TiWi-SL
Power Guide
Application Note

LS RESEARCH, LLC
WIRELESS PRODUCT DEVELOPMENT

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1 Introduction

1.1 Purpose & Scope

The purpose of this document is to provide details regarding the power consumption of the TiWi-SL module when booting and connecting to a WLAN access point (AP). This application note should be used as a guide on how to calculate the power consumed by the TiWi-SL. Software timing and host processor specifications could cause the measured results to vary. The timing and power measurements in this document should only be used as a rough estimate on how the TiWi-SL may perform when used in a different system. In order to determine the power consumption of the TiWi-SL in the user's end application, the current of the module should be monitored and analyzed in the final implementation. Host processor software timing, AP used, data rate, and packet size are all factors that will influence power consumption.

1.2 Audience

This document is intended to be read by engineers and technical management. A general knowledge of common engineering practices is assumed.

1.3 Applicable Documents

- *TiWi-SL Datasheet*
- *CC3000 Doxygen API*
  - *(See* http://processors.wiki.ti.com/index.php/CC3000_Wi-Fi_for_MCU)

1.4 Revision History

Date	Change Description	Revision
3/08/2012	Initial release	1.0

Table 1 Revision History

2 Test Setup

The pieces used for this test were:

1. Texas Instruments DK-LM3S9B96 development kit
2. Stellaris LM3S9B96 EM2 Expansion Board (DK-LM3S9B96-EM2)
3. TiWi-SL EM Board with Chip Antenna (450-0089)
4. Agilent 6611C DC Power Supply
5. TP-LINK TL-WR740N Wireless Router
    a. Wireless Security: Open
    b. Mode: 802.11b only

VCC to the TiWi-SL EM board was supplied by the external power supply at 3.3V on J7 of the TiWi-SL EM Board.

Figure 1 - LM3S9B96 development kit with TiWi-SL module

3 Power Consumption Measurements

The following measurements can be interpreted as:

1. Yellow trace = current consumption (100mA per division, except Figure 2). The current is measured on the VCC module signal.
2. Purple trace = PWR_EN module signal. This signal turns the module on.
3. Pink trace = wlan_start() complete. The wlan_start() function initializes the module for operation. Once this function completes, the module is running under normal operation.
4. Green trace = Connected to AP. Connection to the AP is successful when the asynchronous connection event is received from the TiWi-SL module.

3.1 Inrush current

When enabling the TiWi-SL module there is a short burst of inrush current due to the bulk capacitance of the VCC signal on the module. The scale in Figure 2 is 500mA per division. The inrush current peaks at around 2.7 amps.

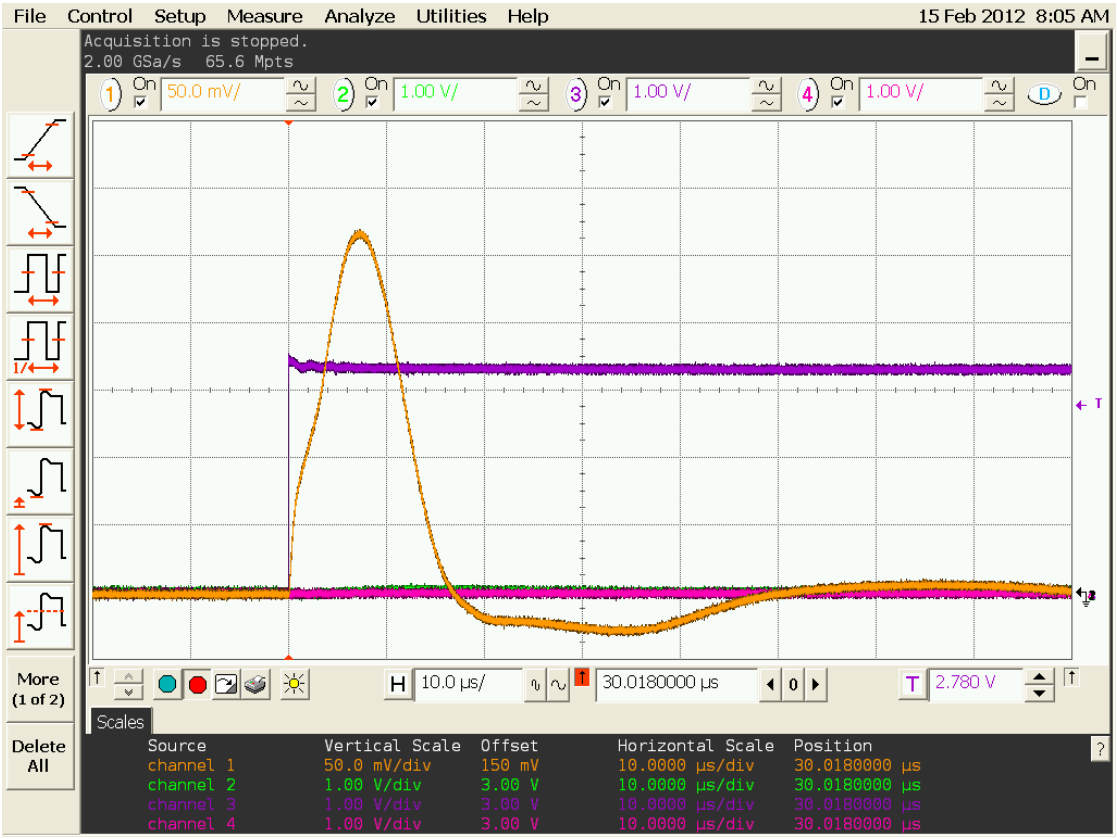

Figure 2 - Inrush current of TiWi-SL module

3.2 TiWi-SL Boot

Once the TiWi-SL is booted, it is always in receive mode and will draw 100mA. It takes between 600 and 800 ms for the TiWi-SL module to boot up and be operational. In Figure 3, the boot time is 640ms. The scale for Figure 3 is 100mA/division.

Figure 3 - TiWi-SL Boot

3.3 Auto Connect to AP

If the TiWi-SL module has already been associated with an AP, and has a valid profile stored, the module can boot up and automatically connect to the AP. The wlan_ioctl_set_connection_policy() command can be used to set how the TiWi-SL module connects to a stored profile after the module has booted. Figure 4 shows the TiWi-SL module booting up and connecting to a previously associated AP with the connection policy set as wlan_ioctl_set_connection_policy(0, 0, 1). In the case of Figure 4, it takes the TiWi-SL module about 2.75 seconds to find and connect to the AP.

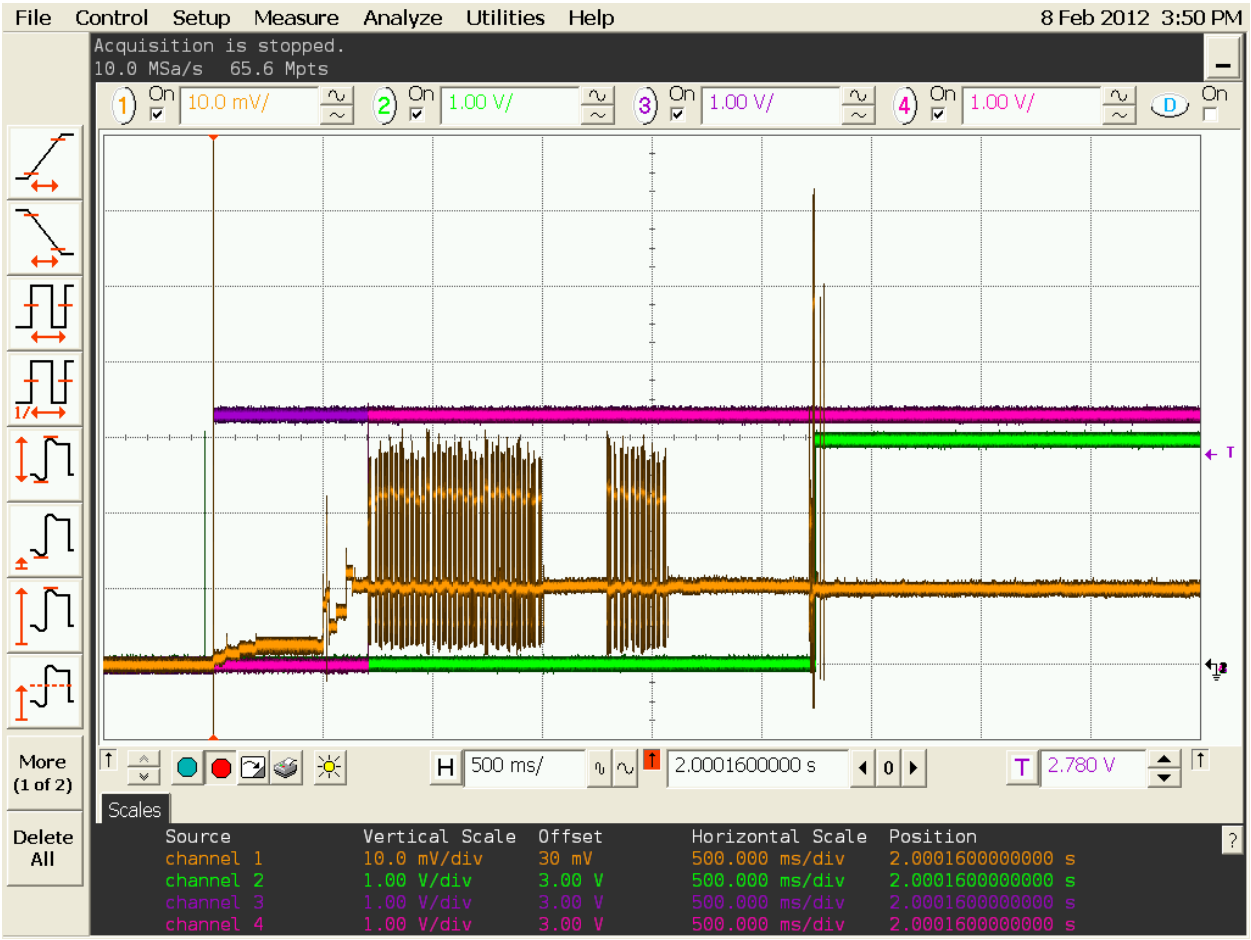

Figure 4 - TiWi-SL Boot and Auto Connect to AP From Stored Profile

3.4 Connect Command

The TiWi-SL can be commanded to connect to an AP with the wlan_connect() function. This saves time and power because the module will try and connect to the AP right away and not need to scan and find the AP. Figure 5 shows the TiWi-SL module booting and connecting to the AP with the wlan_connect() function and the connection policy set to wlan_ioctl_set_connection_policy(0, 0, 0). Notice how the TiWi-SL connects much faster, taking around 1.44 seconds and there is not as much RF traffic.

Figure 5 - TiWi-SL Connect to AP Without Auto Connect Policy

3.5 Fast Auto Connect

The quickest and most power efficient way to connect to an AP is to have the connection policy set to wlan_ioctl_set_connection_policy(0, 1, 1) and be sure the AP profile is already stored in the TiWI-SL. Figure 6 shows the module connecting to the AP with minimal RF traffic and it completes the connection in about 780ms.

Figure 6 - TiWi-SL Fast Auto Connect

4 Practical Use Power Calculation

The following example will show how to calculate the power usage (in mAh) of the TiWi-SL module. The example used, boots the TiWi-SL module, connects to an AP, and then sends a broadcast UDP packet and then is shutdown. The VCC of the TiWi-SL is at 3.3V, the connection policy is set to wlan_ioctl_set_connection_policy(0, 1, 1), and the AP profile has already been stored.

4.1 TiWi-SL Boot Power

Let's define the boot power as the time it takes the wlan_start() function to complete. Once that function completes, the module is operational.

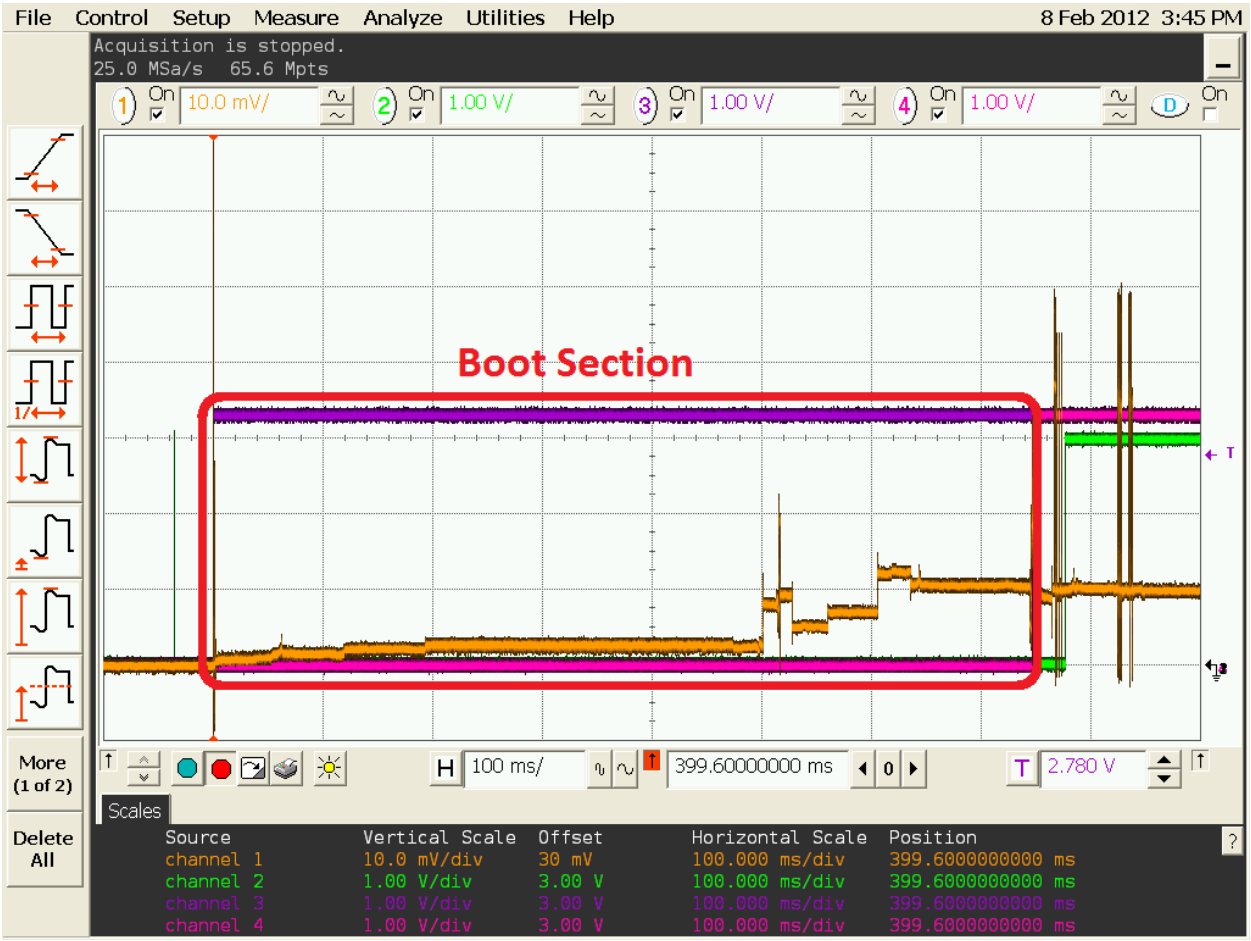

Figure 7 - TiWi-SL Boot Section

The first 120ms ramps to about 18mA, so to obtain the power under the curve we will calculate the rectangular area and then divide by 2 to get an estimate of the ramp area.

$120ms * 18mA \ \div 2 = 0.000600mAh$

The rest of the boot section can be represented by rectangular areas.

$70ms * 21mA = 0.000408mAh$

$310ms * 25mA = 0.002153mAh$

$15ms * 80mA = 0.000333mAh$

$15ms * 90mA = 0.000375mAh$

$30ms * 50mA = 0.000417mAh$

$47ms * 70mA = 0.000914mAh$

$26ms * 120mA = 0.000867mAh$

$117ms * \ 100mA = 0.003250mAh$

Adding all these pieces together equals a total of 0.009317mAh for the TiWi-SL boot sequence. For simplicity we will assume the power required to boot the TiWi-SL module is 0.01mAh.

4.2 TiWi-SL Connect to AP

Once the TiWi-SL is booted, it will try and fast connect to the stored AP profile. During this time there will be high current RF traffic. The connect to AP section is the time from when the TiWi-SL wlan_start() completes to when the TiWi-SL is connected to the AP. In this example the time it takes to connect to the AP is 31.7ms.

Figure 8 - TiWi-SL Connect to AP Section

We'll break the AP connection section into two parts so we can get a better picture. After measuring all the burst times with currents other than 100mA we can determine the length of time the current was at 100mA.

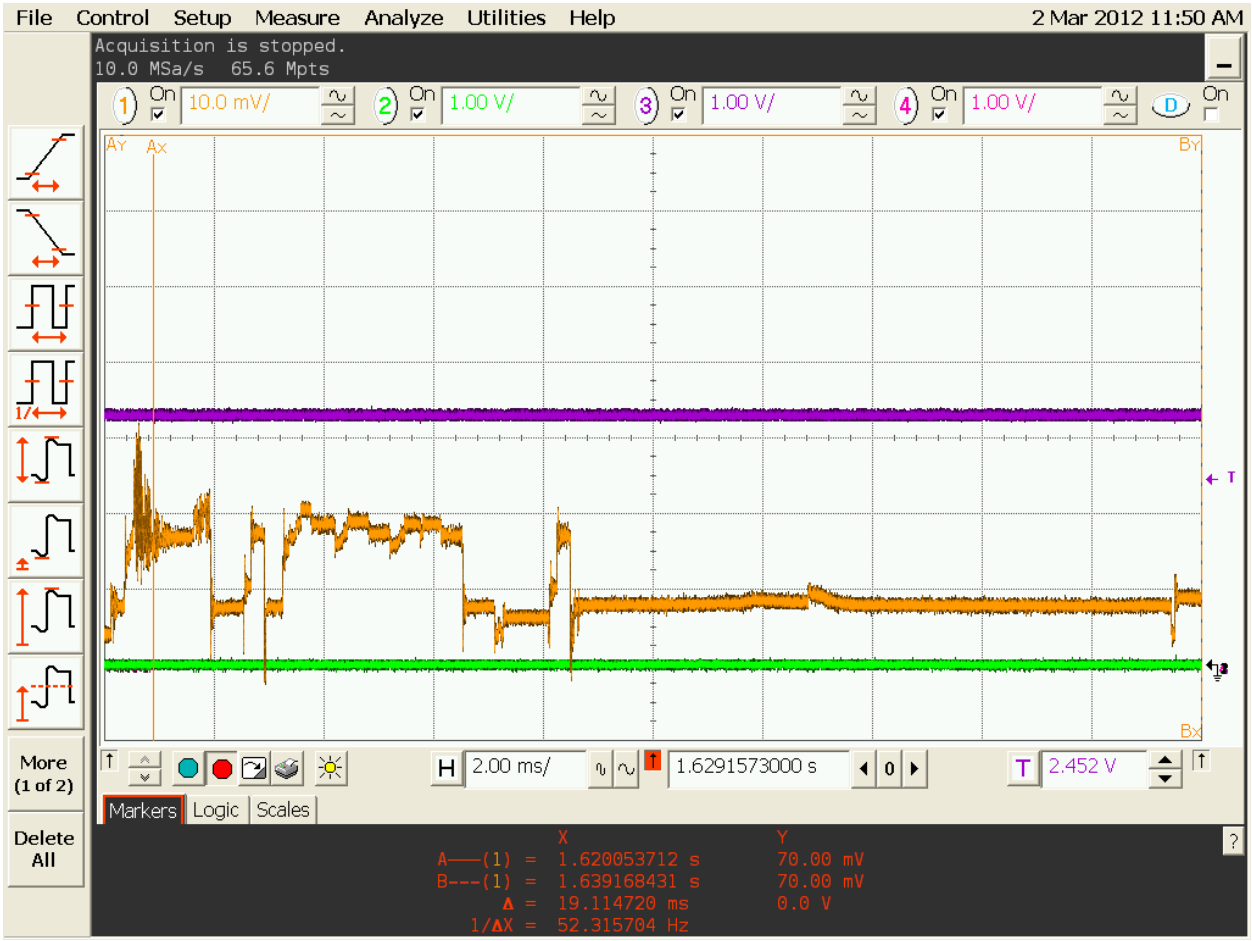

Figure 9 - Connect to AP Section Part 1

The power bursts for part 1 of the AP connection can be calculated as (bursts other than 100mA):

$1.03ms * 190mA = 0.000054mAh$

$0.6ms * 77mA = 0.000013mAh$

$0.4ms * 175mA = 0.000019mAh$

$0.4ms * 75mA = 0.000008mAh$

$3.26ms * 190mA = 0.000172mAh$

$1.6ms * 75mA = 0.000033mAh$

$0.4ms * 175mA = 0.000019mAh$

$11ms * 80mA = 0.000244mAh$

The total power for part 1 of the AP connection is 0.000562mAh, accounting for 18.69ms of time.

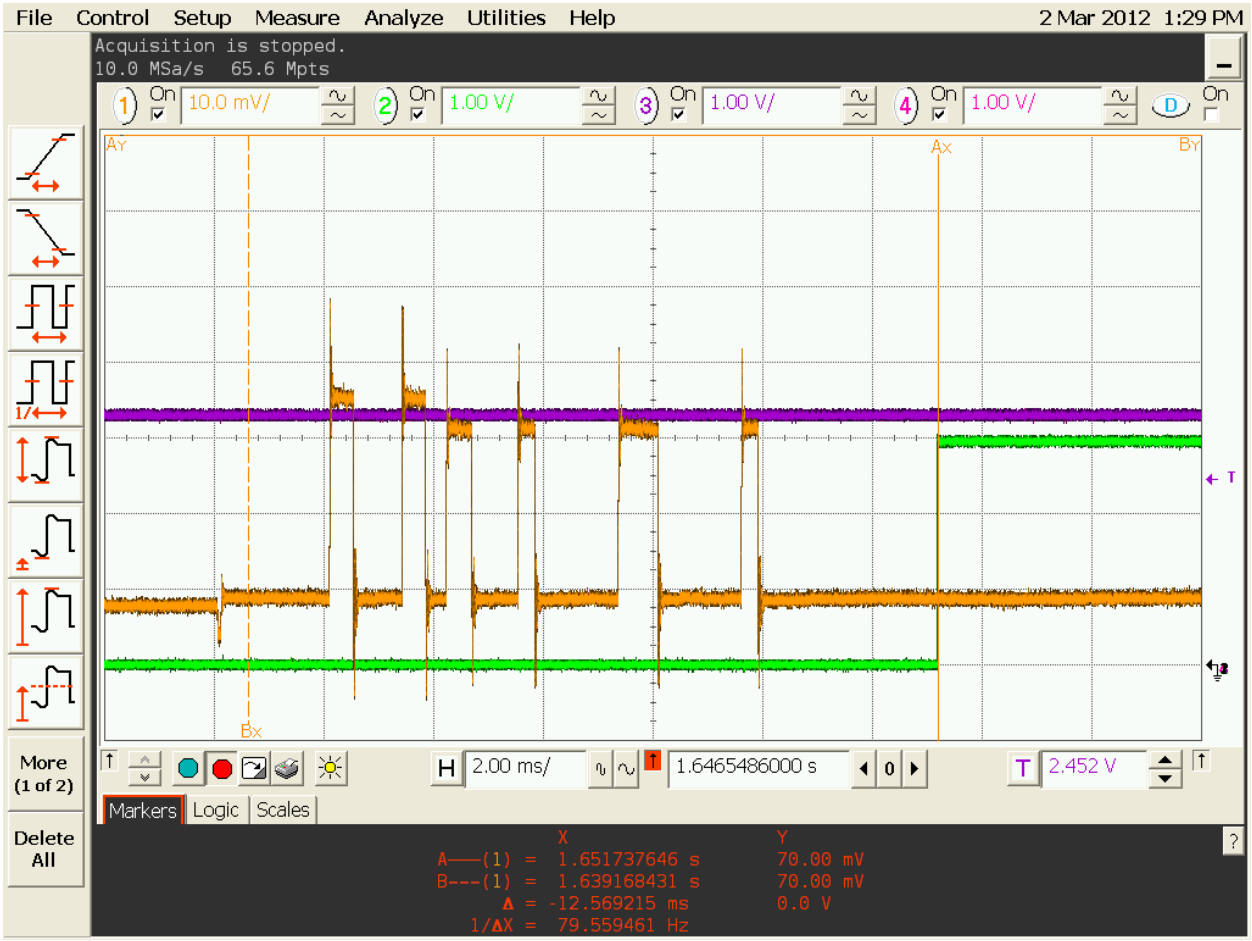

Figure 10 - Connect to AP Section Part 2

The power for part 2 of the AP connection can be calculated as:

$0.45ms * 350mA = 0.000044mAh$

$0.45ms * 350mA = 0.000044mAh$

$0.49ms * 313mA = 0.000043mAh$

$0.32ms * 313mA = 0.000028mAh$

$0.74ms * 313mA = 0.000064mAh$

$0.32ms * 313mA = 0.000028mAh$

The total power for part 2 of the AP connection is 0.000251mAh. Part 2 of connection section consumes 2.77ms of time where the current is something other than 100mA. We can calculate the power consumption for the time the module is at 100mA as: $(31.7ms - 18.69ms - 2.77ms) * 100mA = 0.000284mAh$

The total power for connecting to the AP is:

$0.000562mAh + 0.000251mAh + 0.000284mAh = 0.001097mAh \approx 0.0011\ mAh$

4.3 TiWi-SL Obtain IP Address

When the TiWi-SL has connected to the AP it needs to obtain an IP address before any UDP or TCP data can be sent. The TiWi-SL can obtain an IP address through DHCP or be assigned a static IP address. Depending on which mode is used, there will be a different amount of power consumed.

4.3.1 DHCP IP Address power consumption

After the TiWi-SL has connected to the AP it will take some time for the DHCP process to complete and some RF traffic will take place due to the DHCP transaction. In this case, the DHCP transaction took 67.61ms. The green trace was pulsed low when the HCI_EVNT_WLAN_UNSOL_DHCP event was received from the module. This event lets us know that the DHCP is finished.

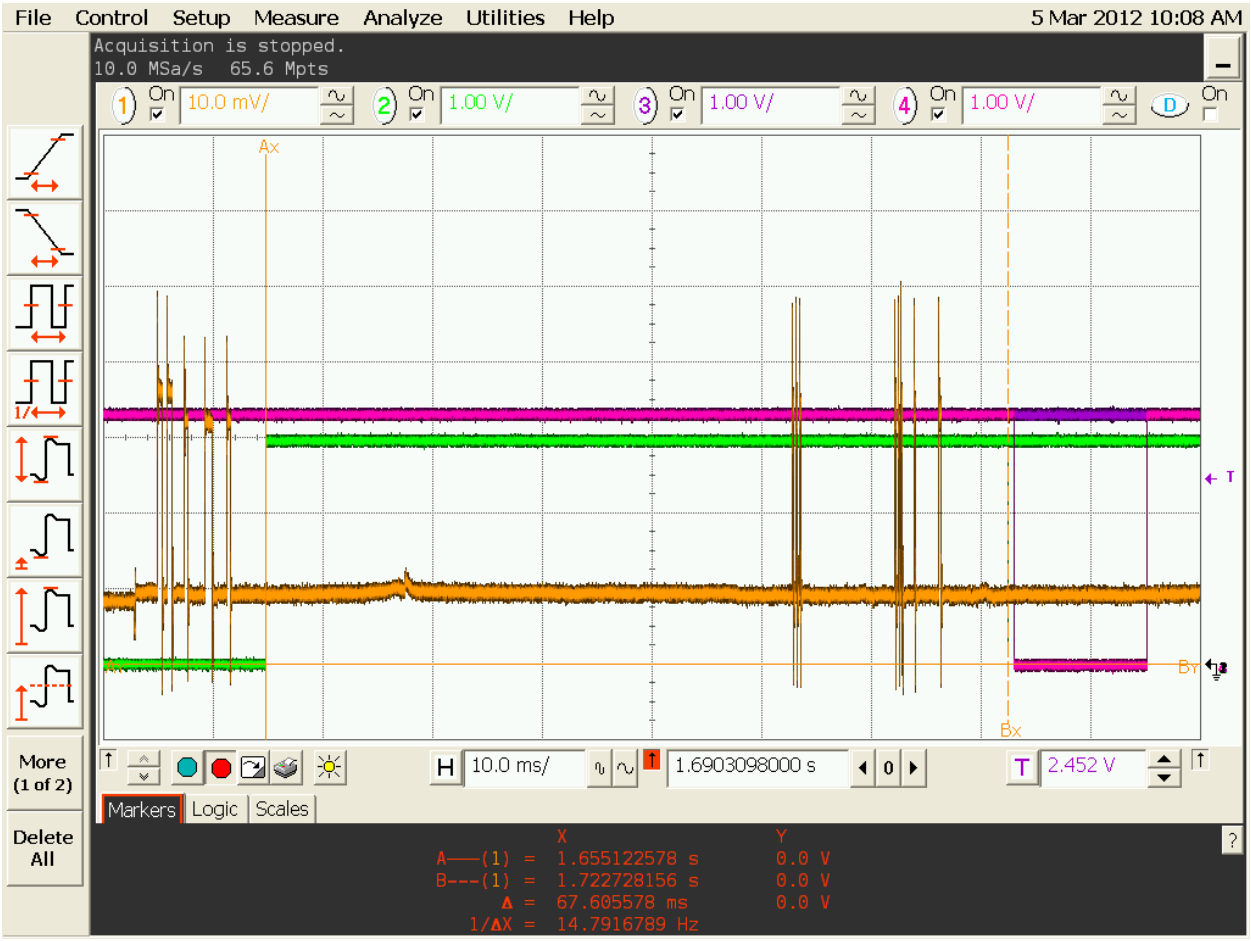

Figure 11 - TiWi-SL DHCP Transaction Time

The power of the RF bursts can be calculated and the remaining time will be accounted for at 100mA.

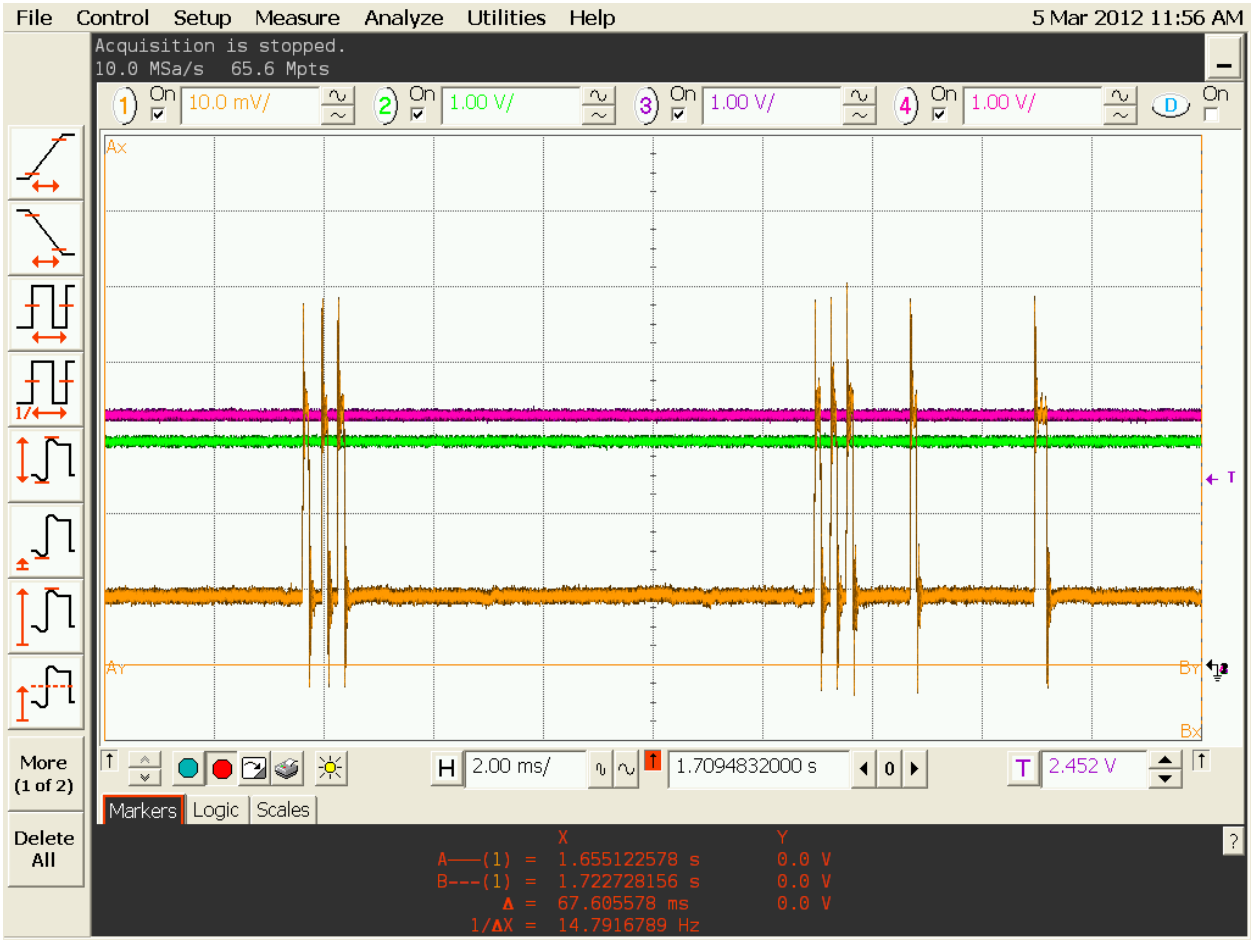

Figure 12 - TiWi-SL DHCP RF Traffic

$$136us * 329mA = 0.000012mAh$$

$$136us * 329mA = 0.000012mAh$$

$$144us * 329mA = 0.000013mAh$$

$$131us * 329mA = 0.000012mAh$$

$$133us * 329mA = 0.000012mAh$$

$$144us * 329mA = 0.000013mAh$$

$$144us * 329mA = 0.000013mAh$$

$$249us * 329mA = 0.000023mAh$$

The power consumed during the RF traffic equals 0.000110mAh. The rest of the time the TiWi-SL is at 100mA for 66.39ms which equals 0.001844mAh. Total, the TiWi-SL DHCP transaction consumes 0.00195mAh ≈ 0.002mAh.

4.3.2 Static IP Address power consumption

With a static IP configuration there is no need for any RF communication between the AP and the module. This means the IP address setup takes place much quicker, thus consuming less power.

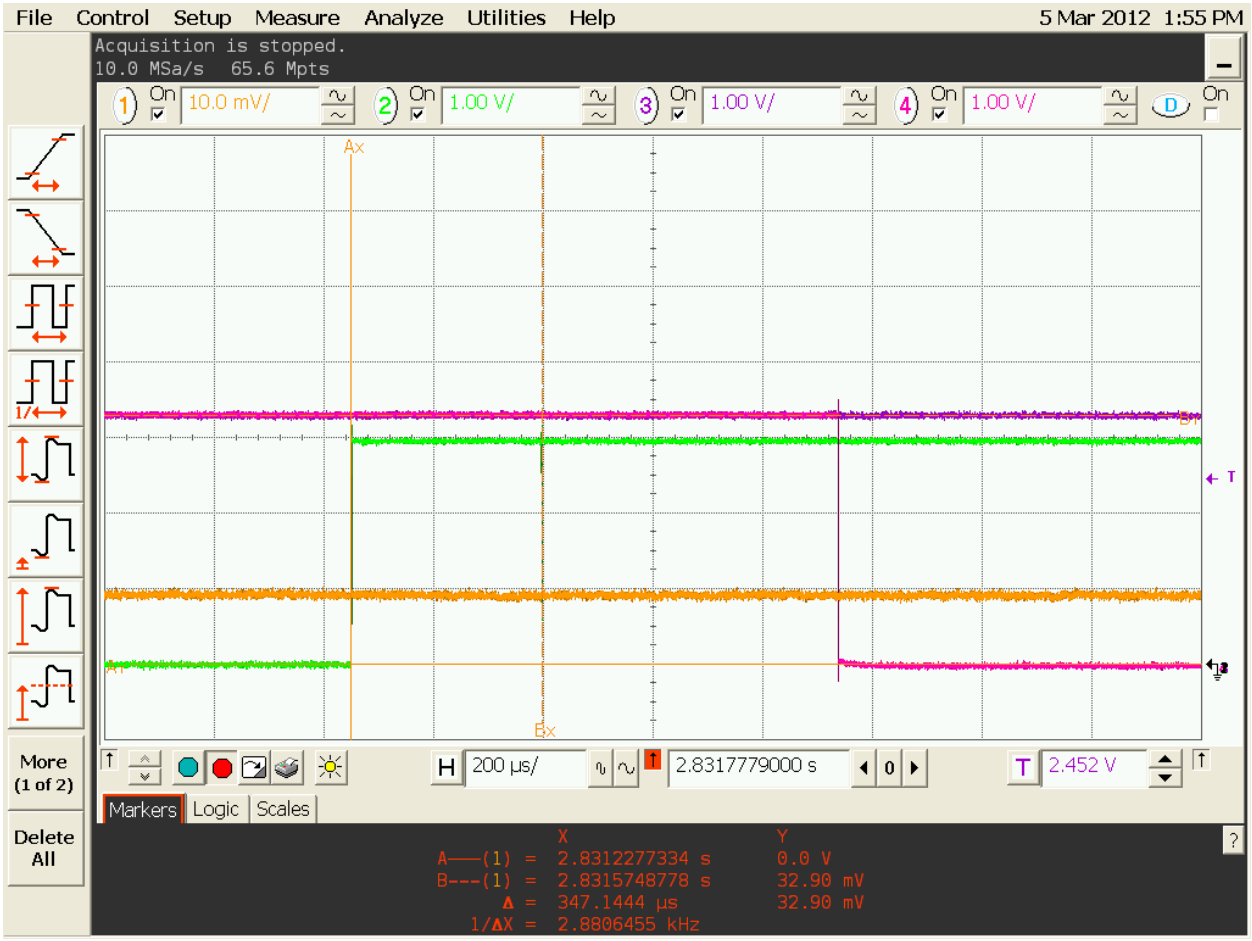

Figure 13 - TiWi-SL Static IP Configuration Time

Figure shows the static IP configuration only takes 347us. The overall power for the static IP configuration section can be calculated as:

$$347us * 100mA = 0.000010mAh$$

This is significant power savings over DHCP. The DHCP process consumes about 200 times more power than the static IP configuration.

5 Contacting LS Research

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