CH201 Ultrasonic Presence Detection Reference Design User Guide

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1 SCOPE AND PURPOSE

Motion detectors are electrical devices that use sensors to detect nearby motion. Such devices are often integrated as system components that automatically generate alerts when motion is detected in an area. These detectors are vital components of security and surveillance systems, automated lighting control, energy efficient systems, and other management systems. They can also enhance public and home safety by automatically triggering smart locks, smart doorbells, and other home and building automation systems.

This document details the specification, the programming and operation of a CH201 ultrasonic senor and M0 MCU Module Reference Board. This module reference board incorporates a M0+ ARM Core IC and a CH201 Ultrasonic Sensor with acoustic housing assembly. When programmed with Chirp's Presence Detection firmware, the module shall operate as a motion detection device, signaling the detection of motion via a GPIO line.

Chirp provides two presence sensing algorithms that can be used in different scenarios: Presence Detection and Static Target Rejection (also known by its acronym, STR). Each algorithm has specific strengths. See the Presence Detection App Note, AN-000214, for discussion on the benefits and tradeoffs of each algorithm. This application note will document the Presence Detection algorithm's usage in a complete reference design module.

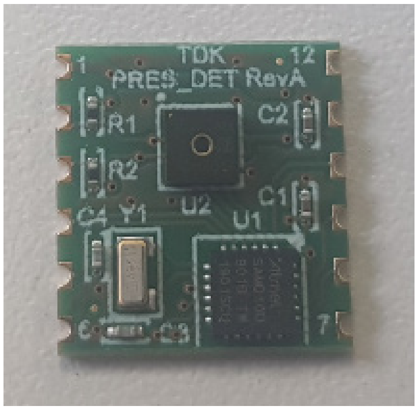

Figure 1. Picture of CH201 Ultrasonic Sensor and M0 MCU Module Reference Board

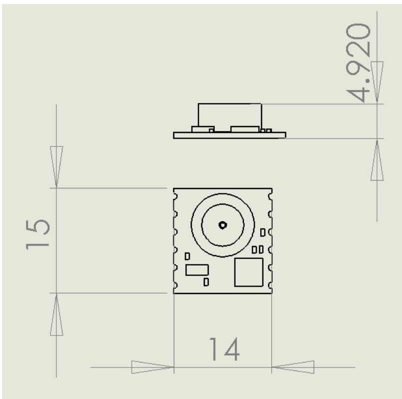

Figure 2. Mechanical dimensions (in mm) of module reference board containing CH201 and M0 MCU

2 CH201 ULTRASONIC PRESNENCE DETECTION REFERENCE DESIGN BOARD

2.1 PIN ASSIGNMENTS

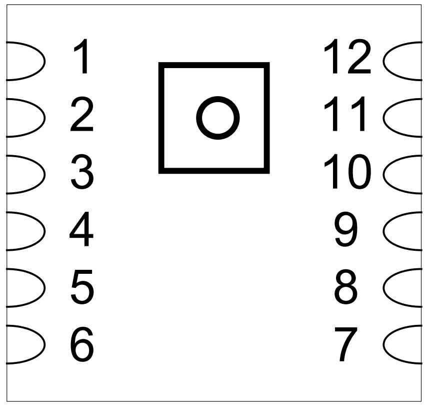

Figure 3. Pin diagram

PIN	NAME	FUNCTION	DESCRIPTION	RECOMMENDED USAGE
1	1V8	Power	Power supply	Connect to 1.8 V power supply
2	I2C_SCL	Digital I/O		
3	I2C_SDA	Digital I/O		
4	UART_TX	Digital I/O		
5	EN	Analog input	Analog input	Tie to ground if DETECTION_OUT is not used
6	GND	Power	Ground	
7	RSTN	System reset		
8	SWCLK	Debug	Serial wire debug clock input for debug and programming	
9	SWDIO	Debug	Serial wire debug I/O for debug and programming	
10	DETECTION_OUT	Digital I/O		
11	Reserved	N/A		
12	Reserved	N/A		

Table 1. Pin Assignments

2.2 ELECTRICAL SPECIFICATIONS

SYMBOL	DESCRIPTION	MIN.	TYP.	MAX.	UNITS
V_{DD}	Power supply voltage		1.8		V
V_{DIS}	Disable conditions detected on EN pin	0		V_{DD} * (2/3)	V
V_{EN}	Enable conditions detected on EN pin	V_{DD} *(2/3)		V_{DD}	V
I_{ACTIVE}	Current drained during Enable conditions	250	350		µA
I_{DEEP_SLEEP}	Current drained in Disable conditions		21		µA
f_{CH201_ODR}	CH201 output data rate	1		10	Hz
$d_{DETECTION\_RANGE}$	Movement detection range	0.2		4	m

Table 2. Electrical Specifications

2.3 SCHEMATICS

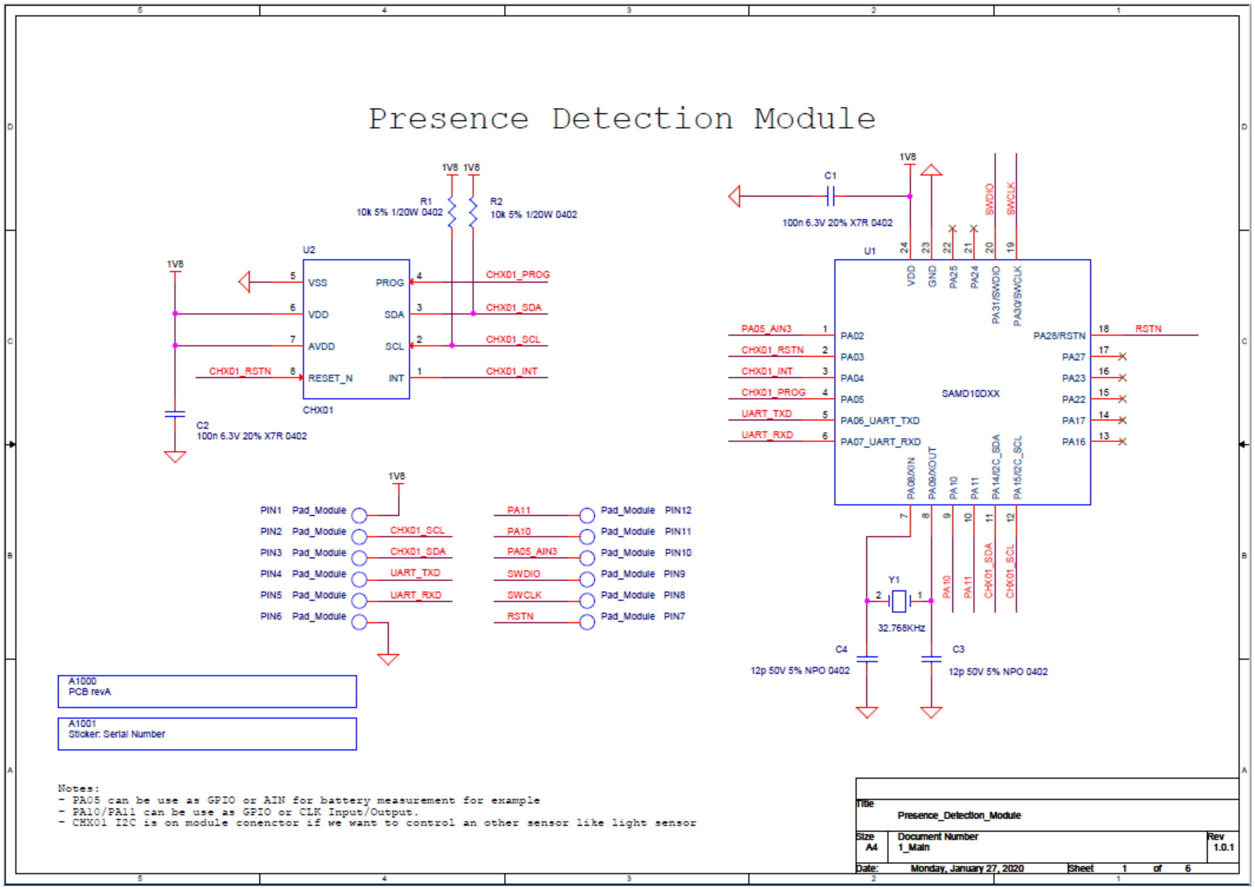

Figure 4. Schematic of module reference board

2.4 BILL OF MATERIAL

QUANTITY	REFERENCE	PART	PCB FOOTPRINT	MANUFACTURER	MANUFACTURER PART NUMBER
1	A1000	PCB revA	NA		
1	A1001	Sticker: Serial Number	NA		
2	C1, C2	100n 6.3V 20% X7R 0402	0402	TDK	CGA2B1X7R1C104K050BC
2	C3, C4	12p 50V 5% NPO 0402	0402	TDK	CGA2B2C0G1H120J050BA
12	PIN1, PIN2, PIN3, PIN4, PIN5, PIN6, PIN7, PIN8, PIN9, PIN10, PIN11, PIN12	Pad_Module	PAD-1mm	NA	NA
2	R1, R2	10k 5% 1/20W 0402	0402	TDK	RC0402FR-0710KL
1	U1	SAMD10DXX	QFN24	TDK	ATSAMD10D14A-MUT
1	U2	CHX01	Custom	TDK	CH201
1	Y1	32.768KHz	2-SMD-3.2x1.5	Vectron	VMK3-1001-32K768

Table 3. Bill of Material

3 FUNCTIONAL DESCRIPTION

3.1 TECHNOLOGY

The Chirp CH201 long-range ultrasonic sensor has numerous advantages over other types of presence and motion sensors. It transmits ultrasonic sound waves at frequencies that are above the human range of hearing, typically 85 kHz, and listens to the reflecting echoes. The "Time of Flight" (ToF) is converted into a range measurement. When someone in the space changes the pattern of the echoes, the motion will be detected. The CH201 contains a MEMS (micro-electromechanical system) element to transmit and receive ultrasound, and an ASIC (application specific integrated circuit) to provide digital IO and to control the MEMS device. The device is an ultra-low power sensor and is not sensitive to ambient lighting conditions. The ultrasonic sensing technology provides highly accurate small-motion detection.

3.2 PRESENCE DETECTION

The presence detection algorithm runs on a processor external to the ultrasonic sensor. The first step of the presence algorithm is to use a high-pass filter to ignore the echoes from static objects to extract motion. Detection is adjusted automatically and adapts to a changing environment.

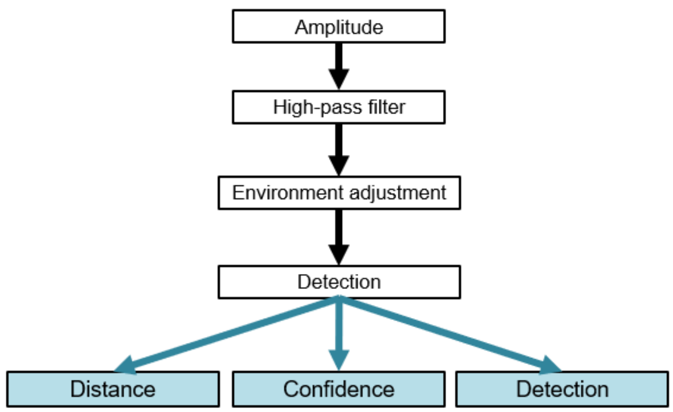

Figure 5. Block diagram of Presence detection algorithm

3.3 NEMA TESTING

We have followed the NEMA testing convention, NEMA standard publication WD 7-2011 (R2016) to compute the performances of our system using a 45° FoV horn (AH-20166-045045).

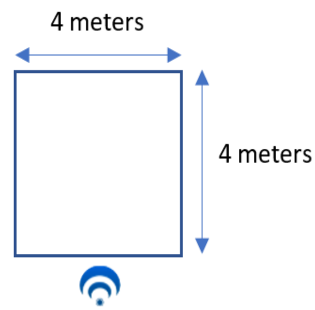

Figure 6. NEMA Testing convention

Test have been conducted for major motion, minor motion and static positions:

- Major motion: 1 person moving within a grid of 1m x 1m cells
- Minor motion: arm robot moving within a grid of 1m x 1m cells
- Static: records motion of empty closed rooms

Static tests have been performed to estimate the number of false positive over a long period of time.

3.4 DETECTION PERFORMANCE

The following NEMA detect grid has been computed with a sensitivity threshold set to the value of 4 with a symmetrical 45 FoV horn (AH-20166-045045). The test follows NEMA standard and has been run on several sensors in the same conditions. The sensors are at (0,0) coordinates on the grid. A value of **x/y** indicates that **x** sensors out of **y** total units pass the test "

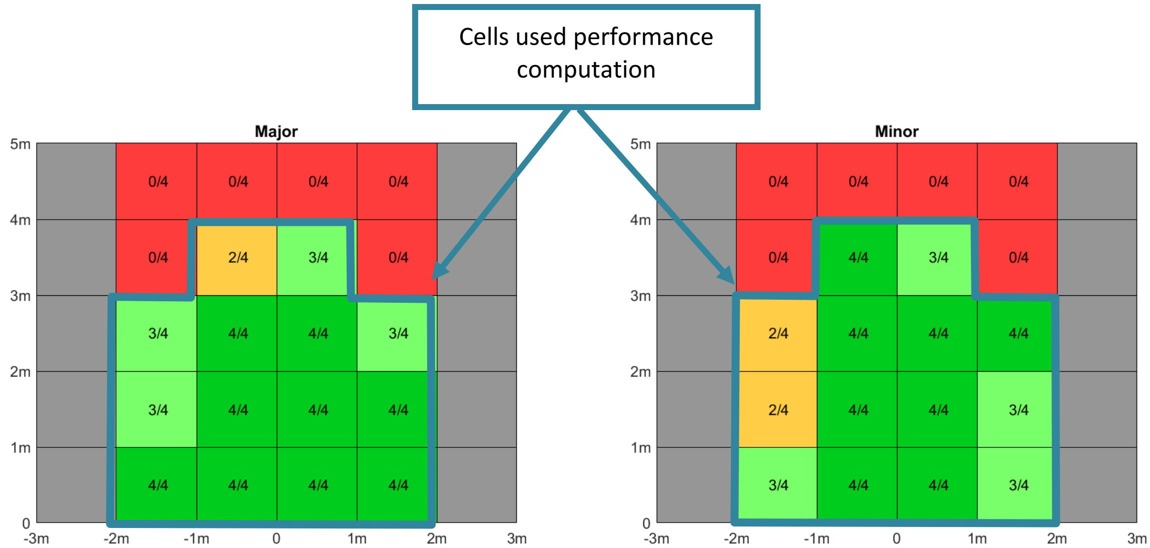

Figure 7. Grid of detection with symmetrical 45 FoV horn (AH-20166-045045). Sensitivity is set to 4.

3.5 FALSE POSITIVE

The algorithm has a sensitivity parameter to adjust the balance between detection rate and false positive rate. The following curve shows the effect of the sensitivity on the performances:

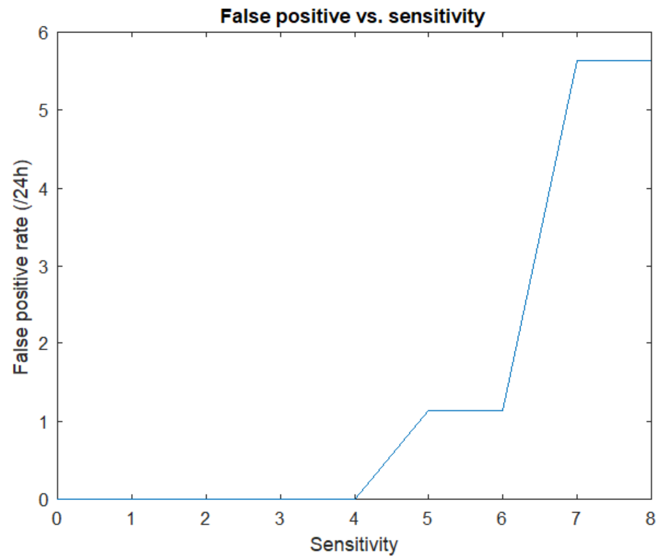

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Figure 8. Sensitivity curve for a 4 meters maximum range

The following NEMA grids show detection performance with sensitivity value set to 8. Results show a better detection at the cost of few false positives.

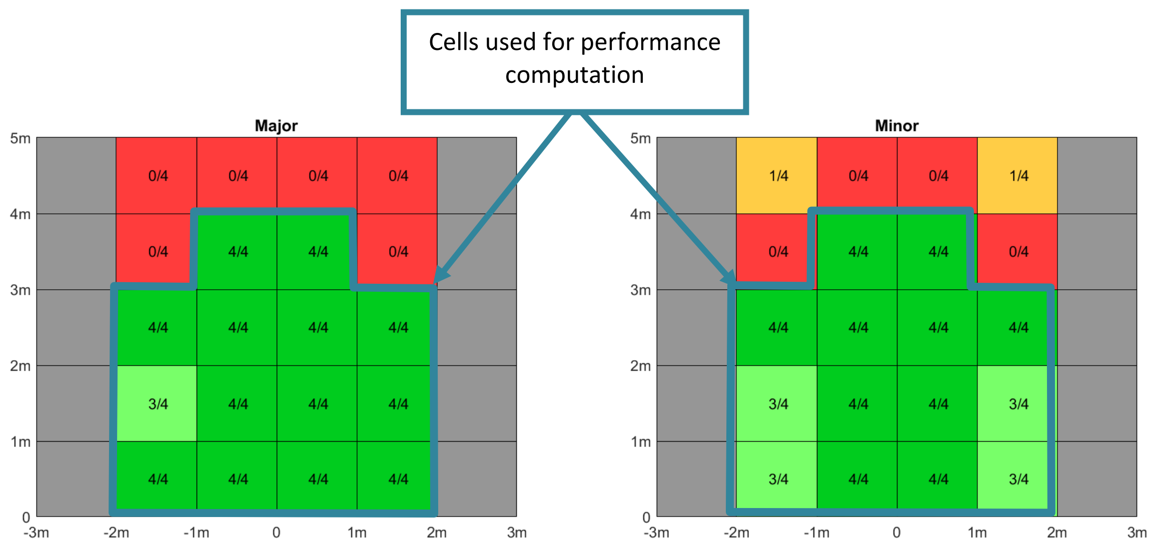

Figure 9. Detection with symmetrical 45 FoV horn (AH-20166-045045) and maximum sensitivity

3.6 LATENCY

The system latency has been computed for various working frequencies:

WORKING FREQUENCY (HZ)	LATENCY (S)
10	0.48
5	1.30
2	2.05
1	5.15

Table 4. System Latency

3.7 POWER

The power figures have been computed for various working frequencies:

WORKING FREQUENCY (HZ)	MAXIMUM RANGE (CM)	SENSITIVITY	POWER FIGURES (MA)
10	400	4	0.245
5	400	4	0.145
2	400	4	0.086
1	400	4	0.048

Table 5. System powers

4 ACOUSTIC HOUSING POSITIONING

Chirp characterized two types of acoustic housing designs in the Presence Detection App Note (see AN-000214). A 45° FoV symmetrical horn, AH-20166-045045, and an asymmetrical 160° FoV by 40° FoV horn, AH-20129-160040.

4.1 SYMMETRICAL 45 FOV HORN: AH-20166-045045

DESIGN	TYPE	DIAMETER (MM)		LENGTH (MM)	FIELD OF VIEW (FOV)	
		VERTICAL	HORIZONTAL		VERTICAL	HORIZONTAL
AH-20166-045045	Exponential	6	6	2.9	45°	45°

Table 6. AH-20166-045045 properties

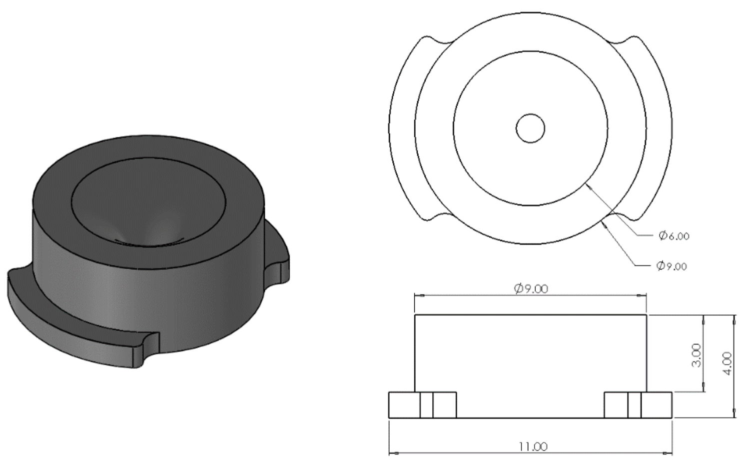

Figure 10. Illustration of AH-20166-045045 3-D printed horn.

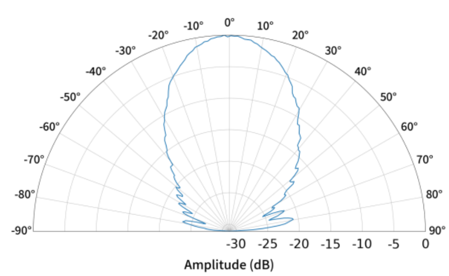

Figure 11. Measured beam pattern for AH-20166-045045

4.2 ASYMMETRICAL 160 FOV BY 40 FOV HORM: AH-20129-160040

DESIGN	TYPE	DIAMETER (MM)		LENGTH (MM)	FIELD OF VIEW (FOV)	
		VERTICAL	HORIZONTAL		VERTICAL	HORIZONTAL
AH-20129-160040	Exponential	9	2	5	40°	160°

Table 7. AH-20129-160040 properties

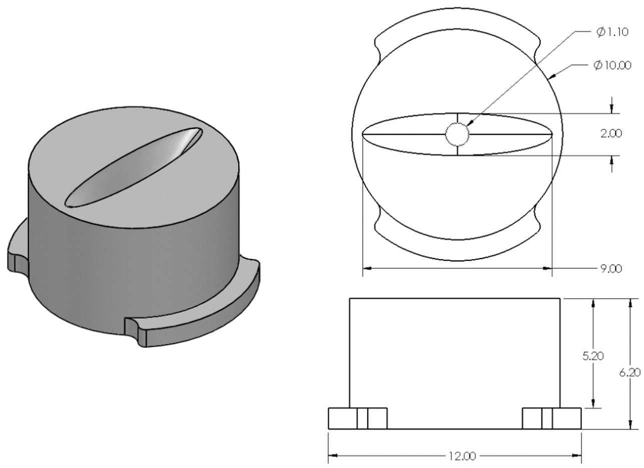

Figure 12. Illustration of AH-20129-160040 3-D printed horn.

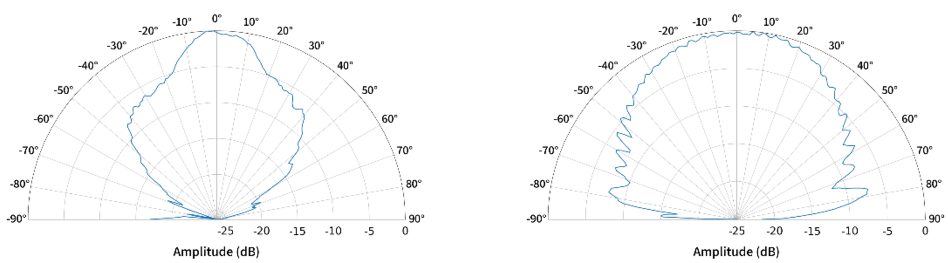

Figure 13. Measured beam pattern for AH-20129-160040. Left plot illustrates the vertical beam pattern, right plot illustrates the horizontal beam pattern.

5 SENSOR CONFIGURATION AND OPERATION

5.1 PARAMETER CONFIGURATION

There are 4 configuration parameters:

Output data rate (ODR):

Defines the sampling rate in Hz. Possible values are 1, 2, 5 and 10 Hz. A higher ODR results in lower latency but increases power consumption.

Maximum range:

Sets the maximum range for the presence sensing feature to detect human motion. It can be any value in the range of 100 to 400 cm. Reducing the range will decrease power levels.

Sensitivity:

Defines the sensitivity of the motion detection. It enables a user to tune the balance between true positives and false positives. The sensitivity value is an integer from 0 to 8, where 8 is the highest sensitivity. The default sensitivity value is 4.

DETECTION_OUT On-Period:

Defines the period in seconds while DETECTION_OUT pin is on after a movement is detected. It can be any integer value between 5 and 30, both included.

5.2 FIRMWARE GENERATION

To modify the Firmware parameters a PC with windows 10 with python 3.8 is needed. Go to the folder that contains generate_firmware_for_customer.py, open a windows terminal and launch «python generate_firmware_for_customer.py».

Then just follow online instructions.

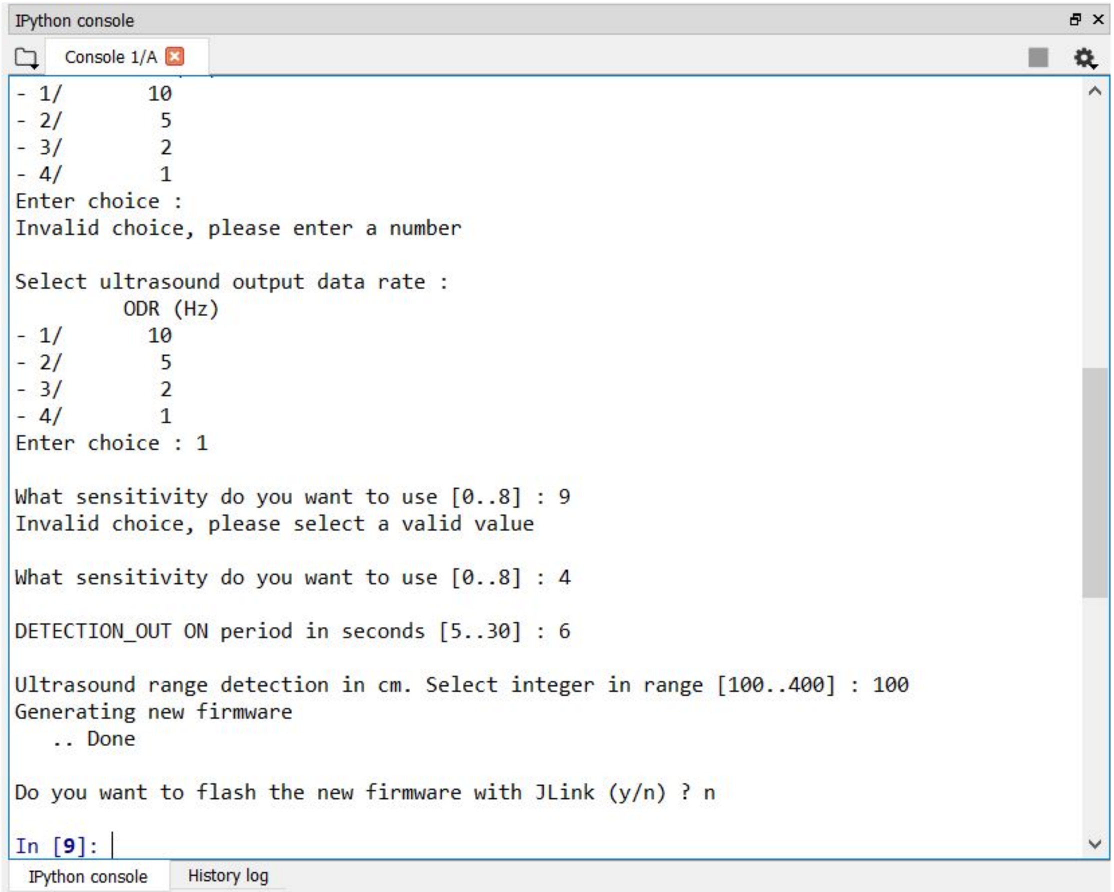

Figure 14. Example of Python run

6 MCU FIRMWARE PROGRAMMING

6.1 MCU FIRMWARE DOWNLOAD TOOLS

For MCU firmware upgrade, ATSAMD10 MCU manufacturer's firmware download HW and SW tools are necessary.

TYPES	TOOLS
HW	Atmel-ICE Full kit Cables w/ male header Power supply
SW	Atmel Studio 7

Table 8. Firmware download tools

Atmel-ICE full kit has a 10-pin 50-mil mini squid cable with 10x100-mil socket. This cable is convenient for connection to M0 module.

Figure 15. Atmel-ICE Full kit

Atmel Studio 7 SW is available for download for free from Microchip website.

Requirement of Memory Size

TYPES	SIZE	USED	FREE
FLASH	16384B	15108B (92.2%)	1276B(7.78%)
SRAM	4096B	2928B(71.48%)	1168B(28.52%)

Table 9. Firmware download tools

6.2 MCU FIRMWARE DOWNLOAD PROCEDURE

Extension Cables from M0 module

Soldering Extension Cables is necessary for Atmel-ICE HW tool connection. The SWD protocol is used for MCU Firmware upgrade. Pin 1, 6, 7, 8, 9 and 10 should be ready for SWD interface.

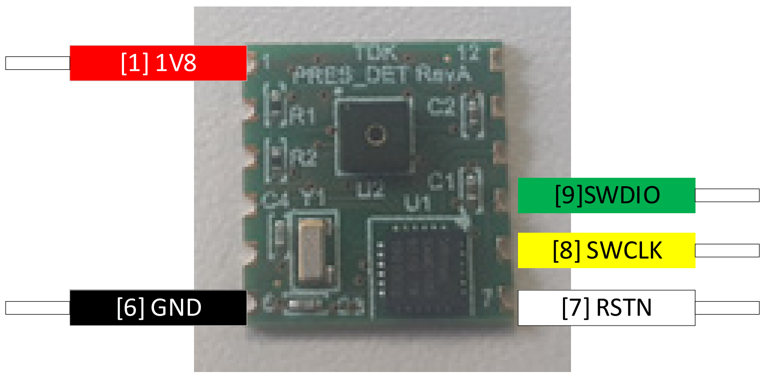

Figure 16. Cable Extensions from module reference board

NUMBER	PIN NAME	NOTE
1	1V8	VTARG for SWD
6	GND	GND for SWD
7	RSTN	RSTN for SWD
8	SWCLK	SWCLK for SWD
9	SWDIO	SWDIO for SWD

Table 10. Module reference board wire mapping

Connection of module reference board and Atmel-ICE

The module reference board and Atmel-ICE tool should be connected to each other with 10-pin 50-mil mini squid cable with 10x100-mil socket. 1.8V and GND should be connected from the power supply.

Figure 2-11. Atmel-ICE SAM Probe Connection

Table 3-8. Atmel-ICE SWD Pin Mapping

Name	AVR port pin	SAM port pin	Description
SWDC LK	1	4	Serial Wire Debug Clock.
SWDIO	5	2	Serial Wire Debug Data Input/Output.
SWO	3	6	Serial Wire Output (optional- not implemented on all devices).
nSRST	6	10	Reset.
VTG	4	1	Target voltage reference.
GND	2, 10	3, 5, 9	Ground.

Figure 17. SWD port of Atmel-ICE tool (from Atmel-ICE tool datasheet)

SWD PINS	MODULE REFERENCE BOARD PINS	ATEM-ICE SAM PORT
VTARG	1	1
GND	6	3
RSTN	7	10
SWDCLK	8	4
SWDIO	9	2

Table 11. Module reference board and Atmel-ICE mapping

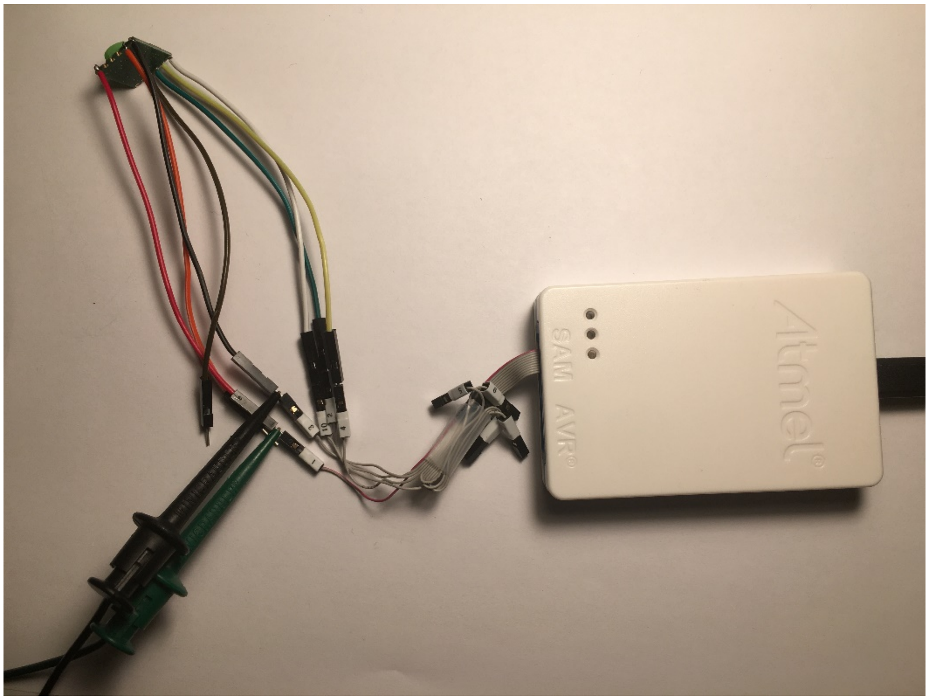

Figure 18. Connection Example

Run Atmel Studio 7

Once Atmel Studio 7 SW is installed, run Atmel Studio 7. Run “Tools> Device Programming” for programmer SW.

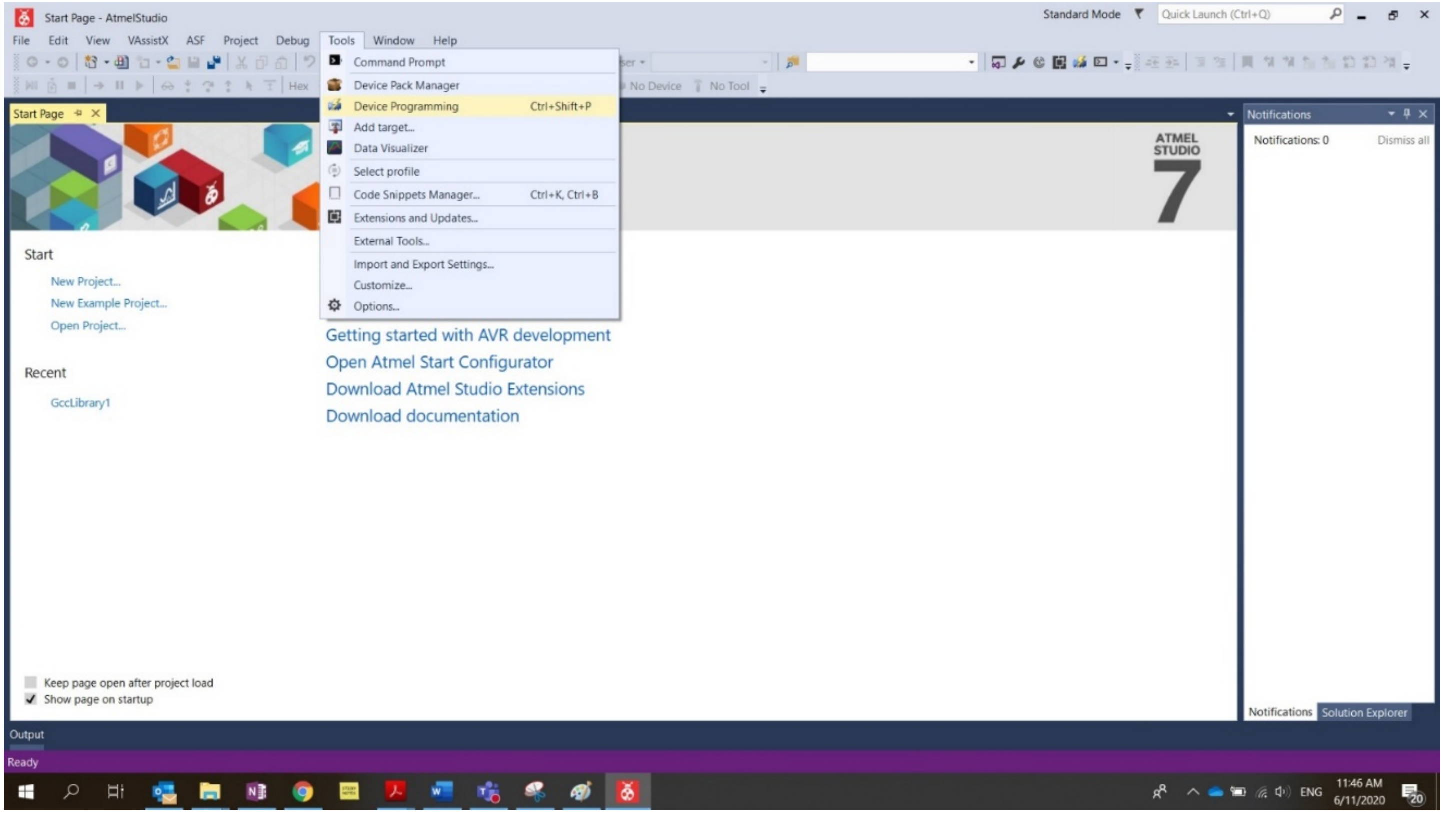

Figure 19. Atmel Studio 7

Supply power 1.8V to the module

Plug the USB cable out of Atmel-ICE to PC which has Atmel Studio 7 SW. Supply power for 1.8V. Green LED and Red LED should be on once connected.

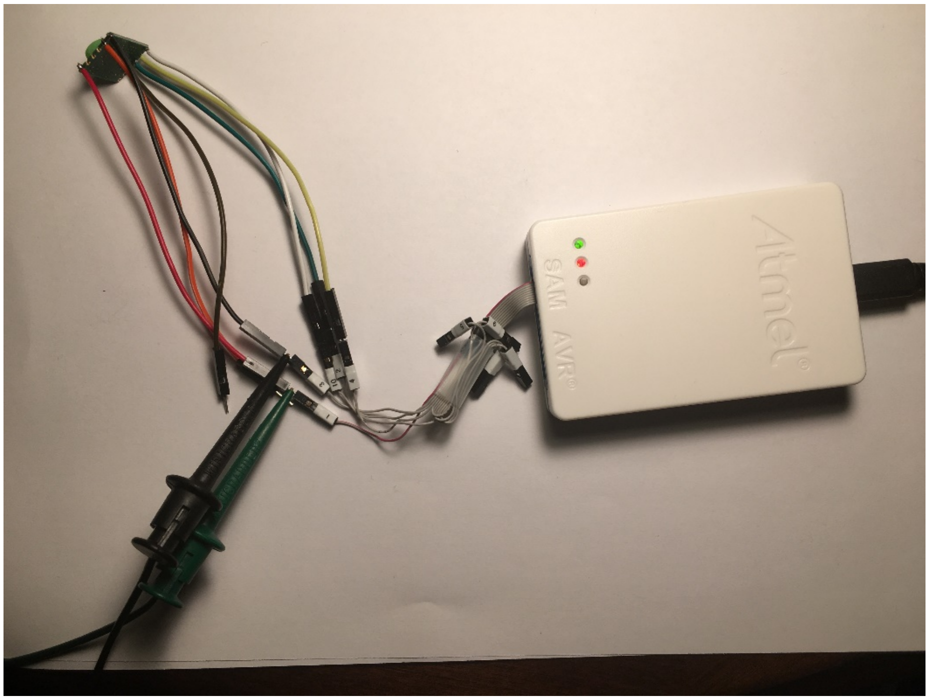

Figure 20. LEDs ON at Atmel-ICE

MCU connection in Device programming tool

- Select **Atmel-ICE** in Tool
- Select **ATSAMD10D14AM** in Device
- Select **SWD** in Interface
- Click the **Apply** button
- Click **Read** button
- 0x10020100 in Device Signature and 1.8V in Target Voltage should be read

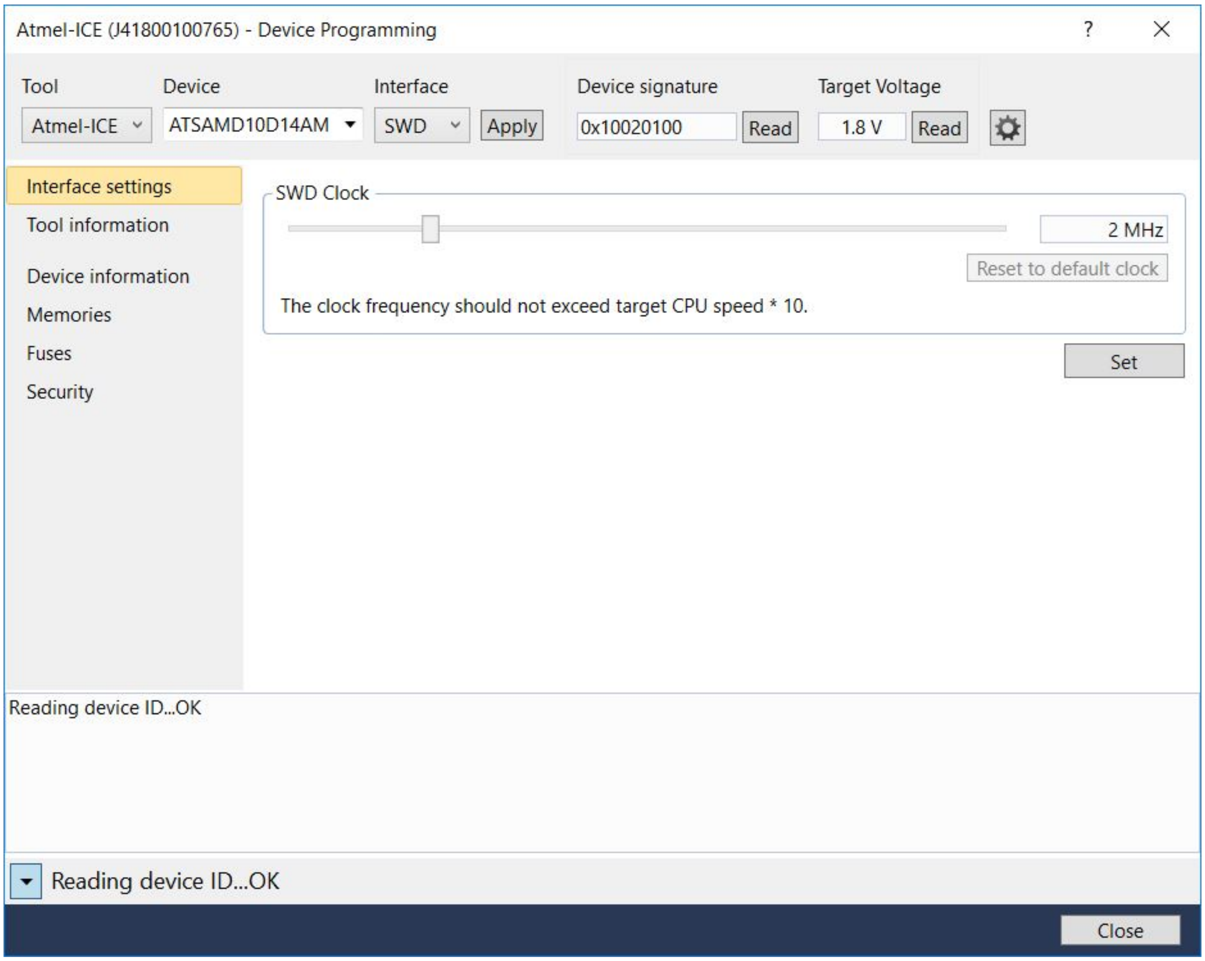

Figure 21. Device connection

Read old FW from MCU (for old FW backup)

- Go to **Memories**
- Click the **Read** button
- Specify the old FW name and path
- Click **OK** button
- **Reading Flash OK** shows up in the message

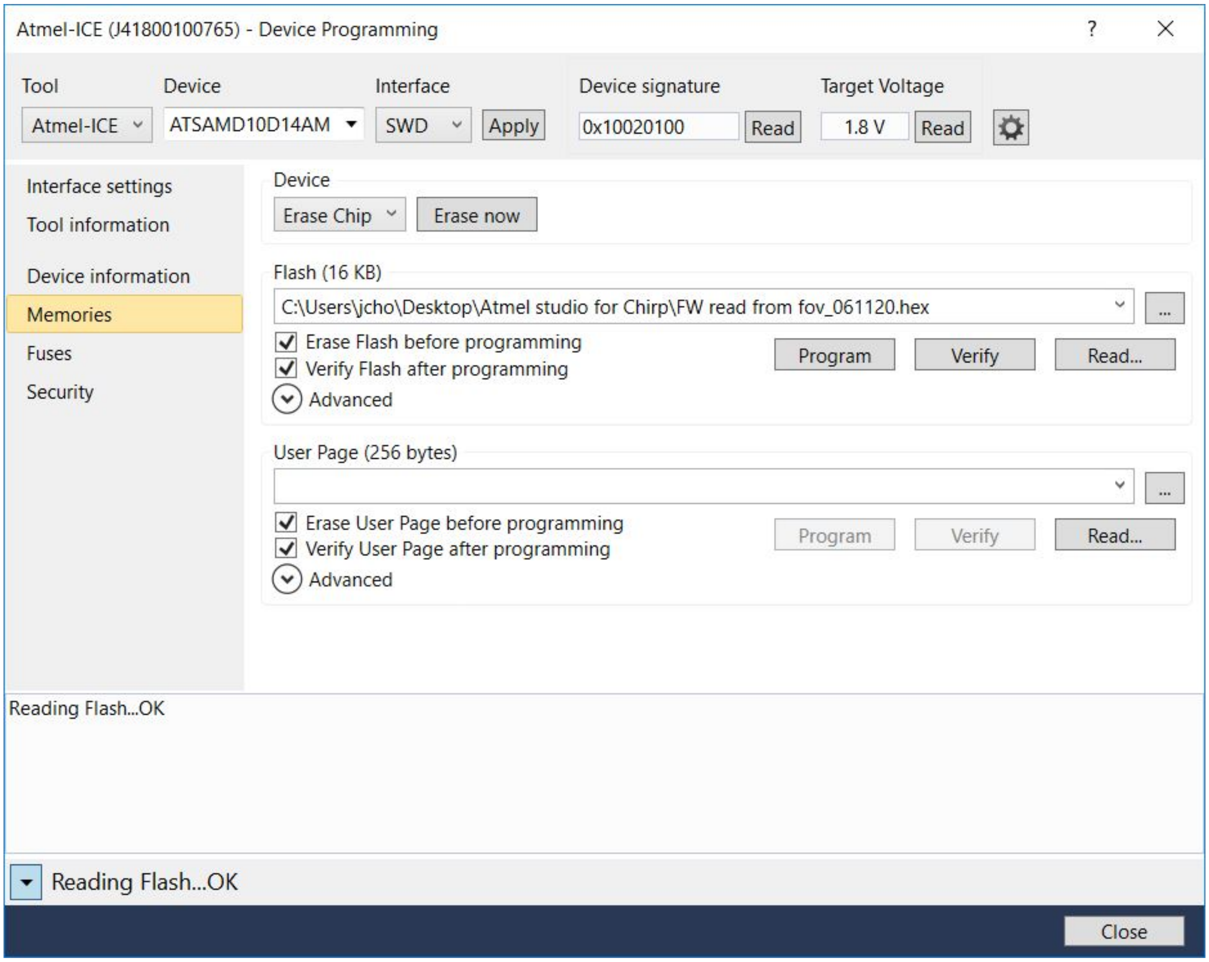

Figure 22. Read old FW from MCU

Download new FW (if needed)

- Go to **Memories**
- Specify new FW's path and file name
- Check **Erase Flash before** programming and **Verify Flash after programming**
- Click **Program** button
- **Erasing device… OK**, **Programming Flash… OK** and **Verifying Flash… OK** show up in the message
- New FW download to flash memory is done

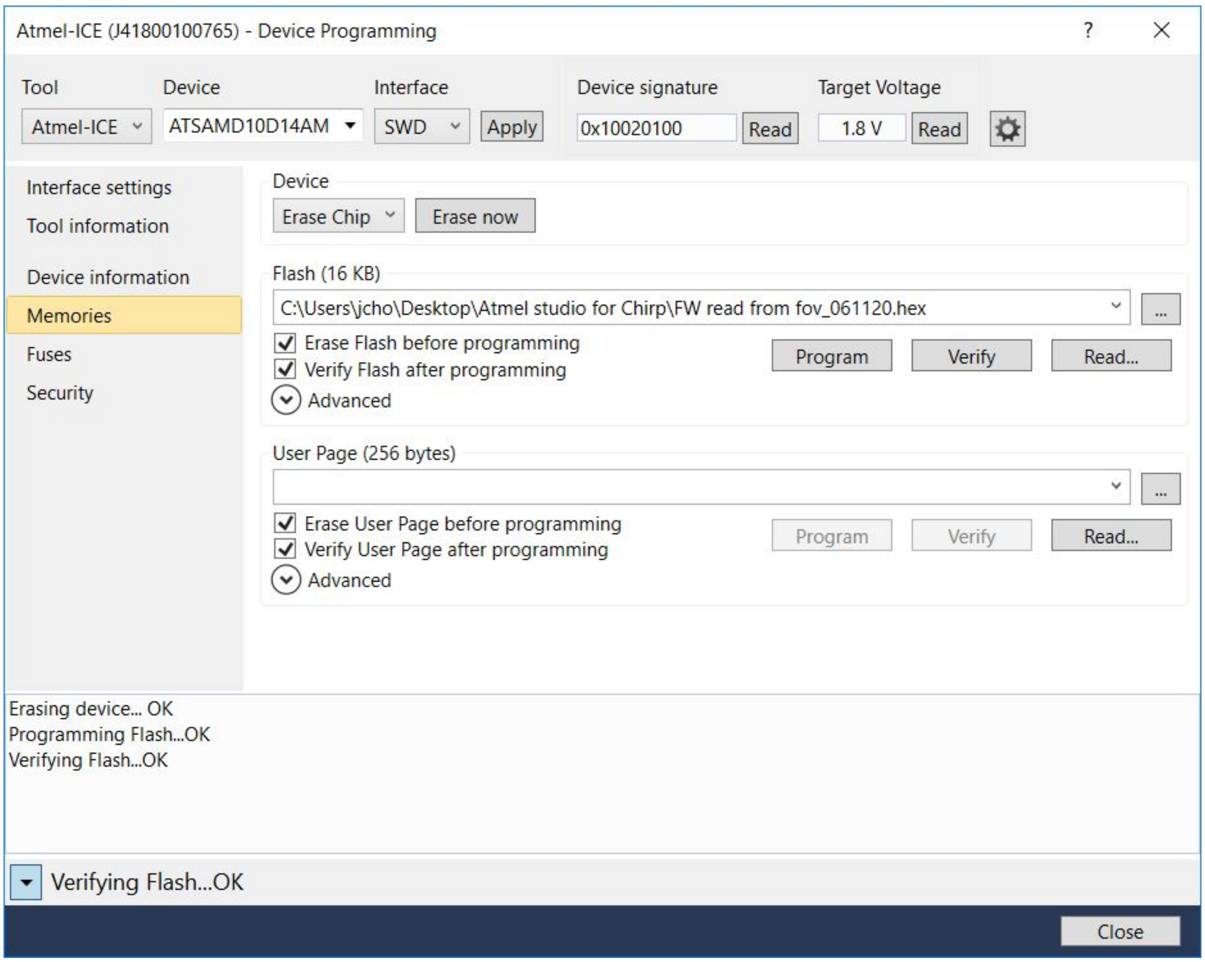

Figure 23. Download new FW

Power Cycle

For MCU to load new FW, power cycle is required.

7 REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
7/16/2020	1.0	Initial Release