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**ATWILC1000B - Deriving Application Gain Table**

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**Introduction**

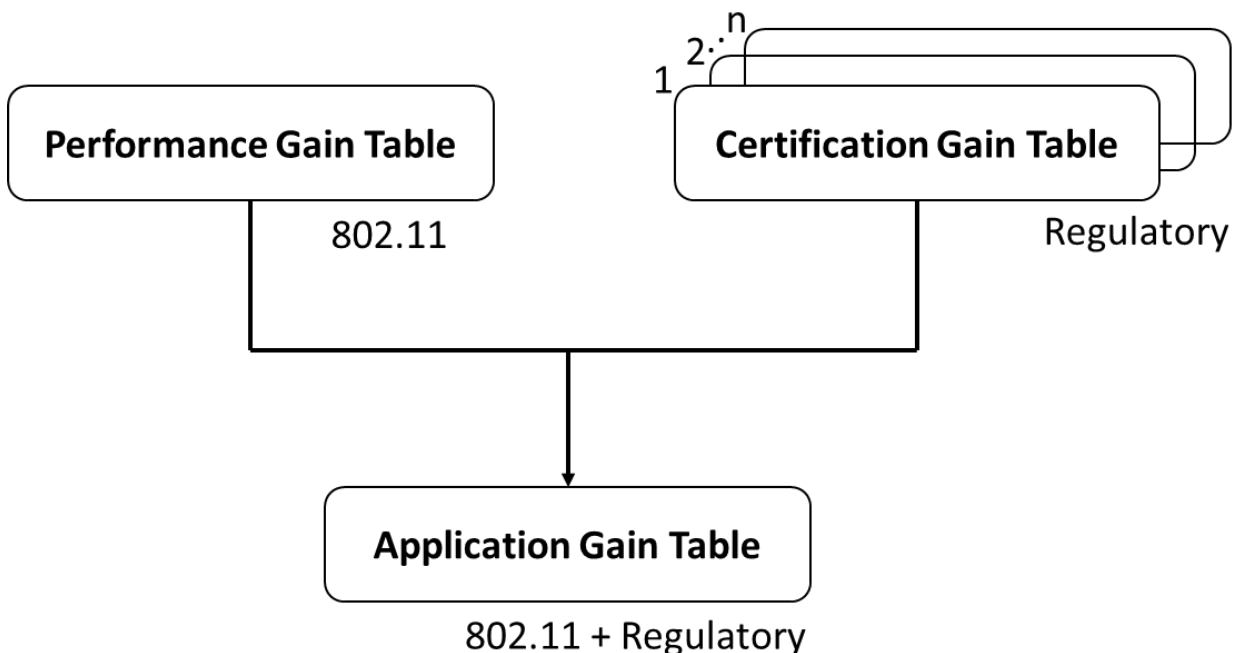
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The gain table controls the RF output power of the ATWILC1000B device. This application note describes the gain table structure and procedure to derive the gain tables during the product development phase.

Perform the following steps to derive the Application Gain Table:

1. Performance Gain Table: Verify the Digital Gain (DG) setting to meet the IEEE 802.11 specifications.
2. Certification Gain Table: Adjust the DG setting for the specific regulatory region compliance.
3. Application Gain Table: Combine step 1 and step 2 to produce a composite gain table, which is used in the firmware.

**Figure 1. Deriving Application Gain Table**

**Prerequisites**

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- [MCHPRT2 Tool](#):
  - Radio test tool for configuring and testing the ATWILC1000B device
  - Refer to the [MCHPRT2 user guide](#) document for detailed information about the MCHPRT2 Graphical User Interface (GUI) and Command Line Interface (CLI).
- [ATWILC1000B Gain Builder Tool](#):
  - Used for merging the gain table to the ATWILC1000B firmware

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## 1. ATWILC1000B Gain Stages

The following are three stages of amplification in the transmitter:

1. Digital Gain (DG)
2. Pre-Power Amplifier (PPA)
3. Power Amplifier (PA)

- **DG Stage:**

- The DG stage is the one to adjust to set the desired output power. The DG values are configured with the negative sign.
- The DG gain is controlled across all channels, 1 to 14, and across all data rates for b, g and n modes of transmissions.
- This DG gain allows the designer to adjust the output power to the desired output to meet the IEEE 802.11 specifications and to meet the required regulatory specification.
- Each DG step is equivalent to approximately a 1 dB change in RF output power. For example, if DG is -7 for a given data rate and channel, and if there is a need to increase transmit power, DG must be configured with a value of -6 or higher.

- **PPA and PA Stage:**

- The PPA and PA gain values are fixed at 6 and 18, respectively.
- No changes need to be made to the PPA and PA gain values.

## 2. Gain Table Format

The gain table of the ATWILC1000B device is in \*.csv file format. It is recommended that this .csv file be opened with Microsoft Excel. Microchip recommends to use the default gain table and edit the gain values based on the user requirement. The default gain table can be accessed from the location mentioned in Section.7 (Gain Values Download) of the *ATWINC15x0/ATWINC3400 – Integrated Serial Flash and Memory Download Procedure Application Note* (DS00002378).

The table below shows the format of the Gain Table. This table must be filled with the Digital Gain (DG) values, which are unique for given RF channels and data rates.

**Table 2-1. Gain Table Format**

Data Rate	Channel													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1														
2														
5.5														
11														
6														
9														
12														
18														
24														
36														
48														
54														
MCS 0														
MCS 1														
MCS 2														
MCS 3														
MCS 4														
MCS 5														
MCS 6														
MCS 7														

**Figure 2-1. Sample Wi-Fi Gain Table Configuration**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	ch		1	2	3	4	5	6	7	8	9	10	11	12	13	14
2		1	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
3		2	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
4		5.5	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
5		11	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
6		6	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
7		9	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
8		12	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
9		18	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
10		24	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
11		36	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
12		48	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
13		54	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
14	mcs0		-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
15	mcs1		-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
16	mcs2		-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
17	mcs3		-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
18	mcs4		-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-8	-8	-8
19	mcs5		-14	-9	-9	-9	-9	-9	-9	-9	-9	-9	-11	-9	-9	-9
20	mcs6		-14	-9	-9	-9	-9	-9	-9	-9	-9	-9	-11	-9	-9	-9
21	mcs7		-14	-9	-9	-9	-9	-9	-9	-9	-9	-9	-11	-9	-9	-9
22	1e9c		0	Specific Configuration Region												
23	1edc		0													

Digital Gain Configuration Region

The first row represents the RF channel number and the first column represents the data rate. The Digital Gain (DG) value must be determined by the user for all the combinations of the RF channel numbers and data rates. No changes need to be made to the Specific Configuration Region.

### 3. IEEE 802.11 Performance Gain Table

The Performance Gain Table refers to the gain setting that allows the ATWILC1000B to be compliant in meeting the limits set in the IEEE 802.11 specification.

- Product characterization of the TX and RX parameters, as defined by IEEE 802.11, is required to be tested with a suitable WLAN test instrument; for example, IQxel-80.
- During characterization, the user has to derive the Performance Gain Table by adjusting the Digital Gain (DG) value for all of the RF channel and data rate combinations using the MCHPRT2 GUI tool for optimal performance and compliance to the IEEE 802.11 specification.

**Note:** During transmitter EVM measurements, the test equipment must use "LTF" for the channel estimation, as required by the IEEE 802.11 specification.

- Product characterization can be done at the typical condition (3.3V, 25°C) and at extreme voltages and temperature conditions also. The ATWILC1000B device transmitter RF output power can vary about 2 to 3 dB at extreme boundary conditions from its typical value.
- The final Performance Gain Table is derived after characterizing the product across operating voltage and temperature conditions.

**Notes:** There is a trade-off between the transmitter RF output power and compliance to the IEEE 802.11 specification. For example:

1. Increasing the RF output power might impact the spectral mask requirements in the IEEE 802.11b signals.
  2. Increasing the RF output power might impact the EVM requirements of the IEEE 802.11g/n signals.
- Below is a sample gain table that the user can use as a starting point. The user has to derive the Performance Gain Table for their product.

**Table 3-1. Sample IEEE 802.11 Performance Gain Table**

Data Rate	Channel													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12
2	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12
5.5	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
11	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
6	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
9	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
12	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
18	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
24	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
36	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
48	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
54	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
MCS 0	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
MCS 1	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
MCS 2	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
MCS 3	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4
MCS 4	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5

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.....continued

Data Rate	Channel													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MCS 5	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
MCS 6	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
MCS 7	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12

## 4. Regulatory Certification Gain Table

The Certification Gain Table refers to the gain setting of the ATWILC1000B device that allows it to be compliant to the specific regulatory region requirements, such as FCC (USA), ISED (Canada), CE (Europe) and so on.

- Certification testing of the product for the relevant standard is done by external accredited test labs such as TuV, Compatible Electronics, etc.
- During the certification, the Digital Gain value needs to be adjusted for compliance to the regulatory specifications.
- The Final Certification Gain Table must be arrived at after including all of the different regulatory regions that the product is targeted for.
- In cases where multi-region compliance is desired with a single-product firmware, use the gain value with the minimum gain setting. For example, once the certification tables for FCC, ISED and CE are derived, and are intended to serve all three regions, the user needs to derive the final gain table by comparing each gain value for the given channel and data rate to choose the lower gain value for the selected channel and data rate. This has to be done for all of the channels and data rates in the gain table to derive the final Certification Gain Table.
- In cases where multi-region compliance is desired with a multiple-product firmware, the device can be loaded with a firmware specific to the intended destination (regulatory region), thereby ensuring that the maximum benefit is achieved out of the regulatory limits of the intended destination.

**Table 4-1. Sample Regulatory Certification Gain Table (FCC/ISED)**

Data Rate	Channel													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-30	-30	-30
2	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-30	-30	-30
5.5	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-30	-30	-30
11	-10	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-30	-30	-30
6	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
9	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
12	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
18	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
24	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
36	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
48	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
54	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 0	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 1	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 2	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 3	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 4	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 5	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 6	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 7	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30

**Note:** This is only a sample. The customer has to derive the Certification Gain Table for their product for each regulatory region.

## 5. Application Gain Table

The gain table setting that the product uses in its Application mode is called the Application Gain Table.

- The Application Gain Table setting is the composite table derived from both the IEEE 802.11 Performance Gain Table and final Regulatory Certification Gain Table by comparing each gain value for the given channel and data rate to choose the lower gain value for the selected channel and data rate. Perform this for all of the channels and data rates in the gain table.

**Table 5-1. Sample Application Gain Table (IEEE 802.11 and FCC/ISED)**

Data Rate	Channel													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-30	-30	-30
2	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-30	-30	-30
5.5	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-30	-30	-30
11	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-30	-30	-30
6	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
9	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
12	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
18	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
24	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
36	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
48	-12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
54	-12	-9	-9	-9	-9	-9	-9	-9	-9	-9	-11	-30	-30	-30
MCS 0	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 1	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 2	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 3	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 4	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 5	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 6	-14	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 7	-14	-12	-12	-12	-12	-12	-12	-12	-12	-12	-11	-30	-30	-30

**Note:** This is only a sample. The customer has to derive the Application Gain Table for their product.

## 6. Updating Application Gain Table into ATWILC1000B Firmware

Once the Application Gain Table is available, the corresponding values need to be updated in the reference configuration \*.csv file using Microsoft Excel.

- In production, added along with the application firmware and TLS/SSL certificates, is the Application Gain Table along with host firmware for the ATWILC1000B device.
- The Gain Builder Tool updates the application gain table settings in the ATWILC1000B firmware binary file.
- Download the [Gain Builder Tool](#), open the tool through the command prompt, then use the following syntax to update the application gain table into the firmware:

```
- gain_builder [-hp <gain_settings_path>] [-fb <binary_fw_path>] [-fh  
  <fw_header_path>]
```

- For Linux Driver Binary Firmware:

- gain\_builder -hp wilc1000\_gain\_setting\_hp.csv -fb  
 wilc1000\_wifi\_firmware.bin

- For RTOS Driver Hex file Firmware:

- gain\_builder -hp wilc1000\_gain\_setting\_hp.csv -fh wifi\_firmware\_1000.h

### Notes:

1. The updated firmware with the Application Gain Table from the Gain Builder tool has to be used in production.
2. The gain\_builder script reads the Application Gain Table configuration in the .csv file format and updates the corresponding device registers.
3. Any formatting issues in the .csv file result in an error.

**7. Document Revision History**

Revision	Date	Section	Description
A	11/2020	Document	Initial Release

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