
Interfacing the MikroElektronika HTU21D Click Board™ with the I²C Module

Preface

**Important: Notice to customers:**

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXXA”, where “XXXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

Introduction

This document describes how to use the device as a development tool to emulate and debug firmware on a target board, as well as how to program devices.

The MikroElektronika HTU21D Click Board™ contains the TE Connectivity HTU21D Relative Humidity and Temperature Sensor that is used to detect relative humidity and temperature. This user's guide explains how to connect the HTU21D Click Board to the PIC18F26K42's I²C module, receive raw humidity and temperature data, and convert the data into a usable format.

Recommended Reading

For the latest information on using the device, read the “Readme for Device #.htm” file (an HTML file) in the Readmes subdirectory of the MPLAB IDE installation directory. The release notes (Readme) contain update information and known issues that may not be included in this user's guide.

Hardware/Software Requirements

This demonstration uses the following hardware and software components:

Hardware:

- Curiosity High Pin Count (HPC) Development Board (DM164136)
- PIC18F26K42 Microcontroller (PIC18F26K42-I/SP)
- MikroElektronika HTU21D Click Board (MIKROE-1687)
- MCP2200 USB-to-UART Breakout Module (ADM00393)
- USB Micro-B 5-pin cable (Curiosity to PC for programming/USB power)
- USB Mini-B 5-pin cable (MCP2200 to PC for displaying data)
- Jumper wires

Software:

- MPLABX IDE v5.05 or higher
- XC8 Compiler v2.00 or higher
- Tera Term or equivalent PC terminal program

Other relevant items:

- ["TE Connectivity HTU21D\(F\) RH/T Sensor IC" Data Sheet](#)
- ["PIC18\(L\)F26/27/45/46/47/55/56/57K42 28/40/44/48-Pin, Low-Power High-Performance Microcontrollers with XLP Technology" Data Sheet \(DS40001919\)](#)
- [TB3191, "I²C Master Mode" Technical Brief \(DS90003191\)](#)

Table of Contents

Preface.....	1
Hardware/Software Requirements.....	2
1. Demonstration Overview.....	4
1.1. Definitions and Equations.....	4
1.2. HTU21D Relative Humidity and Temperature Sensor.....	6
2. Demo Configuration.....	11
2.1. Hardware Configuration.....	11
2.2. Software Configuration	12
3. Additional Demo Information.....	21
4. Conclusion.....	22
5. Revision History.....	23
The Microchip Web Site.....	24
Customer Change Notification Service.....	24
Customer Support.....	24
Microchip Devices Code Protection Feature.....	24
Legal Notice.....	25
Trademarks.....	25
Quality Management System Certified by DNV.....	26
Worldwide Sales and Service.....	27

1. Demonstration Overview

This demonstration uses a PIC18F26K42 microcontroller to communicate with the MikroElektronika HTU21D Click Board to read relative humidity and temperature levels of the environment in which the demo is placed. The PIC[®] microcontroller communicates with the HTU21D sensor via the I²C bus and acts as the bus master. Once the environmental data have been acquired and processed, the information is transmitted to a PC terminal program for display over the UART bus.

1.1 Definitions and Equations

Absolute Humidity: the measure of water vapor or moisture in the air, regardless of temperature, expressed in grams of moisture per cubic meter of air (g/m³). Absolute humidity can be calculated using [Equation 1-1](#).

Equation 1-1. Absolute Humidity

$$AH = \frac{M_{WV}}{V_{AIR}}$$

Where:

AH: absolute humidity

M_{WV}: mass of the water vapor in the air in grams (g)

V_{AIR}: volume of the dry air in cubic meters (m³)

Relative Humidity: the ratio of the actual water vapor pressure in the air to the saturation water vapor pressure in the air at a specific temperature, expressed as a percentage. In other words, relative humidity represents the amount of water vapor present in the air as a percentage of the total amount of water vapor the air can hold relative to temperature. For example, if the relative humidity is at 20% at the ambient air temperature of 25°C, then the air currently holds 20% of the maximum amount of water vapor it can hold at 25°C. If the ambient temperature increases, the air can hold more water vapor, and the relative humidity will decrease since the air can hold more water vapor. Relative humidity can be calculated using [Equation 1-2](#).

Equation 1-2. Relative Humidity

$$RH = \frac{E}{E_S} \times 100$$

Where:

RH: relative humidity (%)

E: actual vapor pressure (hPa)

E_S: saturation vapor pressure (hPa)

Saturation Vapor Pressure: the pressure in which a gas transforms into a liquid or vice versa. When relative humidity is at 100%, the air can no longer hold any additional water vapor (becomes saturated), so the vapor begins to turn into a liquid. Saturation vapor pressure can be calculated using the Tetens equation, as shown in [Equation 1-3](#).

Equation 1-3. Saturation Vapor Pressure (Tetens Equation)

$$E_S = 0.61078 e^{\left(\frac{17.27 \times T}{237.3 + T}\right)} \times 10$$

Where:

E_S : saturation vapor pressure (hPa)

T : measured temperature ($^{\circ}\text{C}$)

$\times 10$: converts kilopascals (kPa) to hectopascals (hPa)

Actual Vapor Pressure: the measured quantity of vapor pressure that is present in the air at a certain temperature. The actual vapor pressure can be calculated using [Equation 1-4](#).

Equation 1-4. Actual Vapor Pressure

$$E = \frac{RH \times E_S}{100}$$

Where:

E : actual vapor pressure (hPa)

RH : relative humidity

E_S : saturation vapor pressure (hPa)

Dew Point: the temperature in which vapor pressure reaches saturation and condensation begins. A high relative humidity percentage indicates that the dew point is close to the current air temperature. When relative humidity reaches 100%, the dew point is equal to the current air temperature, and the air cannot hold any more water. When the dew point remains constant and ambient temperature increases, relative humidity decreases. The dew point temperature can be calculated using [Equation 1-5](#).

Equation 1-5. Dew Point Temperature

$$T_{dew} = \frac{b \left(\frac{aT}{b+T} + \ln(RH) \right)}{a - \left(\frac{aT}{b+T} + \ln(RH) \right)}$$

Where:

T_{dew} : dew point temperature ($^{\circ}\text{C}$)

a : 17.27 (a constant value)

b : 237.7 (a constant value)

T : ambient temperature ($^{\circ}\text{C}$)

$\ln(RH)$: natural log of the relative humidity

Heat Index: a quantity expressing the discomfort felt as a result of the combined effects of the temperature and humidity of the air. The heat index indicates how hot it really *feels* to a person at a given temperature and humidity level. The heat index can be calculated using [Equation 1-6](#).

Equation 1-6. Heat Index

$$T_{HI} = C_1 + (C_2 \times T) + (C_3 \times RH) + (C_4 \times T \times RH) + (C_5 \times T^2) + (C_6 \times RH^2) + (C_7 \times T^2 \times RH) + (C_8 \times T \times RH^2) + (C_9 \times T^2 \times RH^2)$$

Where:

T_{HI} : heat index temperature ($^{\circ}\text{F}$)

T : ambient temperature ($^{\circ}\text{F}$)

RH: relative humidity (%)

Constants:

C_1 : -42.379 C_4 : 0.22475541 C_7 : -0.00122874

C_2 : 2.04901523 C_5 : -0.00683783 C_8 : -0.00085282

C_3 : 10.14333127 C_6 : -0.05481717 C_9 : 0.00000199

1.2 HTU21D Relative Humidity and Temperature Sensor

The HTU21D Click Board contains the HTU21D Relative Humidity/Temperature Sensor. Communication with the sensor is handled over the I²C interface, which can operate at speeds up to 400 kHz. The HTU21D sensor can detect humidity levels from 0 – 100% relative humidity, and temperatures from -40° to +125°C.

1.2.1 User Register

The HTU21D sensor provides a user register that can be configured utilizing a list of commands. The user register contains bits that determine the measurement resolution for both relative humidity and temperature, enable/disable the on-chip heater, and disables the OTP reload (see [Figure 1-1](#)). The user register also contains a Battery Detection Status bit.

Figure 1-1. User Register

R/W – 0	R – 0	R – 0	R – 0	R – 0	R/W – 0	R/W – 1	R/W – 0
RH/T resolution bit 1	End of Battery Status	Reserved	Reserved	Reserved	Enable on-chip heater	Disable OTP reload	RH/T resolution bit 0
Bit 7							Bit 0

Bits <7:0> Relative Humidity (RH) and Temperature (T) measurement resolution

Bit 7	Bit 0	RH	Temp
0	0	12 bits	14 bits
0	1	8 bits	12 bits
1	0	10 bits	13 bits
1	1	11 bits	11 bits

Bit 6: End of Battery Status bit
 0: $V_{DD} > 2.25V$
 1: $V_{DD} < 2.25V$

Bits <5:3> Reserved – do not modify

Bit 2: On-chip Heater enable bit
 0: On-chip heater disabled
 1: On-chip heater enabled

Bit 1: OTP Reload disable bit
 0: OTP Reload enabled
 1: OTP Reload disabled

Bits 7 and 0 are used to configure the measurement resolution for relative humidity and temperature. The maximum resolution for relative humidity and temperature are 12-bits and 14-bits, respectively.

Note: The two Least Significant bits (LSbs) for each data set (RH or temp) are used for diagnostic purposes, regardless of the selected measurement resolution. When the LSbs are '00', the device may be in an Open-Circuit condition, and when the LSbs are '11', the device may be in a Short-Circuit condition. If the two LSb values remain at either '00' or '11' when the external conditions change, the device can be considered defective.

Bit 6 is used as a battery status indicator. When the bit is set, the detected battery voltage is less than 2.25V, and when the bit is clear, the battery voltage is greater than 2.25V. Bit 6 is updated after each measurement.

Bits 5-3 are reserved bits.

Note: These bits must not be modified, and the default values for these bits may change over time without any indication.

It is recommended that before writing to the user register, the reserved bits must be read to ensure that they do not get accidentally modified.

Bit 2 is used to enable/disable the on-chip heater. The on-chip heater can be used for testing purposes. When enabled, the heater provides a slight temperature increase of between 0.5 and 1.5°C. Since relative humidity decreases as temperature increases, the additional heat may slightly reduce the relative humidity.

Bit 1 is used to enable/disable the OTP reload feature. The OTP reload is a safety feature that, when enabled, reloads the default register settings, with the exception of the Heater Enable bit (bit 2), before each measurement. Bit 1 is set (OTP reload disabled) by default and not recommended for use. If the OTP feature is desired, a soft-reset command may be issued prior to each measurement.

1.2.2 HTU21D Command List

The HTU21D's commands are listed in [Table 1-1](#).

After a measurement command is issued, the master device must wait for the measurement to complete. Humidity and temperature measurement commands utilize two different operating modes when communicating with the sensor: 'Hold Master mode' and 'No-Hold Master mode'. These modes determine how the sensor behaves while taking a measurement.

When a measurement command is issued while in Hold Master mode, the HTU21D sensor stretches the I²C SCL line (pulls SCL low), preventing the master device from further communications until the measurement has completed. Once the measurement has completed, the sensor releases the SCL line, allowing the master to read the measurement.

When a measurement command is issued while in No-Hold Master mode, the HTU21D sensor does not stretch the clock, allowing the master to issue new commands, or communicate with other devices on the bus while the measurement is performed. In this case, the master device must continuously poll the sensor to determine when the measurement has completed. The master device must issue a Start condition, followed by the sensor address with the data direction (R/W) set (R/W = 1, read command). If the sensor responds with a Not Acknowledge (NACK) sequence, the measurement is still in progress, and the master must continue to poll. If the sensor responds with an Acknowledge (ACK) sequence, the measurement has completed, and the data will be transmitted following the $\overline{\text{ACK}}$.

The 'Read User Register' command must be issued whenever the master device wants to check the status of the battery, or to verify bit settings.

The 'Write User Register' command must be issued when modification of the user register is desired. As previously mentioned, it is recommended that the user register is read prior to writing since the values of the reserved bits may change over time, and modifying these bits may cause unpredictable behavior. The reserved bits default to a '0' value, and if they happen to change values to a '1' and a '0' is written, unpredictable behavior may occur.

The 'Soft Reset' command resets the user register to its default state, with the exception of the Heater bit (bit 2).

Table 1-1. HTU21D Command List

Command	Code	Comment
Trigger Temperature Measurement	0xE3	Hold Master mode
Trigger Humidity Measurement	0xE5	Hold Master mode
Trigger Temperature Measurement	0xF3	No-Hold Master mode
Trigger Humidity Measurement	0xF5	No-Hold Master mode
Write User Register	0xE6	
Read User Register	0xE7	
Soft Reset	0xFE	

1.2.3 CRC Checksum

Although not used in this demonstration, the HTU21D sensor provides a Cyclic Redundancy Check (CRC) for error detection. CRC error detection is used in digital networks and storage devices to detect accidental changes to data. The CRC covers all data transmitted by the sensor. The CRC-8 generator polynomial used by the sensor is ' $x^8 + x^5 + x^4 + 1$ '. The value of the CRC function is added as the final byte in the data stream. The master device can perform a CRC calculation to determine if the received message is error-free; if the result of the calculation has no remainder, no errors were detected.

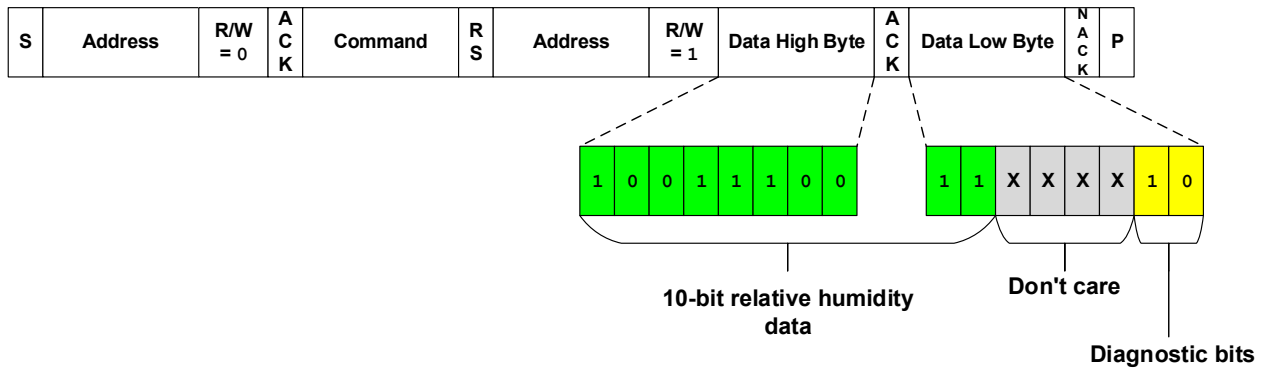
1.2.4 Converting the Data

The measured data is transmitted in two bytes, with the Most Significant bit (MSb) sent first, and is left-aligned. In other words, if the 10-bit relative humidity resolution is used, the first of the two bytes contains the eight MSBs of the 10-bit data, and bits seven and six of the second byte contain the remaining two bits of the 10-bit data (see [Figure 1-2](#)).

To convert the relative humidity raw data into a user-friendly value, [Equation 1-7](#) is used, regardless of which resolution is selected. To convert the temperature raw data into a user-friendly value, [Equation 1-8](#) is used, regardless of the selected resolution.

Although not included in the demonstration, the dew point can be calculated using the relative humidity and temperature outputs from the sensor, and a partial pressure calculation based on ambient temperature. To calculate the dew point, first calculate the partial pressure utilizing [Equation 1-9](#), then use the partial pressure result in [Equation 1-10](#) to find the dew point.

Figure 1-2. 10-Bit Data Alignment



Equation 1-7. HTU21D Relative Humidity Conversion

$$RH = -6 + 125 \times \frac{RH_{RAW}}{2^{16}}$$

Where:

RH = Converted RH (%)

RH_{RAW} = Relative humidity raw data (sensor output)

Equation 1-8. HTU21D Temperature Conversion

$$Temp = -46.85 + 175.72 \times \frac{TEMP_{RAW}}{2^{16}}$$

Where:

$Temp$ = Converted temperature (°C)

$TEMP_{RAW}$ = Temperature raw data (sensor output)

Equation 1-9. Partial Pressure at Ambient Temperature

$$PP_{TAMB} = 10^{\left[A - \frac{B}{(T_{AMB} + C)} \right]}$$

Where:

PP_{TAMB} = Partial pressure at ambient temperature (mmHg)

T_{AMB} = Temperature calculation result (°C) (Result from [Equation 1-8](#))

Constants:

$$A = 8.1332 \quad B = 1762.39 \quad C = 235.66$$

Equation 1-10. Dew Point Calculation

$$T_D = - \left[\frac{B}{\log_{10} \left(RH \times \frac{PP_{TAMB}}{100} \right) - A} + C \right]$$

Where:

T_D = Dew point ($^{\circ}C$)

PP_{TAMB} = Partial pressure at ambient temperature (mmHg) (see [Equation 1-9](#))

RH = Converted RH (%) (see [Equation 1-7](#))

Constants:

$A = 8.1332$ $B=1762.39$ $C=235.66$

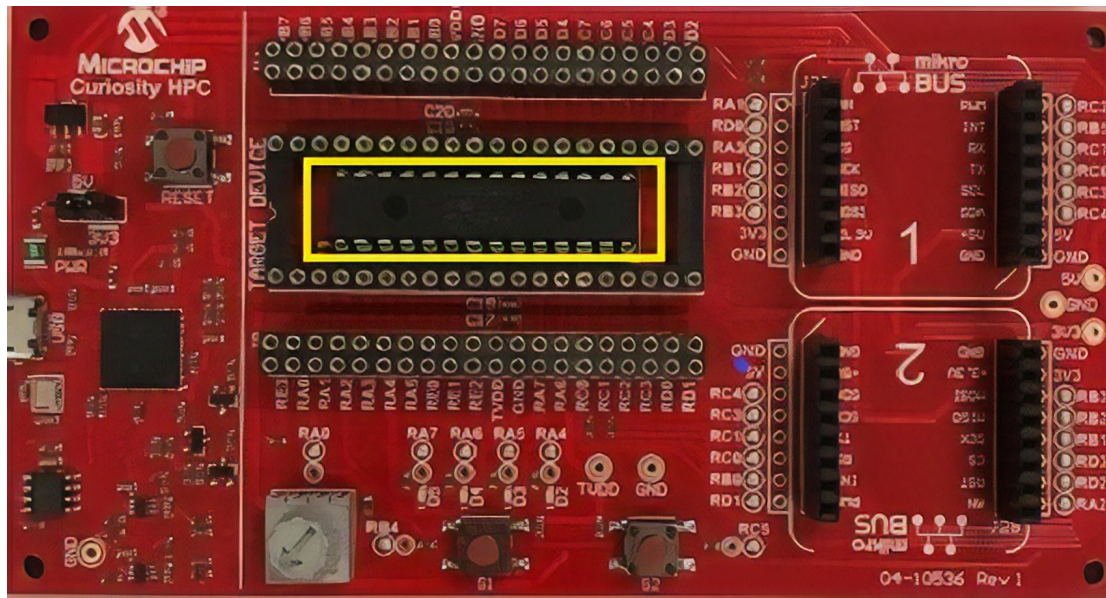
2. Demo Configuration

The following pages describe the configuration of the hardware and software components used in this demonstration.

2.1 Hardware Configuration

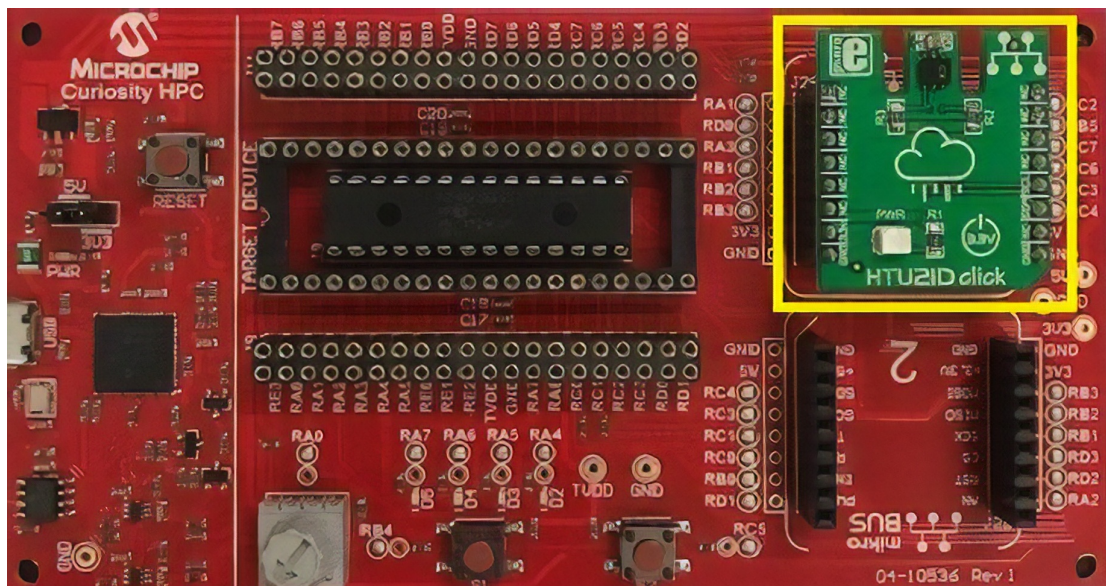
1. Place the PIC18F26K42 microcontroller into the 28-lead socket (J9) of the Curiosity HPC board (see [Figure 2-1](#)).

Figure 2-1. PIC18F26K42 Inserted into the 28-Lead Socket (J9)



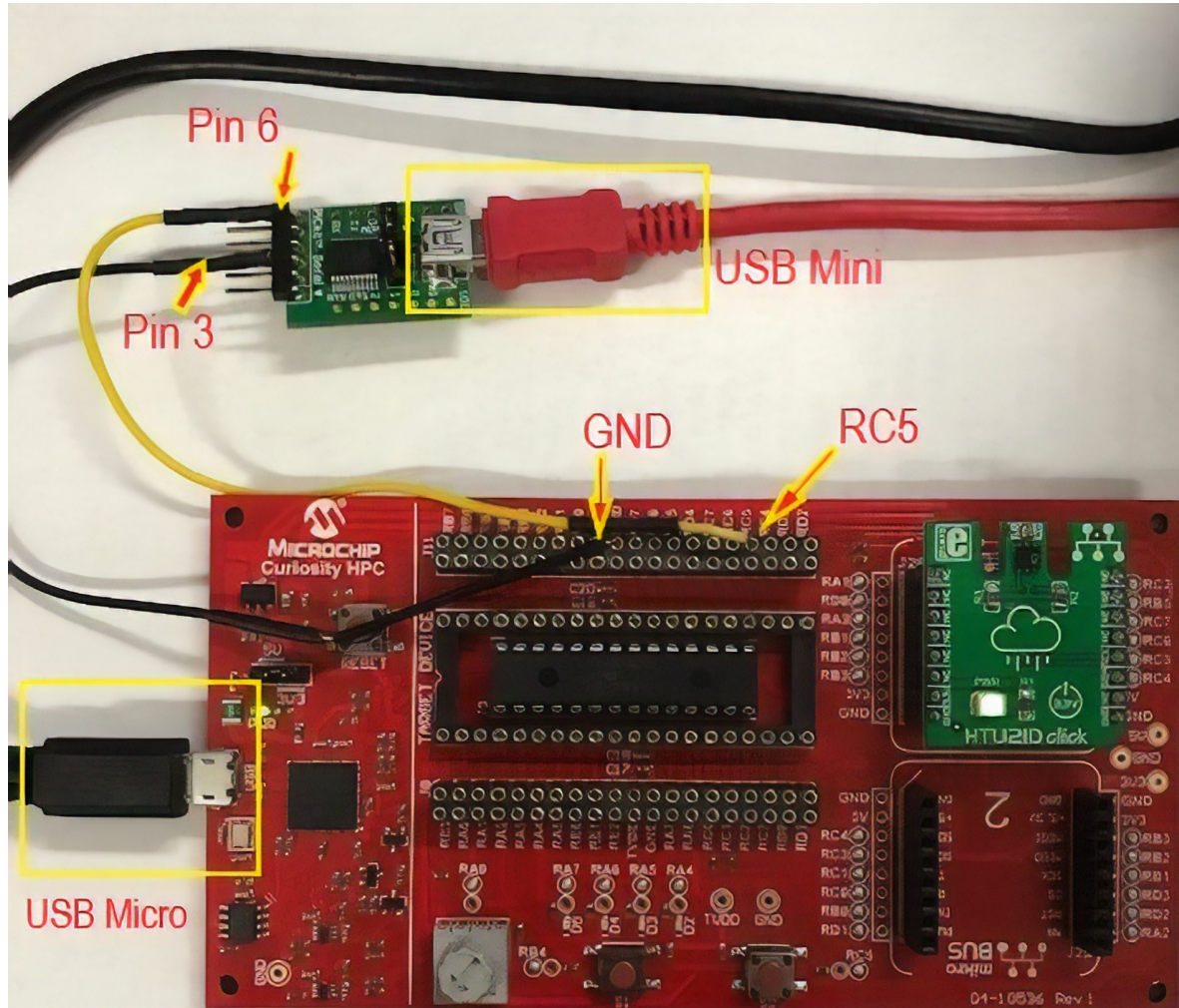
2. Insert the HTU21D Click Board™ into the mikroBUS™ socket 1 (see [Figure 2-2](#)).

Figure 2-2. HTU21D Click Board™ Inserted into the mikroBUS™ Socket 1



3. Connect the MCP2200 USB-to-UART Breakout Module to the Curiosity HPC board using jumper wires, as shown in [Figure 2-3](#). Pin RC5 (UART TX) on the HPC board connects to pin 6 of the MCP2200 board (yellow wire), and the GND pin on the HPC board connects to pin 3 of the MCP2200 board (black wire).

Figure 2-3. Connecting the HPC and MCP2200 Boards

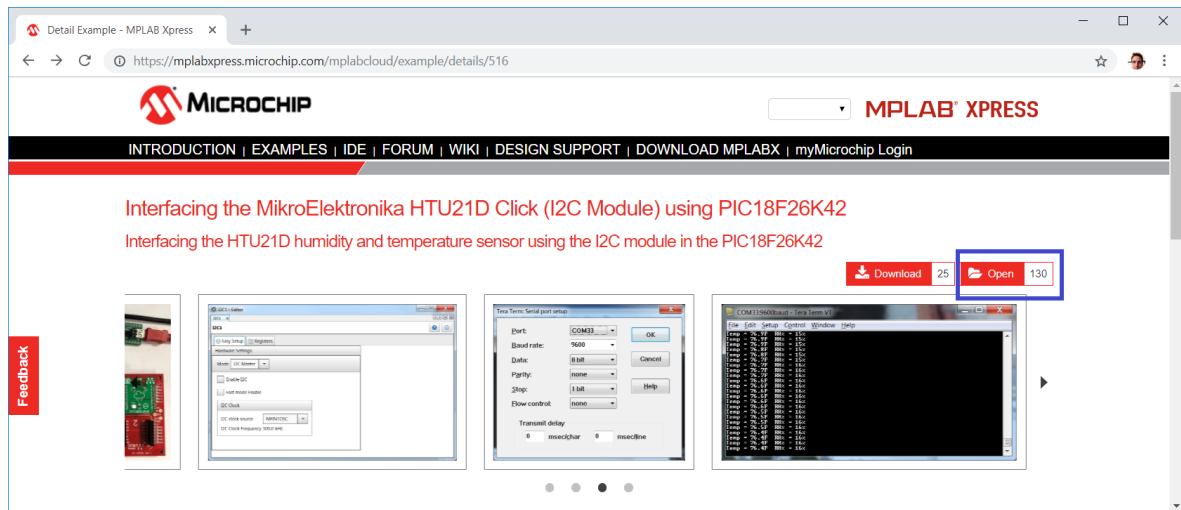


4. Connect the USB Mini-B cable between the MCP2200 board and an available USB port on the PC (see [Figure 2-3](#)). This allows the relative humidity and temperature data to be displayed on the PC.
5. Connect the USB Micro-B cable between the USB connection on the HPC board and an available USB port on the PC (see [Figure 2-3](#)). This allows the PIC microcontroller to be programmed.

2.2 Software Configuration

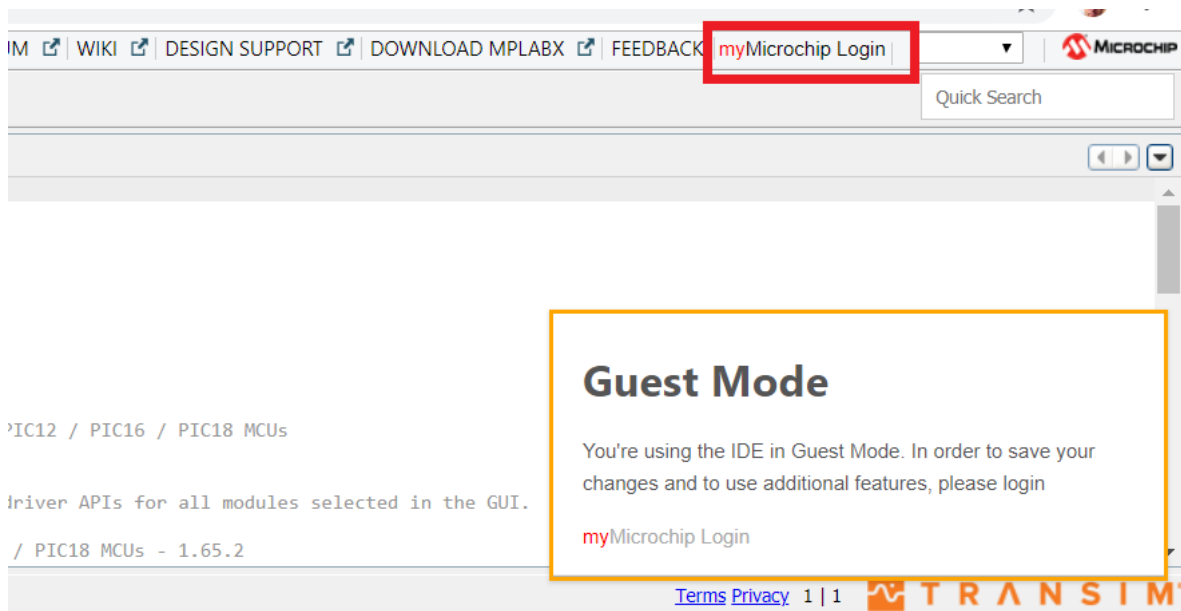
1. Visit the Microchip MPLAB Xpress '[Interfacing the MikroElektronika HTU21D Click \(I²C Module\) using the PIC18F26K42](#)' page and click on the '**Open**' tab, as shown in [Figure 2-4](#). This action will open the MPLAB Xpress IDE, along with the full project. Alternatively, the project can also be downloaded and saved to the PC by clicking the '**Download**' tab. Clicking the '**Download**' tab will allow the project to be saved to the PC and opened in the MPLAB X IDE. The project can be found on the MPLAB Xpress code example page at: <https://mplabxpress.microchip.com/mplabcloud/example/details/516>.

Figure 2-4. MPLAB® Xpress IDE's 'Open' and 'Download' Tabs



2. Click on the **'myMicrochip Login'** tab, as shown in [Figure 2-5](#). If the user does not have a myMicrochip account, one must be created in order to program/debug the project. The account is free.

Figure 2-5. myMicrochip Login



- Once the project has opened, click on the **'Make and Build'** button, as shown in Figure 2-6. Once the project has finished compiling, check the 'Output' window for any errors. If the project was successfully compiled, the 'Build Successful' message will appear, as shown in Figure 2-7.

Figure 2-6. MPLAB® Xpress IDE 'Make and Build' Button

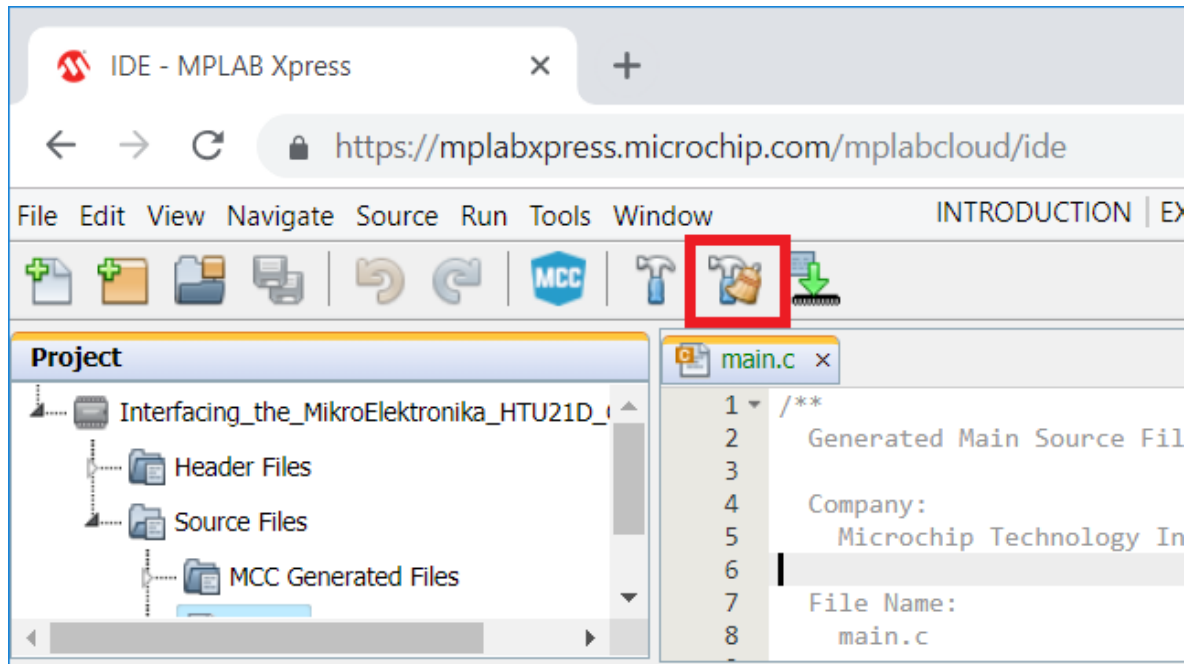
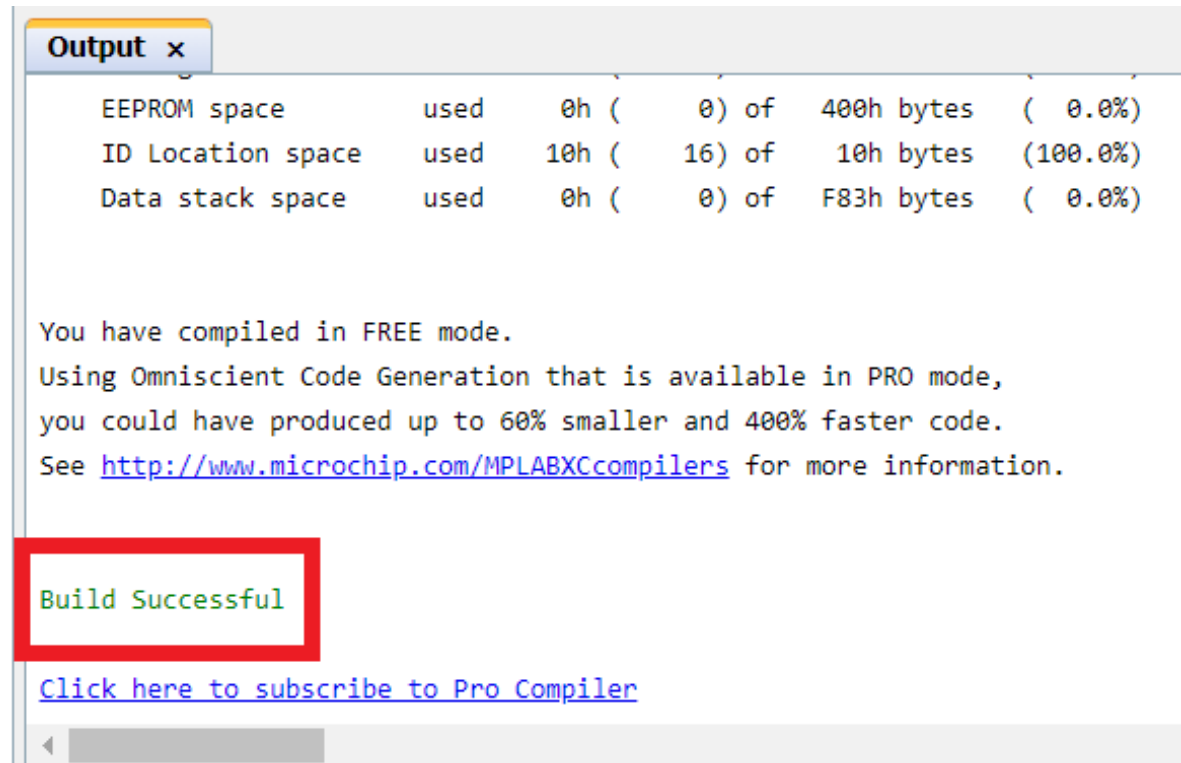


Figure 2-7. MPLAB® Xpress Output Window



4. Press the '**Make and Program Device**' button, as shown in [Figure 2-8](#). The 'USB Bridge Not Connected' window (see [Figure 2-9](#)) will appear. MPLAB Xpress requires the use of a USB bridge tool in order to communicate with the programmer. The USB bridge requires the latest version of Java 8. Click on the '**Download & Install JRE**' button to install the latest Java version. Then, click on the '**Download USB Bridge Tool**' button, which connects the MPLAB Xpress IDE to the programming tool. If prompted, copy the token code found in the 'Step 2' pane and paste into the USB Bridge tool. Once the USB Bridge tool has connected to the IDE, the 'MPLAB Xpress USB Bridge' window will appear, as shown in [Figure 2-10](#).

Additionally, at the bottom left corner of the IDE window, two status indicators – 'USB Bridge Connected' and '1 Programming Tool Connected' – will appear with green dots, indicating that the Bridge tool is active and operational (see [Figure 2-11](#)). The IDE will program the PIC device, and once completed, will show the programming status in the '**Debugger Console**' tab. If the device was programmed, the message 'Programming/Verify complete' will appear, as shown in [Figure 2-12](#).

Note: The 'MPLAB Xpress USB Bridge' window must remain open and connected during programming/debugging. The window may be minimized, but must not be closed.

Figure 2-8. Make and Program Device Button

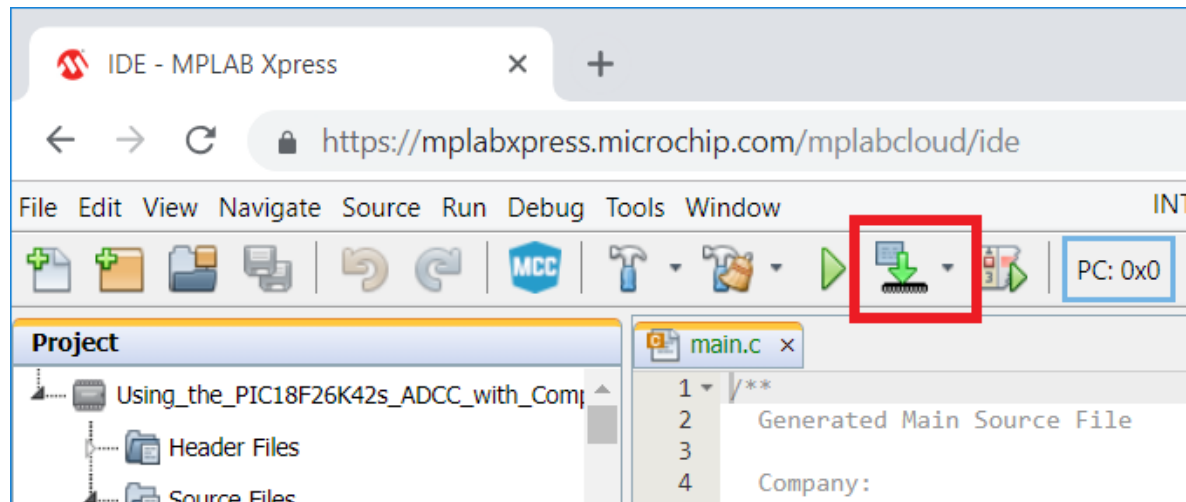


Figure 2-9. USB Bridge Not Connected Window

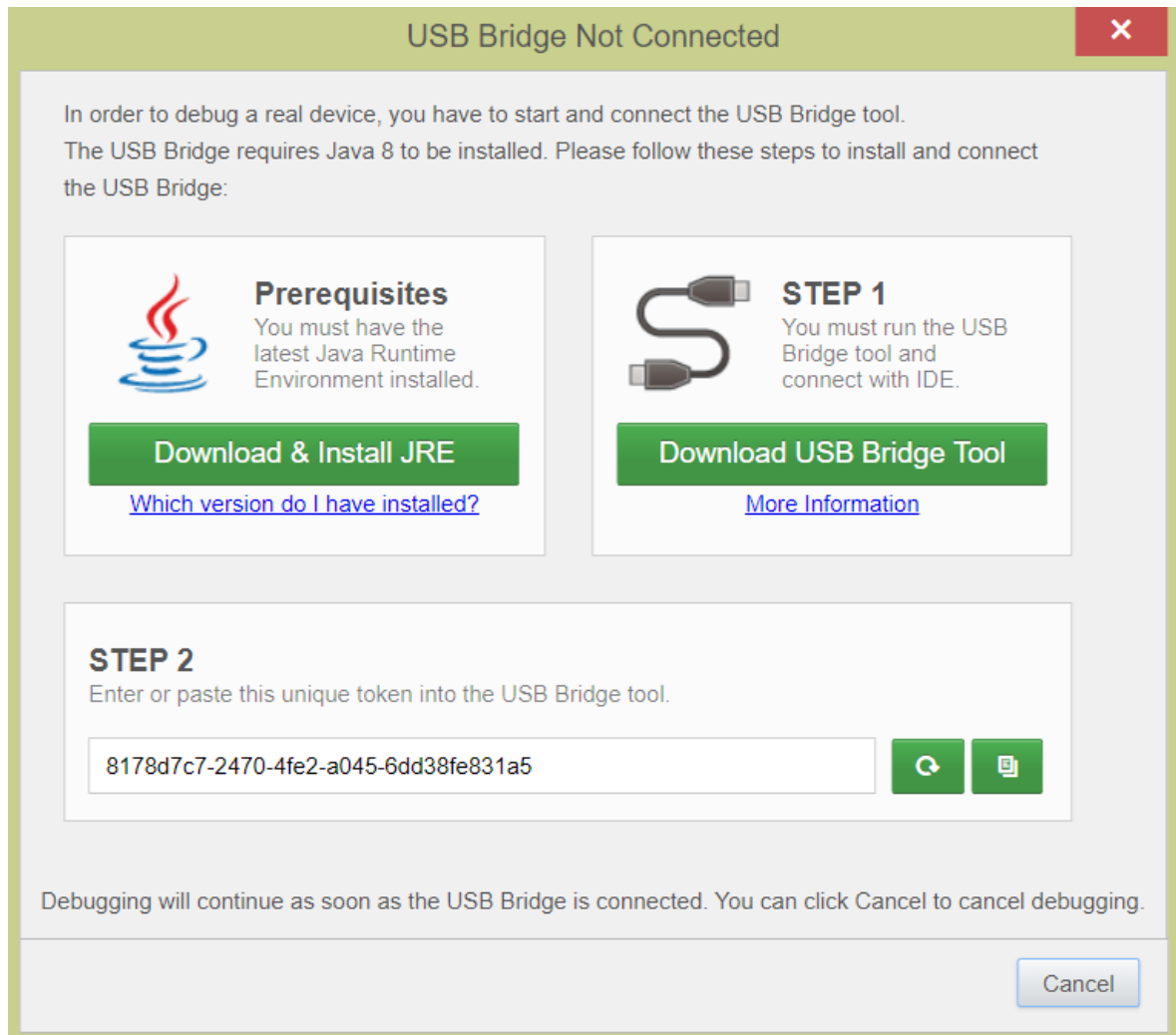


Figure 2-10. MPLAB® Xpress USB Bridge Window

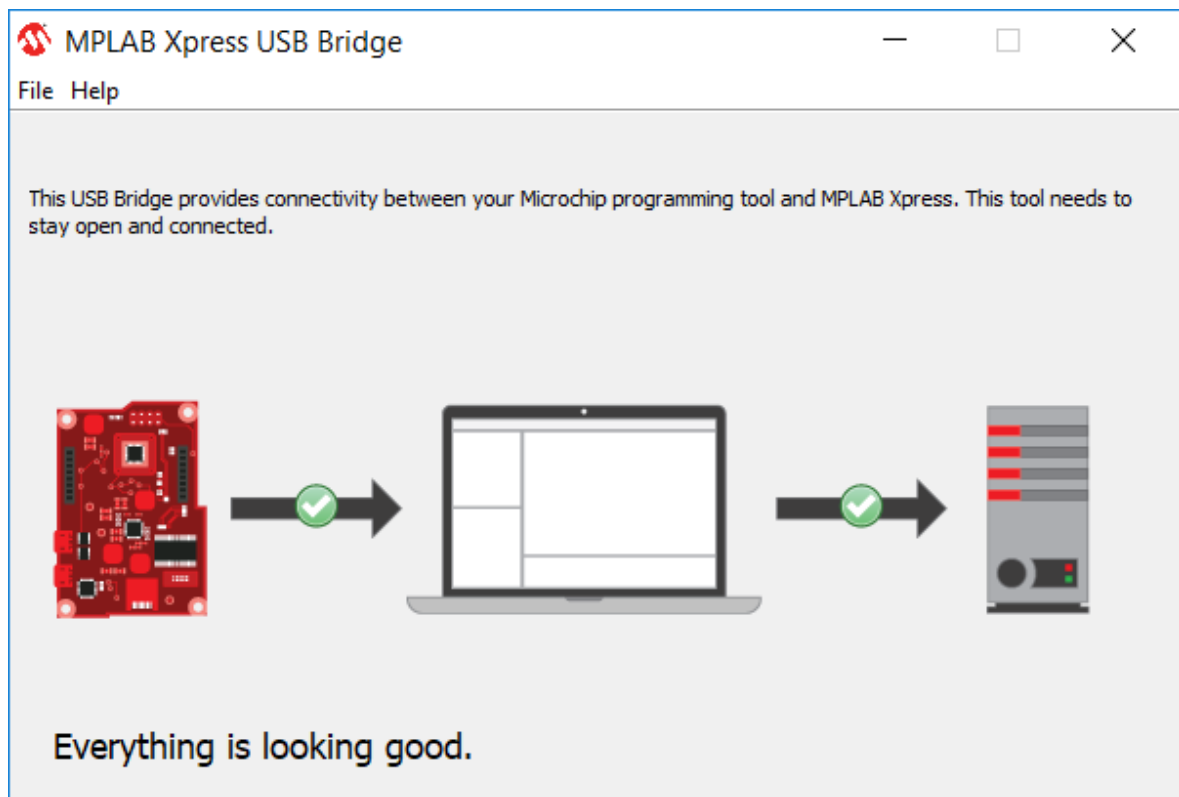


Figure 2-11. USB Bridge Tool Indicators

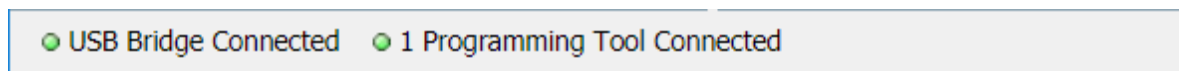
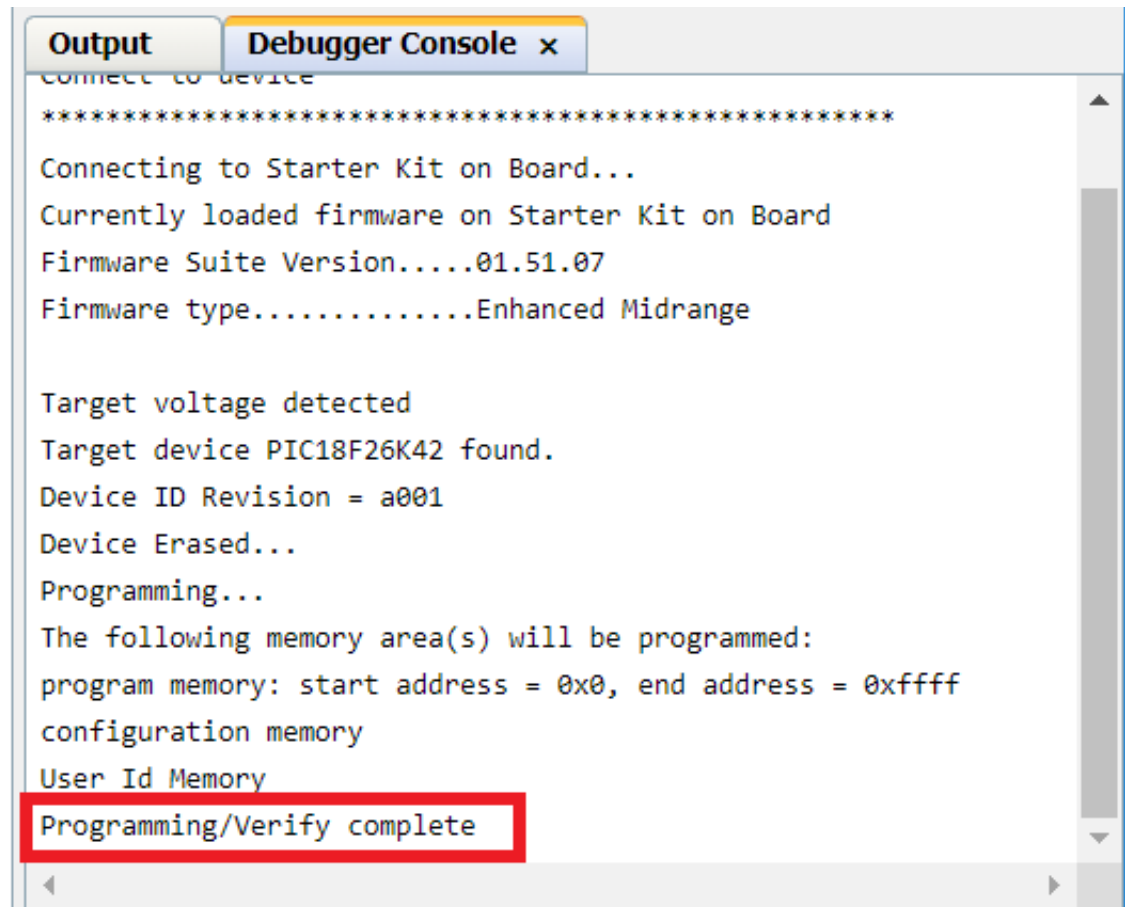


Figure 2-12. Debugger Console Window



5. Open a PC terminal program, such as Tera Term. Tera Term is a free terminal program, and was used during this project's development. The images used in this document are from the Tera Term program. If another terminal program is used, the 'appearance' may be different than depicted in the images, although the terminal settings are the same regardless of the terminal program. Tera Term can be downloaded here: <https://osdn.net/projects/ttssh2/releases/>.
6. When the terminal program opens, a window will appear, in this case, the 'Tera Term: New Connection' window. Select the '**Serial**' option, and under the 'Port' drop-down menu, select the port connected to the MCP2200 and click '**OK**' (see Figure 2-13).
7. Configure the serial port settings. In the Tera Term window, click '**Setup**', then select '**Serial port...**' from the drop-down menu (see Figure 2-14). The 'Tera Term: Serial port setup' window will appear (see Figure 2-15). The serial configuration is as follows:
 - Baud Rate: 9600
 - Data: 8 bit
 - Parity: none
 - Stop: 1 bit
 - Flow Control: none

Once the port settings have been entered, press '**OK**'.

Figure 2-13. Tera Term: New Connection Window

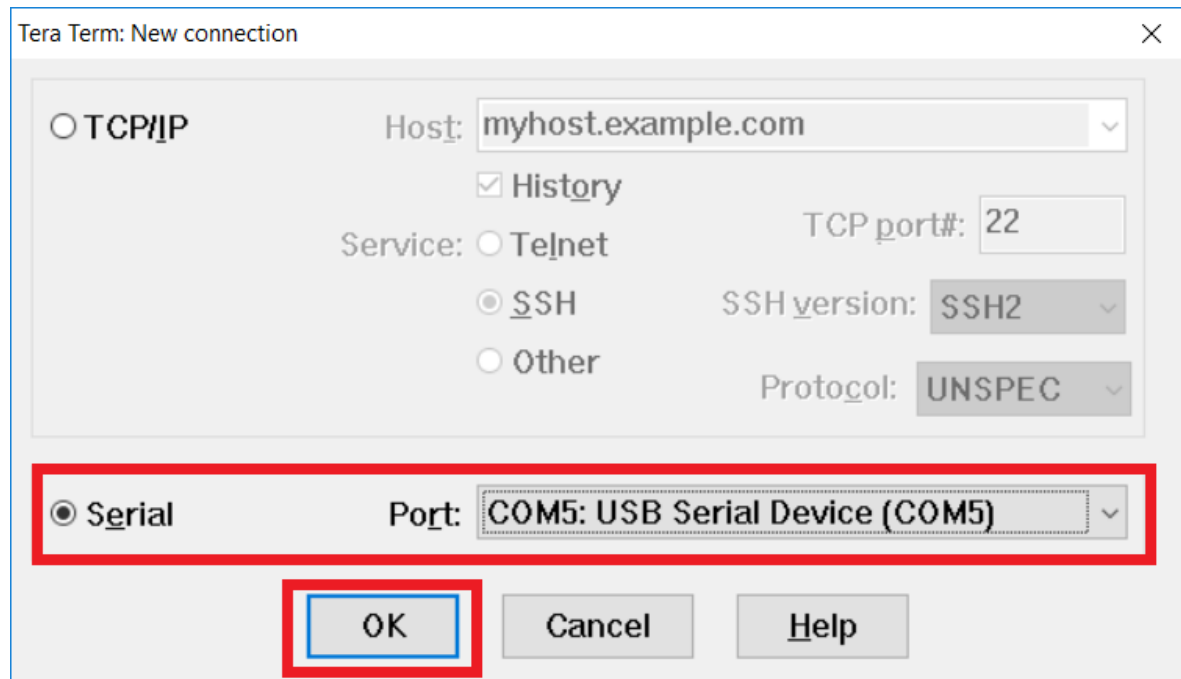


Figure 2-14. Setup Selection

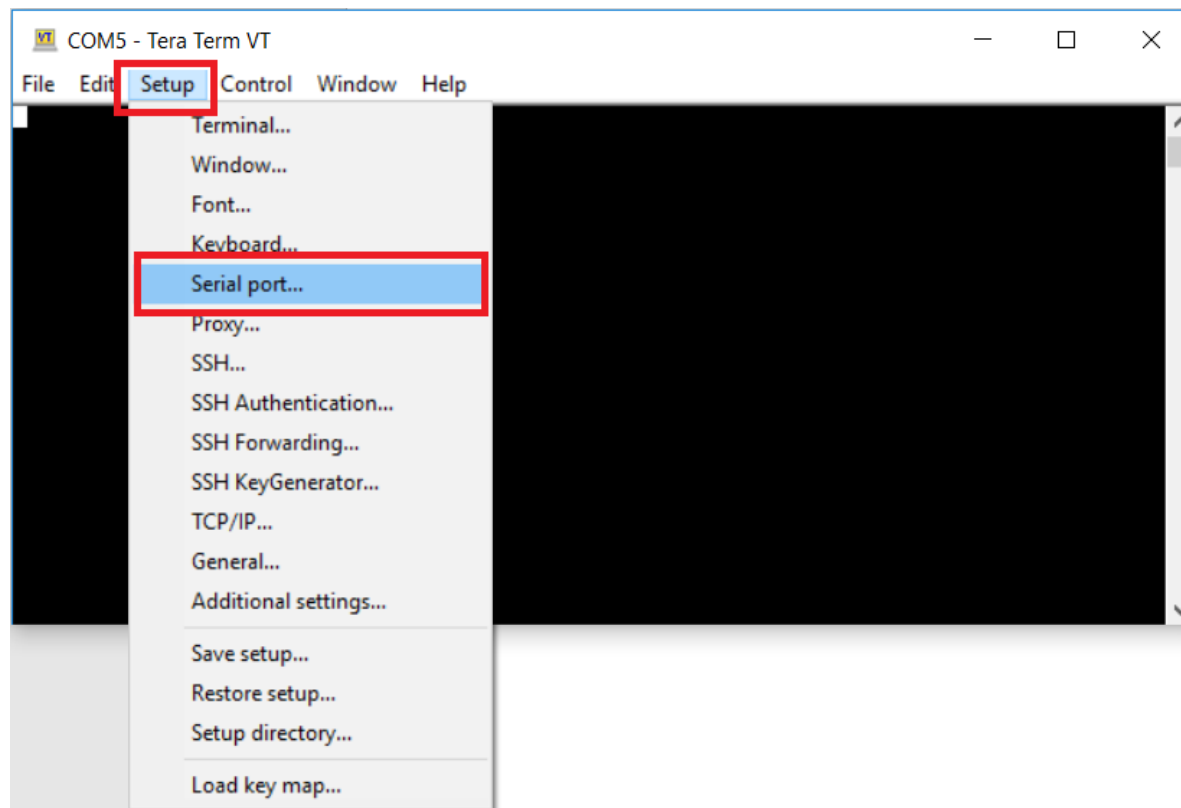
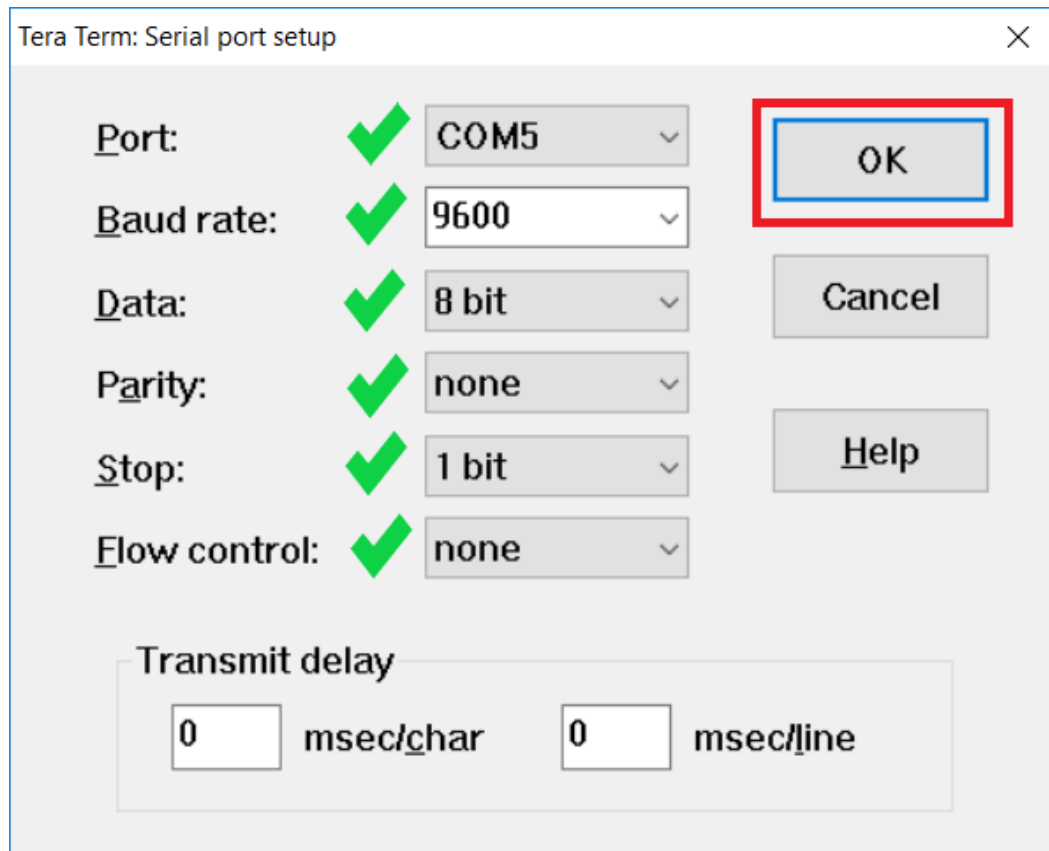
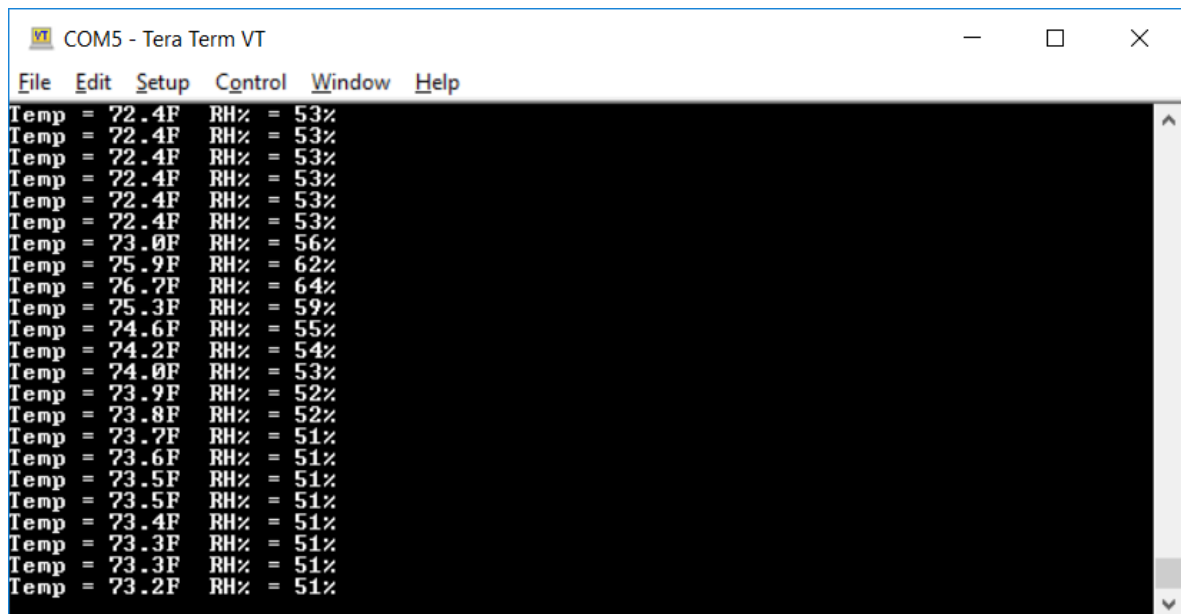


Figure 2-15. Serial Port Configuration Window



8. Once the terminal program has been configured, temperature and relative humidity data will begin to appear in the Tera Term window (see [Figure 2-16](#)).

Figure 2-16. Active Tera Term Window



3. Additional Demo Information

This demo was designed so that the user becomes familiar with the I²C module operating in Master mode. Although the project's settings have been preconfigured, the user may want to change these settings and experiment on their own.

The project's default I²C SCL speed is set at 100 kHz. While this speed is reasonable for this demonstration, the HTU21D sensor can operate up to 400 kHz. The SCL speed can be changed by selecting a new clock source from the I²C Clock Selection register (I2CxCLK); However, this change will require the configuration of a Timer resource, the Clock Reference module, or the system clock (F_{OSC}). I²C changes can be made in the 'i2c1.c' file.

The UART baud rate is set at 9600 bps. The baud rate can be modified in the 'uart1.c' file.

The project is configured to display temperature and relative humidity. Additional data, such as the dew point, can be displayed by adding another routine in the 'HTU21D.c' file. The dew point is calculated using [Equation 1-9](#) and [Equation 1-10](#).

4. Conclusion

This demonstration highlights the use of the I²C module found in the PIC18F26K42 microcontroller. The I²C module, configured in 7-bit Master mode, reads raw temperature and humidity data from the HTU21D sensor and converts the raw data into understandable information, such as temperature in degrees Celsius. For more information on the I²C module operating in Master mode, read [TB3191, "I²C Master Mode"](#) Technical Brief (DS90003191).

5. Revision History

Doc Rev.	Date	Comments
A	11/2018	Initial document release.

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- **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing
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