RTD120D-EVK

Thermopile CO_2 EVK

Overview

The RTD120D Thermopile CO_2 Detector EVK (RTD120D-EVK) monitors CO_2 levels using the Renesas RTD120D dual-thermopile detector. The RTD120D-EVK is intended to:

1. Help evaluate the RTD120D detector in a microcontroller-based system

2. Show how to monitor the performance of an NDIR CO_2 sensor solution based on Renesas thermopiles

3. Demonstrate the process of calibrating such a detection system

Right out of the box, the EVK can begin measuring CO_2 levels. Simply attach the LCD module to the main EVK board (if it is not already attached), and then connect the provided USB cable to the board and to a power source, such as a phone charger or a PC USB port. The LCD will display the software title and version number briefly, then after a 30-second warm-up it will display CO_2 concentration readings in ppm (parts per million). It will also display readings of other sensors on the board; that is, barometric pressure, relative humidity, and ambient temperature.

In addition to the stand-alone operation described above, the EVK can provide advanced functionality when connected to a host computer.

This document explains how to use the EVK with application software running on a host PC in order to provide additional capability, including:

1. Remote monitoring of CO_2 concentration, barometric pressure, relative humidity, and ambient temperature

2. Graphical display of data

3. Calibration of the CO_2 detection process with enhanced visual feedback

Features

- CO_2 Detector Evaluation Software running on Windows®, or end-user supplied software communicating via text commands or ModBus® over USB, using any OS

- Extend functionality to simplify evaluation of RTD120D Thermopile Detector

- Communicate with Thermopile CO_2 Detector EVK using ModBus or simple serial commands for terminal CLI or end-user supplied software

- Capture, graph, process, and export CO_2 concentration and other performance data

- Software supports calibration of CO_2 detection algorithm with an interactive GUI environment

Contents

1.   Connection Modes

The EVK supports two modes of operation when connected to a host computer. Both modes, ModBus mode and terminal mode use the same USB connection. When the EVK powers up, it immediately operates as a stand-alone CO$_2$ detector as described in the *RTD120D-EVK CO$_2$ EVK User Manual*, with the integrated LCD and push-button switches acting as the primary user interface. In the background, the USB interface is continually monitored for an incoming connection. When a USB connection takes place, the first data byte received from the host computer determines which protocol will be used.

If the first byte is binary 0, 1, 2, 3, 4, 5, 6, or 7, it assumes a ModBus client is attempting to talk to it. When this occurs, the EVK operates in *ModBus mode* until the next re-start. Acting as a ModBus agent, that byte and all subsequent received bytes are separated into packets and interpreted as ModBus requests. If the first byte is anything other than binary 0, 1, 2, 3, 4, 5, 6, or 7, it is assumed to be part of a text command. The remaining bytes are interpreted as characters of a text command, and the EVK operates in terminal mode until the next re-start.

Regardless of the communication modes (*ModBus mode* or *terminal mode*), the EVK continues to execute the same algorithms and support the LCD/push-button user interface, even while a host computer is interacting with the kit using one of these two protocols.

1.1   ModBus Mode

Any ModBus client running on a Windows, Linux, or Mac host computer can be used as long as the client is configured to use the ModBus RTU protocol over USB. To get up and running quickly using ModBus, support files are provided for using the DAQFactory® Express application by AzeoTech®, which can be downloaded for free (see Installing DAQFactory Express). These support files can be downloaded from the RTD120D-EVK's product page under "software", and they configure the GUI for various use cases, such as to show live graphs of sensor readings and related variables, and to provide a set of controls and graphs for an enhanced calibration user experience.
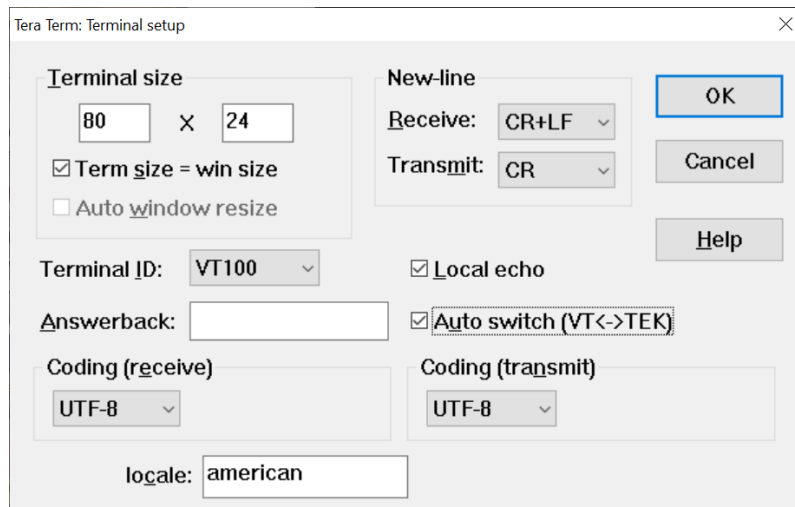
1.2   Terminal Mode

In terminal mode, text commands can be sent over USB from a terminal program or a user's application which can be written in any language and framework that supports serial communication.

Text commands are simple, one-line strings that are terminated by a carriage return. These commands can be used to interrogate and stream data from the board and to perform various functions. An example of a text command is "**=ppm**<CR>". Note that the <CR> is a single carriage return character, so you just need to type **=ppm** and then press **Enter** on the keyboard. A terminal program, such as *Putty* or *Tera Term*, can be used to interact with the EVK in this mode. In order to allow strings of characters to be pasted into such a terminal program without any data loss, Renesas recommends to configure a 5 millisecond delay between sent characters in the terminal program's settings. For example, in Tera Term, the following setup works reliably when pasting text into the terminal window (MENU: Setup - Serial Port...)
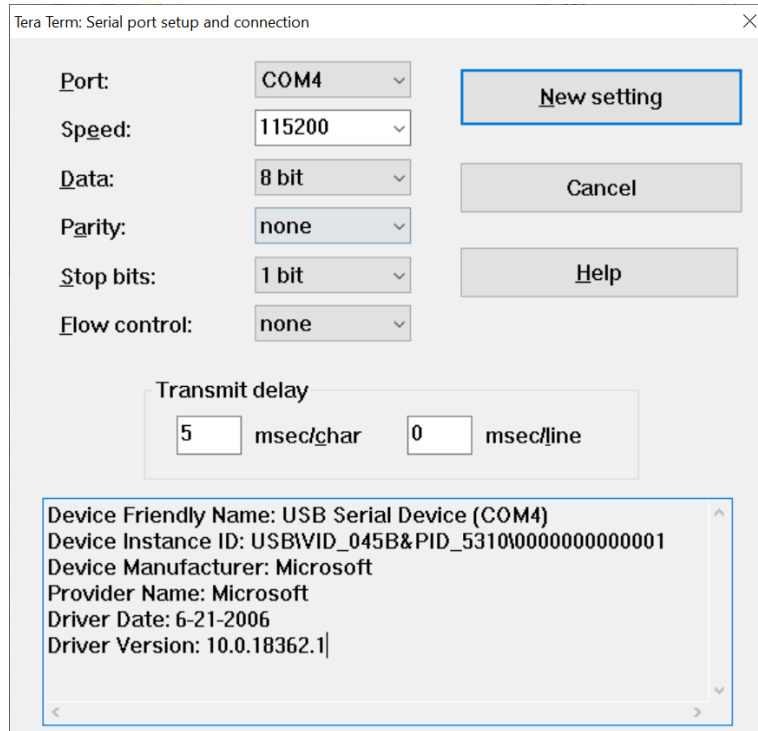
Terminal mode does not echo characters as they are received. This is to make it easier to write host applications that use the terminal mode, without having to distinguish between echoed characters and information responses. As such, to make it easier to type interactively when using a terminal program, you may find it preferable to enable "local echo" in the terminal program's configuration settings. In Tera Term, this is how it is (MENU: Setup - Terminal...)

Note: Terminal mode uses a "stateless" command line interface model, meaning, all commands are available at all times. This is in contrast to a multi-level, menu-driven command line interface, where the available commands depend on commands that have already been executed. The stateless model was chosen as it is more convenient for applications created by the end user, or simple extensions to data processing systems such as MatLab, where a program running on the host computer must be able to access all commands without the complexity of keeping track of the state of the interface. As a basic example, a python script that needs to access various bits of data from the EVK can simply call an interrogation function to read a parameter or sensor reading whenever it needs to.

Commands are not case-sensitive, so "`start ppm`" is equivalent to "START PPM" and to "`Start PPM`", etc.

The available commands include interrogation commands, starting with "`=`" (such as "=PPM"), parameter setting commands starting with "`set`" (such as "`set S1_RAW 1234.56`" and "`set FILTER_ADC`"), and "FORCE_COIL" commands starting with "`!`". FORCE_COIL commands are simple commands with low communications overhead, using the ModBus FORCE_COIL primitive.

For a list of supported commands, see Appendix B: Terminal Mode Commands.

2. ModBus Example: DAQFactory

The *Thermopile CO_2 Detector Software* consists of data acquisition software (DAQFactory Express, available from AzeoTech) and "control" files that configure DAQFactory to be used with the Thermopile CO_2 Detector EVK. The control files are available for download from the RTD120D-EVK product page. When opened by DAQFactory, these control files provide useful functionality without modification but they can also be customized by the user to change and add functionality. New control files can also be created from scratch; however, for the beginner user, it is easier to use one of the provided control files and just modify it instead of creating one from scratch. To do this, save one of the provided control files under a new name and then modify the file in order as not to lose the original capability.

DAQFactory is a data acquisition and processing platform that can communicate using the ModBus RTU protocol, over a USB serial connection transport. It provides a GUI that can be used to monitor and process real-time data streaming from the evaluation board. Actions can also be initiated from the GUI to cause operations on the EVK to be carried out, such as adjusting filter settings and saving calibration data points.

The free version, "DAQFactory Express", has all the functionality needed to access basic features of the EVK, including monitoring readings of CO_2, viewing intermediate variables, calibrating the CO_2 detection algorithm, and monitoring the temperature, relative humidity, and barometric pressure from the other sensors on the EVK.

The DAQFactory "control" files (with extension .ctl) contain GUI screen definitions, application-specific communication settings, and scripts for various purposes. The control files for use with the EVK can be downloaded from the RTD120D-EVK product page. Opening a control file in DAQFactory is all that is needed to start using the GUI with the EVK for control, monitoring and calibrating.

2.1 Installing DAQFactory Express

To install DAQFactory Express, go to the AzeoTech website and download version 18.1 or later of DAQFactory Express. This will install an "Evaluation" version of the full DAQFactory application, as well as the "Express" version, which has no time limit but some functionality is limited.

For basic monitoring and visualization (plotting) of on-board sensors and system parameters, as well as calibration of the CO_2 algorithm and miscellaneous control of the EVK, the "Express" version of DAQFactory has all the necessary functionality. Other applications that can act as a *ModBus RTU* master over USB can also be used. This is supported by the EVK's firmware, but additional configuration is required that is specific to the desired ModBus application.

Note: After installing DAQFactory, either version can be run from the Start menu; however, Renesas recommends running the Express version because it does not have a time limit. If you require more capability beyond the needs

of the RTD120D-EVK, you can later purchase one of the more full-featured versions of DAQFactory directly from AzeoTech. (DAQFactory and AzeoTech are registered trademarks of AzeoTech, Inc. Renesas has no affiliation with AzeoTech.)

2.2   Board Connections

A USB (B-micro) connector is used to power the board and for communications with a host computer. For the current purposes, you only need to connect the USB cable. However, there is also an auxiliary power connector (not needed for normal operation), two jumper headers to facilitate firmware updates (updating the application software that comes pre-loaded on the EVK), and a programming/debug interface using two different connector options. The programming/debug interface can be used to support developing custom firmware to run on the EVK, using Renesas Flexible Software Package (FSP) and the Renesas e2studio Eclipse-based IDE. For more information, contact Renesas Technical Support.

2.3   Establishing a Connection with the EVK

After installing DAQFactory Express, connect the USB cable to the EVK and to a USB port on your PC. Start DAQFactory Express from the Windows Start Menu. Note that both the full and Express versions are available after installation. Using the Express version allows you to use the platform without a time limit.

1. With DAQFactory Express running, open the control file provided by Renesas called "monitor.ctl". Next, select the COM port for use with the EVK as follows:
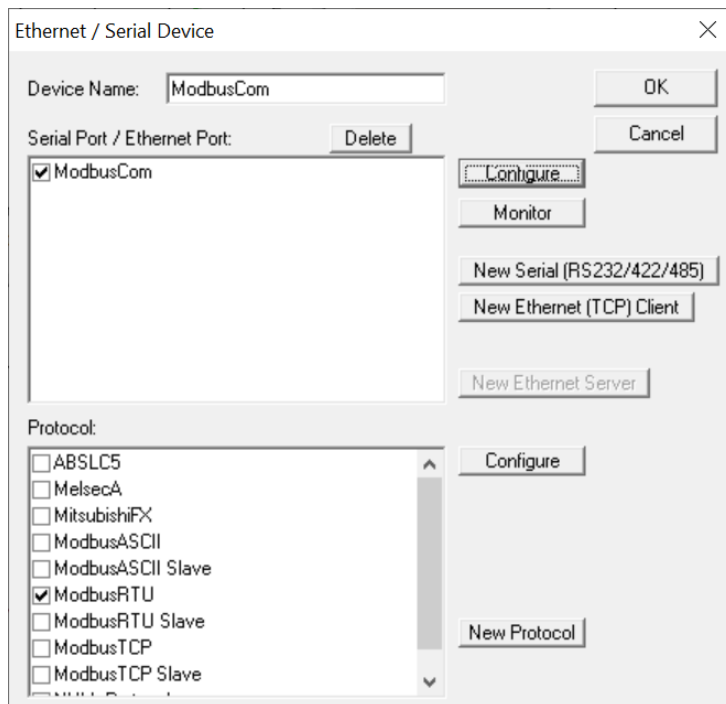

**Figure 1. Menu: Quick - Device Configuration - ModbusCOM - Select - Configure**

2. In the Serial Port Configuration dialog, set Serial Port # (COM) to the port number the EVK is connected to (e.g., 4 for COM4). To determine the correct COM port number, you may need to open Device Manager from the Windows Start menu to observe which COM port appears in response to connecting the USB cable between the kit and your PC. This port number is remembered whenever you save the control file, so it will most likely already be correct if you recently connected to the same EVK on this port.
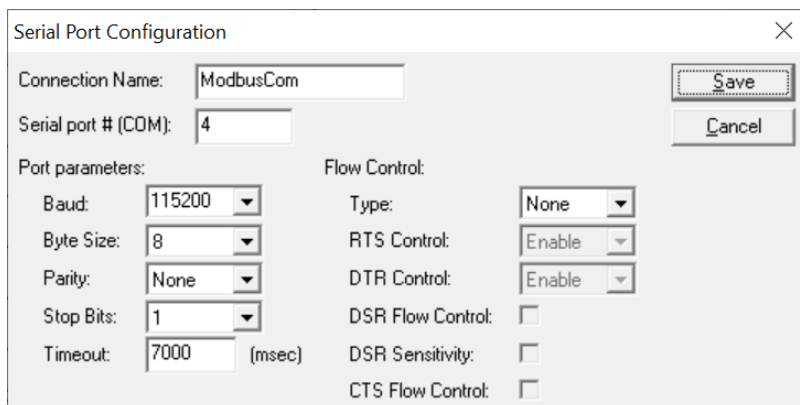
3. Click "Save", then click "OK". Communication between DAQFactory and the EVK will start automatically. If you subsequently disconnect and re-connect the EVK from your PC, then you must complete the following to re-establish communication:

    a. Open the **Communications Monitor** view
        MENU: View - Comm Monitor

    b. Right-click in the view and select **Configure...**

    c. Click **Save**.

2.4   Monitoring CO_2 Concentration and Sensor Readings

After communication is established, the GUI will display live graphs of the CO_2 Concentration and readings of the other sensors on the board. To manipulate the scale and depth of the data displayed in these graphs, refer to the DAQFactory help guides, which can be accessed from the Help menu.
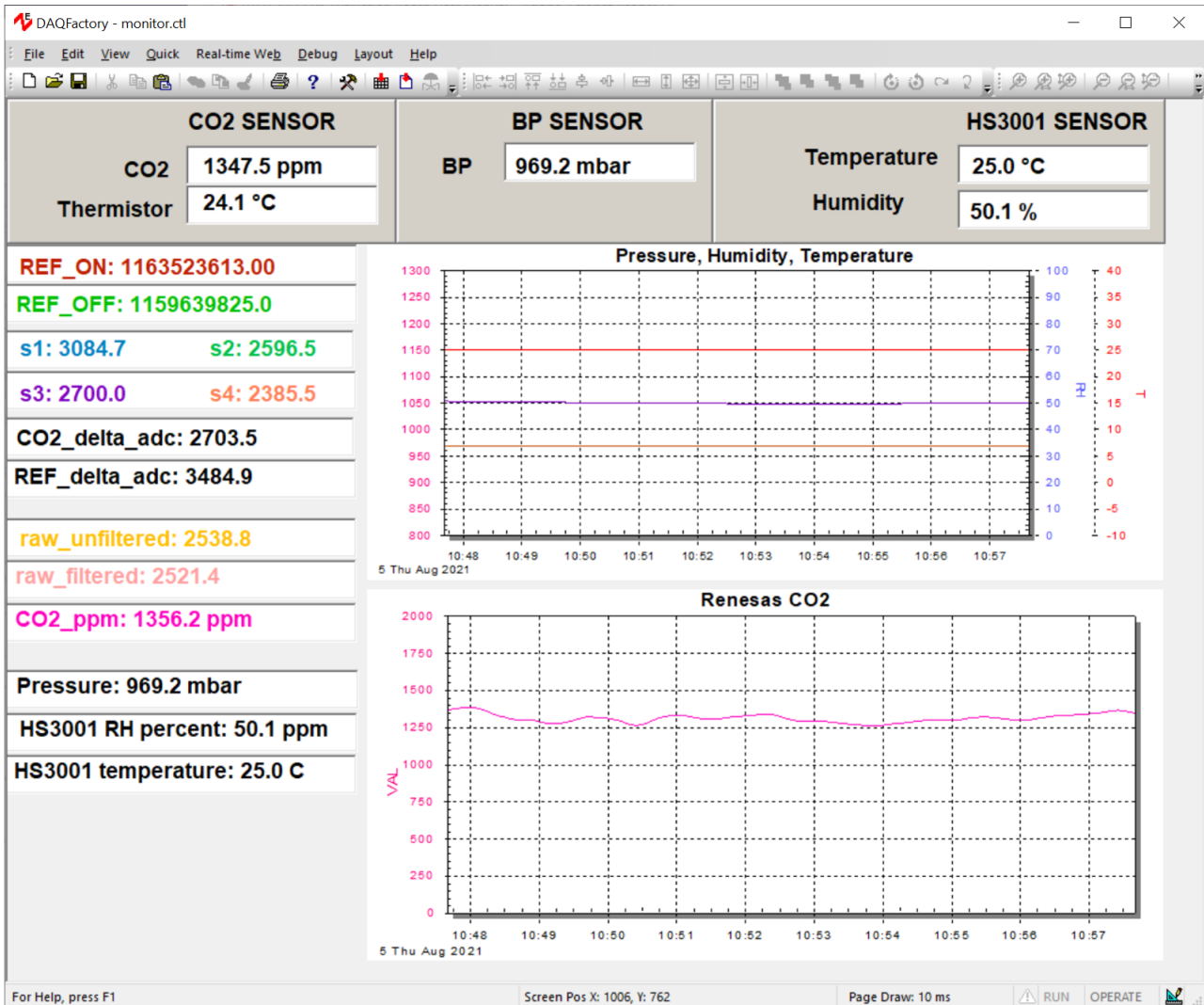
2.5   Calibration Using DAQFactory

The EVK is pre-calibrated but it can be re-calibrated if desired. Calibration can be performed in either of two ways:

▪ In a stand-alone fashion, using the LCD and push-button user interface on the EVK itself

▪ With a GUI, using a connected PC for a more interactive and visual experience

This section describes the GUI-based method of CO_2 calibration. To calibrate the kit without using a connected host computer (instead using the LCD and pushbutton UI), see the *RTD120D-EVK CO_2 EVK User Manual*.

2.5.1   General Calibration Principles

The EVK continuously reads the two thermopile channels, reading each channel once with the lamp ON and once with the lamp OFF, resulting in four readings. After each such sequence, a "raw" value (a positive integer typically between a few hundred and a few thousand) is calculated from the four readings. The sequence occurs every 5 seconds, so a "raw" value is always available in the microcontroller's memory to be used for further processing,

such as for calculating CO_2 concentration or calibrating the kit so that accurate CO_2 concentration determination is possible.

Calibration consists of allowing various gas mixtures of known CO_2 concentration to enter the gas chamber (where CO_2 concentration is measured), and storing in memory the resulting "raw" values that result from those gas mixtures, associating those values with the known CO_2 concentration of each gas. For example, gas with no CO_2 (concentration of 0 ppm) results in a raw value that gets stored in a variable "raw_1", gas with a CO_2 concentration of 1000 ppm results in another raw value that gets stored in a variable "raw_2", and so on. At least three such values must be stored: raw_1, raw_2, and raw_3 corresponding to CO_2 concentrations of 0ppm, 1000ppm, and 400ppm, respectively. For more accuracy in ranges above 1000ppm, a fourth raw value (raw_4) can optionally be stored as well, which corresponds to a CO_2 concentration of 2000ppm. These three or four raw values get stored in flash memory, and are used later when the kit is determining CO_2 concentration of unknown gases (such as ambient air in the vicinity of the kit). This is done by computing raw readings and applying a function that interpolates the CO_2 concentration from the known concentrations associated with the stored raw values.

2.5.2   Calibration Procedure

When the EVK is used with DAQFactory running on a PC, real-time display of a graph of CO_2 concentration and other kit parameters can be viewed. That data can also be processed, analyzed, and logged for further processing and use with other tools.

A useful capability provided by the GUI is to allow the calibration procedure to be performed in a more interactive, visual manner. For this, a control file must be loaded by DAQFactory which defines user-interface elements such as live graphs and buttons to aid in performing calibration.

From DAQFactory, open the control file "calibrate.ctl". This file is included in the GUI download from the RTD120D-EVK product page. The initial display of the calibration GUI consists of several graphs, live value displays, and buttons. The graphs include the following:

▪ Raw value

▪ Raw value peak-to-peak variation

▪ CO_2 concentration

At a high level, calibration is performed by determining and storing "raw" values for several reference CO_2 concentrations. For each reference value, the following steps should be completed:

1. Apply a calibration gas of the reference concentrations to the kit.

2. Watch the graphs to determine when the "raw" reading for the current reference concentration has stabilized (stopped changing).

3. Press the appropriate button to accept the "raw" value, which will be saved for later storing in flash memory. This value will be associated with the current CO_2 reference concentration.
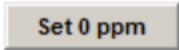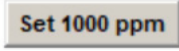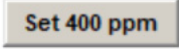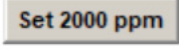
After calibration points have been found for all reference concentrations, store the values into flash memory so that they will be retained after the kit has been powered down. To do so, complete the following:

1. To calibrate a kit using the GUI, first connect the kit to a PC running DAQFactory with the supplied USB cable.

2. *If the kit was already warmed up in advance, then the following step is not necessary*:

    Wait at least 10 minutes for the gas chamber to warm up. Since the kit has a lamp that turns on and off at a regular constant rate, the internal temperature will rise slightly above ambient but soon it will reach a steady state temperature. The temperature is typically stable enough after 5 minutes, but 10 minutes is recommended.

3. Follow the steps using the GUI.

Table 1. Calibration Steps (GUI)

| Step	Button to "accept" raw value or save all results	Note
Determine the "raw" value for Zero gas (N).	Set 0 ppm	Mandatory (*typically pure Nitrogen*)
Determine the "raw" value for CO2 (1000ppm).	Set 1000 ppm	Calibration gas
Determine the "raw" value for CO2 (400ppm)	Set 400 ppm	Calibration gas or outdoor air
Determine the "raw" value for CO2 (2000ppm)	Set 2000 ppm	Calibration gas *(optional step)*
Save all "raw" values to flash.	Flash Write	

So other than the method of determining when the raw value has stabilized and for accepting and storing those values, the procedure is very similar to that used with the LCD and switches. Using the GUI, the detailed procedure is as follows (for each of the three (or four) calibration points of CO_2 concentration):

1. Apply the calibration gas mixture (or outdoor air if that is being used for the 400ppm sample) using *one* of the following methods:
   - Place the kit in an enclosure (gas chamber, plastic bag, etc.) containing the respective concentration of CO_2 gas.
   - Connect a supply hose from a calibration gas canister flowing at approximately 3 liters per minute, to a fitting that guides the flow of gas into one of the holes at the top edge of the kit's aluminum gas chamber.
   - Place the kit in a location where the ambient gas is the gas with the known CO_2 (such as outdoor air).
2. Connect to the EVK (see Establishing a Connection with the EVK).

3. Confirm that the displayed page appears similar to the following screen-shot, and monitoring of the kit's data immediately begins. Watch as the three graphs accumulate and show data arriving from the right side of each plot as time proceeds. The calibration application is now running (calibrate.ctl) for four-point or three-point calibration.
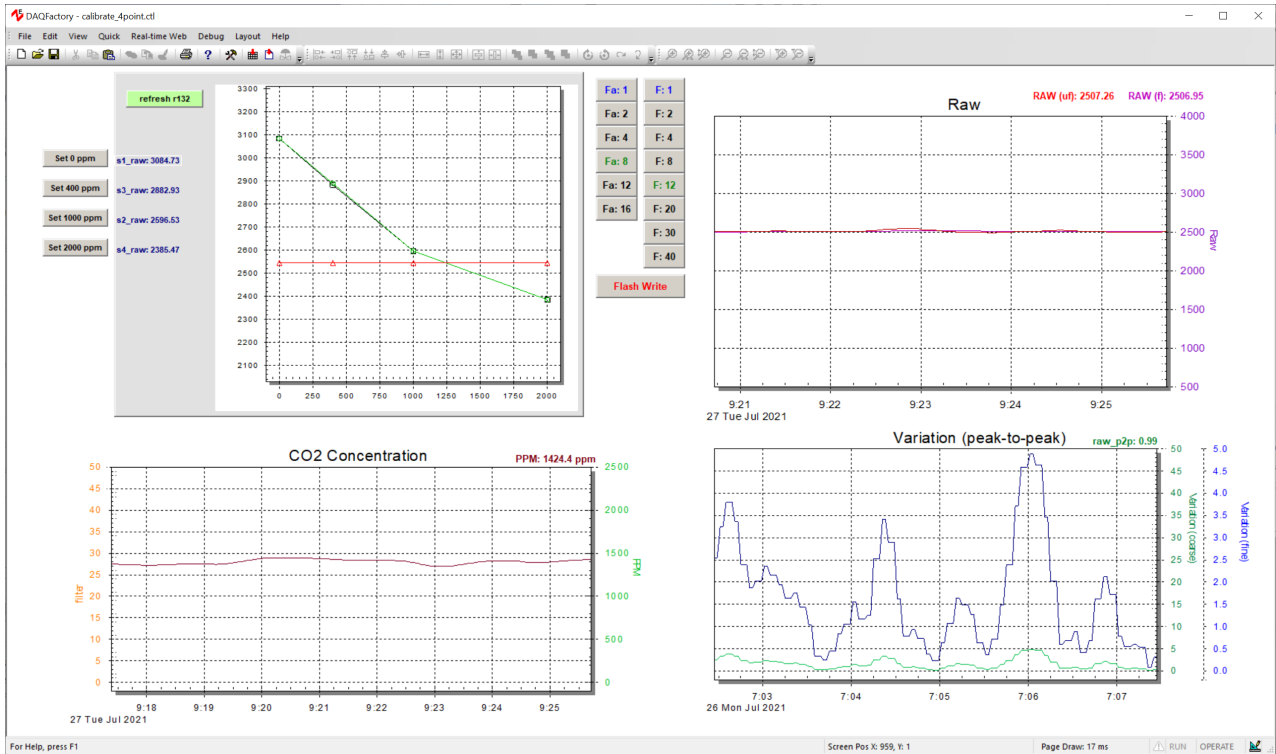
4. The plot on the top-left passively shows the current calibration points visually: raw value versus concentration in ppm. Pressing the green "refresh r132" button refreshes this image at any time during the calibration process.

   If you do 3-point calibration instead of 4-point, the right-most point will show a value of -1, which is OK. It will be ignored in that case, and the extrapolated values over 1000ppm will be co-linear with the middle segment instead of bending upward in the piecewise linear graph.

5. The plot labeled "Raw" will show how the raw value changes over time.
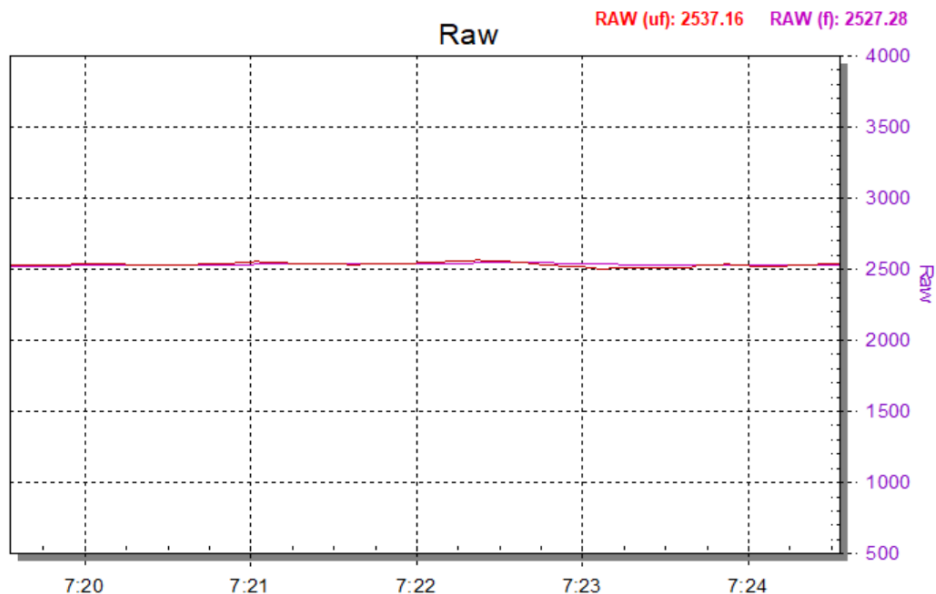
6. The amount of change of the raw value in the last several samples is displayed in the plot labeled "Variation (peak-to-peak)". In this plot, there is a normal (green) and a magnified (blue) trace.
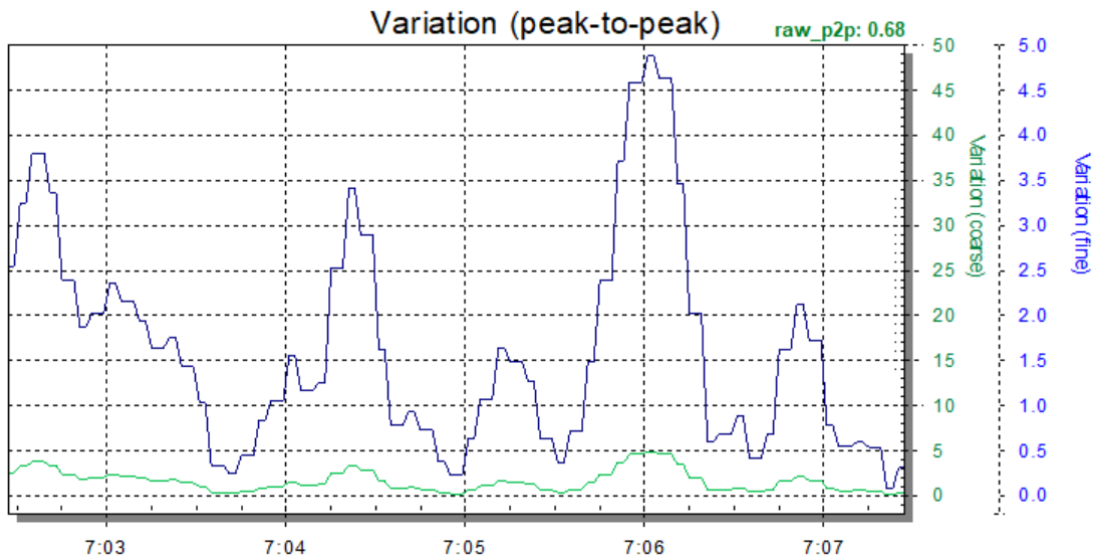
These peak-to-peak values get updated every 5 seconds or so, which is the normal sample period. Watch the blue trace as it goes down in value until it dips below 1.0. This should complete in a minute or two. If the peak-to-peak variation never dips below 1.0, then just wait until it stabilizes around a certain value. It will change a bit continually but only by a small amount

7. *Advanced Operation*: If you learn and understand the effect of adjusting the digital filter stages while you are watching the raw value change, you can use them to save some time in this part of the procedure. The filter buttons can be used to change the number of samples used in the two digital filter stages in order to speed up the convergence of the raw value (and also the calculated CO_2 concentration value) to a steady reading. If you use these buttons, be sure to restore the filter settings to the default values (shown with button text in green).
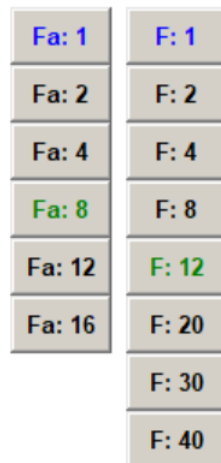
The left column of buttons ("Fa: #") sets the number of samples used in the first filter stage, which filters A/D readings (that is, it filters the difference between CO_2 and Reference A/D readings). The right column ("F: #") is for the second filter stage, which filters raw readings after the $\log(\mathbf{I/I_0})$ function has been applied.

8. Once the peak-to-peak variation is below 1.0 (or stabilizes slightly about that value), store the raw value by clicking the "Set" button associated with the CO_2 concentration you are currently calibrating. For example, for 1000ppm CO_2, click:

9. To write this calibration point to flash memory, press:

<div align="center">

Flash Write

</div>

10. Now you can turn off the gas supply valve if you are using a calibration gas canister, or otherwise remove the reference gas source (or remove the kit form the gas chamber, plastic bag, etc.). If you are using outdoor air as the reference gas then nothing more needs to be done.

11. Repeat the above steps for each remaining calibration point of CO_2 concentration. Note that it is okay if you only click "Flash Write" once, after setting all of the calibration points, but it is a good idea to save after each one.

The EVK is now calibrated, and the kit will immediately begin computing and reporting the CO_2 concentration of gas in the aluminum gas chamber. While DAQFactory is still connected to the kit, the "CO_2 Concentration" plot will continuously display the CO_2 values over time.
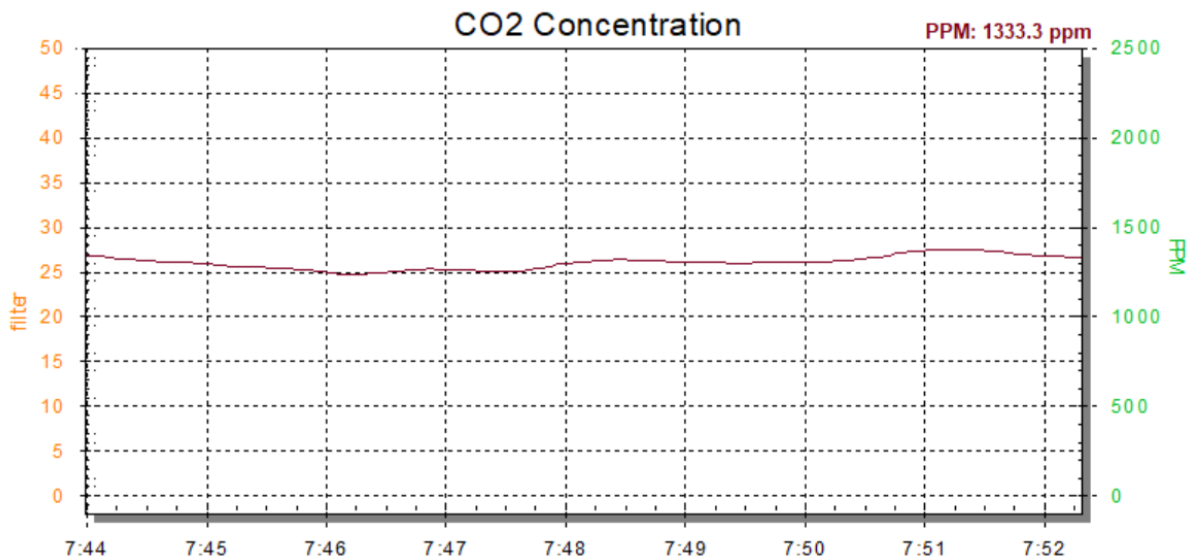
It may take a minute or two for the calibration gas (especially 1000 or 2000 ppm) in the chamber to be replaced by nearby ambient air, so the CO_2 concentration reading will gradually converge toward the measured value.

Note: You can repeat the calibration steps at any time for any or all of the three or four calibration points (0, 1000, 400, and/or 2000 ppm) independently, and in any order. The last saved raw reading for any given calibration points will be used in the CO_2 concentration calculation.

3. Appendix A: Background Information

The following high-level block diagram introduces the structure of this EVK, followed by a basic functional description.
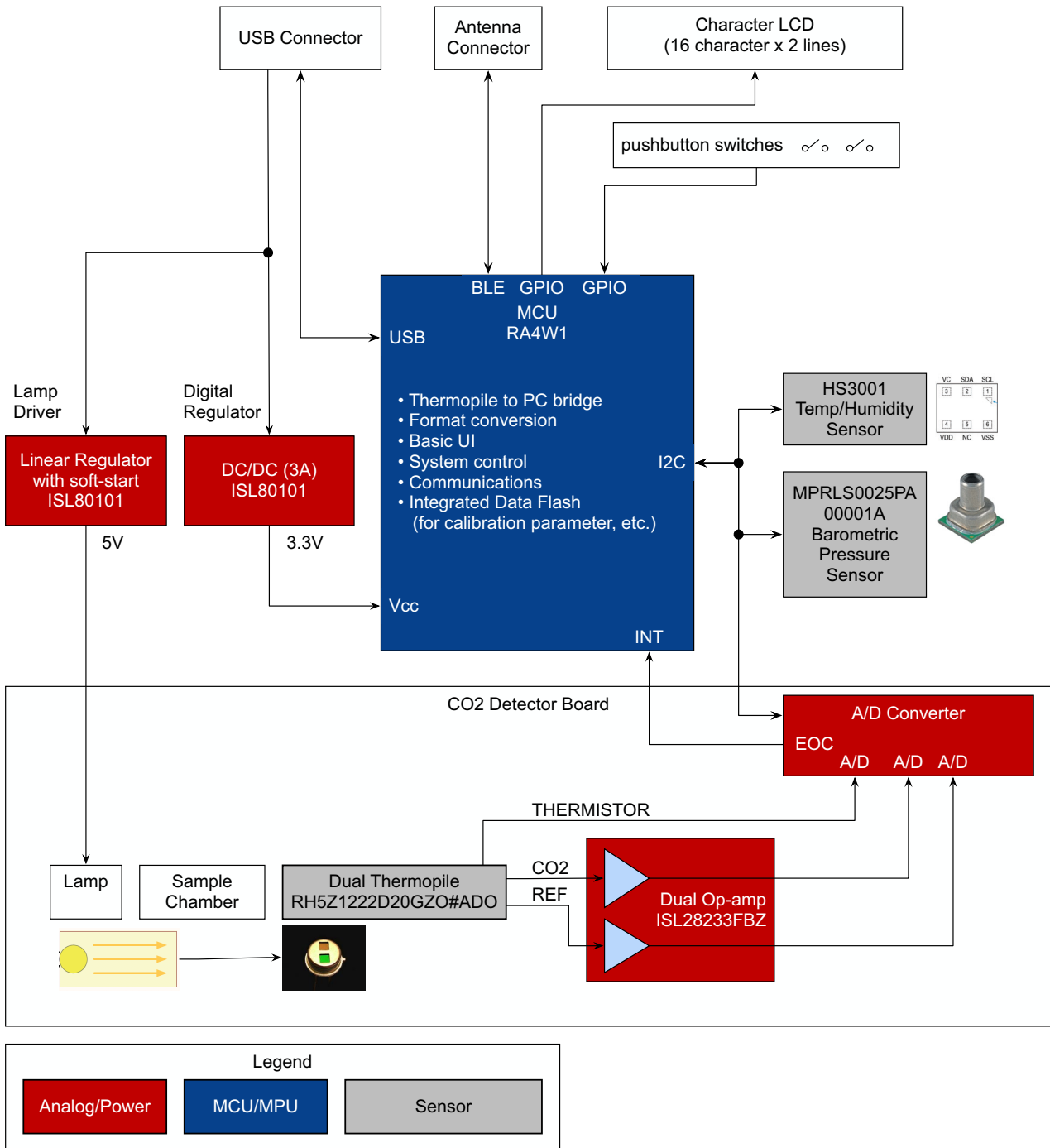
With reference to the diagram, gas enters from the openings in the sample chamber and the infrared light source – in our case a lamp driven by a lamp driver circuit (a linear regulator with soft-start feature) emits infrared light intermittently to penetrate the gas being measured. The dual-channel thermopile sensor is used to simultaneously measure the infrared light intensity of both the sensitive wavelength of CO_2, and of the reference wavelength. The reference light is not affected by CO_2.

4. Appendix B: Terminal Mode Commands

The following table provides a list of supported commands available in terminal mode.

Table 2. Terminal Commands

Command	Parameters	Description / Example
?		Show brief help text
o		Turn lamp ON (overridden by automatic ON/OFF)
f		Turn lamp OFF (overridden by automatic ON/OFF)
start ppm		Start streaming CO2 concentration reports, in parts per million (PPM), once per cycle
stop ppm		Stop streaming CO_2 concentration reports
set	\<param\> \<value\>	set a parameter to a value
set	s1_raw \<value\>	Set calibration **raw** #1 point "set s1_raw 1234.56"
set	s2_raw \<value\>	~
set	s3_raw \<value\>	~
set	s4_raw \<value\>	~
set	s1_ppm \<value\>	Set calibration **ppm** #1 point
set	s2_ppm \<value\>	~
set	s3_ppm \<value\>	~
set	s4_ppm \<value\>	~
set	serial_number \<value\>	Set serial_number 123
set	filter \<value\>	Set second stage filter (default to 8)
set	filter_adc \<value\>	Set first stage(A/D) filter (default to 12)
=config1		Report configuration settings (group 1): ▪ SerialNumber ▪ SwRev ▪ s3_raw_interp ▪ droop_factor ▪ digital_filter ▪ digital_filter_adc

Table 2. Terminal Commands (Cont.)

Command	Parameters	Description / Example
=config2		Report configuration settings (group 2): ▪ s1_ppm ▪ s2_ppm ▪ s3_ppm ▪ s4_ppm ▪ s1_raw ▪ s2_raw ▪ s3_raw ▪ s4_raw ▪ cal_slope
=vars1		Report variables (group 1): ▪ THERM_adc ▪ CO2_delta_adc ▪ REF_delta_adc ▪ raw_unfiltered ▪ raw_filtered ▪ BP_adc ▪ HS3001_RH_adc ▪ HS3001_dC_adc
=vars2		Report variables (group 2): ▪ CO2_ppm ▪ dC ▪ BP_mbar ▪ HS3001_RH_percent ▪ HS3001_dC ▪ THERM_R ▪ THERM_dC ▪ UNUSED_volts
=sn		Get serial number
=sw_rev		Get software revision
=s1_ppm		Get calibration **ppm** #1 point
=s2_ppm		~
=s3_ppm		~
=s4_ppm		~
=s1_raw		Get calibration **raw** #1 point
=s2_raw		~
=s3_raw		~
=s4_raw		~
=thermistor		Get thermistor temperature (degrees C)
=ppm		Get CO_2 concentration, in PPM.
=bp		Get barometric pressure reading (millibars)
=rh		Get relative humidity reading (%)
=amb_t		Get ambient temperature (degrees C)

Table 2. Terminal Commands (Cont.)

Command	Parameters	Description / Example
=raw_uf		Get un-filtered RAW value
=raw		Get filtered RAW value
=co2_on		Get CO$_2$ thermopile reading with lamp ON
=co2_off		Get CO$_2$ thermopile reading with lamp OFF
=ref_on		Get reference thermopile reading with lamp ON
=ref_off		Get reference thermopile reading with lamp OFF
!65		Set Defaults
!66		Load Defaults
!67		Turn lamp ON
!68		Turn lamp OFF
!69		Set calibration **raw** #1 point
!70		Set calibration **raw** #2 point
!71		(unused)
!72		(unused)
!73		filter = 2
!74		filter = 4
!75		filter = 8
!76		filter = 12
!77		filter = 20
!78		filter = 30
!79		filter = 40
!80		clear warm-up flag
!81		compute slope
!82		filter = 1
!83		Set calibration **raw** #3 point
!84		flash read
!85		flash write
!86		flash init
!87		filter_adc = 1
!88		filter_adc = 2
!89		filter_adc = 4
!90		filter_adc = 8
!91		filter_adc = 12
!92		filter_adc = 16

Table 2. Terminal Commands (Cont.)

Command	Parameters	Description / Example
!93		(unused)
!94		compute droop
!95		(unused)
!96		Set calibration **raw** #4 point
save_to_flash		Save parameters to flash memory

5.   Revision History

Revision	Date	Description
1.00	Aug 26, 2021	Initial release.

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES ("RENESAS") PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers skilled in the art designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only for development of an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising out of your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Rev.1.0 Mar 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/