XENSIV™ PAS CO2 for low power applications

Keywords: gas sensor, CO_2 sensor, power consumption

About this document

This application note describes different methods to achieve low power consumption with the XENSIV™ PAS CO2 for different applications like battery-driven applications.

Scope and purpose

There is a wide range of gas sensor products available in the market and very few offer high-performance solutions as well as low power consumption like XENSIV™ PAS CO2. Therefore, extra care is necessary to make sure that the most possible optimization for power consumption is achieved.

Intended audience

Application engineer, Test engineer, Verification engineer, and System engineer

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1 Introduction of XENSIV™ PAS CO2

The XENSIV™ PAS CO2 is a real CO_2 sensor that overcomes the size, performance, and assembly challenges of existing CO_2 sensor solutions. The sensor has been designed based on the unique **P**hoto **A**coustic **S**pectroscopy (PAS) principle. XENSIV™ PAS CO2 comes in an exceptionally miniaturized module that is 4 times smaller and 3 times lighter than the existing commercial real CO_2 sensors that operate based on the NDIR principle. In addition to the unprecedented compact design, XENSIV™ PAS CO2 delivers superior quality data thanks to its high accuracy performance beating state-of-the-art CO_2 gas sensors. The sensor´s high accuracy level makes it the right choice for Indoor air quality monitoring stations, HVAC systems, and IoT applications.

All major components of XENSIV™ PAS CO2 are developed and designed in-house according to Infineon ‘s high-quality standards (e.g. components traceability, Internal and external audits, State of the art qualification standards and tools). As shown in Figure 1 outside of the cavity, there is an XMC microcontroller to support data processing and a MOSFET to drive the light source. Within the cavity, there is a high SNR silicon microphone as the detector and a built-inhouse MEMS-based infrared Emitter as the light source. Since the sensor is a physical sensor, no significant warmup time is required, which in turn reduces the response time and also power consumption.

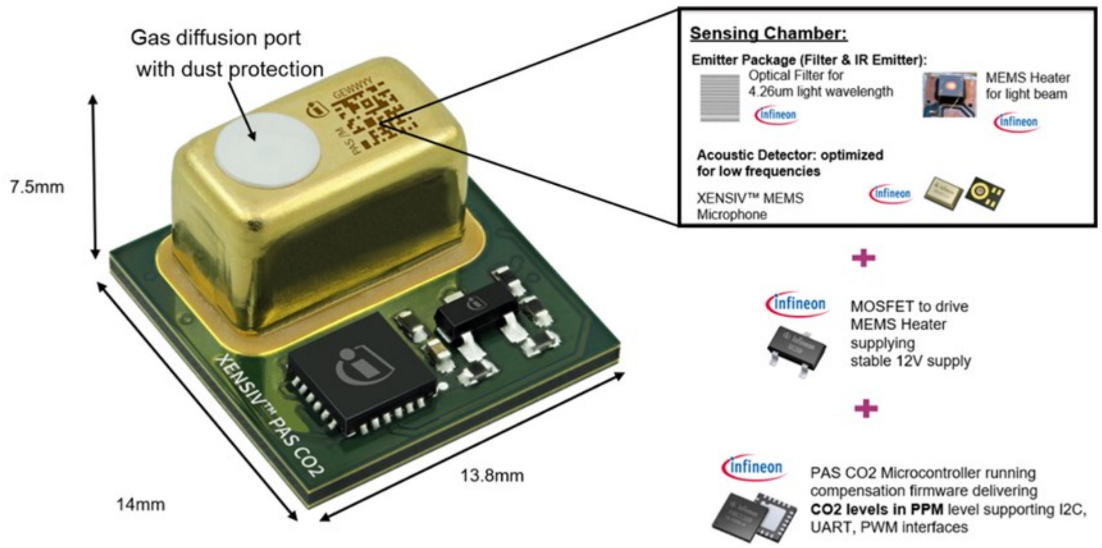

Figure 1 All the key components of XENSIV™ PAS CO2 are developed in-house to ensure best in class quality of the sensor

2 Recommended sequence for power supplies

In order not to damage the sensor or other components, a certain sequence for the power supply must be followed:

- Power on the microcontroller (3.3 V supply for the communication).
- Supply 12 V / 5 V* for the heater.

Figure 2 Power supply sequence

When powering off the sensor, the sequence must be reversed.

*Is referring to XENSIV™ PAS CO2 Gen 1.5 which is using 5 V for the emitter instead of the 12 V compared to XENSIV™ PAS CO2 Gen 1.

3 Methodology to archive low power consumption

3.1 Power consumption overview

For the power consumption assessment, the following assumptions are made:

- The nominal voltage applied (resp. 12 V / 5 V* and 3.3 V) with recommended stability and maximal ripple according to the design-in guideline (see product page)
- Power supply ramps are fast enough that they can be neglected in the power calculation
- Only the XENSIV™ PAS CO2 module is considered (additional current consumption of external circuitry is not considered)

When integrating the XENSIV™ PAS CO2 to the application/product the peak currents listed in Table 1 need to be considered.

Table 1 Current ratings

Parameter	Symbol	Pin	Values			Unit
			Min.	Typ.	Max.	
Peak current[1)]	$I_{peak\ 12}$	VDD12		130	150	mA
Peak current[1)]	$I_{peak\ 5}$	VDD5		265	290	mA
Peak current[1)]	$I_{peak\ 3.3}$	VDD3.3		10	20	mA

[1)] Not subject to production test. This parameter is verified by design/characterization.

The power consumption can be split into three categories according to the state of the sensor. The first state is the power-up mode which covers the power consumption needed for powering up the device. The second state is the active measurement mode where the sensor performs all the needed actions and tasks to excite the IR emitter, capture the raw signals of the sensing element, process those signals, derive a CO_2 concentration value, and make it available for the user to read. The third and last state is the idle mode where the sensor is not actively measuring. Figure 2 is showing the principle of the current consumption including the measurement sequence and idle mode. It should be noted that the scaling of the graph is not correct and just for visualization purposes.

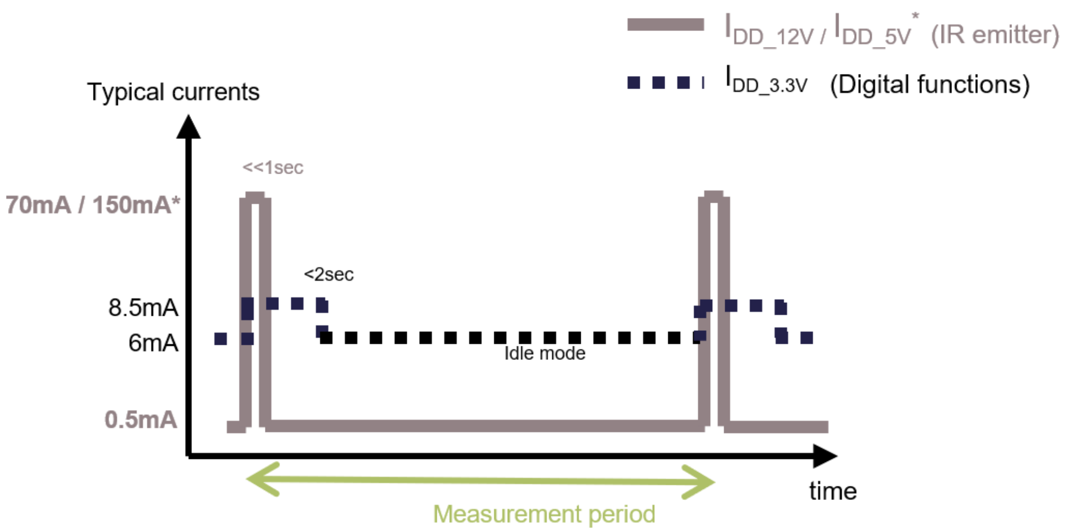

Figure 3 Principle of the current consumption

The power consumption split of the three states is shown in Table 2. Different possibilities which tackle these categories to reduce the overall power consumption are explained in the following sections.

Table 2 Power consumption split

Parameter	Power up	During Measurement		Idle		Unit
	3.3 V	3.3 V	12 V / 5 V*	3.3 V	12 V / 5 V*	
Average current	9	8	70 / 150	6	0.5	mA
Average power	29.7	26.4	840 / 750	19.8	6 / 2.5	mW
Duration	0.8	0.7	0.2	-		s

3.2 Adapting the sampling rate

By adapting the sampling rate, the stressing of the sensor can be reduced and so the power consumption is distributed over time. The measurement rate can be configured in the measurement period configuration register. Registers MEAS_RATE_H (address: 0x02) and MEAS_RATE_L (address: 0x03) define the measurement period used in continuous mode. The concatenation of MEAS_RATE_H (MSB) and MEAS_RATE_L (LSB) defines the period. The concatenated value is coded as a two's complement signed short integer (1 bit = 1 s). In this example, the measuring rate is set to 60 s. In the measurement mode configuration register, MEAS_CFG (address: 0x04) is the operation settings of the device defined. With writing 0x02 to this register, the continuous measurement mode is configurated and triggered.

Configuring the measurement rate in continuous mode

```
001        w 28 02 00 p
002        w 28 03 3C p
003        w 28 04 02 p
```

Attention: ***A full detailed register map has been covered in a separate application note (see product page)***

For calculating the overall power consumption, the power consumption split with the three states and two supplies are summarized in equations (1.1) and (1.2) / (1.3)*. T is defining the sampling rate, thus the period after the next measurement is started. Power consumption results using these equations are listed in Table 3.

$$P_{3.3} = 3.3\,V * \frac{1}{T} * [0.8\,s * 9\,mA + 0.7\,s * 8\,mA + (T - 0.8\,s - 0.7\,s) * 6\,mA] \tag{1.1}$$

$$P_{12} = 12\,V * \frac{1}{T} * [0.2\,s * 70\,mA + (T - 0.2\,s) * 0.5\,mA] \tag{1.2}$$

$$P_{5} = 5\,V * \frac{1}{T} * [0.2\,s * 150\,mA + (T - 0.2\,s) * 0.5\,mA] \tag{1.3}$$

Table 3 Power consumption with an adapted sampling rate

Sampling rate	3.3 V supply	12 V / 5 V* supply	Total	Unit
1 meas / 10 s	21.05	22.68 / 17.45	43.73 / 38.50	mW
1 meas / 1 min	20.01	8.78 / 4.99	28.79 / 25.00	mW
1 meas / 1 h	19.80	6.05 / 2.54	25.85 / 22.35	mW

3.3 Turning off the 12 V / 5 V* supply

When INT_CFG.INT_FUNC =100_b and continuous mode is enabled (MEAS_CFG.OP_MODE =10_b), pin INT acts as an early measurement start notification. Approximately one second before the beginning of a measurement sequence, pin INT is set to issue an active level, for the duration of the measurement sequence. At the end of the measurement sequence, pin INT is reset to issue an inactive level.

The purpose of this function is to notify the application that measurement will start in approximately 1 sec. This function can be used to optimize the system's power consumption. For that purpose, the 12 V / 5 V* supply can be turned off when the device is inactive. After having been notified that a measurement sequence is about to begin, the application has (approx.) 1 sec time to turn the 12 V / 5 V* supply on before the measurement sequence occurs. Pin INT can be configured as a push-pull active high or a push-pull active low output depending on bit field INT_CFG.INT_TYP. In this example, the pin INT acts as an early measurement start notification pin and is configured as push-pull active high. An example of how the INT signal looks in this case is shown in Figure 4. The measurement rate is set to 10 s.

Configuring the early measurement start notification and measurement rate during continuous mode

```
001        w 28 08 18 p
002        w 28 02 00 p
003        w 28 03 0A p
004        w 28 04 02 p
```

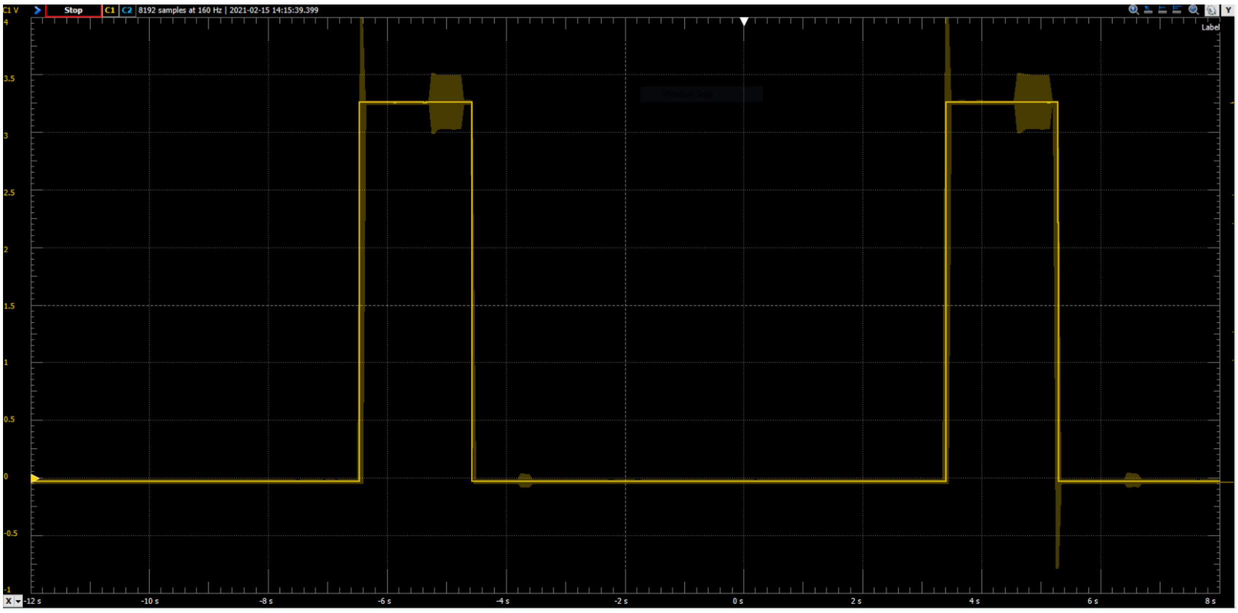

Figure 4 INT signal configured as early measurement notification pin

After using this optimization, the 12 V / 5 V* supply is only active during measurement and the idle part of the equation (1.2) / (1.3)* can be omitted which results in the power consumption equation (1.4) / (1.5)* for the 12 V or 5V* supply. The results of the power consumption using equations (1.1) and (1.4) / (1.5)* are listed in Table 4.

$$P_{12} = 12\,V * \frac{1}{T} * [0.2\,s * 70\,mA] \quad (1.4)$$

$$P_{5} = 5\,V * \frac{1}{T} * [0.2\,s * 150\,mA] \quad (1.5)$$

Table 4 Power consumption with optimized 12 V / 5 V* supply

Sampling rate	3.3 V supply	12 V / 5 V* supply	Total	Unit
1 meas / 10 s	21.05	16.80 / 15.00	37.85 / 36.05	mW
1 meas / 1 min	20.01	2.80 / 2.50	22.81 / 22.51	mW
1 meas / 1 h	19.80	0.05 / 0.04	19.85 / 19.84	mW

3.4 Disconnecting the whole module

By advancing the previous methodology of turning off the 12 V / 5 V* supply to the 3.3 V supply, the power consumption of the microcontroller during the idle phase can be compensated. The device will then only draw current in an active state during a measurement sequence which is reducing the power consumption.

Just as with the 12 V / 5 V* supply, the idle state of the 3.3 V supply in equation (1.1) will now be omitted, and only the power-up and the measurement state need to be considered. The result of the power consumption after taken all optimization methodologies into account using equations (1.4) / (1.5)* and (1.6) are listed in Table 5.

$$P_{3.3} = 3.3\,V * \frac{1}{T} * [0.8\,s * 9\,mA + 0.7\,s * 8\,mA] \qquad (1.6)$$

Table 5 Power consumption with optimized 3.3 V and 12 V / 5 V* supplies

Sampling rate	3.3 V supply	12 V / 5 V* supply	Total	Unit
1 meas / 10 s	4.22	16.80 / 15.00	21.02 / 19.22	mW
1 meas / 1 min	0.70	2.80 / 2.50	3.50 / 3.20	mW
1 meas / 1 h	0.01	0.05 / 0.04	0.06 / 0.05	mW

Note: *When powering down the 3.3 V supply, stable I^2C communication needs to be ensured. The voltage on the pull-up resistances needs to be provided by a separate supply or via for example an I^2C multiplexer.*

4 A recommended power circuit schematic

As a recommendation on how to generate a stable 12 V supply according to the design-in guideline (see product page) the power circuit schematic of the XENSIV™ PAS CO2 Wing board V4 is introduced. The XENSIV™ PAS CO2 Wing board V4 is also taken full advantage of the three introduced methodologies to archive low power consumption. The XENSIV™ PAS CO2 Wing board V4 enables the fast prototyping of an IoT air quality monitor and is fully compatible with the Adafruit™ ecosystem. The board supports the following function:

- Powered via USB or external battery
- Three LEDs (green, yellow, red) for direct visualization of the air quality
- Buzzer for acoustic warning (e.g. air quality index threshold overwritten)
- Reset and user button
- 12 V supply generated on-board to power the sensor
- Power down pin to switch off the XENSIV™ PAS CO2 Wing board V4 for power optimization

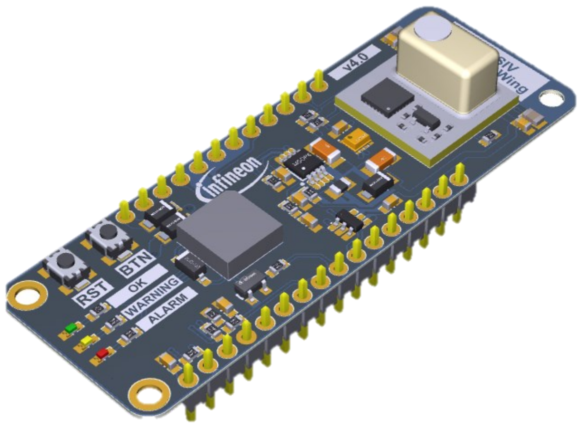

Figure 5 XENSIV™ PAS CO2 Wing board V4

A recommended power circuit schematic

The used PWM DC/DC converter LT3580 with the adjusted schematic for needed application is shown in Figure 5. The INT pin of the XENSIV™ PAS CO2 is connected to the shutdown pin of the converter which is controlling the enabling and disabling of the chip. With the implemented feature of the INT pin as early measurement start notification and push-pull active high is the 12 V supply only during a measurement sequence active. In an inactive state, the INT pin is low which is setting the shutdown pin to low and disabling the whole chip and thus disabling the 12 V supply. For an ideal 12 V supply recommendation, please have a look at our design in the guideline application note.

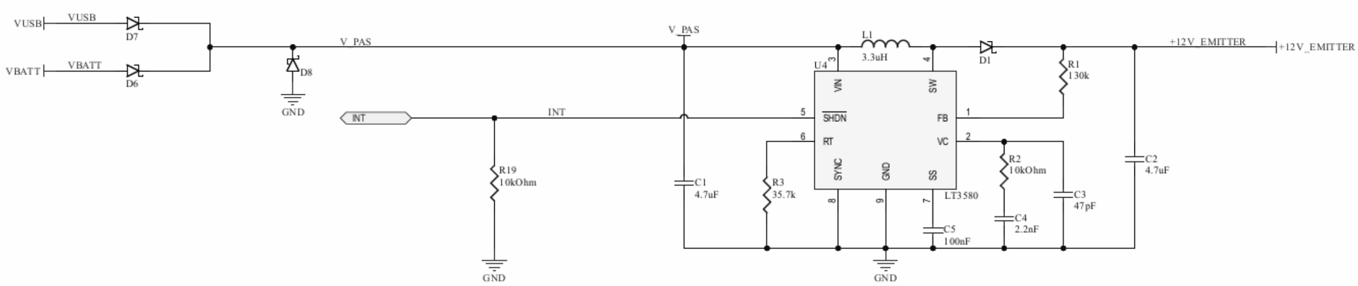

Figure 6 **Schematic of the power circuit for the IR emitter**

The 3.3 V supply of the XENSIV™ PAS CO2 is controlled by a switch. By setting the power-down pin either high or low, the switch is closed or open which results in letting the 3.3 V through or connecting it to the ground.

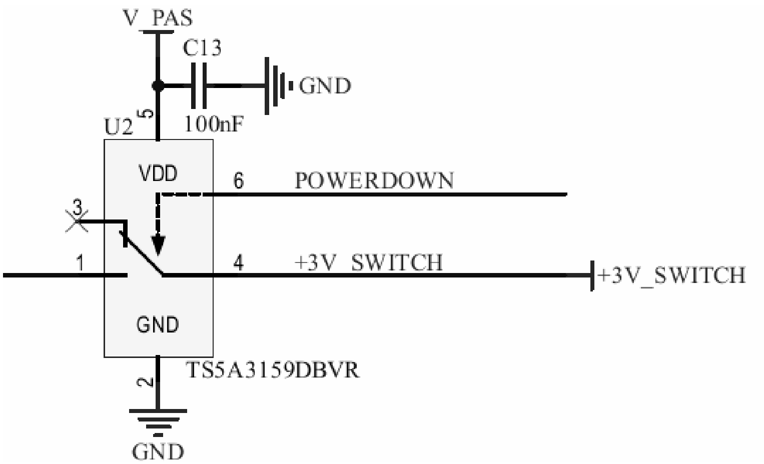

Figure 7 **Switch for controlling the 3.3 V supply**

To facilitate power consumption calculation a power consumption calculator is offered, which can be downloaded from the product page.

4.1 Recommended reference design for

PWM DC/DC converter LT3580 with the adjusted schematic for needed application is shown in Figure 5. The INT pin of the XENSIV™ PAS CO2 is connected to the shutdown pin of the converter which is controlling the enabling and disabling of the chip. With the implemented feature of the INT pin as early measurement start notification and push-pull active high is the 12 V supply only during a measurement sequence active. In an inactive state, the INT pin is low which is setting the shutdown pin to low and disabling the whole chip and thus disabling the 12 V supply. For an ideal 12 V supply recommendation, please have a look at our design in the guideline application note.

A recommended power circuit schematic

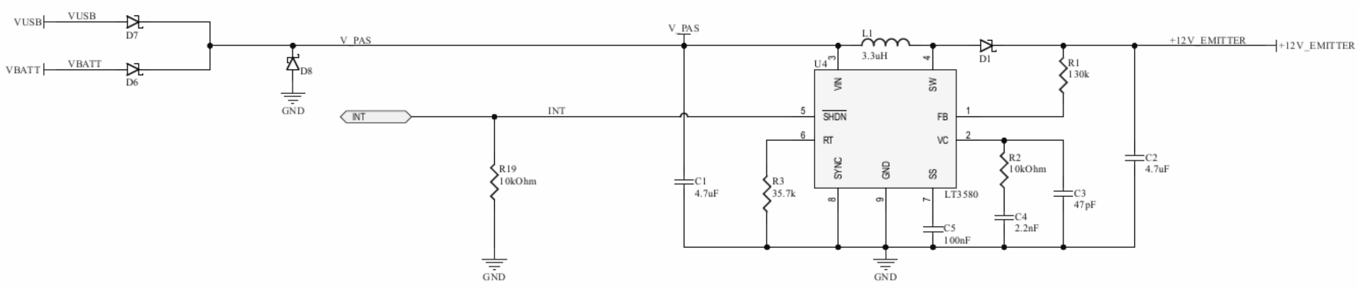

Figure 8 Schematic of the power circuit for the IR emitter

4.2 Recommended reference design

PWM DC/DC converter LT3580 with the adjusted schematic for needed application is shown in Figure 5. The INT pin of the XENSIV™ PAS CO2 is connected to the shutdown pin of the converter which is controlling the enabling and disabling of the chip. With the implemented feature of the INT pin as early measurement start notification and push-pull active high is the 12 V supply only during a measurement sequence active. In an inactive state, the INT pin is low which is setting the shutdown pin to low and disabling the whole chip and thus disabling the 12 V supply. For an ideal 12 V supply recommendation, please have a look at our design in the guideline application note.

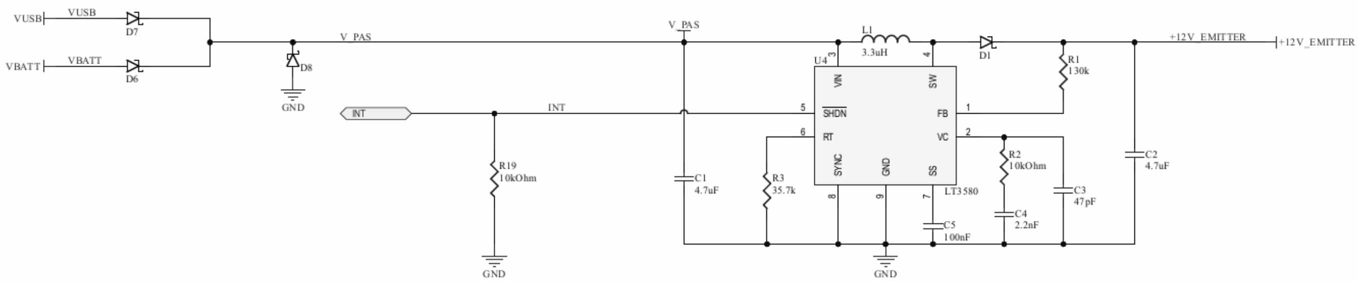

Figure 9 Schematic of the power circuit for the IR emitter

Appendix

The full schematic of the XENSIV™ PAS CO2 Wing board V4 is appended here.

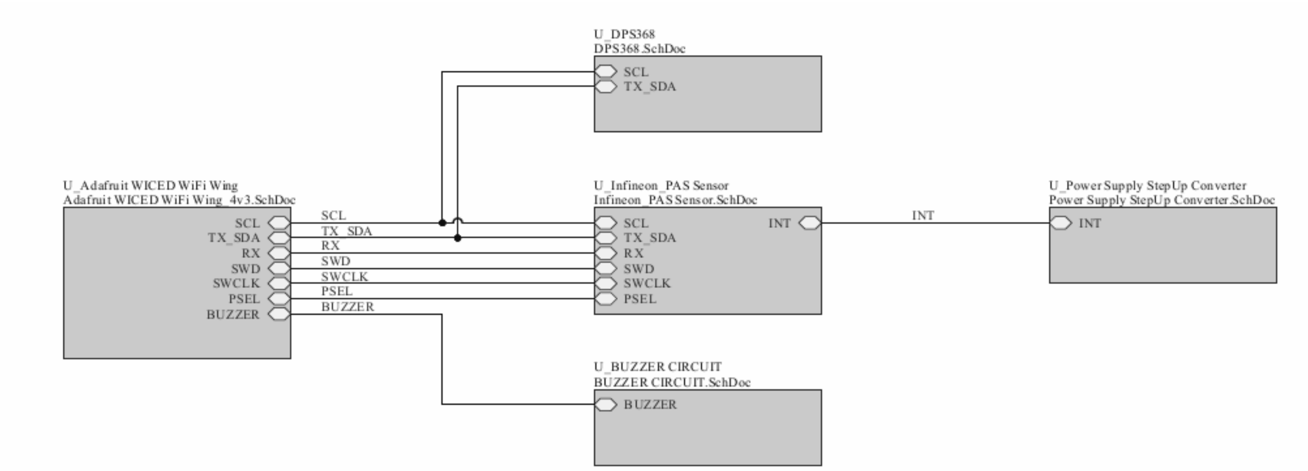

Figure 10 **Top level schematic**

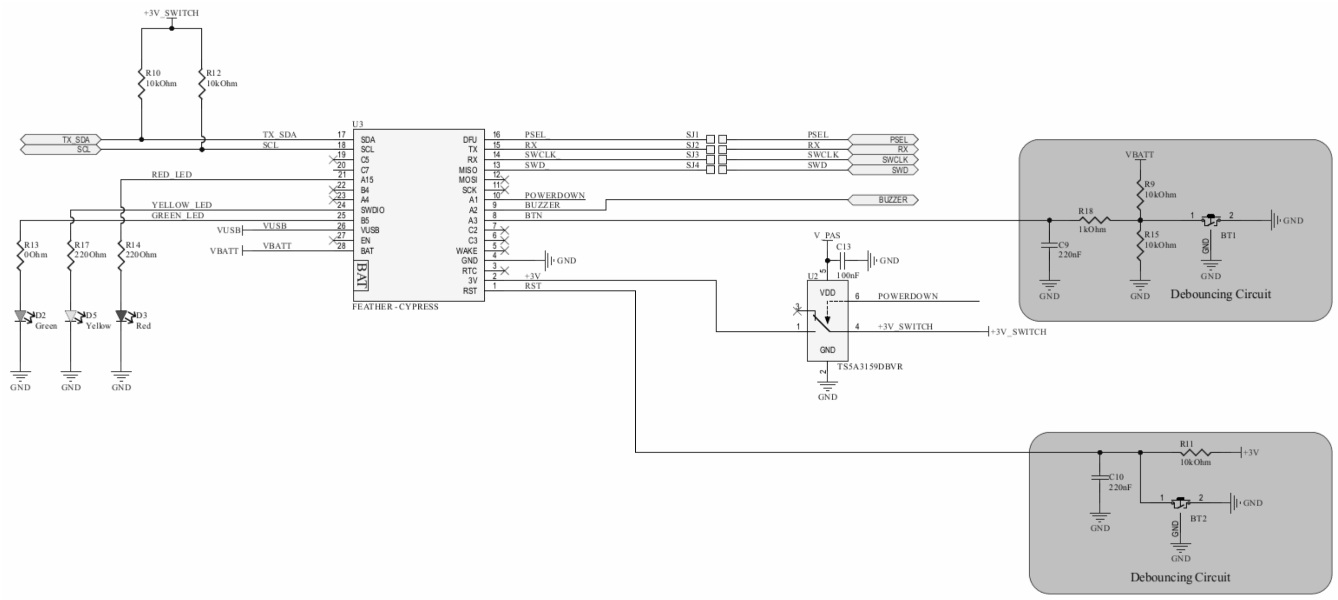

Figure 11 **Adafruit wiced wifi feather board**

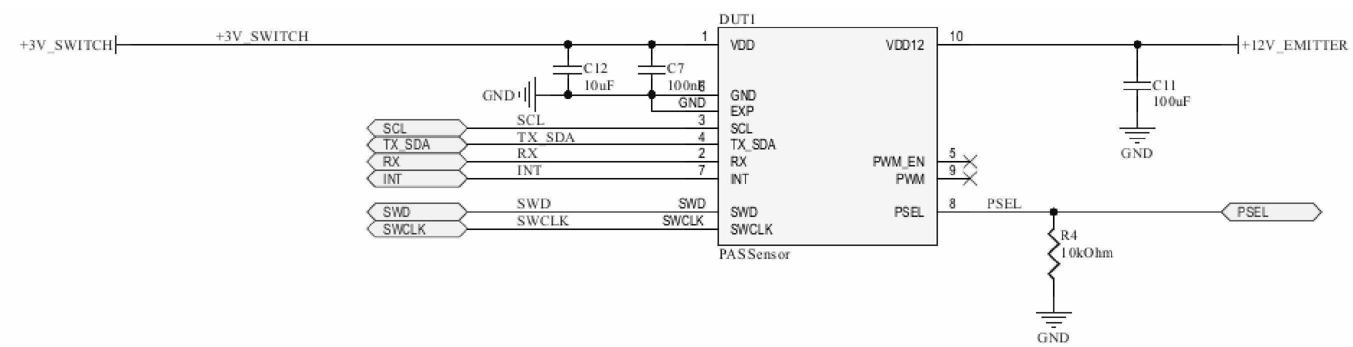

Figure 12 **XENSIV™ PAS CO2 sensor**

Appendix

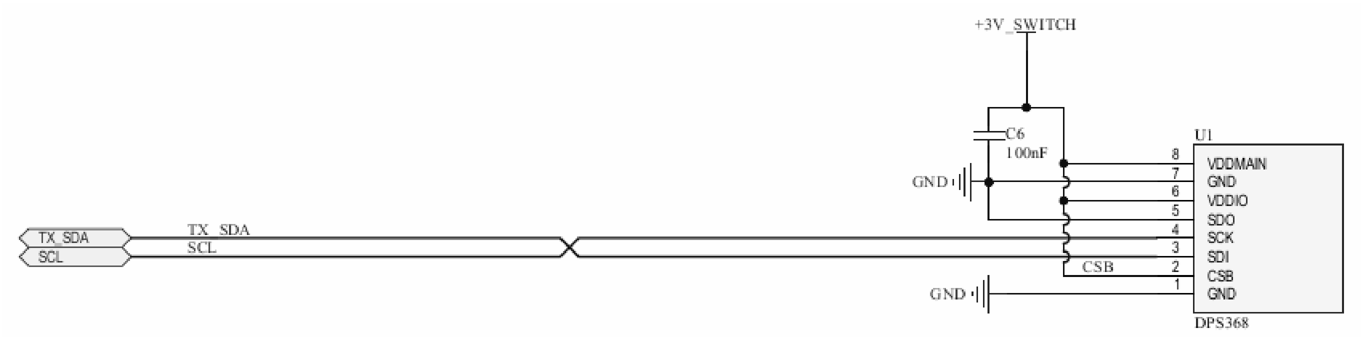

Figure 13 XENSIV™ DPS368 pressure sensor

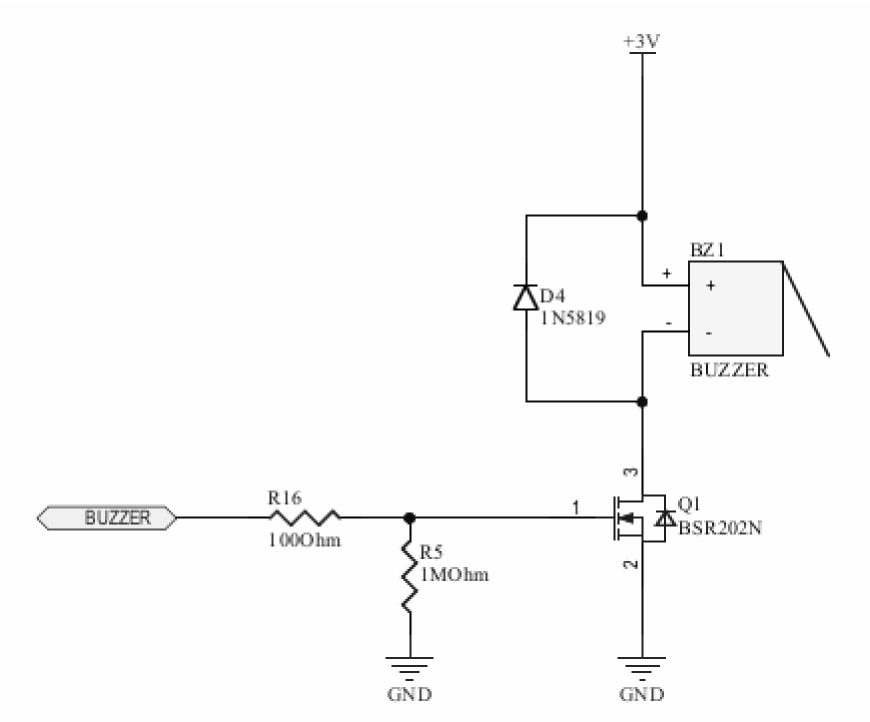

Figure 14 Buzzer circuit

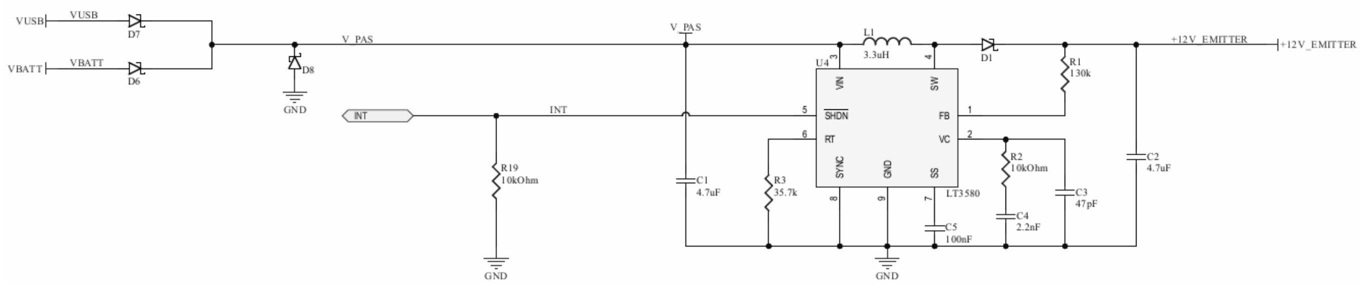

Figure 15 Power supply setup up converter

Revision history

Document version	Date of release	Description of changes
V1.0	01.07.2021	Creation
V1.1	01.07.2022	Added note in section 3.4
V2.0	01.07.2023	Added XENSIV™ PAS CO2 Gen 1.5 relevant information

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