CO^2eq Alarm Application using RutDevKit and Text-to-Speech Solution

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***Abstract* — Many automatization products need to have voice messaging capability. Recording the phrases using the human narrator for a particular product might be a very expensive and time-consuming process. A more elegant approach is suggested to use Epson Text-To-Speech software for phrases generation and Epson ASIC Chip S1V3G340 for the playback. Combined with a Sensirions SGP30 gas sensor and STM32L562 microcontroller in the RutDevKit it makes an ideal demonstrational application that is explained in this application note.**

Index Terms* — *Microcontroller (MCU), Personal Computer (PC), Carbon Dioxide equivalent (CO^2eq), Application-Specific Integrated Circuit (ASIC), Human Interface Device (HID), parts-per-million (ppm).

I. Introduction

CO^2 Alarm Demonstrator (RutCO2Warn Demo) hardware is assembled of four parts:

1. RutDevKit board with STM32L562.
2. RutAdaptBoard-TextToSpeech Arduino Shield with S1V3G340 ASIC.
3. mikroBUS to Arduino adapter "FRDM-K64F click SHIELD".
4. SGP30 Sensor board with mikroBUS interface.

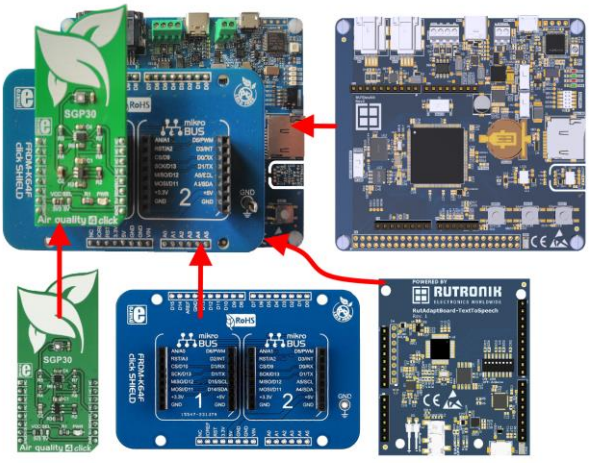

Fig. 1 RutCO2Warn assembly.

The RutDevKit is connected with RutAdaptBoard-TextToSpeech via Arduino connectors and the SGP30 sensor is connected using the mikroBUS interface on the Arduino-mikroBUS adapter board. For the sound output, the external loudspeaker is used. The assembled hardware is connected to the PC/Laptop using a USB Type-C socket located on the RutDevKit.

Sensor values are displayed using an application which may be run on MS Windows OS.

II. Firmware Example

The firmware example runs on the STM32L562ZET6Q MCU located in RutDevKit. It was build using STM32CubeIDE – a free integrated development environment, which is provided by STMicroelectronics.

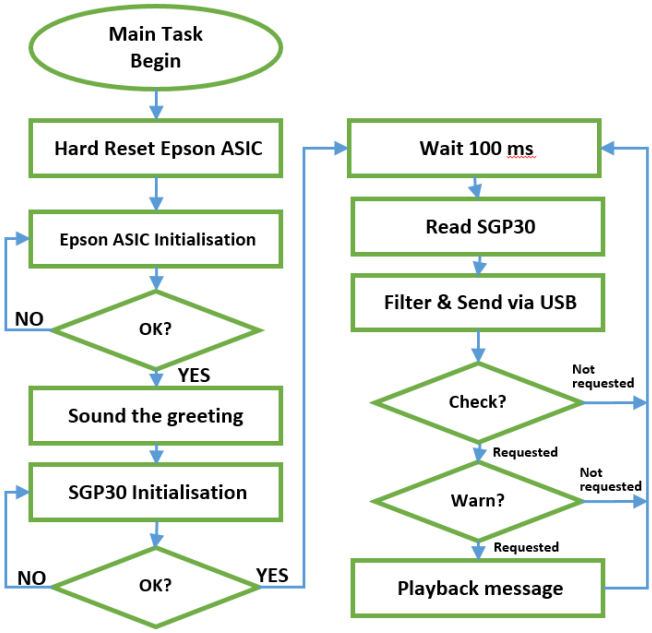

Fig. 2 Main Task workflow.

The FreeRTOS is used to manage sensor data transfer to the PC/Laptop as the "USB Generic HID Device" and warning messages playback control. The CO^2eq data gathered from the sensor is transferred 10 times per second if the USB Type-C cable is attached to the computer. Otherwise, this process stays dormant and only the warning messages playback part is

active, hence the demonstrator may be powered from any power source available and still will play warning messages if the dangerous CO^2eq levels are detected.

Default settings are used for the "Human Interface Device Class (HID)" option selected as the "USB_DEVICE" in CubeMX GUI. But the HID driver needs to be modified each time the code is generated from the CubeMX configurator to meet the "Generic HID Device" specification. The modification is straight forward: the device descriptor `HID_MOUSE_ReportDesc` fourth byte has to be changed to 0x00 "Generic" instead of 0x02 "Mouse". This descriptor is residing in usbd_hid.c file which is located in …ProjectDirectory/Middlewares/USB_Device_Library directory.

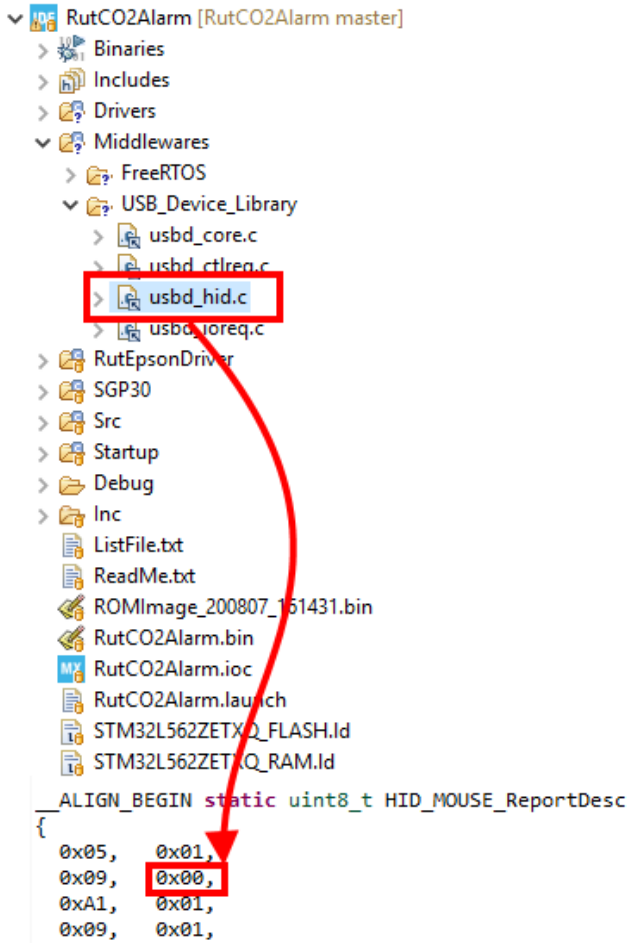

Fig. 3 HID USB Descriptor Modification.

III. Text-To-Speech Device Memory Programming

Before the RutAdaptBoard-TextToSpeech could be used it needs to be updated with an audio file using open-sourced "Rutronik Epson Tool" PC software which is provided by the Rutronik.

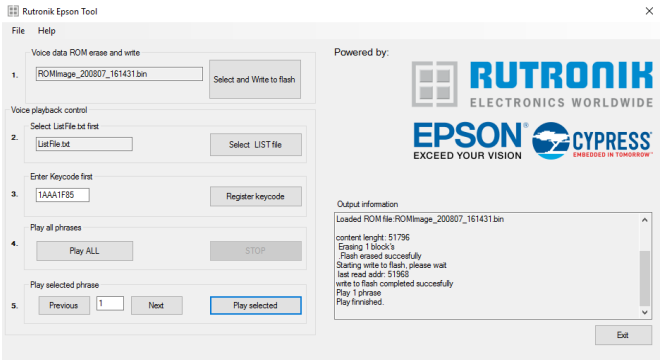

Fig. 4 PC Software "Rutronik Epson Tool".

The binary file containing all the audio phrases necessary for the application is already generated with the "esper2 tool" and provided together with firmware examples.

The binary file is programmed via a micro-USB socket located on the board. The Cypress CY7C65215 USB Serial Bridge controller is used to connect the S1V3G340 SPI interface with the PC, hence the drivers for this device must be installed in advance. The onboard NOR-Flash memory is programmed, but not the S1V3G340 ASIC itself.

IV. PC Software "RutCO2Warn Demonstrator"

The purpose of this application is to represent CO^2eq values received from the assembled demo device. The software automatically detects the HID Device with Vendor ID (VID) 1155 and Product ID (PID) 22315 and starts receiving the data. Only the first device detected with correct VID and PID will be accepted by the software. The CO^2eq numeric values are represented together with a chart that shows changing values in time. The CO^2eq values up to the 1000 ppm are taken as normal readings and are shown in green. From 1000 ppm to 2000 ppm the chart and the numeric values get yellow as an indication of decreased air quality and finally from the 2000 ppm everything turns to the red color indicating a danger.

No setup is needed for the software to work properly. The source code is also provided. It is written with MS Visual Studio in C#.

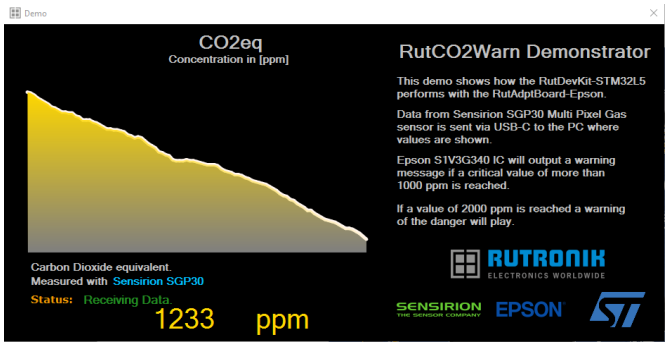

Fig. 5 PC Software "RutCO2Warn Demonstrator".

CO2 Safety levels	
Concentration	**Indications**
250-400ppm	Normal background concentration in outdoor ambient air
400-1000ppm	Concentrations typical of occupied indoor spaces with good air exchange
1000-2000ppm	Complaints of drowsiness and poor air.
2000-5000 ppm	Headaches, sleepiness, and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate, and slight nausea may also be present.
5000 ppm	Workplace exposure limit (as 8-hour TWA) in most jurisdictions.
>40000 ppm	Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma, even death.

Table. 1 CO^2 safety levels.

V. CO^2 Measurement with SGP30

The Sensirion's SGP30 is a Multi-Pixel gas sensor capable to detect a wide range of Volatile Organic Compounds (VOC) and H^2 molecules. Using Sensirions library code the sensor returns a Total Volatile Compounds concentration in parts per billion (ppb) and a Carbon Dioxide equivalent readings in parts per million (ppm). Since CO^2eq readings are based on H^2 measurements the SGP30 sensor might be used only in those applications were real CO^2 is not needed. The application uses a 10 Hz sampling rate instead of the recommended 1 Hz for the whole system's performance demonstration even the measurements are probably less accurate.

CO2eq signal	
Accuracy at 25°C, 50% RH	10%
Sampling rate (Hz)	1
Values	
Range (ppm)	Resolution (ppm)
400 – 1479	1
1479 – 5144	3
5144 – 17597	9
17597 – 60000	31

Table. 2 SGP30 CO^2eq measurement properties.

VI. The Quality of Sound

The Epson S1V3G340 ASIC is used in the RutAdaptBoard-TextToSpeech shield. The S1V3G340 is capable of Epson Original Voice format (EOV) playback with a sampling frequency of 16 kHz and selectable bitrates 16/24/32/40 kbps. EOV has better sound quality and compression in comparison with the ADCPM format.

SPI-Flash size	EPSON(16kHz)	ADPCM(16kHz)	ADPCM(8kHz)
1MB	8min+	2min+	4min+
2MB	16min+	4min+	8min+
4MB	33mini+	8min+	16min+
8MB	1hour 6min+	16min+	33min+
16MB	2hour 13min+	33min+	1hour 6min+

Table. 3 EPSON EOV and ADPCM comparison.

The output sound signal is filtered using a passive low-pass filter with a cut-off frequency of 155Hz and amplified 10 times with STMicroelectronics D-Class amplifier TS4962. The TS4962 can provide up to 2.8W of output power while loaded with 4 Ohms.

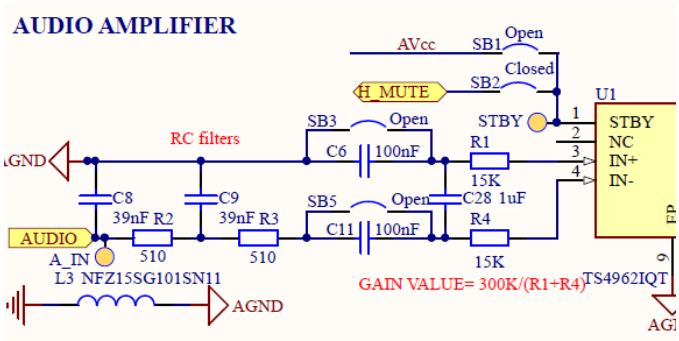

Fig. 6 The input filter of the audio amplifier.

For the best results, the 8 Ohms low frequency enclosed loudspeaker should be used.

VII. Summary

RutCO2Warn demo kits assembly introduces with the Sensirion Gas Sensor SGP30, the Epson Text-to-Speech ASIC S1V3G340 and STM32L562 USB Type-C HID feature. Any additional installations are needed, Generic HID Device is accepted on every PC by default though monitoring software is available for MS Windows 10 only.

References

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