AN3655

ATWINC15x0B - Deriving Application Gain Table

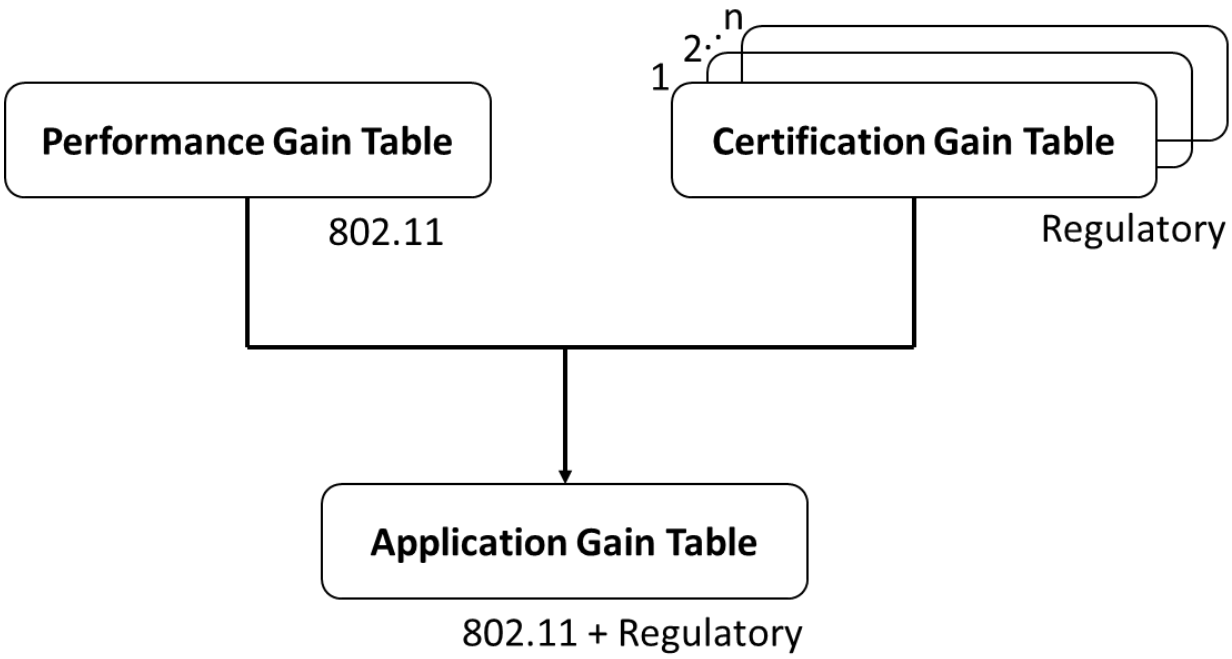
Introduction

The gain table controls the RF output power of the ATWINC15x0 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

- MCHPRT2 Tool:
  - Radio test tool for configuring and testing the ATWINC15x0 device
  - Refer to the MCHPRT2 user guide document for detailed information about the MCHPRT2 Graphical User Interface (GUI) and Command Line Interface (CLI).
- ATWINC15x0/ATWINC3400 - Integrated Serial Flash and Memory Download Procedure - DS00002378:
  - This application note details the gain values download procedure.

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1. ATWINC15x0 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

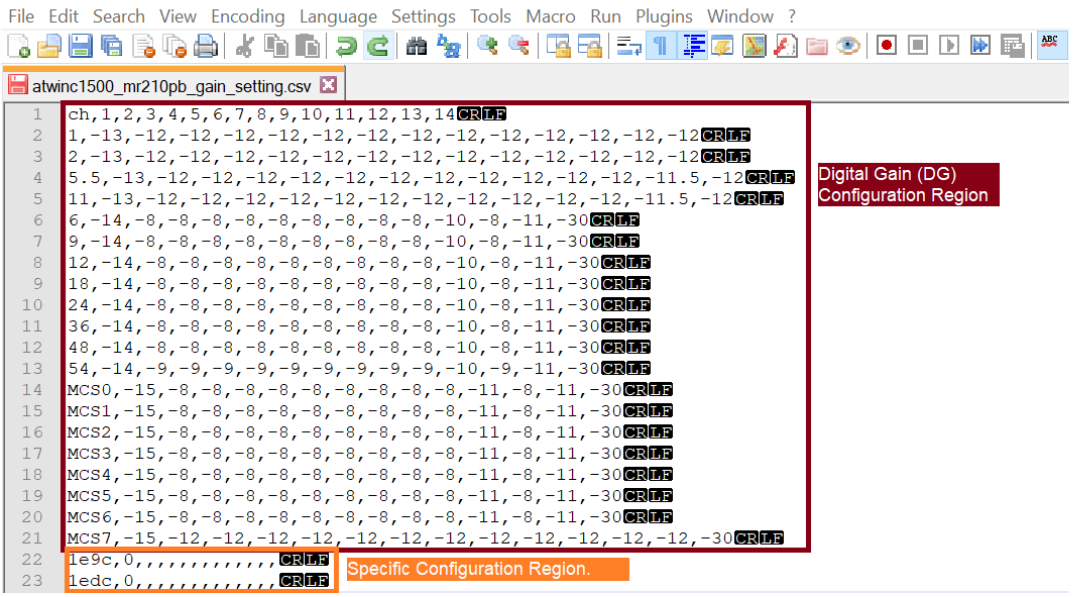
The gain table of the ATWINC15x0 device is in `*.csv` file format. It is recommended that this `.csv` file be opened with Notepad++. Microchip recommends using the default gain table and editing the gain values based on the user requirement. The default gain table can be accessed from the location mentioned in Section 7 (Gain Values Download) of the *ATWINC15x0/ATWINC3400 - Integrated Serial Flash and Memory Download Procedure Application Note* (DS00002378).

The following table 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. The user can update 8 different gain values per channel.

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														

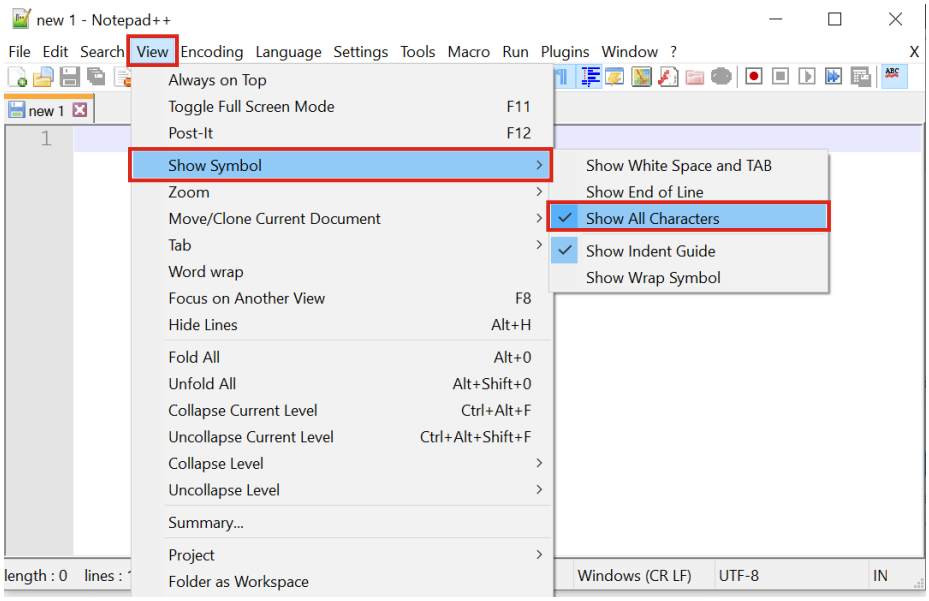
Figure 2-1. Sample Wi-Fi Gain Table Configuration



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.

To enable the CR+LF, in the Notepad++ menu, go to *View>Show Symbol*, then select the *Show All Characters* option. See the following figure.

Figure 2-2. Show All Characters



Note: Microchip recommends following the gain table template as it is in the WINC1500 Firmware Upgrade Project. If upgrading to the newer version of the firmware, use the gain table template from the latest firmware version package to update the gain table with required DG values.

3. IEEE 802.11 Performance Gain Table

The Performance Gain Table refers to the gain setting that allows the ATWINC15x0 to be compliant to meet the limits set in the IEEE 802.11 specification.

- The product characterization of the TX and RX parameters, as defined by IEEE 802.11, must be tested with a suitable WLAN test instrument, for example, IQxel-80.
- During the 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 the transmitter EVM measurements, the test equipment must use the “LTF” channel estimation as required by the IEEE 802.11 specification.
- The product characterization can be done at the typical condition (3.3V, 25ºC) and at extreme voltages and temperature conditions also. The ATWINC15x0 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

	Channel													
Data Rate	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

.....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 ATWINC15x0 device that would allow 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 certification, the Digital Gain value needs to be adjusted for compliance to the regulatory specifications.
- The final Certification Gain Table must be determined after covering all of the different regulatory regions 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 intend 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 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)

	Channel													
Data Rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-9	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-30	-30	-30
2	-9	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-30	-30	-30
5.5	-9	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-30	-30	-30
11	-9	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-30	-30	-30
6	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
9	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
12	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
18	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
24	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
36	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
48	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
54	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
MCS 0	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 1	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 2	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 3	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 4	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 5	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 6	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 7	-13.5	-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 the 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)

	Channel													
Data Rate	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	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
9	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
12	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
18	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
24	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
36	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
48	-12	-7	-7	-7	-7	-7	-7	-7	-7	-7	-10	-30	-30	-30
54	-12	-9	-9	-9	-9	-9	-9	-9	-9	-9	-10	-30	-30	-30
MCS 0	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 1	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 2	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 3	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 4	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 5	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 6	-13.5	-8	-8	-8	-8	-8	-8	-8	-8	-8	-11	-30	-30	-30
MCS 7	-13.5	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-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 ATWINC15x0 Device Flash

Update the Application Gain Table into the ATWINC15x0 device Flash using the procedures mentioned in the *ATWINC15x0/ATWINC3400 - Integrated Serial Flash and Memory Download Procedure Application Note* (DS00002378). This application note details the download procedures of the firmware, TLS/SSL root certificates and TX power gain values into the WINC serial Flash through different supported serial interfaces like SPI/UART. Refer to Chapter 7 in the *ATWINC15x0/ATWINC3400 - Integrated Serial Flash and Memory Download Procedure Application Note* (DS00002378) for the Gain Values Download.

Once the gain table value is loaded into the Flash memory, verify the values using the MCHPRT2 tool. For more details on reading gain table values, refer to the *MCHPRT2 User Guide* (DS50002893).

For firmware versions after 19.6.1 (not inclusive), perform the following steps to update the application gain table in the ATWINC15x0 device Flash.

1. The `atwinc1500_mr210pb_gain_setting.csv` file in the `..\WINC1500_FIRMWARE_UPDATE_PROJECT\src\firmware\Tools\gain_builder\gain_sheets` folder holds the gain values. The values can be changed in this `.csv` file using Notepad++.
2. Run the `prepare_image.cmd 1500` command from the folder location `\firmware\` of the firmware upgrade project.
3. The *ATWINC15x0/ATWINC3400 Integrated Serial Flash and Memory Download Procedure Application Note* (DS00002378) is part of the firmware upgrade project and is available inside the folder `\WINC1500_FIRMWARE_UPDATE_PROJECT\doc`. For a more detailed step-by-step procedure of the Serial Flash Download using the Serial Bridge application or Serial Flash Download via Built-in UART, refer to the *ATWINC15x0/ATWINC3400 Integrated Serial Flash and Memory Download Procedure Application Note* (DS00002378).
4. Review the pass log to ensure that there are no errors generated during the execution of the `prepare_image.cmd` command. For example, see the following pass log:

```
...\firmware>prepare_image.cmd 1500
Converting gain table
Default gain table specified as Tools\gain_builder\gain_sheets\samd21_gain_setting_hp.csv
Change this script if different gain sheet is required!
python gain_converter.py Tools\gain_builder\gain_sheets\samd21_gain_setting_hp.csv -o
new_gain.config
Building flash images for 3A0 variant (prog and OTA format)
Device Image Creation Tool 1.0.2 [r708] (Jul 28 2020)
Copyright (C) Microchip Technology Inc. 2020
processing region '[boot firmware]'
WINCFirmwareImageBuild: opening firmware file 'boot_firmware/release3A0/
boot_firmware.bin'
written 1304 of 4096 bytes to image (32%)
processing region '[control sector]'
WINC1500ControlSectorBuild: creating control sector
written 64 of 8192 bytes to image (1%)
processing region '[pll table]'
Creating WiFi channel lookup table for PLL with xo_offset = 0.0000.
written 456 of 1024 bytes to image (45%)
processing region '[gain table]'
WINC1500GainBuildV2: creating gain tables
written 1600 of 3072 bytes to image (53%)
processing region '[root certificates]'
found certificate: Baltimore CyberTrust Root
found certificate: DigiCert High Assurance EV Root CA
found certificate: DigiCert SHA2 High Assurance Server CA
found certificate: Entrust Root Certification Authority
found certificate: GeoTrust Global CA
found certificate: GlobalSign Root CA
found certificate: GlobalSign
found certificate: Google Internet Authority G3
found certificate: QuoVadis Root CA 2
found certificate: VeriSign Class 3 Public Primary Certification Authority - G5
found certificate: Amazon Root CA 1
written 3620 of 4096 bytes to image (89%)
processing region '[tls certificates]'
written 0 of 8192 bytes to image (0%)
processing region '[http files]'
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/default.html'
```

```
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/style.css'
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/favicon.ico'
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/logo.png'
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/error.json'
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/scanresults.json'
HTTPFileSystemAddFile: opening HTTP file 'provisioning_webpage/ok.json'
written 7760 of 8192 bytes to image (95%)
processing region '[connection parameters]'
written 0 of 4096 bytes to image (0%)
processing region '[downloader firmware]'
WINCFirmwareImageBuild: opening firmware file 'downloader_firmware/release3A0/
downloader_firmware.bin'
written 4628 of 241664 bytes to image (2%)
processing region '[wifi firmware]'
WINCFirmwareImageBuild: opening firmware file 'firmware/wifi_v111/ASIC_3A0/
wifi_firmware.bin'
written 235286 of 237036 bytes to image (100%)
processing region '[ate firmware]'
WINCFirmwareImageBuild: opening firmware file 'ate_firmware/
burst_tx_firmware_winc1500.bin'
written 76736 of 765952 bytes to image (11%)
Device Image Creation Tool 1.0.2 [r708] (Jul 28 2020)
Copyright (C) Microchip Technology Inc. 2020
processing region '[downloader firmware]'
WINCFirmwareImageBuild: opening firmware file 'downloader_firmware/release3A0/
downloader_firmware.bin'
written 4628 of 241664 bytes to image (2%)
processing region '[wifi firmware]'
WINCFirmwareImageBuild: opening firmware file 'firmware/wifi_v111/ASIC_3A0/
wifi_firmware.bin'
written 235286 of 237036 bytes to image (100%)
*******************************************************
Success
Created: firmware\m2m_image_3A0.bin
Created: ota_firmware\m2m_ota_3A0.bin
```

Note: While updating the gain table for the first time, the user can read back the gain table using the commands listed in the 7. Verifying the Gain Value.

7. Verifying the Gain Value

After downloading the firmware with the updated gain table, the new gain table values from the Flash memory can be verified by reading back the same table using the MCHPRT2 CLI tool with the help of the following commands:

- `MCHPRT 0` (with Aardvark I^2C test interface) or `MCHPRT 0_UART` (with host serial bridge UART interface)
- `MCHPRT 11 2` (Change to Flash mode)
- `MCHPRT 19` (Read Gain Table based on the selected mode)

For more details, refer to the *MCHPRT2 User Guide* (DS50002893).

8. Document Revision History

Revision	Date	Section	Description
B	03/2022	Document	Minor updates
		2. Gain Table Format	• Updated section • Updated Figure 2-1 • Added Figure 2-2
		6. Updating Application Gain Table into ATWINC15x0 Device Flash	Updated section
		7. Verifying the Gain Value	Updated section
A	11/2020	Document	Initial Release

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