application. Contact an Atmosic representative for help determining how much PV harvesting capacity and storage is required for your application.

Starting battery free operation requires that the beacon’s storage capacitor have sufficient energy to cold start the ATM3. If the storage capacitor is depleted it may require up to 10 minutes of light exposure at moderate to high (500-1000 lux) indoor light levels to energize the capacitor to a sufficient level to start operation.

From a fully charged storage capacitor the beacon can operate for approximately 60 (sensor beacon) to 80 (non-sensor beacon) minutes at a once per second beacon interval without any ambient light. See [Table 3](#).

Beacon Type	Cold Start Latency	Sustainability without PV
Non-Sensor	9 minutes	80 minutes
Sensors (Temperature/Humidity & Accelerometer)	10 minutes	62 minutes

Table 3 - Beacon Operation with Fully Charged Storage Capacitor

6.2 Battery Life Extension

Installing a battery into the battery holder will ensure continuous beacon operation even when ambient light is not available for extended periods. The ATM3 is designed to operate from harvested energy as its primary energy source, from stored excess harvested energy when harvested energy is insufficient for operation, and finally from the battery when harvested and stored energy is not enough. This method of operation maximizes both the utilization of harvested energy and battery life.

For some applications, relying solely on harvested energy may not be feasible when available light is inconsistent and continuous operation is critical. When operating in this type of environment using energy harvesting to extend battery life can ensure much longer intervals between battery changes or possibly enough continuous operation to never require battery replacement.

If the battery is exhausted the beacon is designed to continue to operate with the same behavior as a battery free beacon.

7 Changing PV Beacon Parameters

Atmosic PV beacons support re-configuration of a limited number of parameters via AT commands issued over the air when connected via the GATT profile. This section covers the procedure for issuing commands to the beacon as well as the AT command and return message formats.

Many mobile phone based applications that support the GATT profile are available and can be used to configure the PV Beacon, contact Atmosic support for additional information.

7.1 Connecting to the Beacon

The following steps are required to get the beacon into a state ready to accept AT commands:

1. Using an application that supports GATT connections, scan for the beacon and initiate a connection.

2. Once connected, look for the Generic Attribute with the service UUID `41746D6F-7369-6300-0000-000000000000`
3. Under this attribute select the characteristic with Write Response properties and the service ID `41746D6F-7369-6300-0000-000000000001`
4. Connect to this characteristic and enable notifications

At this point AT commands can be issued as strings to the PV beacon.

NOTE: Connections to the PV beacon require much more energy than normal beacon advertisements. During any reconfiguration, Atmosic recommends that a battery be installed or that the PV cell be exposed to bright light levels for the duration of the connection. Difficulty connecting to the beacon or maintaining a connection is an indication that insufficient energy is available and a battery should be installed or the beacon should be moved closer to a bright light source.

7.2 Sending AT Commands

Once connected, all AT commands are sent to the beacon as strings. If notifications are turned on, the beacon will respond with OK if the command is accepted and an ERROR message with a response code if the command is invalid. The ERROR messages are described in section [7.3 Error Messages](#) of this document.

[Table 4](#) provides a summary of AT commands supported by the beacon. Each command is detailed in the sub-sections that follow.

AT Command	Function
AT+UNLOCK	Unlocks the beacon for configuration
AT+ADVDATA	Sets the advertising data
AT+ADVINT	Sets the advertising interval
AT+TXPWR	Sets the beacon's transmit power
AT+NAME	Sets the beacon's device name
AT+SYSRESET	Initiates a system reset of the beacon

Table 4 - Supported AT Commands

7.2.1 Unlock Beacon

This command unlocks the beacon for configuration. The UNLOCK command with the beacon password must be correctly sent to the beacon before any other commands will be accepted.

The default password for unlocking the beacon is *atm1atm123*.

AT+UNLOCK=	
Parameter Format	S(~31)
Example	AT+UNLOCK=atm1atm123
Return Value	OK

7.2.2 Set Advertising Data

The ADVDATA command sets advertising data output by the beacon.

AT+ADVDATA=	
Parameter format	A(~31)
Example	AT+ADVDATA=051250015001
Return Value	OK
Description	Example: AT+ADVDATA=051250015001 05 # len 12 # «Slave Connection Interval Range» 5001 #Conn_Interval_Min little endian 5001 #Conn_Interval_Max little endian

7.2.3 Set Advertising Interval

The advertising interval of the beacon may be set with this command to values between 250 ms and 10.24 seconds. The interval is set in increments of 0.625 ms, so values between 400 (250 ms) and 16384 (10.24 seconds) are permitted.

AT+ADVINT=	
Parameter format	D(400~16384)
Example	AT+ADVINT=640

Return Value	OK
Description	Example: to set the interval for 250 ms, the required value is $250/0.625=400$. Full command is <code>AT+ADVINT=400</code>

7.2.4 Set Beacon Transmit Power

This command changes the transmit output power of the beacon. Only specific values between -20 dBm and +4 dBm are supported as outlined in the table below.

NOTE: Some GATT applications may require a `0x` before non-numeric values to indicate hexadecimal data - i.e. `AT+TXPWR=0xFC`

AT+TXPWR=																			
Parameter format	B(0~)																		
Example	AT+TXPWR=00																		
Return Value	OK																		
Description	Valid output levels																		
	<table border="1"> <thead> <tr> <th>Value (string)</th> <th>Output Power (dBm)</th> </tr> </thead> <tbody> <tr> <td>EC</td> <td>-20</td> </tr> <tr> <td>F6</td> <td>-10</td> </tr> <tr> <td>FA</td> <td>-6</td> </tr> <tr> <td>FC</td> <td>-4</td> </tr> <tr> <td>FE</td> <td>-2</td> </tr> <tr> <td>00</td> <td>0</td> </tr> <tr> <td>02</td> <td>2</td> </tr> <tr> <td>04</td> <td>4</td> </tr> </tbody> </table>	Value (string)	Output Power (dBm)	EC	-20	F6	-10	FA	-6	FC	-4	FE	-2	00	0	02	2	04	4
	Value (string)	Output Power (dBm)																	
	EC	-20																	
	F6	-10																	
	FA	-6																	
	FC	-4																	
	FE	-2																	
	00	0																	
	02	2																	
04	4																		

7.2.5 Set Beacon Device Name

This command allows the user to change the device name of the beacon. String lengths of up to 18 characters can be used.

AT+NAME=	
Parameter format	S(~18)
Example	AT+NAME=AtmosicBCN
Return Value	OK

7.2.6 Initiate System Reset

This command initiates a reset of the beacon. If the command is accepted the beacon will reset immediately with no response. The system reset command should be issued after any configuration activity to ensure the beacon is operating with the new parameters.

Note that the equals sign (=) is required.

AT+SYSRESET=	
Parameter format	None
Example	AT+SYSRESET=
Return Value	None

7.3 Error Messages

There are two types of error messages, specific error responses that are based on the state of the beacon and general command errors that relate to the command string that was sent.

Specific error responses will result in a return message that identifies the command and error code. These errors are related to the need to send the correct password to unlock the beacon before any other commands are sent. [Table 5](#) lists the specific error values.

Specific Errors

Return Value	Error Reason
1	APP_ERR_UNLOCK_FIRST
2	APP_ERR_WRONG_PASSWORD

Table 5 - Specific Errors

Example - command sent before beacon unlocked:

AT+ADVINT=640

*+ADVINT:1
ERROR*

Example - incorrect password sent:

AT+UNLOCK=1234

*+UNLOCK:2
ERROR*

Command specific errors will return the ERROR string with a number indicating the reason for the error. These types of errors are related to the command format or argument values issued with the command. [Table 6](#) details the different error values returned.

Command Errors	
Return Value	Error Reason
0	AT_ERR_NO_ERROR
1	AT_ERR_CMD_NOT_SUPPORT
2	AT_ERR_WRONG_ARGU_CNT
3	AT_ERR_WRONG_ARGU_RANGE
4	AT_ERR_WRONG_ARGU_TYPE
5	AT_ERR_WRONG_ARGU_TYPE_OR_RANGE
6	AT_ERR_WRONG_ARGU_CONTENT

Table 6 - Command Errors

Example - Command not supported:

AT+AD=

ERROR:1

Example - Argument out of range:

AT+ADVINT=65550

ERROR:5

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