EU070 Smoke Detector

Hardware Guide

Contents

1. Introduction

1.1 Functional Principle of a Photoelectric Smoke Detector

A photoelectric smoke detector consists of an IR photo diode (sender) and a photo transistor (receiver/detector) arranged inside a so-called smoke chamber. Inside this chamber air is flowing, and this air may contain smoke from a nearby (upcoming) fire etc.

The construction of the smoke chamber avoids (day)light to get into the chamber in order to not disturb the measurements. As both transmitter and detector are positioned at an angle of ~120 … 150 degrees, the light is not directed at the sensor in clean or "low polluted" air. But if the air in the chamber contains particles (e.g. due to smoke or dust), the light is scattered and some of it reaches the detector, which derives in triggering an audible alarm (piezo-horn, buzzer).

1.2 Residential vs. Commercial Smoke Detector

Smoke detectors are called **residential** type, when (as the name already implies) they are dedicated for installation in any residential home (house, flat). Mostly these detectors are streamlined on simple but reliable function as well as lowest cost, as annual installation volumes of such detectors only in Europe is up to ~100 million pcs. and are typically battery-operated, without any communication (neither wired nor wireless).

In comparison, **commercial smoke detectors** typically are more comprehensive when it comes to functionality and scope of operation. The requirements for commercial installations are extended with wired (or wireless) communication, DC supply voltage (12 … 48V) or sometimes even AC Mains, battery backup, additional features like temperature measurement or gas detection (ranging from simple CO detection up to complex VOC gas sensing).

2.   Proof of Concept (PoC) Overview

2.1   PoC Overview

This document describes the functionality of a (residential) smoke detector based on the Photoelectric Smoke Detector Analog Front-End (AFE) IC RAA239101. A complete smoke detection can be performed using only just the IC together with a microcontroller, an infrared photo diode (sender), a photo transistor (receiver) and few external components. The sender diode is placed in the way that the light beam is scattered to the receiver only when smoke or dust is present.

The IC provides an SPI bus for microcontroller interface and a general-purpose IO. The operating voltage can be set to 3-5V or 9V battery (an integrated Lineare Regulator - LDO - is available to provide power to microcontroller) which may be monitored through an integrated battery test feature.

2.2   PoC Features and Components

EU070 Smoke Detector Proof-of-Concept (PoC) Board provides the following features:

- 'OR' type power supply configuration (DC 3 … 5V, DC 9V, USB, Emulator, optional AC/DC)
- compact, low power and high function microcontroller
- AC/DC switching buck regulator (optional)
- Analog Front-End IC which provides the smoke detection drivers & OpAmps
- presence LED (green color)
- alarm LED (red color) and an audible piezo horn
- test (user) button
- mechanical (3D printed) smoke chamber

2.3   System benefits of integrated Renesas components

- Low-Power Smoke Detector Analog Frontend RAA239101 includes all necessary peripherals like 2xLED Driver, 2xPhotodetector Input with programmable-gain Transimpedance Amplifier, ADC+DAC, Horn driver, Linear regulator for MCU supply, operational from 9V or 3-5V battery, ... which dramatically reduces component count, board space and total system cost vs. a discrete design.
- Highly integrated AFE allows the use of 2 different IR Wavelength diodes/photodetectors, which dramatically enhances the accuracy of the smoke detector and enables construction of an UL217 compliant photoelectric smoke detector (or UL268 compliant smoke detector systems, respectively).
- Utilizing Low Pincount and Low Cost RL78/G12 MCU with DataFlash, enabling non-volatile data storage (e.g. alarm counter, operating hours meter).
- Very few external components needed => Lowest BOM count & small solution size.
- Optional AC mains power supply with small-sized and Low IQ AC/DC Buck Regulator

2.4   Features of RAA239101 Analog Front-End IC

The highly integrated RAA239101 Low-Power Analog Frontend IC includes all necessary peripherals & features required for a photoelectric smoke detector system, mainly focused on residential smoke detector designs. Therefore, it is very simple and straight-forward to realize a complete photoelectric smoke detector electronics circuitry with only two key components: MCU + AFE

- Two LED drivers with 8-Bit DAC adjustable current (45mA … 300mA)
- Enables UL217 compliant smoke detector designs
- Photodetector TIA amplifiers + PGA (programmable Gain up to 160MV/A)
- 10-Bit ADC for Photodetector Input
- Driver for Piezoelectric Horn
- General Purpose I/O - Single wire TX/RX interface
- Battery load test / battery monitor
- LDO for microcontroller supply
- SPI Interface
- Compatible with 9V and 3-5V batteries
- Ultra-Low 3~4μA average IC supply current, extends battery lifetime

2.5   Smoke Detector Use Cases

With all integrated features and flexible parametrization capabilities (LED-Current selection, PGA Gain setting, integrated battery test settings) this AFE enables a very flexible implementation for solving different system approaches.

We defined the mainstream system solutions, exemplified as use cases 1 … 5, whereas we clearly highlight use case 1 as the most relevant application design use case.

- ✓ Use case 1 – Operation from AC mains power + 9V battery backup
- ✓ Use case 2 – Operation from a 3.6V Lithium Battery (3 … 5V)
- ✓ Use case 3 – Operation from a 9V Battery (PP3)
- ✓ Use case 4 – Operation from AC mains power + 3.6V battery backup
- ✓ Use case 5 – AC Mains powered, 9V battery backup, additional CO sensor

3.   Board Components

3.1   Power Supply Options

The board offers a wide range of power supply options like:

- 3V DC Battery connector
- 5V DC microUSB connector
- 9V DC Battery connector
- 3.3V or 5VDC Debugger power supply
- 220V AC connector *)

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*) 220VAC SUPPLY – ATTENTION !

The EU070 Smoke Detector PoC board offers the possibility to be supplied from 220VAC source BUT WE CANNOT GUARANTEE the safety of the overall circuitry & PoC Board as there is no Isolation. The user is totally responsible for the AC supply and for switch slider position.

3.1.1   Power Supply Operation

- **Operating voltage range:**   2.7V to 5.5VDC or 9VDC

- **Power supply:**   3 … 5V DC battery

                                     9V battery

                                     5V microUSB connector

- **Measurement range:**   -

- **Precision:**   -

- **Power consumption:**   While operating: ≤ 120.12mW

                                     While in sleep: ≤ 26.4µW

3.1.2   Power Supply OR-ing

EU070 PoC Board is designed to support lots of different use cases, meaning also lots of different power supply options. Some of them are targeted for easy bringing-into-service (e.g. power supply via Debugger or USB connector on the „Break-Off-Board"), and some of them for real-life use cases (3 … 5V Battery, 9V Battery, AC mains supply).

Please be aware that all of the power sources are OR-ed via Schottky Diodes and remove them accordingly if necessary for your system application setup.
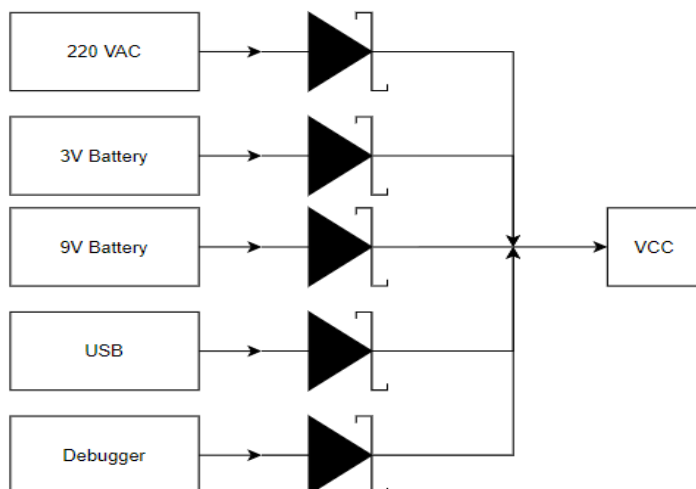
3.1.3   Supply via DC Battery (either 3 … 5V or 9V Battery)
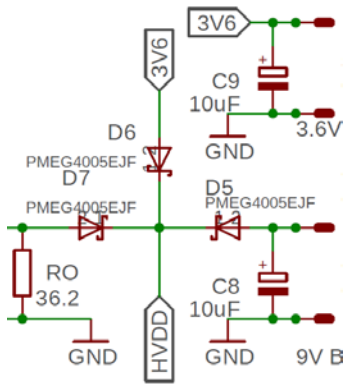
3.1.4   Supply via microUSB Connector
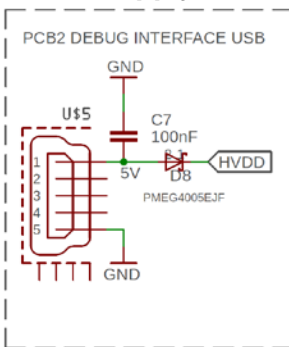
3.1.5   Supply via E1/E2 Debugger Interface
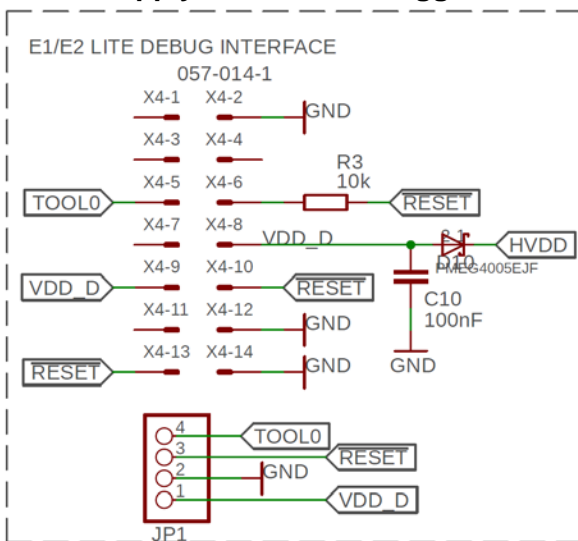
3.1.6 AC mains supply - RAA223012 (optional)

EU070 PoC Board is prepared for offering AC Mains supply (Wide-Range AC Input 90 … 240 VAC) based on AC/DC Buck Regulator RAA223012 (which is a lower power variant of RAA223011) offering ultra-low standby power. The integrated MOSFET can deliver up to 2W output power and supports output voltages from 3.3V to 20V. The RAA223012 combines constant off-time control of heavy load Pulse Frequency Modulation for light-load operation. The circuit components are designed for a 9.6V output voltage and maxim 60 mA current.

IMPORTANT:

The EU070 Smoke Detector PoC board offers the possibility to be supplied from 220VAC source BUT WE CANNOT GUARANTEE the safety of the overall circuitry & PoC Board as there is no Isolation. The user is totally responsible for the AC supply and for switch slider position.
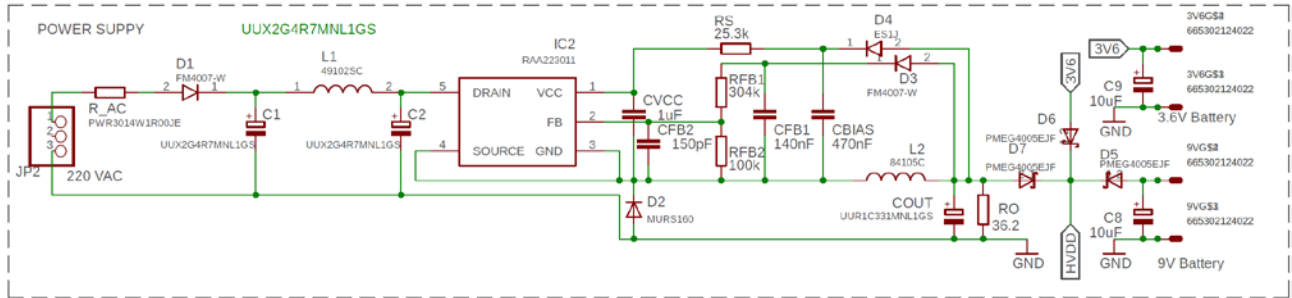

3.2 Power Supply Selection Switch

IMPORTANT:

The switch slider must be selected manually by the user BEFORE connecting the board to the power supply source as described below:

3.2.1 Switch Position 1

for power supply from 3V/5V battery and 5V micro USB connector and E1/E2 debugger.
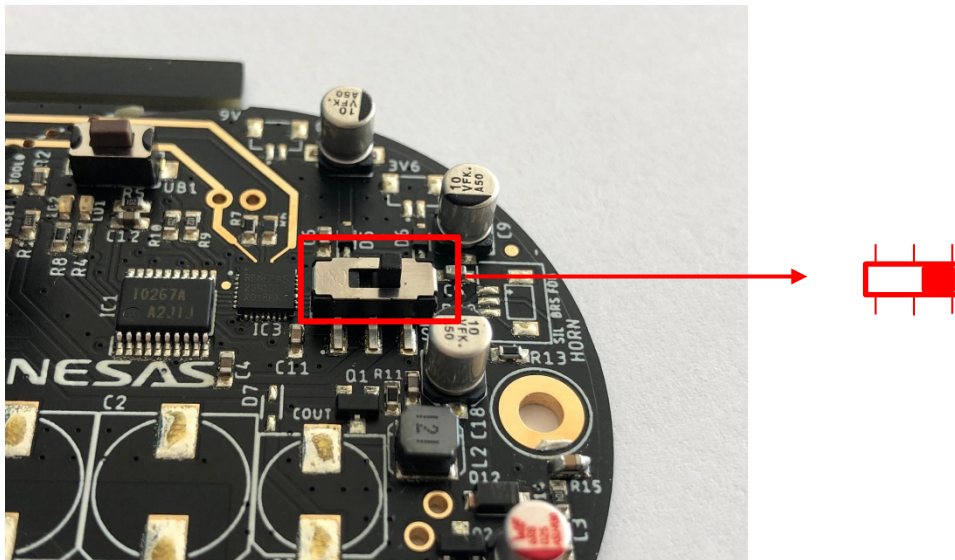
3.2.2 Switch Position 2

for power supply from 9V battery and 220V AC connector.
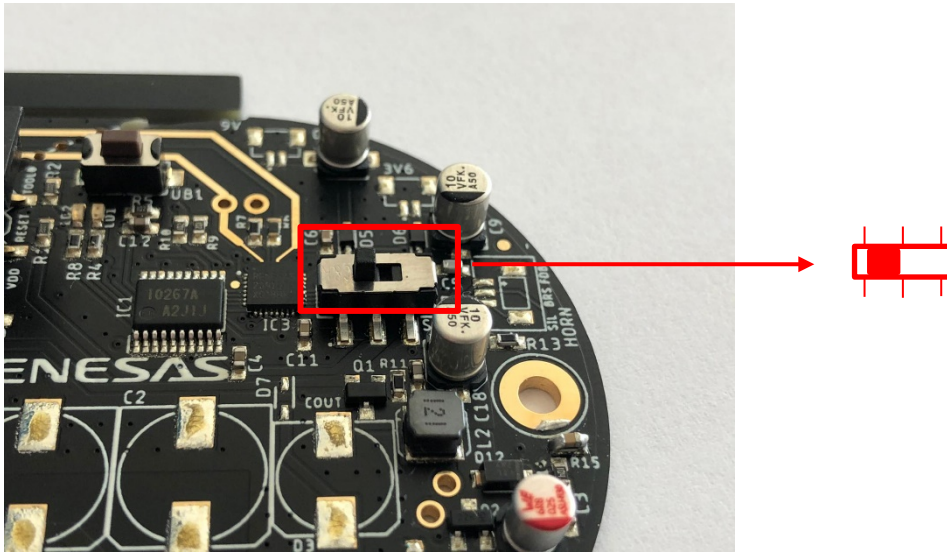
3.2.3 Power Supply Selection Switch - Schematic
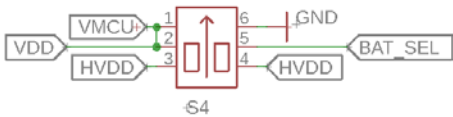
3.3 Microcontroller RL78/G12

The microcontroller used for this application is RL78/G12, from RL78 family, a 16-Bit Single-Chip, which has the following features: 8-24 MHz on-chip oscillator, 15 kHz low-speed on-chip oscillator, 4kB code flash Memory, 2KB of data flash memory, 512 Bytes RAM, 12-bit interval timer, 10-bit A/D converter.

In smoke detection application, the MCU will work mostly in low power mode, with 3 states available: HALT mode, SNOOZE mode and SLEEP mode
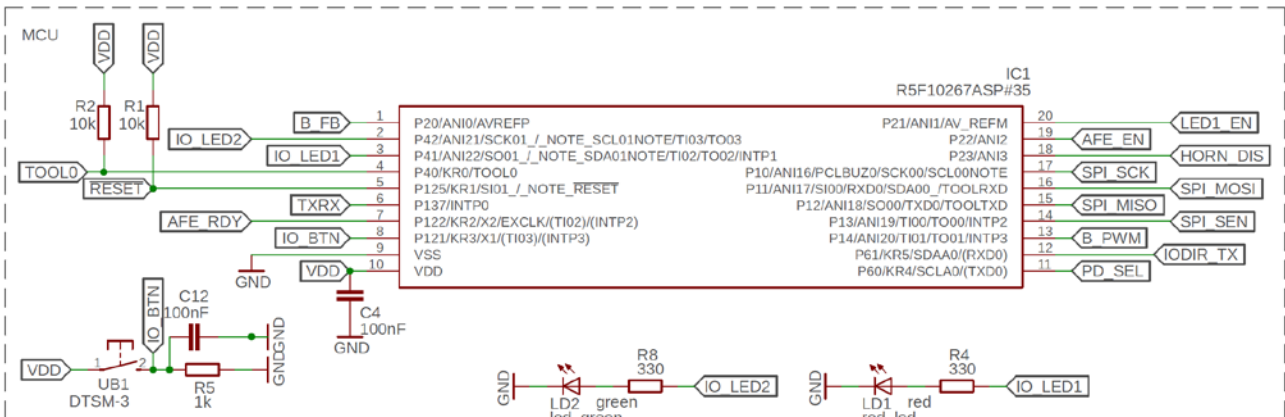
3.3.1 Microcontroller Pinout

Pin	Port	Function / Description
1	P20	ANI0 = Analog Input 0 / Voltage-Feedback from Boost Circuit Output
2	P42	ANI21 / green User LED
3	P41	ANI22 / red User LED
4	P40	TOOL0 / for debugging
5	P125	nRESET
6	P137	INTP0 / TXRX Line of AFE IC
7	P122	P62
8	P121	P31
9	VSS	VSS = GND
10	VDD	VDD = VDD
11	P60	TXD0 / PD_SEL = Photodetector Select Pin
12	P61	RXD0 / IODIR_TX = IO Direction of AFE IC TX/RX
13	P14	B_PWM / PWM Output for Booster Circuit
14	P13	SPI_SEN / SPI Enable
15	P12	SPI_MISO / SPI Data Output to AFE IC
16	P11	SPI_MOSI / SPI Data Input to AFE IC
17	P10	SPI_SCK / SPI Clock
18	P23	HORN_DIS / Horn Disable to AFE IC
19	P22	AFE_EN / Enable AFE IC
20	P21	LED1_EN / Enable IR LED1

3.4 LEDs and Buttons

Description of User LEDs and Buttons

- o IO_LED1 – Red alarm LED, that is enabled together with piezo horn.
- o IO_LED2 – Green presence LED, that blinks every 1 second.
- o Test button – it is used for 2 possible states:
  1. **Test Horn** - turns ON the audible piezo horn and "Alarm LED" (IO_LED1) for 3 seconds.
  2. **Smoke Detected** – After the smoke was detected, the audible piezo horn and "Alarm LED" (IO_LED1) turns ON and can be turned OFF using the "Test button".

3.5 Analog Front-End IC RAA239101

3.5.1 RAA239101 connections
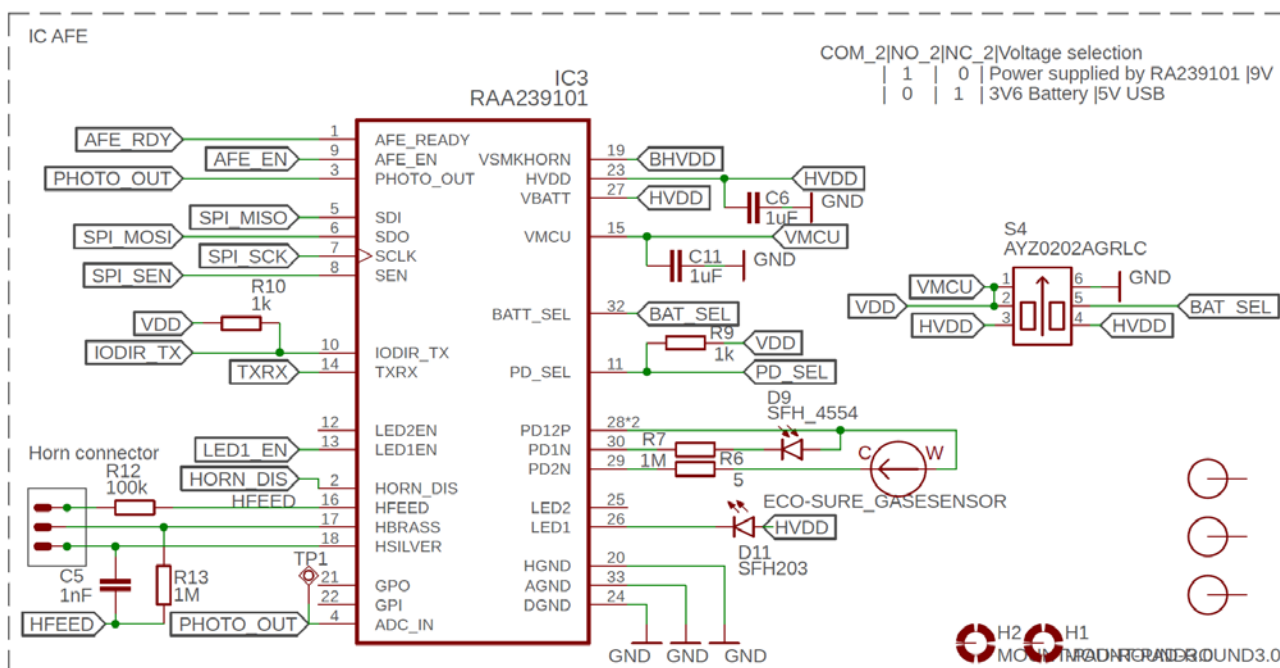
3.5.2 RAA239101 Peripherals & Functions

The AFE IC provides the following features:

✓ **LDO for microcontroller supply**
The AFE IC can be powered from:

- 3 - 5V configuration– the VMCU, VBATT, BAT_SEL and HVDD must be tied to power supply and LDO is disabled.
- 9V – the HVDD pin must be tied to power supply and the BAT_SEL to ground. The LDO is automatically enabled and the MCU is supplied through VMCU pin with 3V.

✓ **Battery load test/ battery monitor**
The VBATT pin is used together with BATT_TEST_LOAD register to read the current provided by the power supply.

✓ **SPI Interface**
The AFE IC has 31 volatile registers that can be accessed through a 4MHz SPI protocol.

✓ **Two LED drivers with 8-Bit DAC adjustable current (45mA – 300mA)**
An internal 8-bit DAC provides the current to one of the two infrared LEDs, which emits a light beam at every 10 seconds. In this configuration it is used a single transceiver LED.

✓ **Photodetector amplifier, TIA, PGA and 10-Bit ADC for Photodetector Input**
The photodiodes are set on a small voltage pedestal on the PD12P pin and their input currents are converted in voltage by the Analog Signal Path. The output voltage of TIA is amplified by the PGA. The gains of TIA and PGA are adjustable and an offset for both photodiodes can be set.

PHOTO_OUT represents the PGA output and must be externally connected with a 10-bit ADC input (ADC_IN pin).

✓ **General Purpose I/O – Single wire TX/RX Interface**

The GPIO circuit is bi-directional and it can transmit or receive signals from other devices connected to the GPIO wire. In the present configuration these pinouts are not used

3.6 Boost Circuit (for Horn Supply)

3.6.1 Scope of Boost Circuit

As a special Usecase we implemented a dedicated Voltage Boost-Circuit for e.g. Horn Operation at higher voltages which may be possibly required depending on Horn Type.

The AFE IC provides a horn driver which has an independent power supply, one of all other supplies on the chip (VSMKHORN pin). The HSILVER and HBRASS pins have built-in diodes to clamp reactive kickback energy from the piezoelectric horn.

3.6.2 Implementation of Boost Circuit

If used horn nominal voltage is higher than the one provided by the battery, the on-board boost converter can be used to supply the horn driver. The boost converter can be used only for power supply between 3 and 5V. For power 9V power supply the boost converter is bypassed. The integrated software is detecting the board power supply and enable/disable the boost converter accordingly.

The components were designed for the following specification:

- 2.7V minim input voltage,
- 5.5V maxim input voltage,
- 7V output voltage,
- 60mA maxim current output,
- +/- 100mV output voltage ripple

The feedback loop for convertor control was implemented using a PWM signal and A/D channel converter from the microcontroller. The feedback loop resistive voltage divider is designed to fit with the ADC input limitations.

For a low power consumption, the boost converter is supplied only when the piezo horn is activated.

The control loop is executed every 500us.

3.6.3 Boost-Circuit on EU070 PoC

See below Boost Circuit as it is currently implemented on EU070 PoC Hardware Rev. B0:
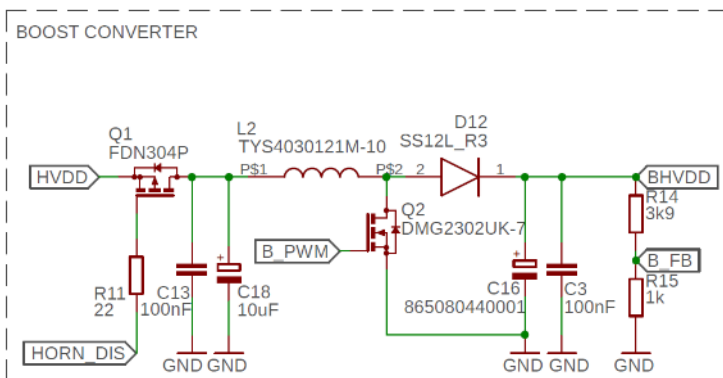
3.6.4   Recommended Boost Circuit on Customer Hardware

Please find our recommendation for implementing Boost-Circuit on customer hardware.
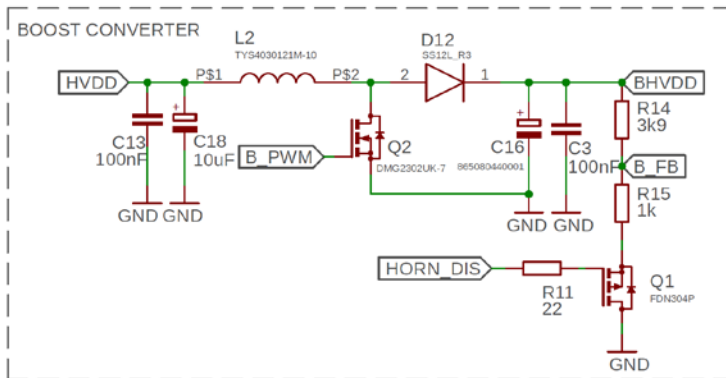
3.7   Photoelectric Detection Components (IR LED, IR Photodetector)

The infrared photo diode and the photo transistor are mounted at an angle of 120 degree, and the light beam does not hit the receiver directly, just when the smoke presence scatters it.

3.7.1   Transmitter (IR LED)

SFH4550 is the infrared emitter model, controlled by the AFE DAC driver. This provides 20degree beam angle, 850nm wavelength and 12ns rise and fall time.

3.7.2   Receiver (IR Photodetector)

This sensor module works by the principle of reflection of infrared light and needs a direct beam to receive it. The SFH203 model has a 20degree half intensity angle, 850nm peak wavelength and 5ns rise and fall time.
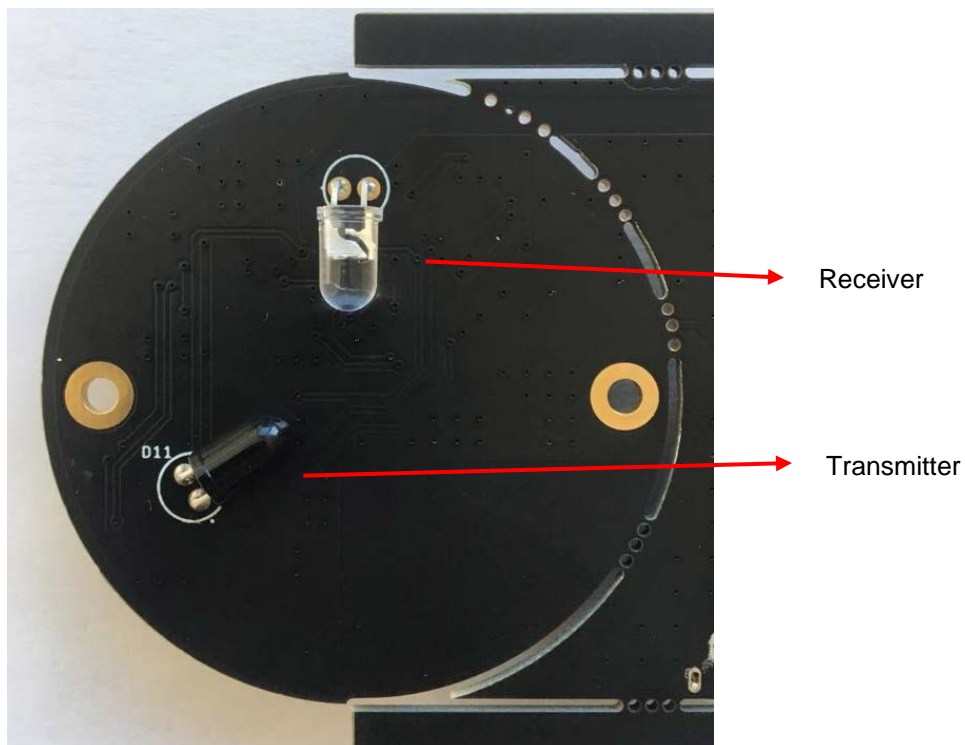
3.8 RL78/G12 Programming Adapter

EU070 PoC Board can either be programmed/debugged via standard Renesas E1/E2 emulator 14-pin connector (as long as the "break-off" board is still connected with the EU070 PoC Main-Board.

Please find below the schematic of the programming/debugger adapter which is required to connect the EU070 board to a standard Renesas E1/E2 emulator, when using only 4-pin connector for programming/debugging.
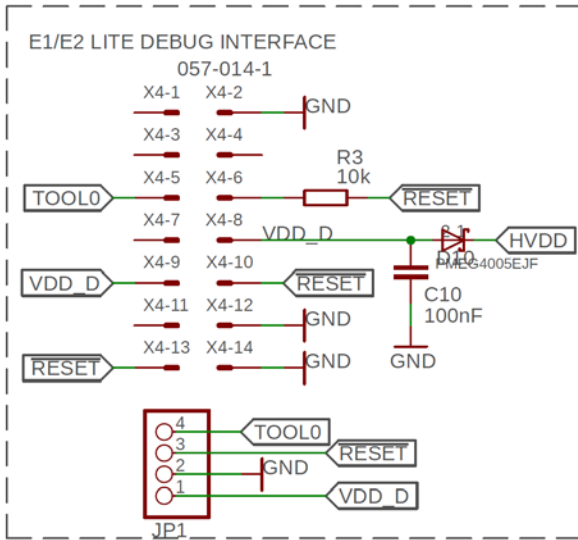
Refer to [4] for more information.

4. BOM – Bill of Materials

4.1 BOM - Renesas Components

Device Category	P/N	Key Features
MCU	RL78/G12 *R5F10267ASP*	Compact, low power general-purpose 16-Bit microcontroller. With an on-chip oscillator, A/D converter, comparator and industry´s lowest level of consumption current it is an ideal choice for small and battery-powered low-cost electronic devices.
Analog	RAA239101 *RAA239101GNP*	Low-power Analog Front-End IC for a UL217 compliant photoelectric smoke detector. Combined with a microcontroller, photoelectric emitter/detector(s), horn, and minimal external components, it forms a complete smoke detector.
Power	RAA223012 *RAA2230124GP3*	700V AC/DC Buck Regulator with integrated MOSFET. Ultra Low Standby Power, Low Quiescent Current with Output Voltage as low as 3.3V; up to 2 W in tiny SOT23-5 package. Low EMI (conducted & radiated), no audible noise.

4.2 BOM - all Components (DC Supply only)

Part	Value	Package	Manufacturer number	Description
C10	100nF	C0603	CC0603KRX7R8BB104	Capacitor
C11	1uF	C0603	CC0603KRX7R8BB105	Capacitor
C12	100nF	C0603	CC0603KRX7R8BB104	Capacitor
C13	100nF	C0603	CC0603KRX7R8BB104	Capacitor
C16	6.8uF	153CLV-0405	865080440001	Polarized Capacitor
C18	47uF	153CLV-0405	EEE-FN1V470V	Polarized Capacitor
C3	100nF	C0603	CC0603KRX7R8BB104	Capacitor
C4	100nF	C0603	CC0603KRX7R8BB104	Capacitor
C5	1nF	C0603	12062C102KAT2A	Capacitor
C6	1uF	C0603	CC0603KRX7R8BB105	Capacitor
C7	100nF	C0603	603-CC603KRX7R8BB104	Capacitor
C8	10uF	153CLV-0405	UUR0J471MNL1GS	Polarized Capacitor
C9	10uF	153CLV-0405	UUR0J471MNL1GS	Polarized Capacitor
Connector 3V6		-	665302124022	Connector / Pad
Connector 9V		-	665302124022	Connector / Pad
Connector Debugger		-	75869-202LF	Connector / Pad
Connector HORN		-	665303124022	Connector / Pad
D10		SOD2512X80N	PMEG4005EJF	Schottky Diode
D11		5mm_LED	SFH213FA	IR Photodiode
D12		SODFL3618X143N	SS12L_R3	Schottky Diode
D5		SOD2512X80N	PMEG4005EJF	Schottky Diode
D6		SOD2512X80N	PMEG4005EJF	Schottky Diode
D8		SOD2512X80N	PMEG4005EJF	Schottky Diode
D9		5mm_LED	SFH_4550	IR LED
IC1		SSOP20	R5F1027AANA	RL78/G12
IC3		QFN40	RAA239101	AFE IC
JP1		1X04SMD	10129380-904002ALF	Pin Header
L1	1mH	49102SC	49102SC	Fixed Inductors
L2	120uH	TYS4030121M-10	TYS4030121M-10	Fixed Inductors

L3	1mH	L2AC	84105C	Fixed Inductors
LD1		CHIP-LED0603	150060GS75000	Green LED
LD2		CHIP-LED0603	150060RS75000	Red LED
mUSB Connector		47589-0001	47589-0001	microUSB Connector
Q1		SOT23	FDN304P	P-Channel MOSFET
Q2		SOT23	DMG2302UK-7	N-Channel MOSFET
R1	10k	R0603	RC0603JR-0710KL	Chip Resistor
R10	1k	R0603	ERJ-3EKF1001V	Chip Resistor
R11	22	R0603	ERJ-UP3F22R0V	Chip Resistor
R12	220k	R0603	ERJ-3EKF2202V	Chip Resistor
R13	1M	R0603	667-ERJ-3EKF1004V	Chip Resistor
R14	100k	R0603	RC0603JR-07100KL	Chip Resistor
R15	27k	R0603	ERJ-3RED27R0V	Chip Resistor
R2	10k	R0603	RC0603JR-0710KL	Chip Resistor
R3	10k	R0603	RC0603JR-0710KL	Chip Resistor
R4	1k	R0603	ERJ-3EKF1001V	Chip Resistor
R5	1k	R0603	ERJ-3EKF1001V	Chip Resistor
R6	5	R0603	CRCW06034R99FKEA	Chip Resistor
R7	1M	R0603	ERJ-3EKF1004V	Chip Resistor
R8	1k	R0603	ERJ-3EKF1001V	Chip Resistor
R9	1k	R0603	ERJ-3EKF1001V	Chip Resistor
S4		JS202011SCQN	JS202011SCQN	Slide switch
UB1		DTSM-3	DTSM-3	User button

4.3 BOM – additional Components (for optional AC Supply)

Part	Value	Package	Manufacture number	Description
C1	4.7uF	153CLV-1010	UUX2G4R7MNL1GS	Capacitor
C2	4.7uF	153CLV-1010	UUX2G4R7MNL1GS	Polarized Capacitor
CBIAS	470nF	C0603	CC0603KRX7R8BB474	Capacitor
CFB1	140nF	C0603	CGA3E2X7R1E154K080AA	Capacitor
CFB2	150pF	C0603	CGA3E2C0G1H151J	Capacitor
COUT	330uF	153CLV-0810	UUR1C331MNL1GS	Polarized Capacitor
CVCC	1uF	C0805	885012206071	Capacitor
D1		DIOM5025X231N	FM4007-W	Rectifier
D2		CASE_403A-03	MURS160	Rectifier
D3		DIOM5025X231N	FM4007-W	Rectifier
D4		DIOM5436X245N	ES1J	Rectifier
D7		SOD2512X80N	PMEG4005EJF	Schottky Diode
IC2		SOT23-5L	RAA223011	Buck Regulator
JP2		-	10129380-903002ALF	Pin Header
R_AC	1Ω	3.5 X 4.64 mm	PWR3014W1R00JE	Chip Resistor
RFB1	304k	R0603	RT0603DRE07305KL	Chip Resistor
RFB2	100k	R0603	RC0603JR-07100KL	Chip Resistor
RO	36,2	R0603	RN731JTTD3612D50	Chip Resistor
RS	25.3k	R0603	RT0603DRE0725K2L	Chip Resistor

5. PoC Board Layout

5.1   Board Layout structure

Initial idea was: having two separable parts – left side for programming/debugging, right side as the "main" Eu070 PoC Board.
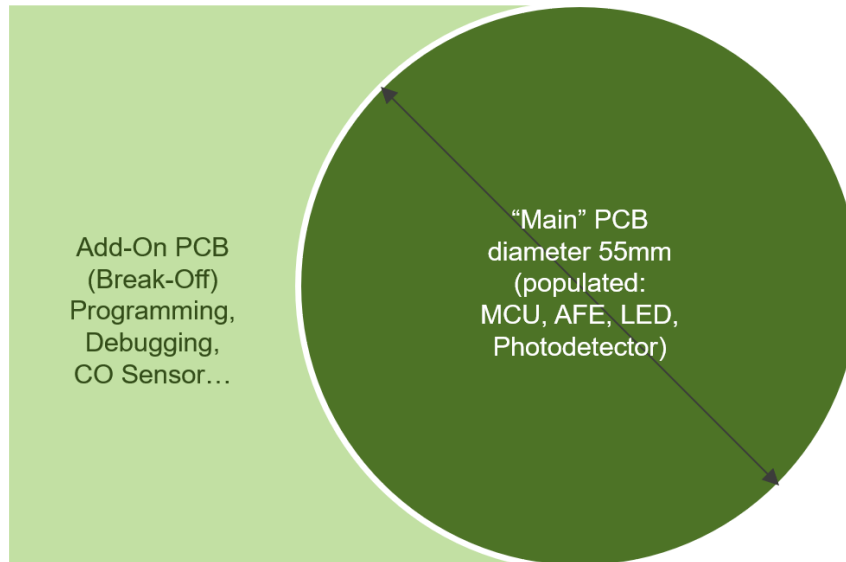
5.2   Layout Features / Overview

PCB Rev. B0
- Simple, Low-Cost 2-Layer PCB
- Single-sided assembly (except IR-LED and PD)
- Including smoke-chamber assembled
- Optional: CO-Sensor
- Optional: AC/DC Supply (SMD parts only)
- Standard Debugging & Programming Connector
- USB connector only for 5V supply (no debugging)

5.3   TOP- and BOTTOM Layer View
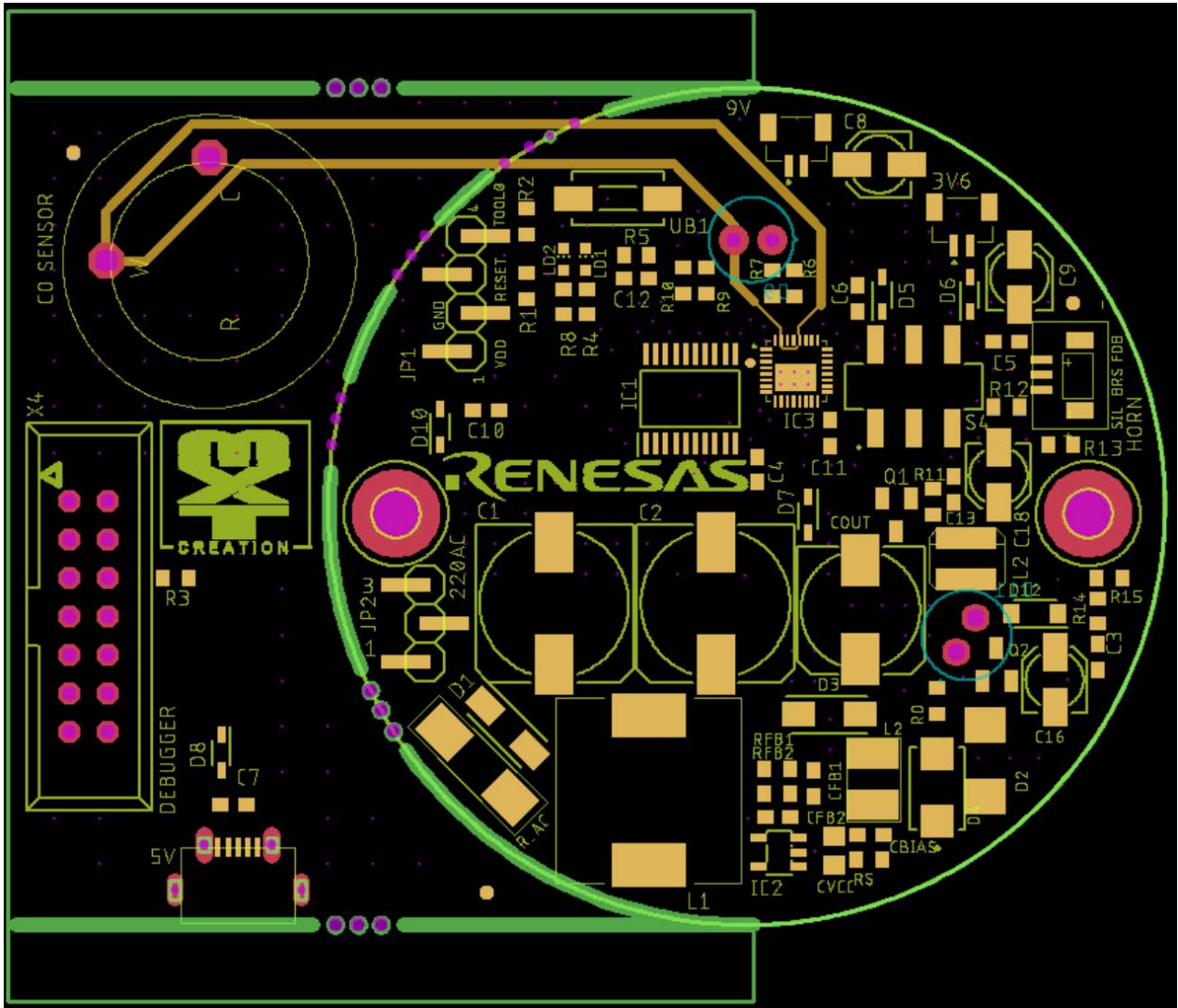
5.4 Top Layer Assembly
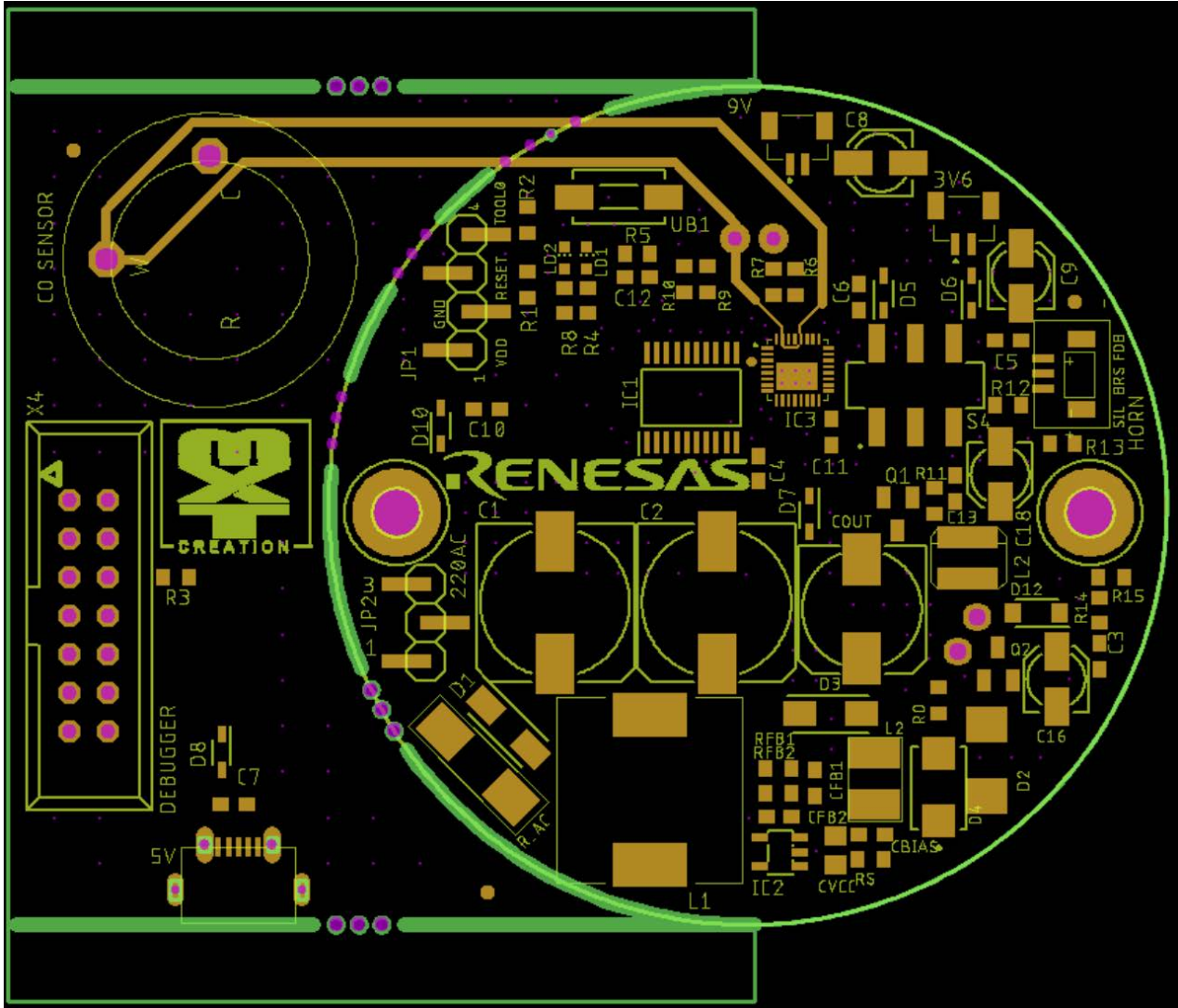
Top-Layer assembly:
All parts are assembled on Top-Layer,
Except IR LED and IR Photodetector
(THT mounted)

5.5   Bottom Layer Assembly
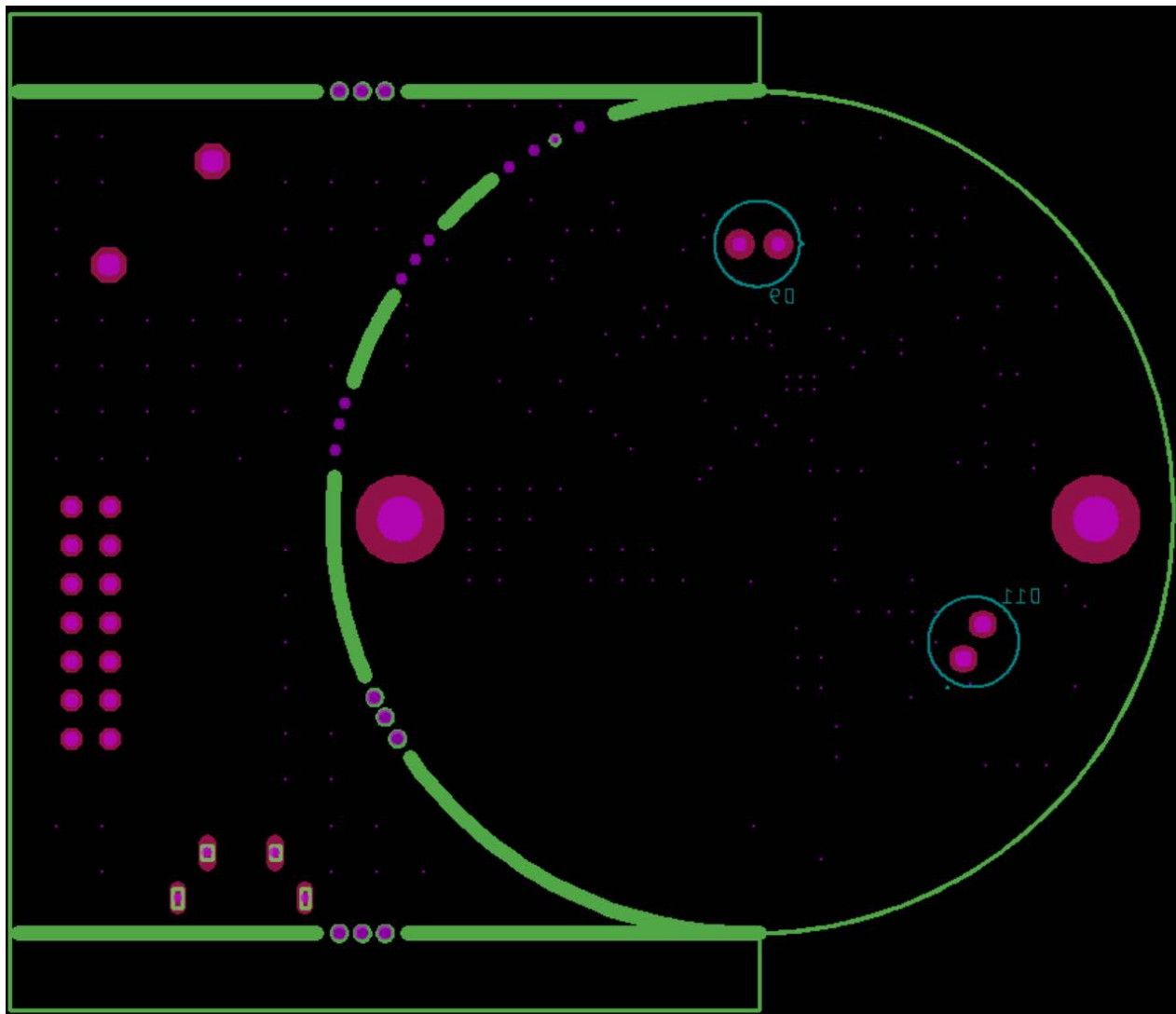
Bottom-Layer assembly:
Only IR-LED and Photodetector are assembled (both in 5mm THT package)
This PCB bottom side is also the area where the smoke chamber will be mounted (2 screw holes)

6.   PoC Board Pictures

6.1   Smoke Chamber

Diameter: 55mm (exactly fitting onto EU070 PoC Board)

6.2   DC Battery supply only

AC/DC Supply not assembled / Smoke Chamber assembled (incl. IR-LED and Photodetector)
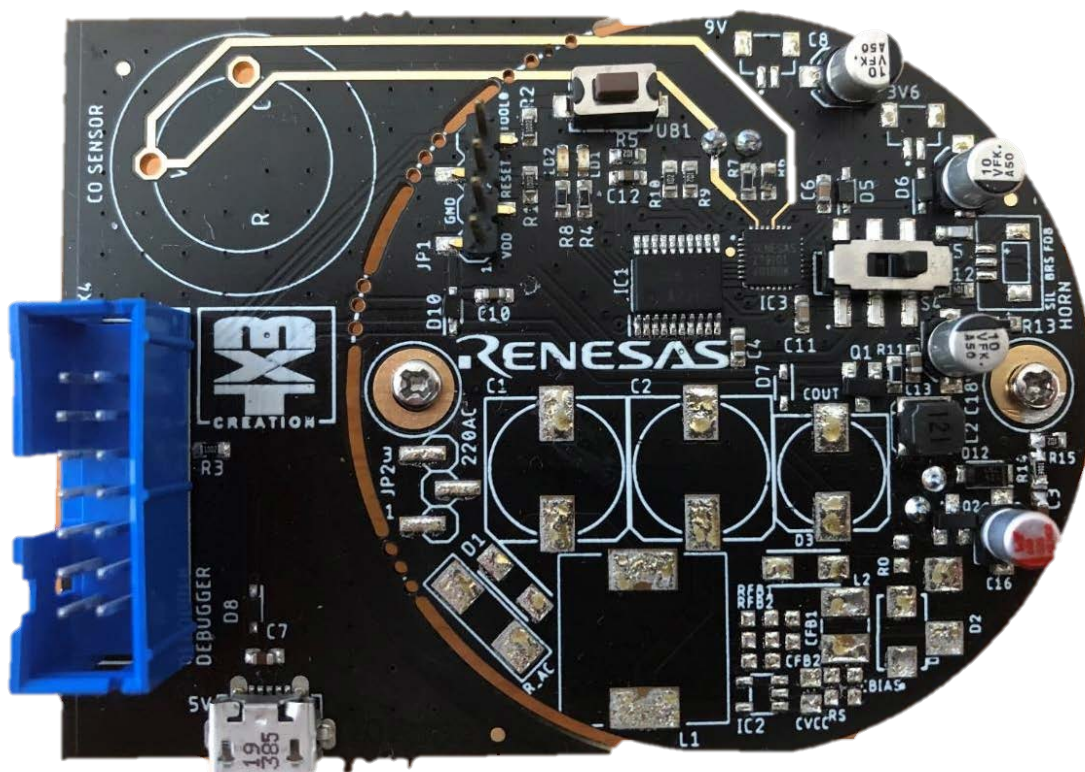
6.3   With optional AC/DC Supply

AC/DC Supply assembled / Smoke Chamber NOT assembled (incl. IR-LED and Photodetector)
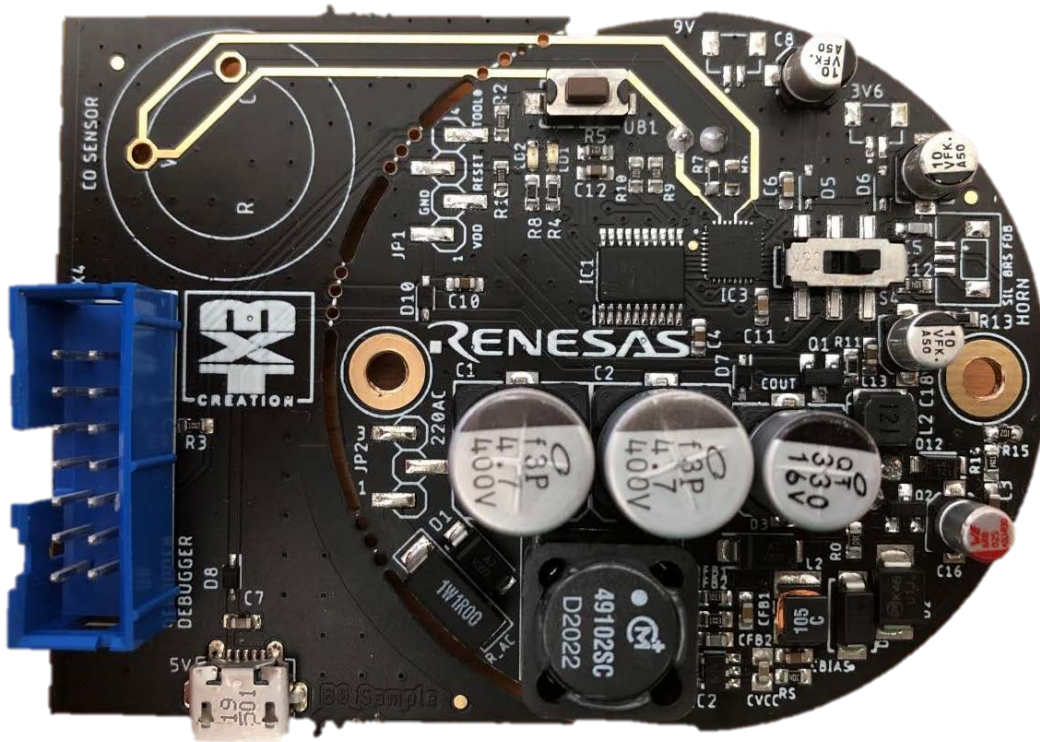
6.4   Bottom side – IR LED & IR Photodetector

6.5   Key Components Arrangement
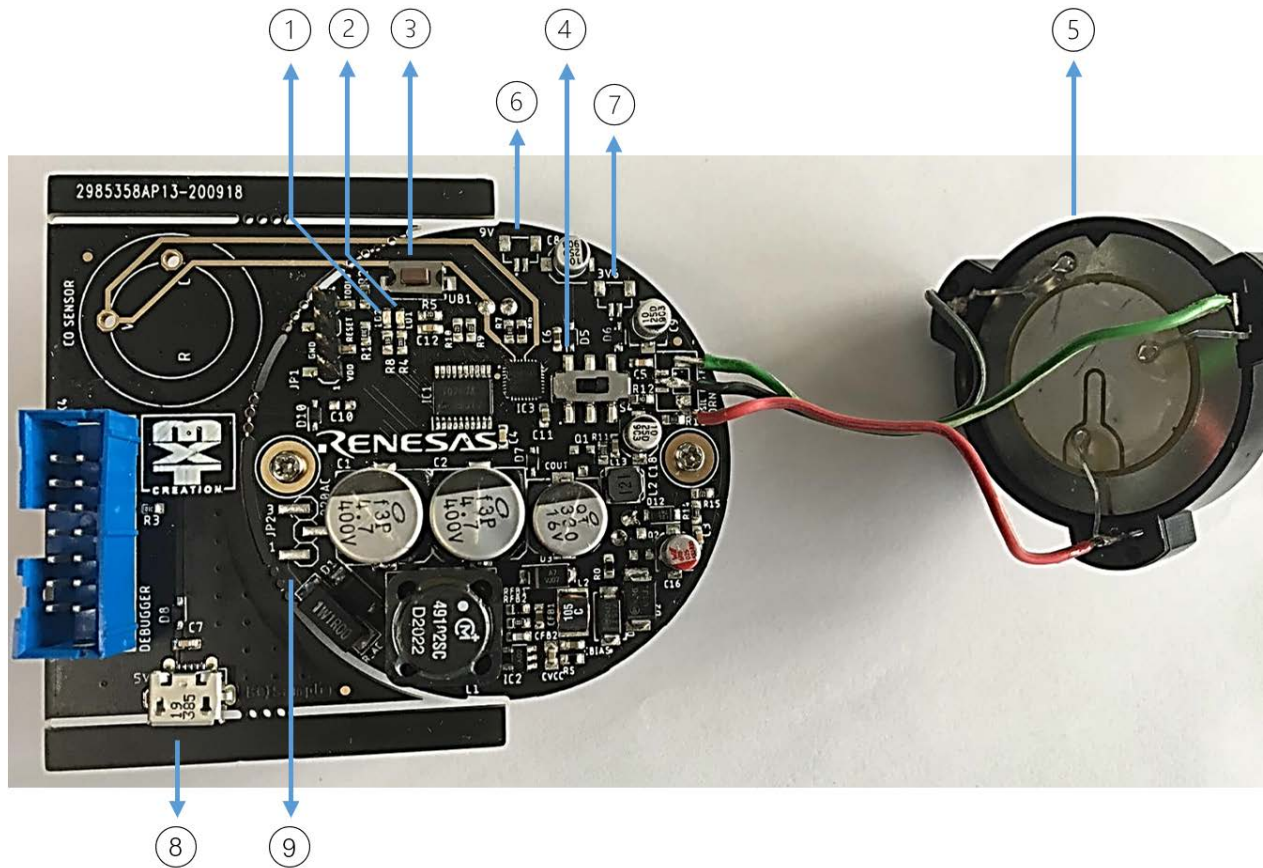
1) **Presence LED (green)**

2) **Alarm LED (red)**

3) **Test Button**

4) **Power Supply Selection Switch**

5) **Piezo Horn**

6) **9V DC Connector pads**

7) **3.6V DC Connector pads**

8) **5V DC USB Connector**

9) **AC Connector pads**

7.   Nomenclature

- IC   Integrated Circuit
- PoC   Proof of Concept
- SW   Software
- HW   Hardware
- MCU   Microcontroller
- AFE   Analog Front-End
- LED   Light Emitting Diode
- IR   Infrared
- TIA   Transimpedance Input Amplifier
- PGA   Programmable Gain Amplifier
- DAC   D/A converter or Digital to Analog Converter
- ADC   A/D converter or Analog to Digital Converter
- SPI   Serial Peripheral Interface
- DC   Direct Current
- AC   Alternating Current
- LDO   Low-Dropout Voltage Regulator
- GPIO   General-Purpose Input/Output
- SINI   System Initialization
- APP   Application
- IDE   Integrated development environment
- CO   Carbon Monoxide

References

[1]   Renesas Electronics, "EU070 – Software User Guide".

[2]   Renesas Electronics, "EU070 – Quick Start Guide".

[3]   Renesas Electronics, "EU070 – Hardware User Guide". *[>> THIS DOCUMENT <<]*

[4]   Renesas Electronics, "RL78/G12 - User's Manual: Hardware".

[5]   Renesas Electronics, "E1/E20/E2 Emulator, E2 Emulator Lite - Additional Document for User's Manual - (Notes on Connection for RL78)"

Revision History

Rev.	Date	Description / Summary
0.1	12.01.2021	Initial REE version

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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