



Inventek Systems

Embedding Connectivity Everywhere

eS-WiFi Module Application Note

Power Saving Modes

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Inventek Systems

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1. Scope

The scope of this document is an application note to assist users in taking advantage of several power saving features in the eS-Wifi modules. 802.11 Wi-Fi standard has a number of techniques and parameters to allow stations to save power, but it is important to note that some of these changes may affect throughput and latency of the Wi-Fi station.

This application note is currently in process and the findings are not complete and subject to change. The document will be updated upon conclusion of the testing.

1.1. Supported Product Versions

This application is applicable to the eS-WiFi firmware release 1.x and is currently available on the following eS-WiFi modules:

- ISM4319-M3-L44-C (Ceramic Antenna w/STM32F103)
- ISM4319-M3-L44-E (Printed Micro-strip Antenna w/STM32F103)
- ISM4319-M3-L44-U (U.FL Connector to external antenna w/STM32F103)
- ISM4319-M3E-L44-E (Printed Micro-strip Antenna w/STM32F205RE)
- ISM4319-M3G-L44-E (Printed Micro-strip Antenna w/STM32F205RG)

2. AT Commands To Save Power for the WIFI Radio

To save battery power, there are a variety of methods that can be used depending on your application. You need to look at your use case to evaluate the different options. In summary here is a list of basic power saving options:*

**Table 2.1. Summary of AT Command Power Modes and
mA usages for each mode**

***Notes:**

Preliminary measurements only

WiFi On: Connected to network: Max 120 mA (340 mA burst of not more than 5 ms)

Access Point Mode: Waiting for someone to join: Max 120 mA (340 mA burst of not more than 5 ms).

Power Save mode does not work when in Access mode. To save power, AT Commands, ZP=2 and ZP=6, can be used allow the MCU to sleep and reduce the beacon intervals by turning the radio on /off at a duty cycle.

3. Listen Interval

To save battery power, WiFi Stations power down as much of the Wi-Fi subsystem

Power Management Modes	Description	Current (mA)*	AT Commands
WiFi On/Off	MCU is powered on, but Wifi radio can be powered off	37	ZP=3,0 - stop ZP=3,1 - start
WiFi Power Save On/Off	After you join a network, Power Save mode can be entered. The unit will automatically wake up when data is ready. AP will buffer data	50 mA (160 mA burst of not more than 5ms)	ZP=1,0 - Off ZP=1,1 - On
WiFi Beacon Listen Skip MCU Sleep	You can extend beacon time to save additional power while sleeping the MCU	Beacons Set to 1, ~7.2mA Beacons Set to 2, ~4.7mA Beacons Set to 3, ~4.2mA One Second Sleep	ZP=2,1; ZP=6,<ms> ZP=2,5; ZP=6,<ms> ZP=2,10; ZP=6,<ms>

as possible. While Stations are asleep, Access Points (AP's) must buffer frames intended for a WiFi Station. Sleeping Stations periodically wakeup to listen to traffic announcements to determine whether or not the AP has any buffered frames. When Stations Associate with an AP, part of the data in the Association Request

Frame is the Listen Interval. The Listen Interval is used to indicate to the AP how often a WiFi Station will wake to listen to Beacon frames.

An AP may use the Listen Interval as a guide to how long it should retain buffered frames for a WiFi Station in a Power Save mode. Larger listen intervals require more AP memory for frame buffering.

In reality, AP's generally do not pay much attention to the Listen Interval requested by a WiFi Station. If a WiFi station sets the Listen Interval to a particular value, there is no guarantee that the AP will buffer all of the packets received for the WiFi Station while asleep. WiFi Certification test plans do not currently test behavior related to the Listen Interval, and implementation of Listen Interval functionality is not enforced.

Most AP's enforce an Association Timeout on WiFi Stations, i.e. if the AP has not received a frame from a WiFi Station within the Association Timeout (usually 60 seconds) or the WiFi Station has not returned an ACK to an AP keep-alive frame, the WiFi Station will be Disassociated from the AP. Also, testing may be required to find the Association Timeout that is supported by a particular AP. The AT Command ZP can be used to test an AP Association Timeout.

4. DTIM Period

The DTIM period is a parameter associated with an infrastructure network, and is advertised in an Access Point Beacon frame. All Beacon frames include a Traffic Indication Map (TIM), which indicates to WiFi Stations that buffered frames are available. Unicast frames buffered for individual WiFi Stations are delivered in response to a query from the WiFi Station. This polled approach is not suitable for multicast and broadcast frames. Instead of the polled approach, broadcast and multicast frames are delivered after every Delivery TIM (DTIM).

Decreasing the DTIM period allows WiFi Stations to conserve power more effectively at the cost of buffer space in the AP and delays in reception of multicast and broadcast frames by all WiFi Stations, including WiFi Stations in active mode.

The default DTIM interval for most AP's is either DTIM=1 or DTIM=3. In case of DTIM=3, the station need only wake from Low Power Mode to receive every third beacon to received any ensuing queued broadcast or multicast traffic.

5. Practical Power saving

The generally accepted settings for WiFi Stations to use 802.11 Power Saving based on the DTIM period are as follows.

1. STA (Client Station) sends an 802.11 packet to AP with the Power Save bit set.

2. STA goes to sleep. AP notes the STA has gone to sleep and buffers packets for the STA.
3. STA wakes up at every DTIM to check the AP beacon frame for an indication of buffered packet(s).
4. If the AP has buffered packet(s) for the STA, the STA sends a Null Function data frame, or a data packet if available, to the AP with the Power Save bit cleared.
5. The AP notes the STA is awake and sends buffered packets.
6. STA returns to sleep as described in Step 1

Note:

These steps are handled by the AT Command ZP.

If a WiFi Station does not expect to receive directed packets from the AP asynchronously, and it is not interested in receiving broadcast or multicast traffic, then further power savings may be achieved.

Since AP's generally have an Association Timeout Limit with a default value of 60 seconds, a Power Save WiFi Station must wake before the expiry of the Association Timeout to send or receive a directly addressed packet, and to inform the AP that the WiFi Station is still Associated. Failure to comply, will result in Disassociation or De-authentication of the WiFi Station by the AP. Some AP's allow the Association Timeout Limit to be set to a higher value than 60 seconds but the higher limit is not signaled to the WiFi Station and must be manually configured.

The WiFi Alliance is currently working to adopt various new Power Save features that are in the 802.11v standard.

6. Power Consumption

Despite the fact that 802.11 transmit power consumption is at least five times higher than receive power consumption, for even medium transmit duty cycle applications, much of the energy in a battery powered WiFi Station is consumed by the WiFi Radio Receiver. Unless Power Save techniques are used, the 802.11 Receiver may be powered on for significant periods of time while the WiFi Station waits for network clients to respond to requests. It does not take too long for 150mW of receiver power consumption to drain a battery.

The key to minimizing power consumption is to minimize the ON duty cycle of the system. Minimizing the integrated area under the current consumption curve is critical to obtaining maximum life from a battery.

7. MCU Power Saving

The description in this selection applies to the MicroController Units (MCU). The MCU Power Save Mode is enabled via the eS-WiFi's AT Command ZP, which allows changes the Beacon Interval Time, and allows Sleeping of MCU.

1.1. Description

In MCU Sleep Mode, all clocks except the 32 kHz Real Time Clock (RTC) are powered down. All memory and registers retain state.

With Sleep Mode enabled, the eS-WiFi Module enables an Out-of-Band (OOB) interrupt on an external GPIO from the WiFi chip. The OOB interrupt is required because the SDIO clock and interrupt handling on the MCU are disabled in Sleep Mode.

There should be no noticeable difference in operation of a standard application when Sleep Mode is enabled, except that the MCU current consumption is greatly reduced whenever the processor is sleep.

1.1. Example Power Measurement Tests

The plots provided in this section show various aspects of the power consumption of the eS-WiFi Module under tests. The eS-WiFi Module during tests is brought up, associated with an AP, and a Ping is performed. After the Ping, the AT Command ZP is used to set the Beacon Interval and Sleep time of the MCU. When the MCU wakes from Sleep, another Ping is performed to verify the eS-WiFi Module is still associated with the AP. The Ping tests running on a eS-WiFi module is acting as a functional Wi-Fi Station. All plots show current consumption saved by using the eS-WiFi's AT Command ZP.

The power supply to the module is 3.3V. The Current is measured by a Maxim Single, High-Side, Current-Sense Amplifier (MAX4376FAUK+T) with an Internal Gain set at 20, which is connected across a 0.2ohm resistor. The Current-Sense Amplifier gives a value of Volts measured divided by ten to equal measured current. To verify when the MCU had entered into sleep mode, an I/O pin was set up to drive its level low for Sleep, and drive its output level high for Awake. An oscilloscope was set up to trigger off the I/O pin and capture the Sleep Voltage measured by the Current-Sense Amplifier.

The Oscilloscope used during the tests was an Hantek DSO-5200 Digital Oscilloscope with an ability to save Oscilloscope trace data to a file. Signal processing of the Oscilloscope trace data was handled via Octave.

1.2. Power Save Testing of Beacons Set to One

Figure 7.2.1, below, shows the eS-WiFi Module associating with an AP and performing a ping to verify AP connectivity.

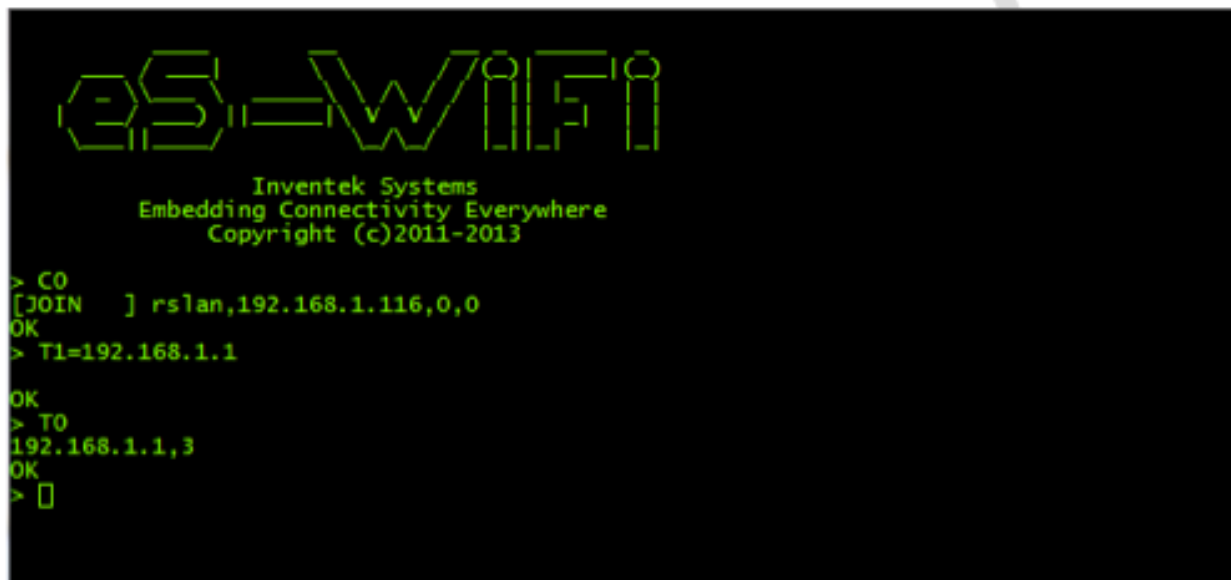


Figure 7.2.1. eS-WiFi AP Association and Ping

Once the eS-WiFi has successfully associated with an AP, the AT Command 'ZP=2,1' is used to set the Beacon Interval to one (default). 'ZP=6,1000' is used to set the MCU to sleep for one second, and the WiFi Radio is set to sleep between Beacons. Figure 7.2.2, below, shows the steps and that the MCU has gone to sleep,



Figure 7.2.2. eS-WiFi Beacons set to 1 and MCU Sleep to one Second

Figure 7.2.3, below, shows the Oscilloscope trace for the eS-WiFi set to a Beacon Listen Interval of one, and the MCU put to sleep for one second.

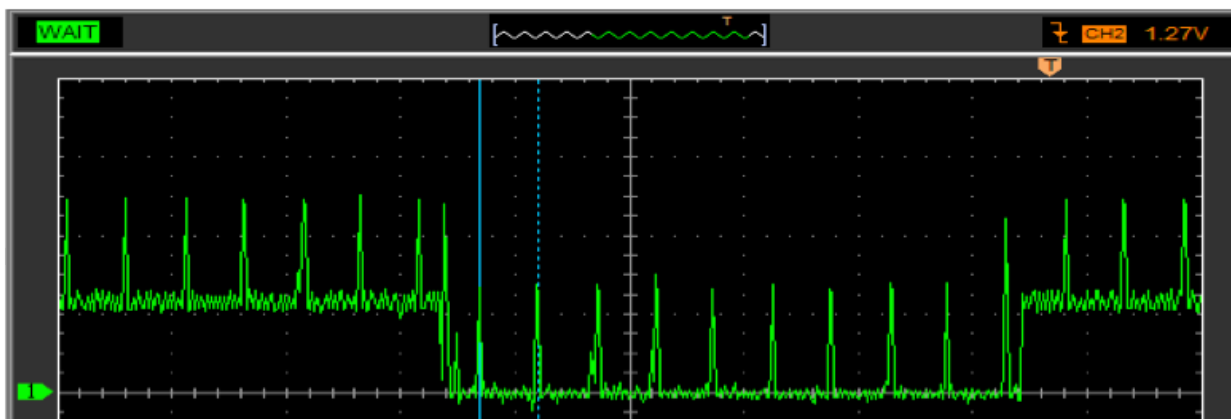


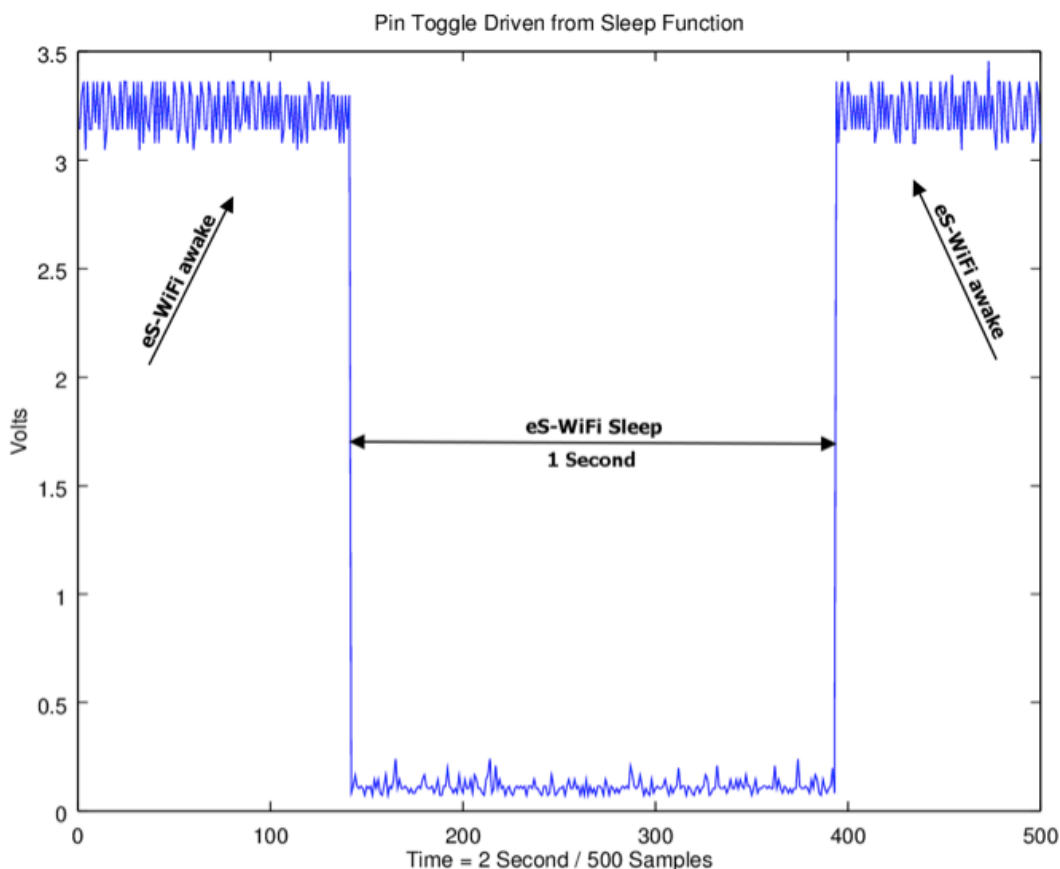
Figure 7.2.3. Oscilloscope Trace of ZP=2,1, and ZP=6, 1000 Sleep Mode

Figure 7.2.3, shows that the MCU went from a wake state to a sleep state of one second with a reduction in overall system power of the eS-Wifi Module. Figure 7.2.3 also shows that the Beacon Interval is approximately 100ms.

The data capture vis the Oscilloscope, was post processed by Octave to analyze the power saving mode of the eS-WiFi. Figure 7.2.4, below, shows a screen capture Octave of the Oscilloscope data with annotation on the awake and sleep modes of the MCU and WiFi Radio.

Figure 7.2.4. Processed Oscilloscope Data of ZP=2,1, and ZP=6, 1000 Sleep Mode

The Oscilloscope was set up to capture the Current-Sense Voltage on Channel One, Channel Two of the Oscilloscope was set to capture the I/O pin state show when the MCU was awake and a sleep. Figure 7.4.5, below, shows the data captured by the Oscilloscope and processed via Octave. Figure 7.4.5 clearly shows when the MCU when into and out of Sleep Mode.



Using the data shown in Figure 7.2.4, shown above, and the data show below in Figure 7.2.5, the Voltage Measured by the Current-Sense Amplifier for Sleep Mode only was cutout and reviewed for the average voltage of the eS-WiFi over the MCU Sleep Interval of one second with Beacons set to 1 (100ms).

Figure 7.2.6 below shows the isolated voltage measured by the Current-Sense Amplifier for the Sleep only part of the Captured Oscilloscope data. Reviewing Figure 7.2.6, we

Figure 7.2.5. Octave Oscilloscope Data Analysis
showing I/O Trigger Pulse

can see that the MCU power has been greatly reduced between Beacons, and the average voltage calculated over the Sleep Mode Interval of one second is 0.072587V or ~72mV, which is much smaller that the awake voltage of approximately ten times higher.

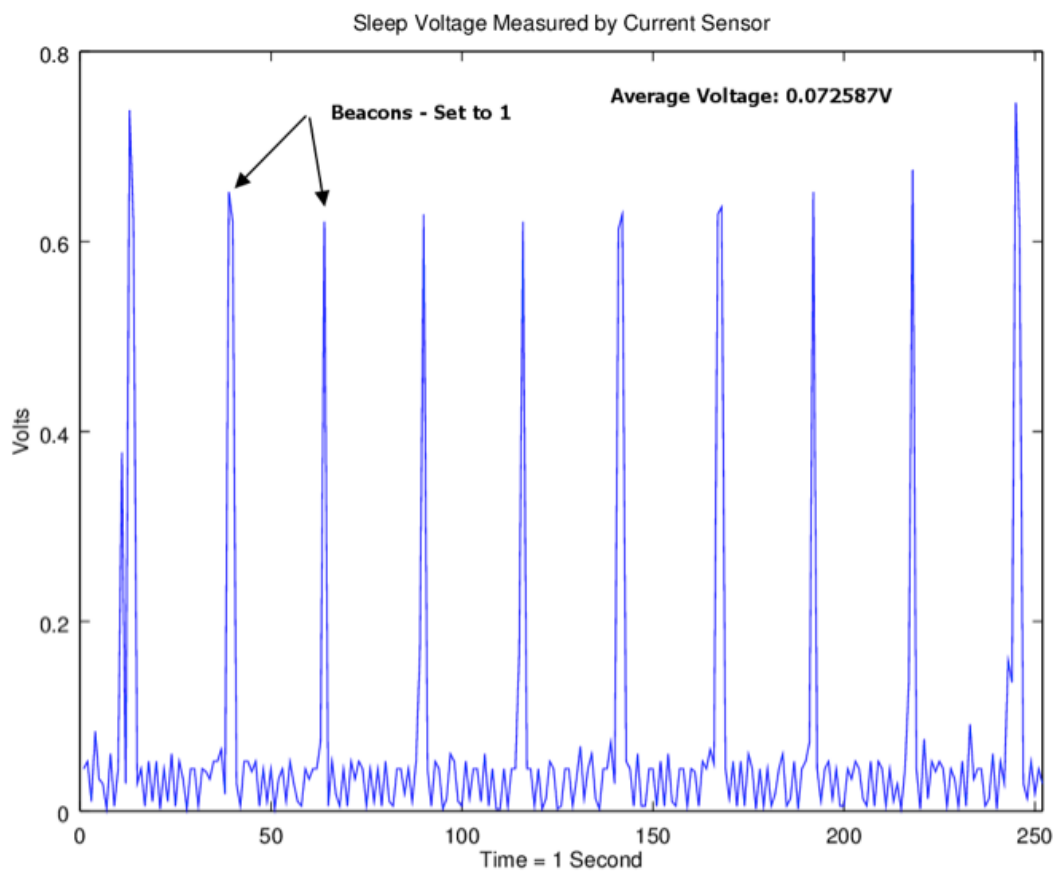
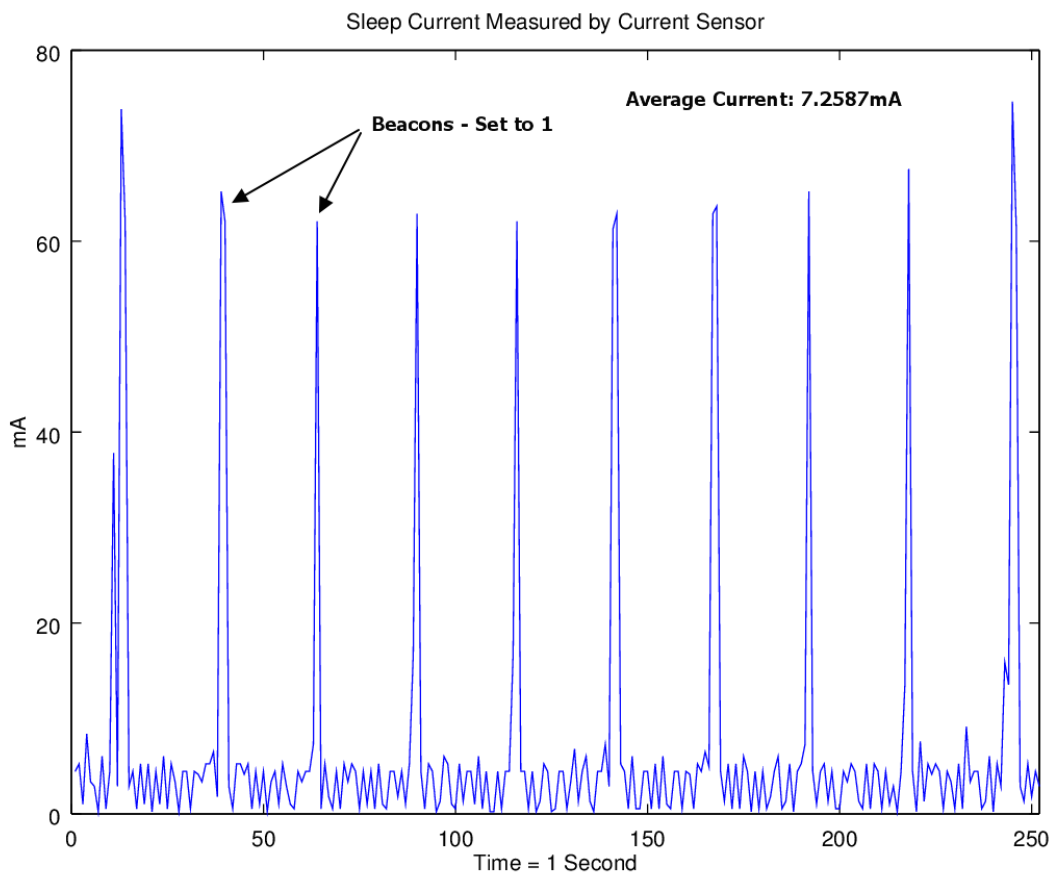


Figure 7.2.6. Sleep Only Mode Voltage Measured.

In order to convert the voltage measured by the Current-Sense Amplifier to the mA current we are interested in for Power Save Applications, the measured voltage needs to be divided by 10. Figure 7.2.7, below, shows the measure voltage converted in mA. From Figure 7.2.7, we can see that our average current used during putting the MCU to sleep for one second and the Beacon Interval set to 1 was approximated 7.2mA, which again is a factor of nearly 10 times lower than the eS-WiFi awake mode. Further Figure 7.2.7 shows that there is a benefit to Sleeping the MCU and setting a Beacon Listen



Intervals.

Figure 7.2.7. Sleep Only Mode Voltage Converted into Current.

The next step was to verify that the MCU and WiFi Radio recovered from Sleep and was not Dissociated with AP. This test was accomplished by a set of Pings to AP. Figure 7.6.8, shows that the MCU woke up, and was able to successfully Ping the AP; thereby, remaining Associated with the AP.

The above test steps were repeat using Beacon Listen Intervals of 5 and 10 with MCU set to sleep to one second during each each test. The following set of

```
> ZP=2,1
OK
> ZP=6,1000
sleep
wake
OK
> T0
192.168.1.1,69
OK
> T0
192.168.1.1,29
OK
> 
```

figures, shown in Section 7.3 and Section 7.4, detail the tests, and test results. Please refer back to Table 2.1 for a summary of the measured currents for each of these Beacon Modes.

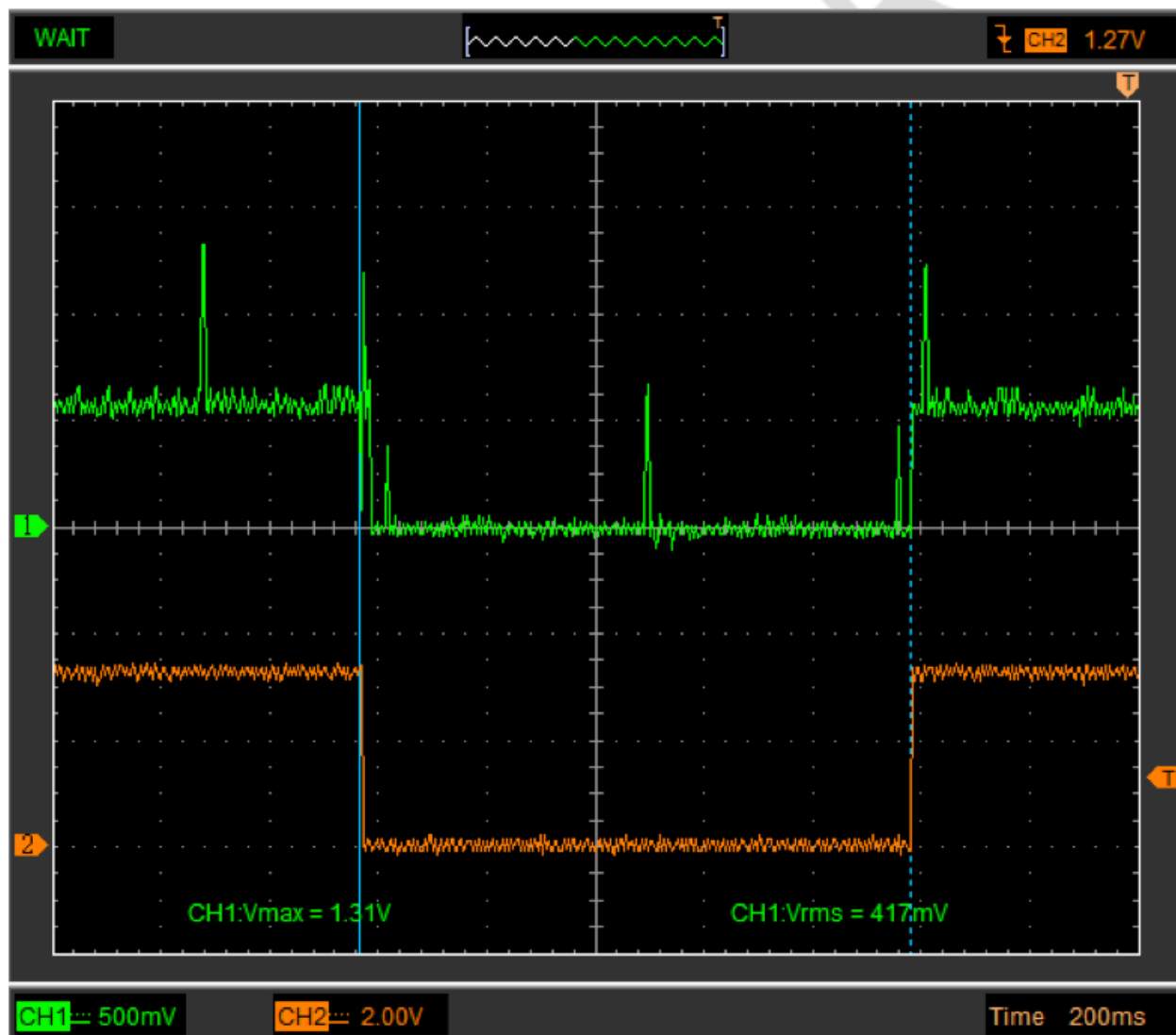
Figure 7.2.8. Terminal Output Showing the eS-WiFi still associated with the AP after Sleeping

1.3. Power Save Testing of Beacons Set to Five

```
> ZP=2,5  
OK  
> ZP=6,1000  
sleep
```

Figure 7.3.1. eS-WiFi Beacons set to 5 and MCU Sleep to one Second

Figure 7.3.2. Oscilloscope Trace of ZP=2,5, and ZP=6, 1000 Sleep Mode



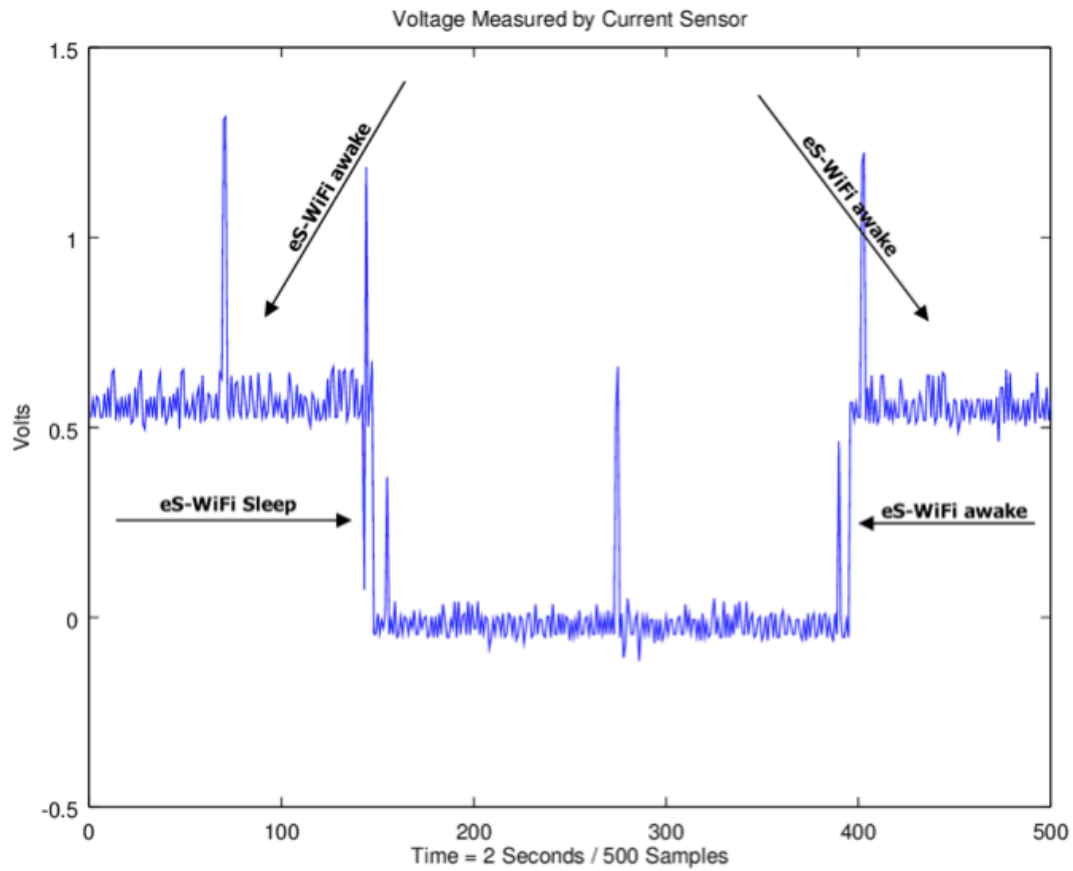
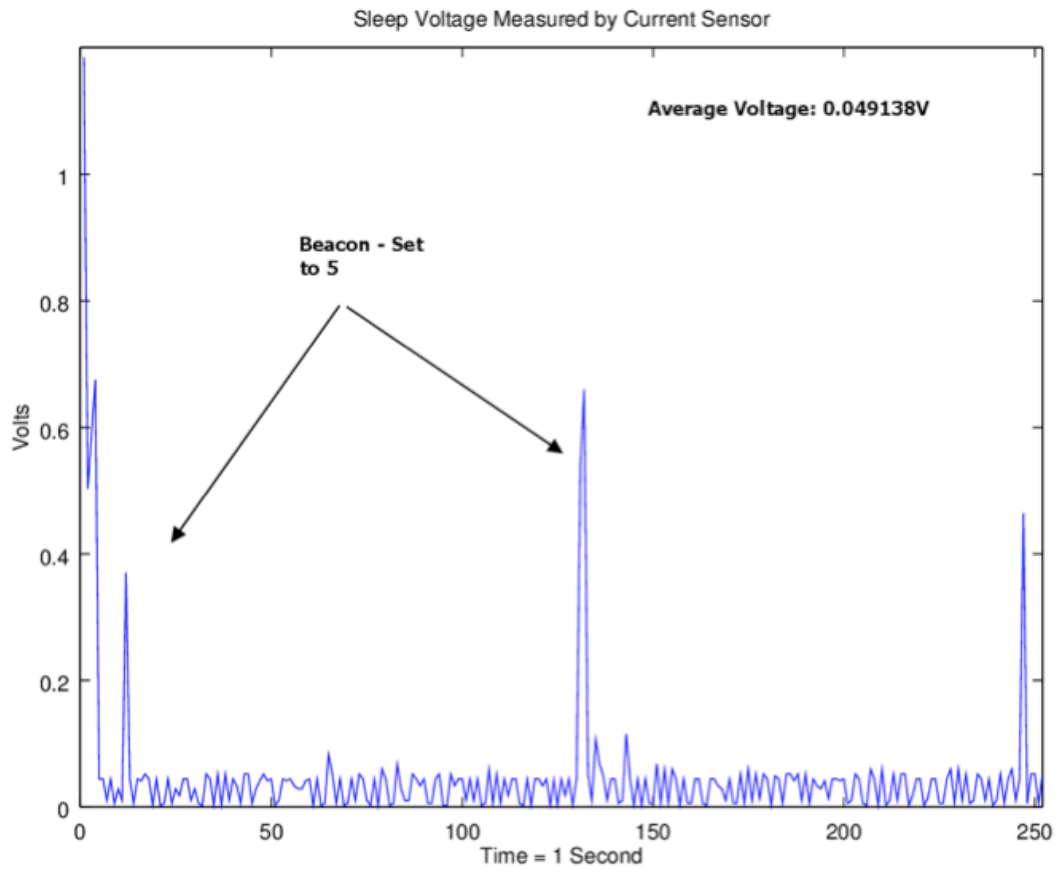


Figure 7.3.3. Processed Oscilloscope Data
of ZP=2,5, and ZP=6, 1000

Figure 7.3.4. Octave Oscilloscope Data Analysis



showing I/O Trigger Pulse

Figure 7.2.5. Sleep Only Mode Voltage Measured

Figure 7.2.6. Sleep Only Mode Voltage Converted into Current

```
> ZP=2,5
OK
> ZP=6,1000
sleep
wake

OK
> T0
192.168.1.1,480
OK
> T0
192.168.1.1,447
OK
> █
```

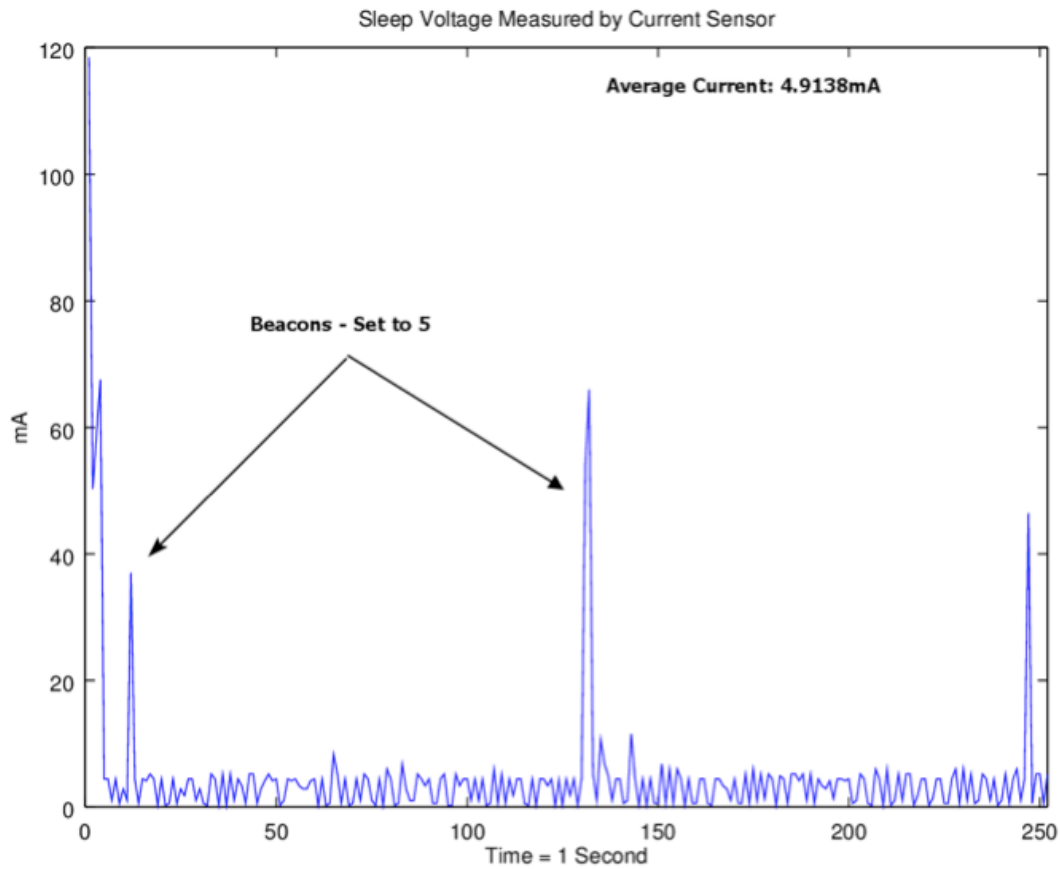
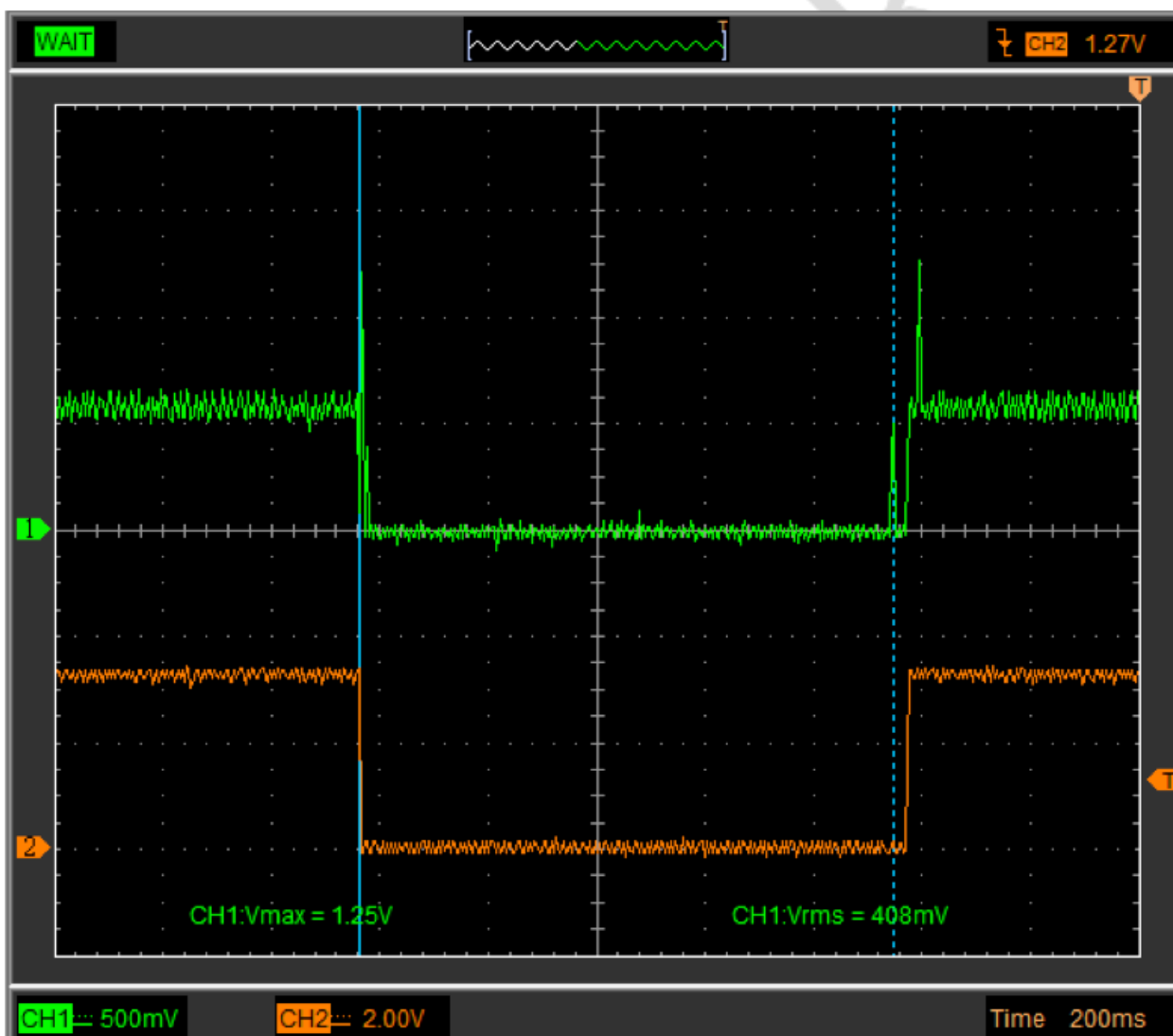


Figure 7.2.7. Terminal Output Showing the eS-WiFi still associated with the AP after Sleeping

1.4. Power Save Testing of Beacons Set to Ten

Figure 7.4.1. eS-WiFi Beacons set to 10 and MCU Sleep to one Second
Figure 7.4.2. Oscilloscope Trace of ZP=2,10, and ZP=6, 1000 Sleep Mode

```
> ZP=2,10
OK
> ZP=6,1000
sleep
```



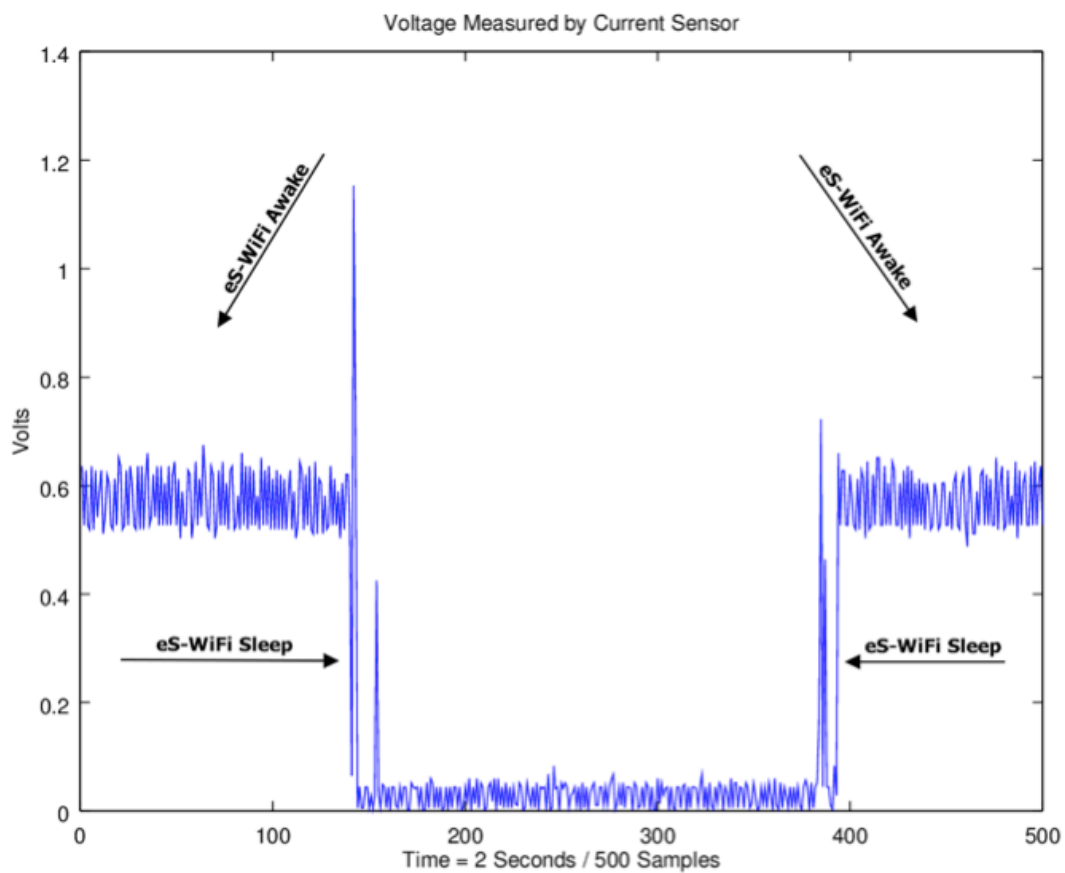


Figure 7.4.3. Processed Oscilloscope Data
of ZP=2,10, and ZP=6, 1000

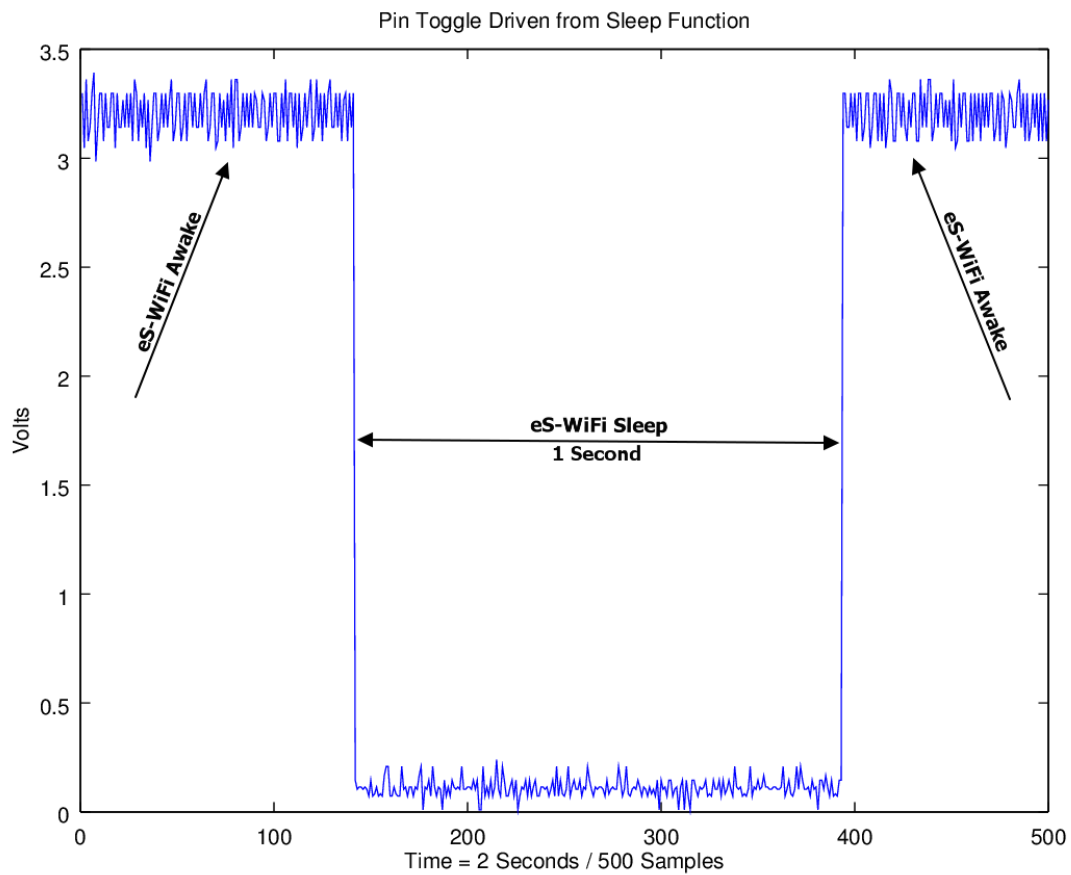


Figure 7.4.4. Octave Oscilloscope Data Analysis
showing I/O Trigger Pulse

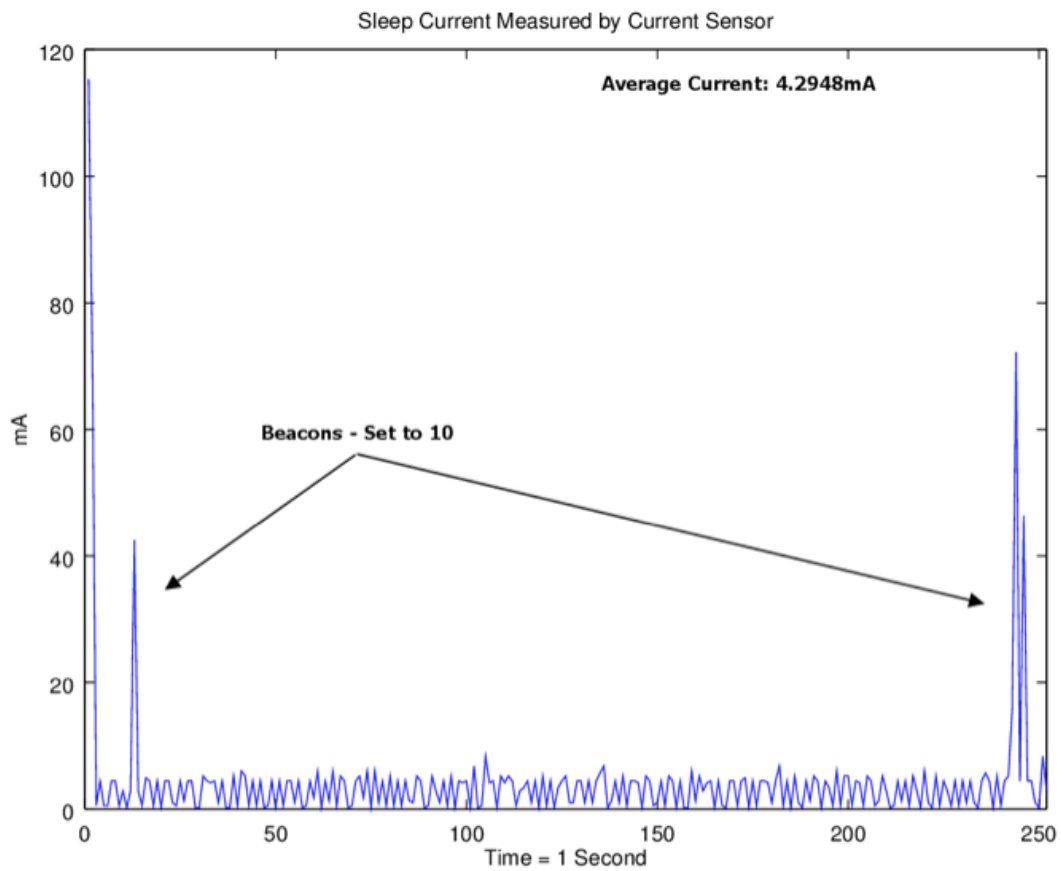


Figure 7.4.5. Sleep Only Mode Voltage Measured

Figure 7.4.6. Sleep Only Mode Voltage Converted into Current.

PRELIMINARY

```
> ZP=2,10
OK
> ZP=6,1000
sleep
wake

OK
> T0
192.168.1.1,Timeout
OK
> T0
192.168.1.1,1084
OK
> T0
192.168.1.1,1015
OK
> T0
192.168.1.1,1014
OK
> 
```

Figure 7.4.7. Terminal Output Showing the eS-WiFi still associated with the AP after Sleeping

8. Summary

As shown in Section 7, changing the Beacon Interval as well as the MCU Sleep Time can greatly affect the Power Saving capabilities of the eS-WiFi module, which allows for better battery life WiFi application. Refer back to Table 2.1 for power savings achieved during making of this Application note.

Testing various Beacon Interval and MCU Sleep Times for the best power savings is left up the user. It recommend that user keep in mind that the Beacon Interval are affected by the capabilities of the Access Point, so testing various Access Points will help pin down the maximum usable Beacon Interval. Also, adjusting the MCU Sleep Time can be affect by the capabilities of the Access Point because most Access Points have limit memory for buffering frames intended for a WiFi Station. Again, testing various Access Points will help pin down the Maximum MCU Sleep Time for further Power Saving advantages.

9. Document History

Date	Name	Description	Revision	File Name
1/02/12	MFT	Initial Creation	1 . 0	User Manual Initial Release
08/03/14	RES	Updated for Wiced 2.4.x	1 . 1	eS-WiFi AN20046 Power Save Modes 1.1.docx