

# CCS811

## Ultra-Low Power Digital Gas Sensor for Monitoring Indoor Air Quality

### General Description

The CCS811 is an ultra-low power digital gas sensor solution which integrates a metal oxide (MOX) gas sensor to detect a wide range of Volatile Organic Compounds (VOCs) for indoor air quality monitoring with a microcontroller unit (MCU), which includes an Analog-to-Digital converter (ADC), and an I<sup>2</sup>C interface.

CCS811 is based on **ams** unique micro-hotplate technology which enables a highly reliable solution for gas sensors, very fast cycle times and a significant reduction in average power consumption.

The integrated MCU manages the sensor drive modes and raw sensor data measured while detecting VOCs. The I<sup>2</sup>C digital interface significantly simplifies the hardware and software design, enabling a faster time to market.

CCS811 supports intelligent algorithms to process raw sensor measurements to output a TVOC value or equivalent CO<sub>2</sub> (eCO<sub>2</sub>) levels, where the main cause of VOCs is from humans.

CCS811 supports multiple measurement modes that have been optimized for low-power consumption during an active sensor measurement and idle mode extending battery life in portable applications.

CCS811 is available in a 10 lead 2.7mm x 4.0mm x 1.1mm, 0.6mm pitch LGA package.

*[Ordering Information](#) and [Content Guide](#) appear at end of datasheet.*

## Key Benefits & Features

The benefits and features of CCS811, Ultra-Low Power Digital Gas Sensor for Monitoring Indoor Air Quality are listed below:

**Figure 1:**  
**Added Value of Using CCS811 Sensor**

| Benefits  | Features  |
|---|---|
| <ul style="list-style-type: none"> <li>Manages the sensor drive modes and measurements while detecting VOCs</li> </ul>        | <ul style="list-style-type: none"> <li>Integrated MCU</li> </ul>                            |
| <ul style="list-style-type: none"> <li>Provides eCO<sub>2</sub> level or TVOC indication with no host intervention</li> </ul> | <ul style="list-style-type: none"> <li>On-board processing</li> </ul>                       |
| <ul style="list-style-type: none"> <li>Simplifies the hardware and software integration</li> </ul>                            | <ul style="list-style-type: none"> <li>Standard I<sup>2</sup>C digital interface</li> </ul> |
| <ul style="list-style-type: none"> <li>Extend battery life in portable applications</li> </ul>                                | <ul style="list-style-type: none"> <li>Optimised low-power modes</li> </ul>                 |
| <ul style="list-style-type: none"> <li>Suitable for small form-factor designs</li> </ul>                                      | <ul style="list-style-type: none"> <li>2.7mm x 4.0mm x 1.1mm LGA package</li> </ul>         |
| <ul style="list-style-type: none"> <li>Saves up to 60% in PCB footprint</li> </ul>  | <ul style="list-style-type: none"> <li>Low component count</li> </ul>                       |
| <ul style="list-style-type: none"> <li>Designed for high volume and reliability (&gt;5years lifetime)</li> </ul>              | <ul style="list-style-type: none"> <li>Proven technology platform</li> </ul>                |

## Applications

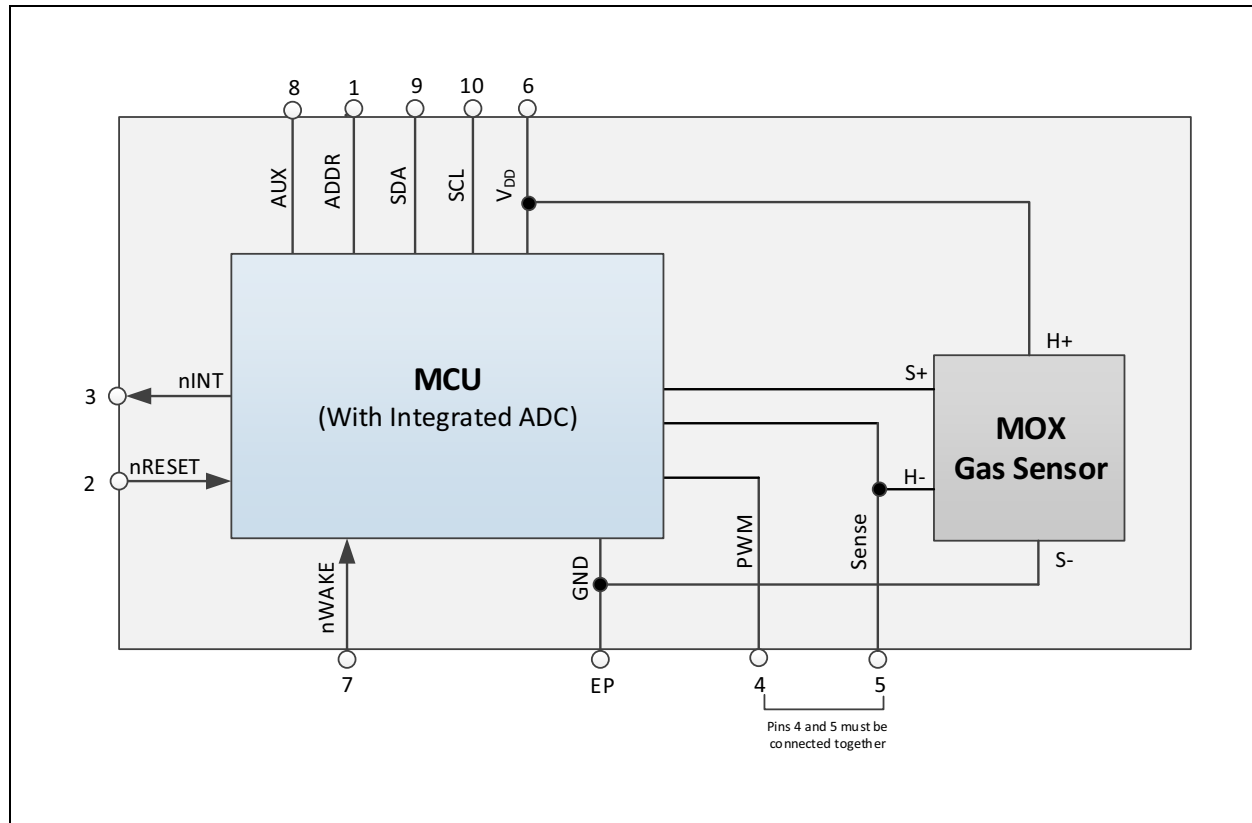
This device can be mainly used for indoor air quality monitoring in:

- Smart phones
- Wearables
- Home and Building automation
- Accessories

## Block Diagram

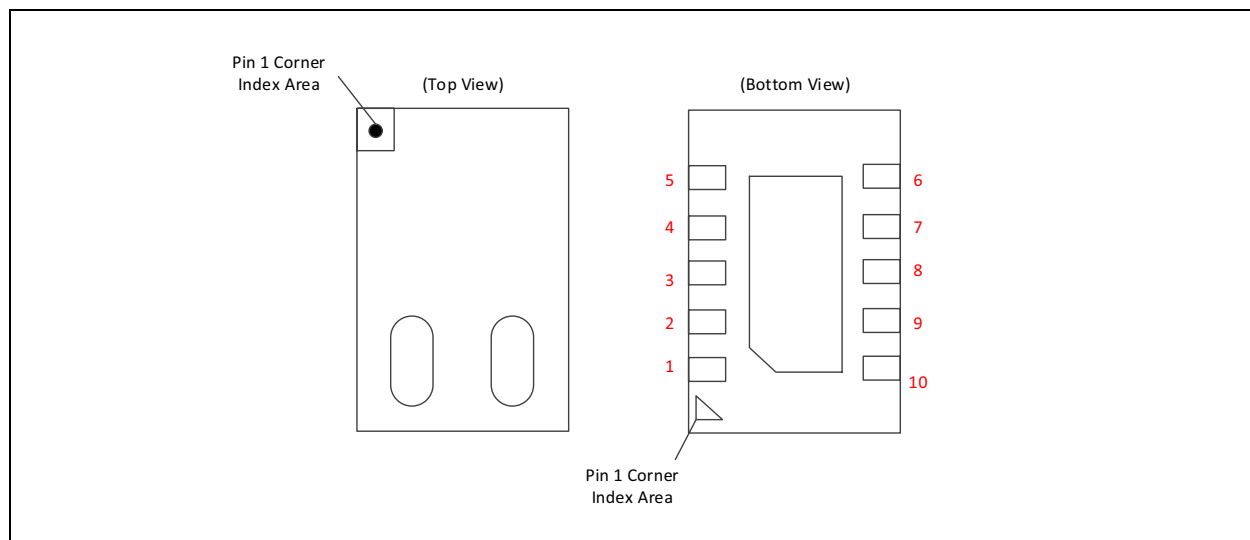
The functional blocks of this device are shown below:

**Figure 2:**  
**CCS811 Block Diagram**



## Pin Assignment

**Figure 3:**  
Pin Diagram



**Pin Diagram:** The Exposed Pad is underneath

**Figure 4:**  
CCS811 LGA Pin Assignment

| Pin No. | Pin Name        | Description  |
|---------|-----------------|--|
| 1       | ADDR            | Single address select bit to allow alternate address to be selected <ul style="list-style-type: none"> <li>When ADDR is low the 7 bit I<sup>2</sup>C address is decimal 90 / hex 0x5A</li> <li>When ADDR is high the 7 bit I<sup>2</sup>C address is decimal 91 / hex 0x5B.</li> </ul> |
| 2       | nRESET          | nRESET is an active low input and is pulled up to V <sub>DD</sub> by default. nRESET is optional but 4.7kΩ pull-up and/or decoupling of the nRESET pin may be necessary to avoid erroneous noise-induced resets. This pin will be pulled low internally during reset.                  |
| 3       | nINT            | nINT is an active low optional output. It is pulled low by the CCS811 to indicate end of measurement or a set threshold value has been triggered.  |
| 4       | PWM             | Heater driver PWM output. Pins 4 and 5 must be connected together.   |
| 5       | Sense           | Heater current sense. Pins 4 and 5 must be connected together.   |
| 6       | V <sub>DD</sub> | Supply voltage.  |
| 7       | nWAKE           | nWAKE is an active low input and should be asserted by the host prior to an I <sup>2</sup> C transaction and held low throughout.  |
| 8       | AUX             | Optional AUX pin which can be used for ambient temperature sensing with an external NTC resistor. If not used leave unconnected.   |
| 9       | SDA             | SDA pin is used for I <sup>2</sup> C data. Should be pulled up to V <sub>DD</sub> with a resistor.   |
| 10      | SCL             | SCL pin is used for I <sup>2</sup> C clock. Should be pulled up to V <sub>DD</sub> with a resistor.  |
| EP      | Exposed Pad     | Connect to ground.   |

## Absolute Maximum Ratings

Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under [Electrical Characteristics](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability

**Figure 5:**  
**Absolute Maximum Ratings**

| Symbol                         | Parameter                          | Min                | Max | Units | Comments                       |
|--------------------------------|------------------------------------|--------------------|-----|-------|--------------------------------|
| Electrical Parameters          |                                    |                    |     |       |                                |
| V <sub>DD</sub> <sup>(1)</sup> | Supply Voltage                     | 1.8 <sup>(2)</sup> | 3.6 | V     |                                |
| I <sub>DD</sub>                | Supply Current                     |                    | 30  | mA    | In mode 1                      |
| P                              | Power Consumption                  |                    | 60  | mW    | In mode 1                      |
| Electrostatic Discharge        |                                    |                    |     |       |                                |
| ESD <sub>HBM</sub>             | Human Body Model                   | ±2000              |     | V     |                                |
| Environmental Conditions       |                                    |                    |     |       |                                |
| T <sub>AMB</sub>               | Ambient Temperature for Operation  | -5                 | 50  | °C    |                                |
| T <sub>STRG</sub>              | Storage Temperature                | -40                | 125 | °C    |                                |
| RH <sub>NC</sub>               | Relative Humidity (non-condensing) | 10                 | 95  | %     |                                |
| L <sub>T</sub> <sup>(3)</sup>  | Product Lifetime                   | >5                 |     | Years | In mode 1                      |
| MSL                            | Moisture Sensitivity Level         | 1                  |     |       | Unlimited max. floor life time |

**Note(s):**

1. The supply voltage  $V_{DD}$  is sampled during boot and should not vary during operation.
2. The minimum supply voltage  $V_{DD}$  is 1.8V and should not drop below this value for reliable device operation.
3. Product lifetime for CCS811 will be longer in modes 2 and 3.

## Electrical Characteristics

**Figure 6:**  
Electrical Characteristics

| Parameters                                      | Conditions                                      | Min            | Typ <sup>(6)</sup> | Max      | Units |
|---|---|----------------|--------------------|----------|-------|
| Supply Voltage ( $V_{DD}$ ) <sup>(1), (2)</sup> |   | 1.8            |                    | 3.3      | V     |
| Supply Current ( $I_{DD}$ ) <sup>(3)</sup>      | During measuring at 1.8V                        |                | 26                 |          | mA    |
|   | Average over pulse cycle <sup>(3)</sup> at 1.8V |                | 0.7                |          | mA    |
|   | Sleep Mode at 1.8V                              |                | 19                 |          | μA    |
| Power Consumption                               | Idle Mode 0 at $V_{DD}$ = 1.8V                  |                | 0.034              |          | mW    |
|   | Mode 1 & 4 at $V_{DD}$ = 1.8V                   |                | 46                 |          | mW    |
|   | Mode 2 at $V_{DD}$ = 1.8V                       |                | 7                  |          | mW    |
|   | Mode 3 at $V_{DD}$ = 1.8V                       |                | 1.2                |          | mW    |
| Logic High Input <sup>(5)</sup>                 | nRESET, nWAKE, ADDR                             | $V_{DD} - 0.6$ |                    | $V_{DD}$ | V     |
| Logic Low Input <sup>(5)</sup>                  | nRESET, nWAKE, ADDR                             | 0              |                    | 0.6      | V     |
| Logic High Output                               | nINT  | $V_{DD} - 0.7$ |                    |          | V     |
| Logic Low Output                                | nINT  |                |                    | 0.6      | V     |
| Analogue Input                                  | AUX   | 0              |                    | $V_{DD}$ | V     |

**Note(s):**

1. The supply voltage  $V_{DD}$  is sampled during boot and should not vary during operation
2. The maximum  $V_{DD}$  ramp time for Power On is 3ms
3. Typical values for 1.8V supply voltage ( $V_{DD}$ )
4. Average Supply Current ( $I_{DD}$ ) for a sensor measurement once every 60 seconds
5. For SDA and SCL timing refer NXP I<sup>2</sup>C – bus specification and user manual UM10204
6. Typical values at 25°C and 50% RH

**Figure 7:**  
**Timing Characteristics**

| Parameters               | Conditions                                  | Min | Typ | Max | Units         |
|--------------------------|---|-----|-----|-----|---------------|
| $t_{\text{AWAKE}}^{(1)}$ | Time until active after nWAKE asserted.     | 50  |     |     | $\mu\text{s}$ |
| $t_{\text{DWAKE}}$       | Minimum time nWAKE should be de-asserted    | 20  |     |     | $\mu\text{s}$ |
| $t_{\text{RESET}}$       | Minimum nRESET low pulse                    | 20  |     |     | $\mu\text{s}$ |
| $t_{\text{START}}^{(2)}$ | Time until active after Power on            |     | 18  | 20  | ms            |
|                          | Time until active after nRESET              |     | 1   | 2   | ms            |
| $f_{\text{I}^2\text{C}}$ | Frequency of I <sup>2</sup> C Bus Supported | 10  | 100 | 400 | kHz           |

**Note(s):**

1. nWAKE should be asserted prior to and during any I<sup>2</sup>C transaction
2. Up to 70ms on the first Reset after new application download

## Detailed Description

### Modes of Operation

The CCS811 has 5 modes of operation as follows

- Mode 0: Idle, low current mode
- Mode 1: Constant power mode, IAQ measurement every second
- Mode 2: Pulse heating mode IAQ measurement every 10 seconds
- Mode 3: Low power pulse heating mode IAQ measurement every 60 seconds
- Mode 4: Constant power mode, sensor measurement every 250ms

In Modes 1, 2, 3, the equivalent CO<sub>2</sub> concentration (ppm) and TVOC concentration (ppb) are calculated for every sample.

- Mode 1 reacts fastest to gas presence, but has a higher operating current
- Mode 3 reacts more slowly to gas presence but has the lowest average operating current.

When a sensor operating mode is changed to a new mode with a lower sample rate (e.g. from Mode 1 to Mode 3), it should be placed in Mode 0 (Idle) for at least 10 minutes before enabling the new mode. When a sensor operating mode is changed to a new mode with a higher sample rate (e.g. from Mode 3 to Mode 1), there is no requirement to wait before enabling the new mode.

Mode 4 is intended for systems where an external host system wants to run an algorithm with raw data and this mode provides new sample data every 250ms.

**Note(s):** Mode timings are subject to typical 2% tolerance due to accuracy of internal clock

### Early-Life Use (Burn-In)

CCS811 performance in terms of resistance levels and sensitivities will change during early life use. The change in resistance is greatest over the first 48 hours of operation. **ams** advises customers to run CCS811 for 48 hours in the selected mode of operation to ensure sensor performance is stable.



## Conditioning Period (Run-In)

After early-life (Burn-In) period is complete the conditioning period is the time required to achieve good sensor stability before measuring VOCs after long idle period.

After writing to MEAS\_MODE to configure the sensor in mode 1-4, run CCS811 for 20 minutes, before accurate readings are generated.

The conditioning period must also be observed before writing to the BASELINE register.

## eCO<sub>2</sub>

The equivalent CO<sub>2</sub> (eCO<sub>2</sub>) output range for CCS811 is from 400ppm to 8192ppm. Values outside this range are clipped.

## TVOC

The Total Volatile Organic Compound (TVOC) output range for CCS811 is from 0ppb to 1187ppb. Values outside this range are clipped.

This is calibrated to a typical TVOC mixture in an indoor environment. If the ratio of compounds in the environment is significantly different the TVOC output will be affected as some VOC compounds will have greater or lesser effect on the sensor.

## Temperature and Humidity Compensation

If an external sensor is available this information can be written to CCS811 so that they will be used to compensate gas readings due to temperature and humidity changes. Refer to the [ENV\\_DATA \(Environment Data\) Register \(0x05\)](#).

## Interrupt and Interrupt on Threshold

At the end of each measurement cycle (250ms, 1s, 10s, 60s) a flag is set and optionally interrupt (nINT) pin asserted. Refer to the [MEAS\\_MODE \(Measurement and Conditions\) Register \(0x01\)](#). The user can choose to only assert nINT if the eCO<sub>2</sub> value changes into a different range set by register values. Refer to the [THRESHOLDS Register \(0x10\)](#).

## Optional NTC Circuit (AUX)

CCS811 supports an external interface for connecting a negative thermal coefficient (NTC) thermistor to provide a cost effective and power efficient means of calculating the local ambient temperature.

The thermistor enables the application to determine the ambient temperature in the location where the CCS811 is deployed. This temperature can subsequently be used for environmental compensation on the CCS811 MOX gas sensor.

Refer to application note **ams** AN000372 for more details on NTC configuration.

If an external temperature sensor is not available the external NTC circuit can be used to determine the ambient temperature and write this information to CCS811.

The NTC Register provides the voltages across the  $R_{NTC}$  and the  $R_{REF}$  if fitted (mV) – to enable host system to calculate the ambient temperature. The calculated temperature can be written to CCS811 to compensate for gas changes due to temperature changes.

## Automatic Baseline Correction

The resistance  $R_S$  of the sensitive layer is the output of the sensor. However, metal oxide sensors do not give absolute readings. The resistance  $R_S$  varies from sensor to sensor (manufacturing variation), from use-case to use-case, and over time. To mitigate this problem, the output of the sensor is normalized:  $R_S$  is divided by  $R_A$ . The value of  $R_A$  is known as the baseline.  $R_A$  cannot be determined by a one-time calibration; it is maintained on-the-fly in software. This process is known as baseline correction. The air quality is expected to vary in a typical environment so the minimum time over which a baseline correction is applied is 24 hours.

## Manual Baseline Correction

There is a mechanism within CCS811 to manually save and restore a previously saved baseline value using the BASELINE register.

The correct time to save the baseline will depend on the customer use-case and application.

- For devices which are powered for >24 hours at a time:
  - During the first 500 hours – save the baseline every 24-48 hours.
  - After the first 500 hours – save the baseline every 5-7 days.
- For devices which are powered <24 hours at a time:
  - If the device is run in, save the baseline before power down
  - If multiple operating modes are used, a separate baseline should be stored for each
  - The baseline should only be restored when the resistance is stable (typically 20-30 minutes)
  - If changing from a low to high power mode (without spending at least 10 minutes in idle), the sensor resistance should be allowed to settle again before restoring the baseline

**Note(s):**

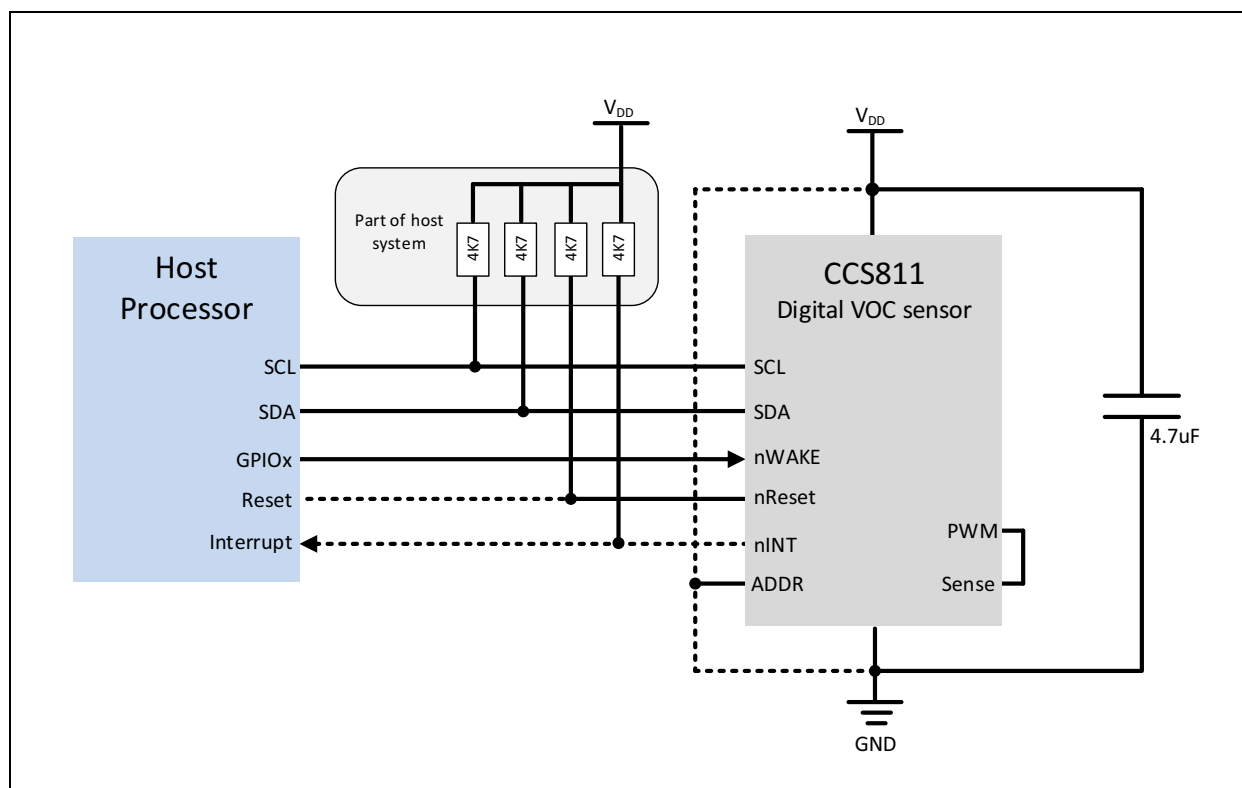
1. If a value is written to the BASELINE register while the sensor is stabilising, the output of the TVOC and eCO<sub>2</sub> calculations may be higher than expected.
2. The baseline must be written after the conditioning period

For additional information on using the CCS811 please refer to application note **ams** AN000369: CCS811 Programming and Interfacing Guide.

## Application Information

The recommended application circuit for CCS811 is shown below.

**Figure 8:**  
**Recommended Application Circuit**



**Note(s):**

1. The PWM (Pin 4) and Sense (Pin 5) signals on CCS811 must be connected together.
2. A decoupling capacitor must be placed close to the supply pin VDD on the CCS811.
3. Pull-up resistors for SCL and SDA assumed will be part of host system.
4. If power is not an issue, nWake can be connected to ground if a spare GPIO is not available on the host processor.
5. ADDR must be connected to either VDD (logic 1) or ground (logic 0) depending on the required Isb of the CCS811's I<sup>2</sup>C slave address.

## Host System Software Requirements

1. The minimum level of driver support that a host system needs is read and write I<sup>2</sup>C transactions of data bytes where the nWAKE pin is asserted at least tAWAKE before the transaction and kept asserted throughout.
2. An Interrupt handler is also recommended to tell the application code that the device has asserted an interrupt.

## I<sup>2</sup>C Interface

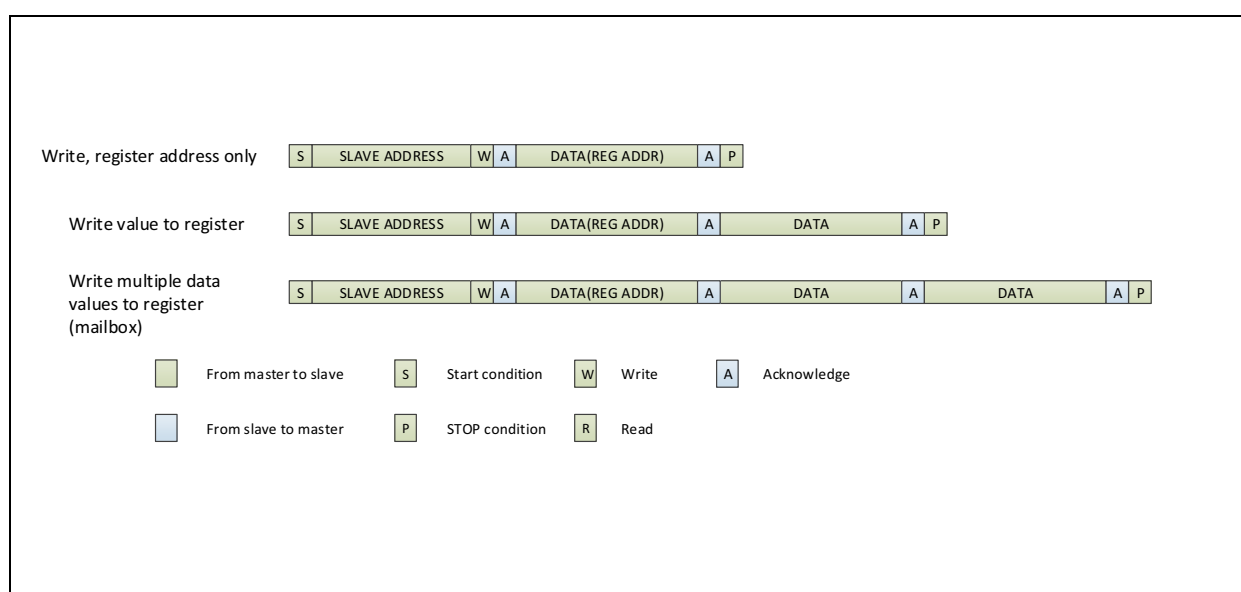
I<sup>2</sup>C transactions require a register address to be selected (written) and followed by data, as described by the transaction types in the subsections below. Each Register location corresponds to a byte or multiple bytes.

Multiple reads or writes in a single sequence will be to or from the same location (the address does not increment).

Therefore, registers are sometimes referred to as mailboxes in this document.

### I<sup>2</sup>C Register Write

**Figure 9:**  
I<sup>2</sup>C Register Write

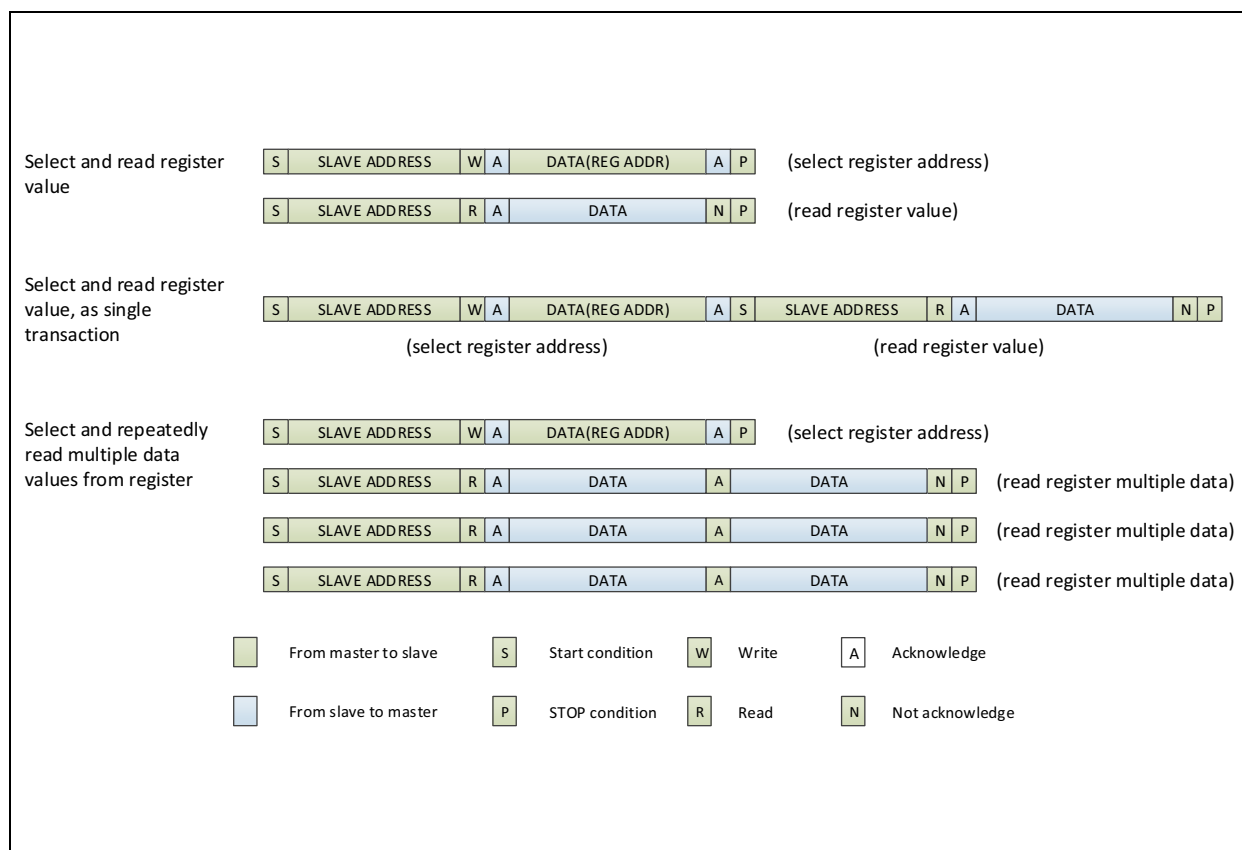


As shown above, a transaction may be:

- Single Byte to select a register address for subsequent read
- Two Bytes to select a register address and write a byte to it, typically to set a single-byte register value
- Multi-Bytes to select a register address and write several bytes to it, typically to set multiple configuration bytes

## I<sup>2</sup>C Register Read

**Figure 10:**  
I<sup>2</sup>C Register Read



- Since no register address can be supplied during an I<sup>2</sup>C read, an I<sup>2</sup>C write needs to be prepended to select the required register first.
- The write and read operations can optionally be combined into a single transaction using a repeated start condition, as shown in the second example above.
- Select and repeatedly read multiple data values from register, if the three reads are from the same register (mailbox), or from three subsequent registers (mailboxes).

## Application Register Overview

All I<sup>2</sup>C transactions must use the (7 bits) slave address 0x5A or 0x5B depending on status of ADDR pin when writing to and reading from the CCS811. [Figure 11](#) shows the register map for CCS811. [Figure 23](#) shows the bootloader register map.

**Figure 11:**  
**CCS811 Application Register Map**

| Address | Register        | R/W | Size          | Description  |
|---------|-----------------|-----|---------------|--|
| 0x00    | STATUS          | R   | 1 byte        | Status register  |
| 0x01    | MEAS_MODE       | R/W | 1 byte        | Measurement mode and conditions register   |
| 0x02    | ALG_RESULT_DATA | R   | up to 8 bytes | Algorithm result. The most significant 2 bytes contain a ppm estimate of the equivalent CO <sub>2</sub> (eCO <sub>2</sub> ) level, and the next two bytes contain a ppb estimate of the total VOC level. |
| 0x03    | RAW_DATA        | R   | 2 bytes       | Raw ADC data values for resistance and current source used.  |
| 0x05    | ENV_DATA        | W   | 4 bytes       | Temperature and humidity data can be written to enable compensation  |
| 0x06    | NTC             | R   | 4 bytes       | Provides the voltage across the reference resistor and the voltage across the NTC resistor – from which the ambient temperature can be determined.   |
| 0x10    | THRESHOLDS      | W   | 5 bytes       | Thresholds for operation when interrupts are only generated when eCO <sub>2</sub> ppm crosses a threshold  |
| 0x11    | BASELINE        | R/W | 2 bytes       | The encoded current baseline value can be read. A previously saved encoded baseline can be written.  |
| 0x20    | HW_ID           | R   | 1 byte        | Hardware ID. The value is 0x81   |
| 0x21    | HW Version      | R   | 1 byte        | Hardware Version. The value is 0x1X  |
| 0x23    | FW_Boot_Version | R   | 2 bytes       | Firmware Boot Version. The first 2 bytes contain the firmware version number for the boot code.  |
| 0x24    | FW_App_Version  | R   | 2 bytes       | Firmware Application Version. The first 2 bytes contain the firmware version number for the application code   |
| 0xE0    | ERROR_ID        | R   | 1 byte        | Error ID. When the status register reports an error its source is located in this register   |
| 0xFF    | SW_RESET        | W   | 4 bytes       | If the correct 4 bytes (0x11 0xE5 0x72 0x8A) are written to this register in a single sequence the device will reset and return to BOOT mode.  |

**Note(s):**

1. The number of bytes read from a register must not exceed the size in this table.
2. For more information on CCS811 programming requirements please refer to **ams** application note AN000369.

## STATUS Register (0x00)

Single byte read only register which indicates if a device is active, if new data is available or if an error occurred.

**Figure 12:**  
Status Register

|         |   |   |           |            |   |   |       |
|---------|---|---|-----------|------------|---|---|-------|
| 7       | 6 | 5 | 4         | 3          | 2 | 1 | 0     |
| FW_MODE | - |   | APP_VALID | DATA_READY | - |   | ERROR |

| Bit(s) | Field      | Description  |
|--------|------------|--|
| 7      | FW_MODE    | 0: Firmware is in boot mode, this allows new firmware to be loaded<br>1: Firmware is in application mode. CCS811 is ready to take ADC measurements                       |
| 6:5    | -          | Reserved   |
| 4      | APP_VALID  | 0: No application firmware loaded<br>1: Valid application firmware loaded  |
| 3      | DATA_READY | 0: No new data samples are ready<br>1: A new data sample is ready in ALG_RESULT_DATA, this bit is cleared when ALG_RESULT_DATA is read on the I <sup>2</sup> C interface |
| 2:1    | -          | Reserved   |
| 0      | ERROR      | 0: No error has occurred<br>1: There is an error on the I <sup>2</sup> C or sensor, the ERROR_ID register (0xE0) contains the error source                               |



## MEAS\_MODE (Measurement and Conditions) Register (0x01)

This is Single byte register, which is used to enable sensor drive mode and interrupts.

**Figure 13:**  
**Measure Mode Register**

|   |            |   |   |           |        |   |   |
|---|------------|---|---|-----------|--------|---|---|
| 7 | 6          | 5 | 4 | 3         | 2      | 1 | 0 |
| - | DRIVE_MODE |   |   | INTERRUPT | THRESH | - |   |

| Bit(s) | Field       | Description   |
|--------|-------------|---|
| 7      | -           | Reserved – write '0'  |
| 6:4    | DRIVE_MODE  | <p>000: Mode 0 – Idle (Measurements are disabled in this mode)<br/>           001: Mode 1 – Constant power mode, IAQ measurement every second<br/>           010: Mode 2 – Pulse heating mode IAQ measurement every 10 seconds<br/>           011: Mode 3 – Low power pulse heating mode IAQ measurement every 60 seconds<br/>           100: Mode 4 – Constant power mode, sensor measurement every 250ms<br/>           1xx: Reserved modes (For future use)</p> <p>In mode 4, the ALG_RESULT_DATA is not updated, only RAW_DATA; the processing must be done on the host system.</p> <p>A new sample is placed in ALG_RESULT_DATA and RAW_DATA registers and the DATA_READY bit in the STATUS register is set at the defined measurement interval.</p> |
| 3      | INT_DATARDY | <p>0: Interrupt generation is disabled<br/>           1: The nINT signal is asserted (driven low) when a new sample is ready in ALG_RESULT_DATA. The nINT signal will stop being driven low when ALG_RESULT_DATA is read on the I<sup>2</sup>C interface.</p> <p>At the end of each measurement cycle (250ms, 1s, 10s, 60s) a flag is set in the STATUS register regardless of the setting of this bit..</p>  |
| 2      | INT_THRESH  | <p>0: Interrupt mode (if enabled) operates normally<br/>           1: Interrupt mode (if enabled) only asserts the nINT signal (driven low) if the new ALG_RESULT_DATA crosses one of the thresholds set in the THRESHOLDS register by more than the hysteresis value (also in the THRESHOLDS register)</p>   |
| 1:0    | -           | Reserved  |

### ALG\_RESULT\_DATA (Algorithm Results Data) Register (0x02)

This multi-byte read only register contains the calculated eCO<sub>2</sub> (ppm) and TVOC (ppb) values followed by the STATUS register, ERROR\_ID register and the RAW\_DATA register.

- If only eCO<sub>2</sub> is required, only the first 2 bytes need to be read.
- If TVOC is required, 4 bytes need to be read.
- In a system where interrupts are not implemented and the host needs to poll the STATUS register to determine whether there is new data, an efficient alternative is to read 5 bytes in a single transaction since that returns eCO<sub>2</sub>, TVOC and the status register.
- Optionally, all 8 bytes could be read in a single transaction, so that even the error status and the raw data is available.

**Figure 14:**  
Algorithm Results Register Byte Order

| Byte 0                     | Byte 1                    | Byte 2         | Byte 3        | Byte 4 | Byte 5   | Byte 6 & 7   |
|----------------------------|---------------------------|----------------|---------------|--------|----------|--------------|
| eCO <sub>2</sub> High Byte | eCO <sub>2</sub> Low Byte | TVOC High Byte | TVOC Low Byte | STATUS | ERROR_ID | See RAW_DATA |

### RAW\_DATA Register (0x03)

Two byte read only register which contains the latest readings from the sense resistor.

The most significant 6 bits of the Byte 0 contain the value of the current through the sensor (0μA to 63μA).

The lower 10 bits contain (as computed from the ADC) the readings of the voltage across the sensor with the selected current (1023 = 1.65V)

**Figure 15:**  
RAW\_DATA Register Byte Order

| Byte 0               |   |   |   |   |   |   |   | Byte 1              |   |   |   |   |   |   |   |
|----------------------|---|---|---|---|---|---|---|---------------------|---|---|---|---|---|---|---|
| 7                    | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7                   | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Current Selected 5:0 |   |   |   |   |   |   |   | Raw ADC reading 9:0 |   |   |   |   |   |   |   |

**ENV\_DATA (Environment Data) Register (0x05)**

A multi-byte register that can be written with the current Humidity and Temperature values if known.

**Relative Humidity**

**Figure 16:**  
Relative Humidity Fields and Byte Order

| Byte 0             |    |    |   |   |   |   |     | Byte 1              |     |      |      |      |       |       |       |
|--------------------|----|----|---|---|---|---|-----|---------------------|-----|------|------|------|-------|-------|-------|
| Humidity High Byte |    |    |   |   |   |   |     | Humidity Low Byte   |     |      |      |      |       |       |       |
| 7                  | 6  | 5  | 4 | 3 | 2 | 1 | 0   | 7                   | 6   | 5    | 4    | 3    | 2     | 1     | 0     |
| 64                 | 32 | 16 | 8 | 4 | 2 | 1 | 1/2 | 1/4                 | 1/8 | 1/16 | 1/32 | 1/64 | 1/128 | 1/256 | 1/512 |
| Humidity %         |    |    |   |   |   |   |     | Humidity % Fraction |     |      |      |      |       |       |       |

Humidity is stored as an unsigned 16 bits in 1/512%RH. The default value is 50% = 0x64, 0x00. As an example 48.5% humidity would be 0x61, 0x00.

**Temperature**

**Figure 17:**  
Temperature Fields and Byte Order

| Byte 2                |    |    |   |   |   |   |     | Byte 3                    |     |      |      |      |       |       |       |
|-----------------------|----|----|---|---|---|---|-----|---------------------------|-----|------|------|------|-------|-------|-------|
| Temperature High Byte |    |    |   |   |   |   |     | Temperature Low Byte      |     |      |      |      |       |       |       |
| 7                     | 6  | 5  | 4 | 3 | 2 | 1 | 0   | 7                         | 6   | 5    | 4    | 3    | 2     | 1     | 0     |
| 64                    | 32 | 16 | 8 | 4 | 2 | 1 | 1/2 | 1/4                       | 1/8 | 1/16 | 1/32 | 1/64 | 1/128 | 1/256 | 1/512 |
| Temperature 25°C      |    |    |   |   |   |   |     | Temperature 25°C Fraction |     |      |      |      |       |       |       |

Temperature is stored as an unsigned 16 bits integer in 1/512 degrees; there is an offset: 0 maps to -25°C. The default value is 25°C = 0x64, 0x00. As an example 23.5% temperature would be 0x61, 0x00.

The internal algorithm uses these values (or default values if not set by the application) to compensate for changes in relative humidity and ambient temperature.

### NTC Register (0x06)

Four byte read only register which contains the voltage across resistor ( $R_{REF}$ ) and the voltage across the NTC resistor from which the ambient temperature can be determined.

The resistance of the NTC resistor can be determined by the ratio value and knowledge of the reference resistor used.

$R_{NTC} = V_{NTC} \times R_{REF} / V_{REF}$ . The temperature can be determined from the resistance of the NTC resistor from the datasheet of the NTC resistor used.

**Figure 18:**  
NTC Register Byte Order

| Byte 0                        | Byte 1   | Byte 2                        | Byte 3   |
|-------------------------------|----------|-------------------------------|----------|
| Voltage across $R_{REF}$ (mV) |          | Voltage across $R_{NTC}$ (mV) |          |
| High Byte                     | Low Byte | High Byte                     | Low Byte |

This enables the host to calculate the ambient temperature and this information can be written to CCS811 to compensate for temperature changes.

### THRESHOLDS Register (0x10)

If 'interrupt on threshold change' has been set in the Mode register (see above), the values in this multi- byte write only register are used to determine the thresholds and the level of hysteresis desired.

**Figure 19:**  
Thresholds Register Byte Order

| Byte 0                  | Byte 1   | Byte 2                   | Byte 3   | Byte 4           |
|-------------------------|----------|--------------------------|----------|------------------|
| Low to Medium Threshold |          | Medium to High Threshold |          | Hysteresis Value |
| High Byte               | Low Byte | High Byte                | Low Byte |                  |

An interrupt is asserted if the  $eCO_2$  value moved from the current range (Low, Medium, or High) into another range by more than the Hysteresis value (used to prevent multiple interrupts close to a threshold).

- Low to Medium Threshold default = 1500ppm = 0x05DC
- Medium to High Threshold default = 2500ppm = 0x09C4
- Hysteresis value default = 50 = 0x32

### **BASELINE Register (0x11)**

A two byte read/write register which contains an encoded version of the current baseline used in Algorithm Calculations.

A previously stored value may be written back to this two byte register and the Algorithms will use the new value in its calculations (until it adjusts it as part of its internal Automatic Baseline Correction).

### **HW\_ID (Hardware identifier) Register (0x20)**

Single byte read only register which holds the HW ID which is 0x81 for this family of CCS81x devices.

### **HW\_Version (Hardware Version) Register (0x21)**

Single byte read only register which holds the Hardware Major and Minor Hardware versions.

The top four bits read major hardware version 1 – identifying the product as CCS811. The bottom four bits identify any build variant. The default value is 0x1X.

### **FW\_Boot\_Version (Firmware Bootloader Version) Register (0x23)**

Two byte read only register which contain the version of the firmware bootloader stored in the CCS811 in the format Major.Minor.Trivial

**Figure 20:**  
**Firmware Bootloader Version Format**

| Byte 0 |   |   |   |       |   |   |   | Byte 1  |   |   |   |   |   |   |   |
|--------|---|---|---|-------|---|---|---|---------|---|---|---|---|---|---|---|
| 7      | 6 | 5 | 4 | 3     | 2 | 1 | 0 | 7       | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Major  |   |   |   | Minor |   |   |   | Trivial |   |   |   |   |   |   |   |

### FW\_App\_Version (Firmware Application Version) Register (0x24)

Two byte read only register which contain the version of the firmware application stored in the CCS811 in the format Major.Minor.Trivial

**Figure 21:**  
Firmware Application Version Format

| Byte 0 |   |   |   |       |   |   |   | Byte 1  |   |   |   |   |   |   |   |
|--------|---|---|---|-------|---|---|---|---------|---|---|---|---|---|---|---|
| 7      | 6 | 5 | 4 | 3     | 2 | 1 | 0 | 7       | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Major  |   |   |   | Minor |   |   |   | Trivial |   |   |   |   |   |   |   |

### ERROR\_ID (Error Identifier) Register (0xE0)

If the ERR bit [0] of the STATUS Register is set, this single byte read only register indicates source(s) of the error.

**Figure 22:**  
ERROR\_ID Register Codes

| Bit | ERROR_CODE        | Description  |
|-----|-------------------|--|
| 0   | WRITE_REG_INVALID | The CCS811 received an I <sup>2</sup> C write request addressed to this station but with invalid register address ID |
| 1   | READ_REG_INVALID  | The CCS811 received an I <sup>2</sup> C read request to a mailbox ID that is invalid                                 |
| 2   | MEASMODE_INVALID  | The CCS811 received an I <sup>2</sup> C request to write an unsupported mode to MEAS_MODE                            |
| 3   | MAX_RESISTANCE    | The sensor resistance measurement has reached or exceeded the maximum range  |
| 4   | HEATER_FAULT      | The Heater current in the CCS811 is not in range   |
| 5   | HEATER_SUPPLY     | The Heater voltage is not being applied correctly  |
| 6   | -                 | Reserved for Future Use  |
| 7   | -                 | Reserved for Future Use  |

**SW\_RESET Register (0xFF)**

As an alternative to Power-On reset or Hardware Reset a Software Reset is available.

Asserting the SW\_RESET will restart the CCS811 in Boot mode to enable new application firmware to be downloaded.

To prevent accidental SW\_RESET a sequence of four bytes must be written to this register in a single I<sup>2</sup>C sequence: 0x11, 0xE5, 0x72, 0x8A.

For details, please refer to application notes **ams** AN000369 and **ams** AN000371.

## Bootloader Register Overview

All I<sup>2</sup>C transactions must use the (7bits) slave address 0x5A or 0x5B depending on status of ADDR pin when writing to and reading from the CCS811. [Figure 23](#) shows the bootloader register map for CCS811.

**Figure 23:**  
CCS811 Bootloader Register Map

| Address | Register        | R/W | Size    | Description   |
|---------|-----------------|-----|---------|---|
| 0x00    | STATUS          | R   | 1 byte  | Status register   |
| 0x20    | HW_ID           | R   | 1 byte  | Hardware ID. The value is 0x81  |
| 0x21    | HW Version      | R   | 1 byte  | Hardware Version. The value is 0x1X   |
| 0x23    | FW_Boot_Version | R   | 2 bytes | Firmware Boot Version. The first 2 bytes contain the firmware version number for the boot code.   |
| 0x24    | FW_App_Version  | R   | 2 bytes | Firmware Application Version. The first 2 bytes contain the firmware version number for the application code.   |
| 0xE0    | ERROR_ID        | R   | 1 byte  | Error ID. When the status register reports an error it source is located in this register   |
| 0xF1    | APP_ERASE       | W   | 4 bytes | If the correct 4 bytes (0xE7 0xA7 0xE6 0x09) are written to this register in a single sequence the device will start the application erase  |
| 0xF2    | APP_DATA        | W   | 9 bytes | Transmit flash code for the bootloader to write to the application flash code space.  |
| 0xF3    | APP_VERIFY      | W   | -       | Starts the process of the bootloader checking though the application to make sure a full image is valid.  |
| 0xF4    | APP_START       | W   | -       | Application start. Used to transition the CCS811 state from boot to application mode, a write with no data is required. Before performing a write to APP_START the Status register should be accessed to check if there is a valid application present. |
| 0xFF    | SW_RESET        | W   | 4 bytes | If the correct 4 bytes (0x11 0xE5 0x72 0x8A) are written to this register in a single sequence the device will reset and return to BOOT mode.   |

**Note(s):**

1. The number of bytes read from a register must not exceed the size in this table.
2. For more information on performing application code download please refer to application note **ams** AN000371.



Registers not detailed below are documented in the [Application Register Overview](#) section.

### **APP\_ERASE (Application Erase) Register (0xF1)**

To prevent accidental APP\_ERASE a sequence of four bytes must be written to this register in a single I<sup>2</sup>C sequence: 0xE7, 0xA7, 0xE6, 0x09.

The APP\_ERASE can take a variable amount of time. The status register can be polled to determine when this function is complete. The 6<sup>th</sup> bit (0x40) is initialised to 0 and set to a 1 on completion of the APP\_ERASE function. After an erase this bit is only cleared by doing a reset or starting the application.

### **APP\_DATA (Application Data) Register (0xF2)**

Nine byte, write only register for sending small chunks of application data which will be written in order to the CCS811 flash code.

### **APP\_VERIFY (Application Verify) Register (0xF3)**

Single byte write only register which starts the application verify process run by the bootloader to check for a complete application code image. Command only needs to be called once after a firmware download as the result is saved in a flash location that gets checked during device initialisation.

The APP\_VERIFY can take a variable amount of time. The status register can be polled to determine when this function is complete. The 5<sup>th</sup> bit (0x20) is initialised to 0 and set to a 1 on completion of the APP\_VERIFY function. After an APP\_VERIFY this bit is only cleared by doing a reset or starting the application.

For details on downloading new application firmware please refer to application note **ams** AN000371.

### **APP\_START (Application Start) Register (0xF4)**

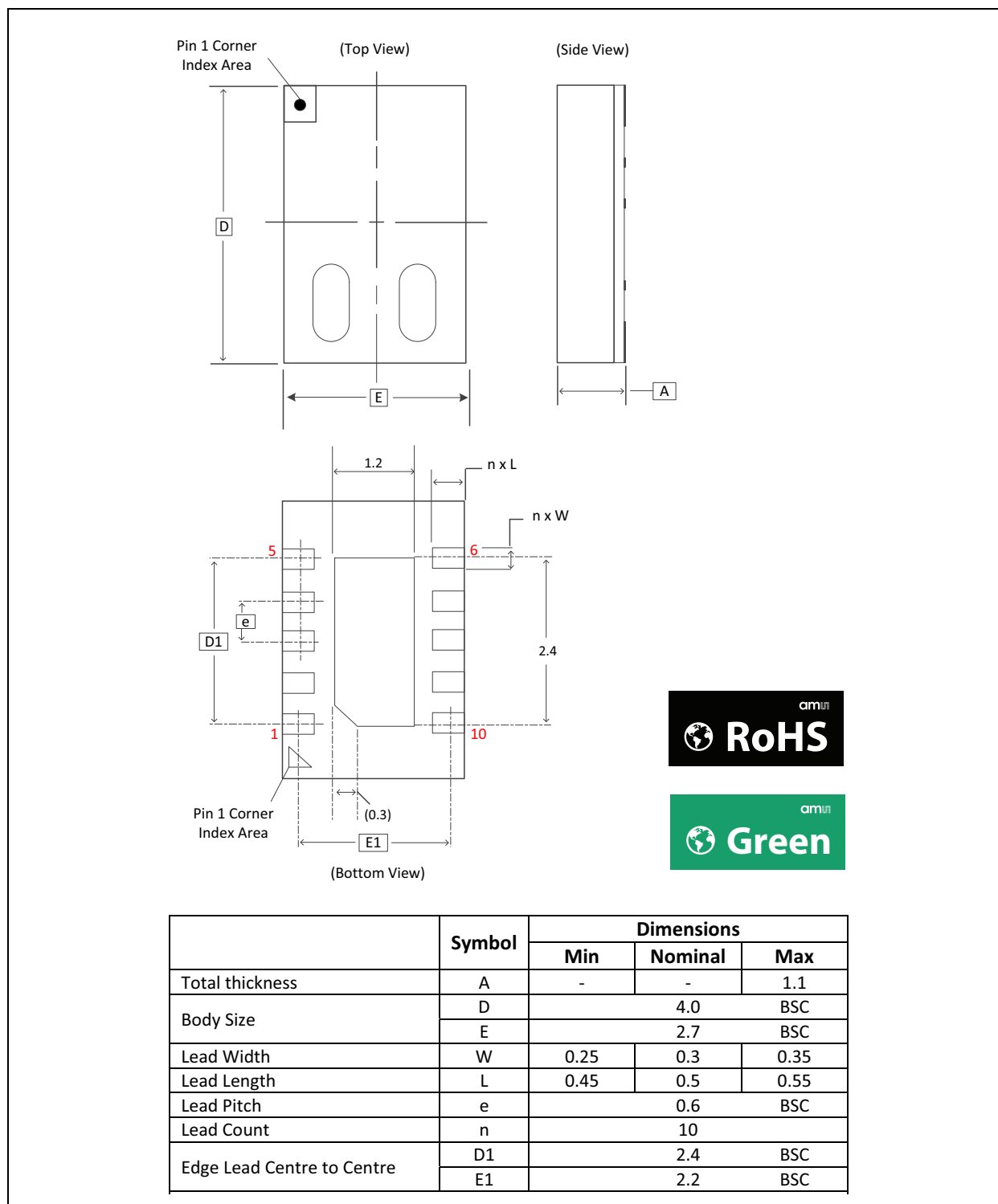
To change the mode of the CCS811 from Boot mode to running the application, a single byte write of 0xF4 is required.

The CCS811 interprets this as an address write to select the 'APP\_START' register and starts running the loaded application software if it is a valid version (Refer to the [STATUS Register \(0x00\)](#)).

## Package Drawings & Marking

### LGA Package Outline

**Figure 24:**  
LGA Package Drawings

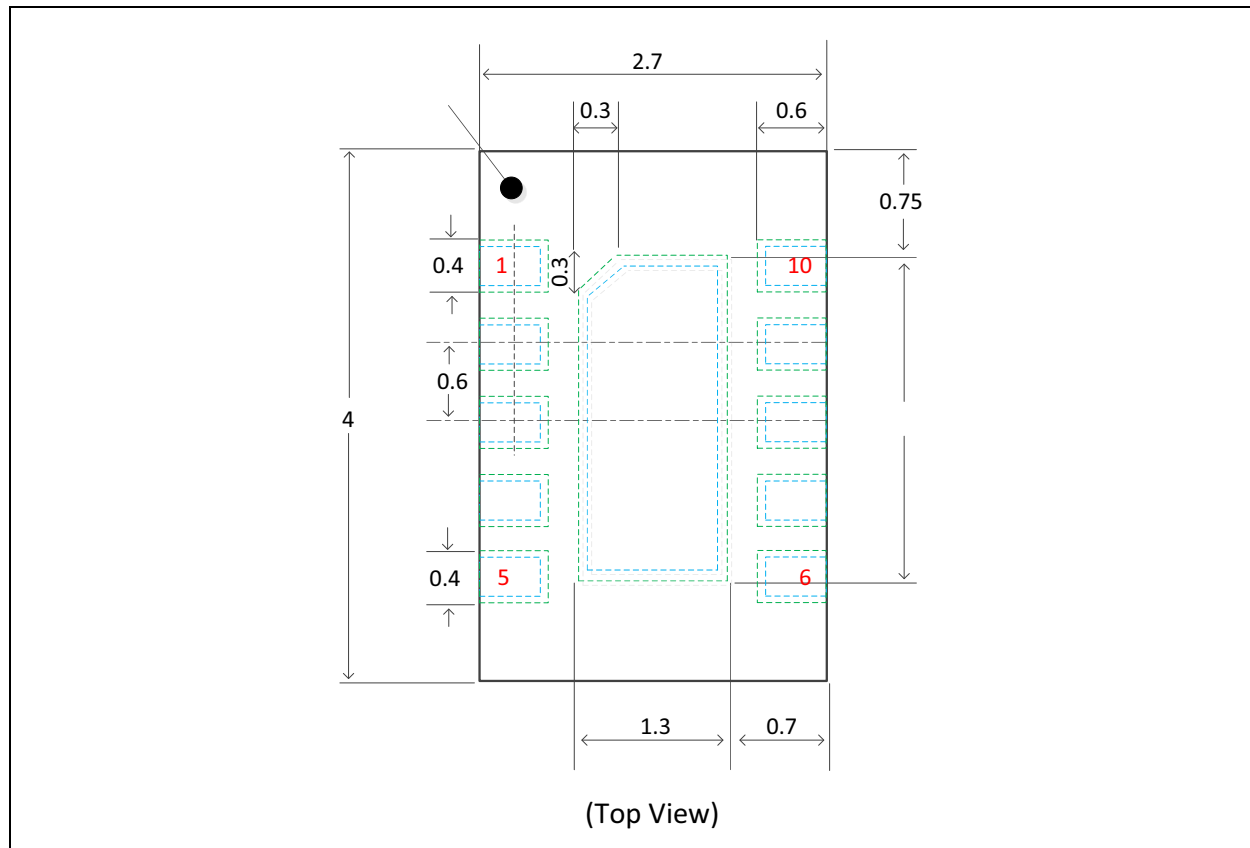


**Note(s):**

1. All dimensions are in millimeters.

The recommended package footprint or landing pattern for CCS811 is shown below:

**Figure 25:**  
**Recommended Package Footprint for CCS811**



**Note(s):**

1. All dimensions are in millimeters.
2. PCB land pattern in **Green** dash lines
3. Pin numbers are in **Red**
4. Add 0.05mm all around the nominal lead width and length for the PCB land pattern

## Ordering & Contact Information

**Figure 26:**  
Ordering Information

| Ordering Code   | Description   | Package                   | MOQ  |
|-----------------|---|---------------------------|------|
| CCS811B-JOPR5K  | CCS811 digital gas sensor for Indoor Air Quality Monitoring           | 2.7mm x 4.0mm x 1.1mm LGA | 5000 |
| CCS811B-JOPD500 | Sample of CCS811 digital gas sensor for Indoor Air Quality Monitoring | 2.7mm x 4.0mm x 1.1mm LGA | 500  |

**Note(s):**

1. Refer to JEDEC J-STD020 lead-free standard for typical soldering reflow profile

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## Document Status

| Document Status          | Product Status  | Definition   |
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| Product Preview          | Pre-Development | Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice  |
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## Revision Information

| Changes from 1-00 (2016-Dec-23) to current revision 1-02 (2017-Mar-15) | Page |
|--|------|
| <b>1-00 (2016-Dec-23) to 1-01 (2017-Feb-16)</b>                        |      |
| Updated Figure 2   | 3    |
| Updated Figure 4   | 4    |
| Updated Figure 8 and notes below                                       | 12   |
| <b>1-01 (2017-Feb-16) to 1-02 (2017-Mar-15)</b>                        |      |
| Removed Product Marking information                                    |      |
| Updated Figure 5   | 5    |
| Updated Figure 8 and notes under it                                    | 12   |
| Updated Figure 26  | 28   |

**Note(s):**

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.



## Appendix

### References

**Figure 27:**  
**Document Reference**

| Document Reference  | Description                                  |
|---------------------|--|
| <b>ams</b> AN000367 | Assembly guidelines for CCS811               |
| <b>ams</b> AN000368 | Mechanical considerations for CCS811         |
| <b>ams</b> AN000369 | CCS811 programming and interfacing guide     |
| <b>ams</b> AN000370 | CCS811 Clean Air Baseline Save and Restore   |
| <b>ams</b> AN000371 | CCS811 Performing a Firmware download        |
| <b>ams</b> AN000372 | Connecting an NTC Thermistor to the CCS811   |
| <b>ams</b> AN000373 | CCS811 Manufacture Test Procedure            |
| <b>ams</b> WP000102 | IAQ User experience during initial operation |

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