AmbiMate Sensor Module

NOTE
All numerical values are in metric units [with U.S. customary units in brackets]. Dimensions are in millimeters [and inches]. Unless otherwise specified, dimensions have a tolerance of ±0.13 [±.005] and angles have a tolerance of ±2°. Figures and illustrations are for identification only and are not drawn to scale.

1 INTRODUCTION

1.1 Applications

The AmbiMate MS4 Sensor Module is suitable for sensing the characteristics of indoor environments, and utilizes a cluster of common sensors to report current conditions. The AmbiMate measures temperature, humidity, ambient light, motion, and optionally sound and/or VOC/eCO_2. The AmbiMate reports data via an I^2C bus to a customer supplied host PCB Assembly. The variety of sensors and small package size make the AmbiMate suitable for multiple indoor applications:

- Indoor Lighting
- Thermostat and HVAC inputs
- Building Automation networks

1.2 Solution Overview

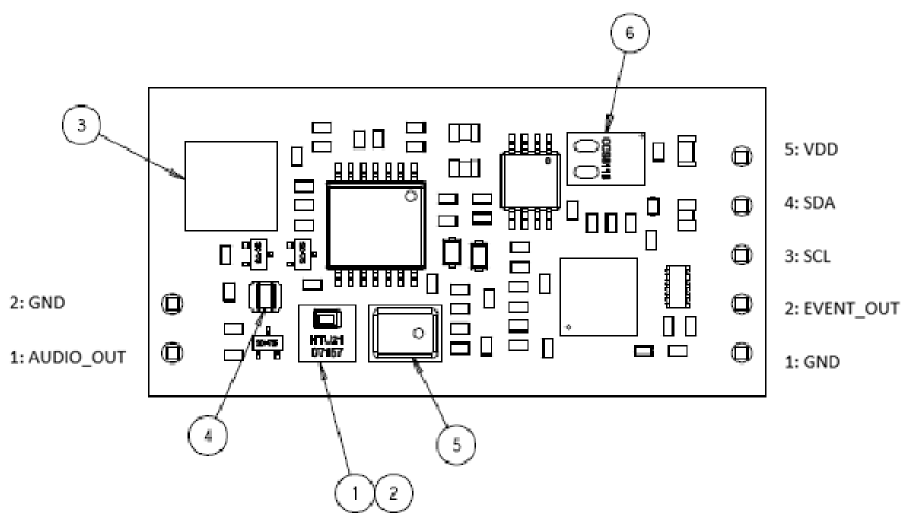

Figure 1: AmbiMate Layout
1: Temperature, 2: Humidity, 3: Motion, 4: Light, 5: Audio, 6: eCO_2/VOC

Figure 1 shows the defined sensor locations for the AmbiMate. This diagram and the terminology in Table 1 are used throughout this document to describe functionality, capabilities and design practice.

1.3 Customer Assistance

Reference Product Base Part Number 2316851, 2316852, 2314277, and 2314291. Use of these numbers will identify the product line and help you to obtain product and tooling information when visiting www.te.com or calling the number at the bottom of this page.

1.4 Drawings

Customer drawings for product part numbers are available from www.te.com. Information contained in the customer drawing takes priority.

1.5 Specifications

Product Specification 108-133092 provides product performance.

Application Specification 114-133115 provides information regarding application software.

2 REQUIREMENTS

2.1 Safety

Perform all electrical connections to the AmbiMate with power turned OFF. Always make sure, a ground connection is established first before adding power to the product.

2.2 Limitations

The AmbiMate is designed to operate in a temperature range of -5° to 50°C [23° to 122°F].

2.3 Material

This is a PCB assembly made from FR4 material.

2.4 Storage

2.4.1 Ultraviolet Light

Prolonged exposure to ultraviolet light may deteriorate the chemical composition used in the product material.

2.4.2 Shelf Life

The product should remain in the shipping containers until ready for use to prevent deformation to components. The product should be used on a first in, first out basis to avoid storage contamination that could adversely affect performance.

2.4.3 Chemical Exposure

Do not store product near any chemical listed below as they may cause stress corrosion cracking in the material.

Alkaline	Ammonia	Citrates	Phosphates Citrates	Sulfur Compounds
Amines	Carbonates	Nitrites	Sulfur Nitrites	Tartrates

2.5 Handling

The AmbiMate is a PCB Assembly, and should be handled with care to avoid ESD

ATTENTION
— Observe precautions for handling electrostatic sensitive devices.

2.6 Cleaning

CAUTION
— Do not wash the product with aqueous or solvent based cleaners. Do not blow the product off with compressed air pressure greater than 20 psi.

3 ELECTRONIC DESIGN GUIDANCE

3.1 Electrical Design Guidance

Term/Acronym	Meaning
AmbiMate	AmbiMate Sensor Module
ACK	Acknowledgement
ADC	Analog to Digital Converter
Baud	Pulses per second
CO_2	Carbon Dioxide
DAC	Digital to Analog Converter
I^2C	Inter-Integrated Circuit bus protocol. Multi-master, multi-slave, single-ended, serial computer bus
NACK	Negative Acknowledgement
PCBA	Printed Circuit Board Assembly. A PCBA comprises a printed circuit board (PCB) and all the installed components to create a functional assembly.
PIR	Passive Infrared
SCL / SDA	Serial Clock / Serial Data
S/N	Signal to Noise Ratio
VOC	Volatile Organic Compound

Table 1. Terminology

3.2 Functional Element Overview

Figure 2 shows a block diagram of the functional blocks of the AmbiMate printed circuit board assembly. The following sections overview the capability of each block. More detailed description, where applicable, can be found in the architecture and sensors sections.

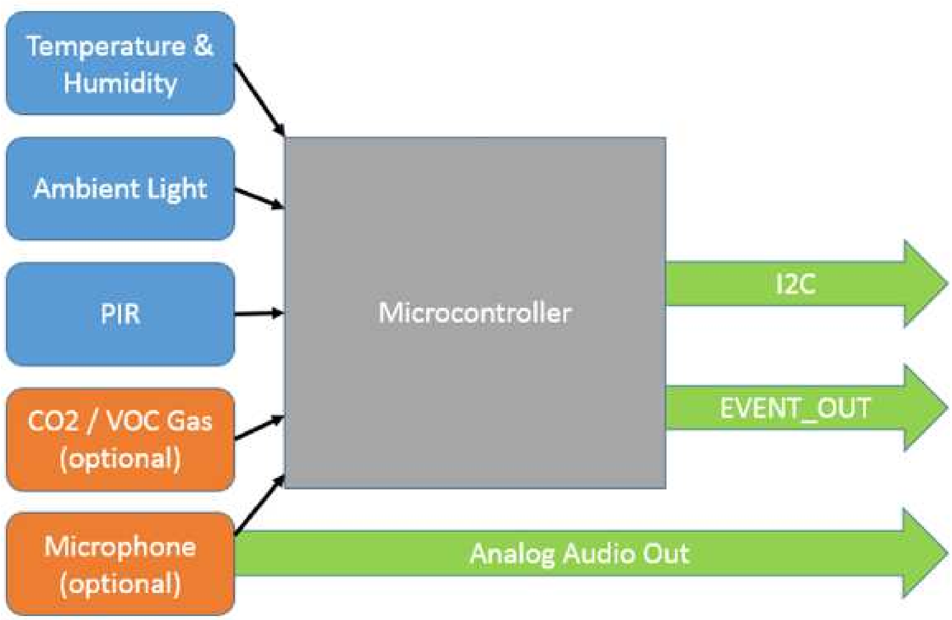

Figure 2. AmbiMate Functional Block Diagram

3.3 Power Supply

The AmbiMate is powered by 3.3 ± 0.2 V dc, required for I^2C communication. This voltage is to be provided by the host board, whether that is a battery or other regulated supply.

3.4 Sensors

3.4.1 Temperature Sensor: The temperature sensor is combined with the relative humidity sensor in the same package. The sensor's I^2C output is read by the AmbiMate's microcontroller.

Note: Actual performance may vary due to customer enclosure design. Enclosure should allow for air circulation to ensure sensor is responding to temperature changes within the intended environment of use. Please refer to 108-133092 for performance of product.

3.4.2 Relative Humidity Sensor: The relative humidity sensor is combined with the temperature sensor in the same package. The sensor's I^2C output is read by the AmbiMate's microcontroller.

Note: Actual performance may vary due to customer enclosure design. Enclosure should allow for air circulation to ensure sensor is responding to humidity changes within the intended environment of use. Please refer to 108-133092 for performance of product.

3.4.3 Ambient Light Photo Sensor: The photo sensor mimics the responsivity of the human eye. The analog output from the sensor is read by the AmbiMate's microcontroller's analog to digital converter.

Note: Ambient light impinges directly on the sensor, no light pipe. If in the final application the photo sensor becomes shadowed, then a light pipe will be required to achieve optimum performance. The light pipe design is dependent upon the final application and use and is beyond the scope of this application specification. Please refer to 108-133092 for performance of product.

3.4.4 Passive Infrared Motion Sensor (PIR): The PIR senses motion. The output from the sensor is read by the AmbiMate's microcontroller. During design-in and mounting the AmbiMate consideration should be given for placement of the device on a ceiling, wall or in a corner to maximize the PIR sensors effectiveness. A Fresnel lens is required, please contact TE customer support for information on the lens. During a motion event, the Event_Out pin will go high. Related to the PIR sensor is the motion event LED. When the AmbiMate senses motion the motion event LED will illuminate. For enhanced motion detection, please contact TE customer support.

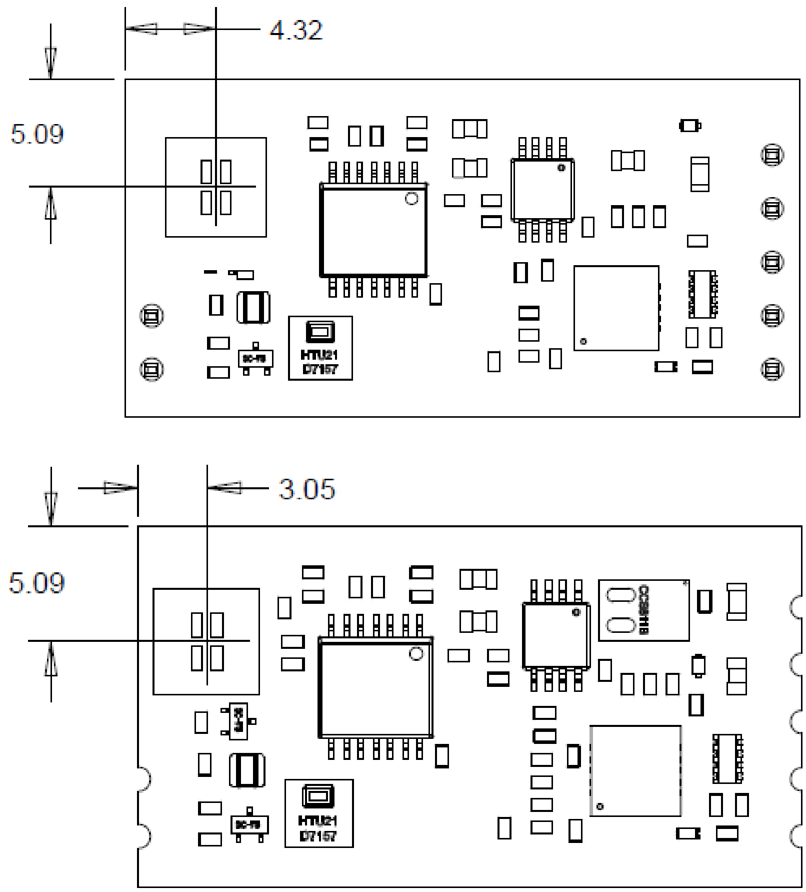

Figure 3: PIR sensor location

3.4.5 Acoustic Microphone with Pre-Amp: The microphone is omnidirectional with an analog output. The analog output from the microphone is read by the AmbiMate's microcontroller's analog to digital converter and is available to the host application via the 2-pin connector. The AmbiMate is configured to identify an audio event which can be set by writing to register 0xC1. At audio levels below 75 dB, quantization of the ADC will limit reported values to the following: 20, 58, 64, 67, 70, 73, 75. Above 75 dB, the AmbiMate will report in 1 dB increments. The preset sound level can be adjusted by the host. The analog output can be used to define a specific gain circuit. Please refer to the 108-133092 for detailed test data on the analog output. The characteristics of the microphone are summarized in the table below:

Conditions: 23 ±2°C, 55 ±20% R.H.

Parameter	Symbol	Specification		SPECIFICATION		
			Units	Min	Typ.	Max
Sensitivity[1]	S	94 dB SPL @ 1 kHz	dBV/Pa	-25	-22	-19
S/N ratio	SNR	94 dB SPL @ 1 kHz, A-weighted	dB(A)	-	59	-
Total Harmonic Distortion	THD	94dB SPL @ 1 kHz, S=Typ	%	-	-	1
Acoustic Overload Point	AOP	10% THD @ 1 kHz, S=Typ	dB SPL	115	-	-
Directivity[1]	Omnidirectional					

Note: Actual performance may vary due to customer enclosure design. Customer enclosure design should be optimized to avoid resonances. Please refer to 108-133092 for performance of product.

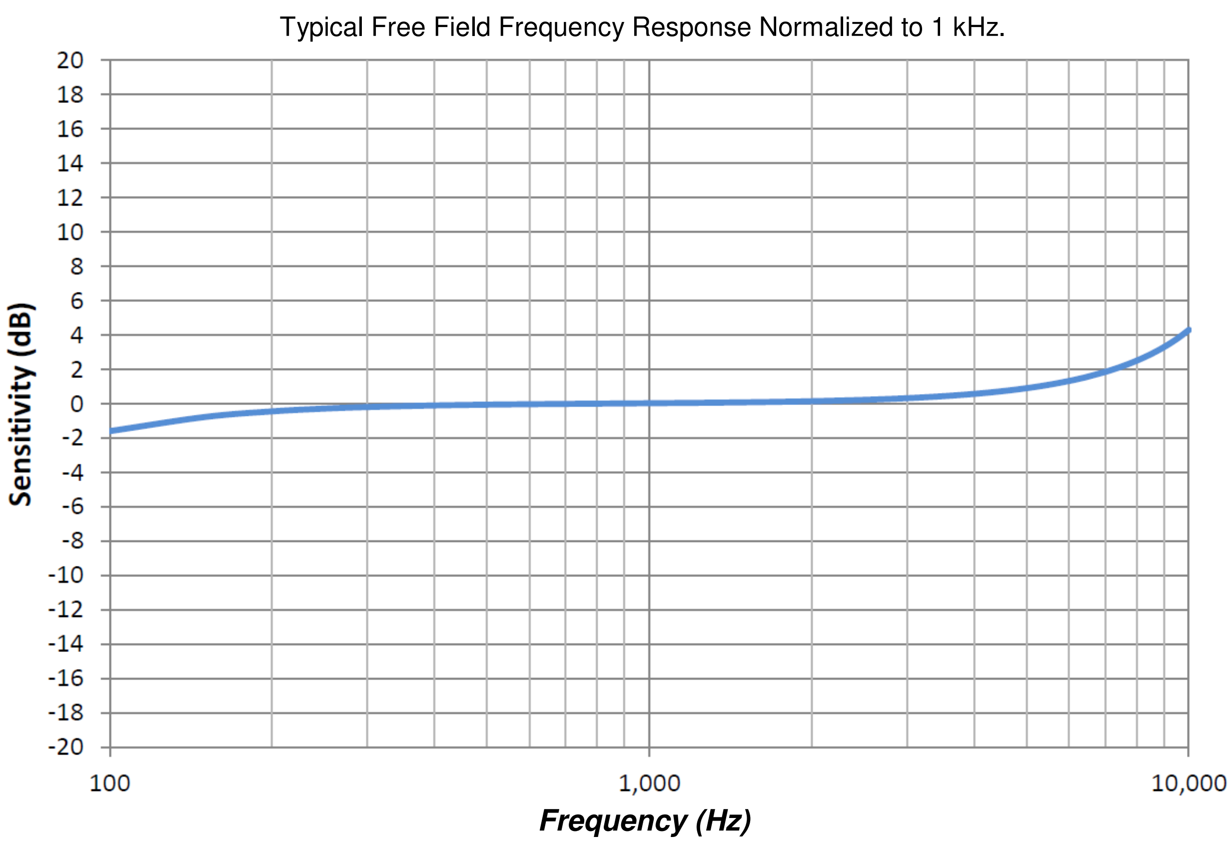

Figure 4, Microphone Sensitivity vs Frequency Curve

3.4.6 Equivalent CO_2 / VOC Gas Sensor: The gas sensor measures TVOC or equivalent-CO_2 with a digital output via an I^2C interface. The output from the sensor is read by the AmbiMate's microcontroller. The eCO_2/VOC sensor is suitable to perform optimal in office conditions. Please be aware that any type of silicones, cause sensor poisoning and will reduce the sensitivity irrecoverably. The sensor will perform an automatic baseline correction every 24 hours. The characteristics of the sensor are summarized in the table below

Operating Conditions: 25°C

Parameter	Specification or Condition		SPECIFICATION		
		Units	Min	Typ.	Max
Operating Temperature Range	Operating temperature limits to remain within spec	°C	-5	-	50
Operating Humidity Range	Operating temperature limits to remain within spec	%RH	5	-	95
VOC measurement range	Measurement range for TVOC (Total Volatile Organic Compounds)	ppb	0	-	1187
CO2 measurement range (note 1)	Measurement range for eCO2 (Equivalent CO2)	ppm	400	-	8192
Sample Interval	Time between sample measurements	seconds	-	60	-

Notes:

- *eCO_2 concentration is inferred from VOC measurement.*
- *The equivalent CO_2 output range is from 400ppm to 8192ppm. Values outside this range can be ignored.*
- *The Total Volatile Organic Compound (TVOC) output range is from 0ppb to 1187ppb, Values outside this range can be ignored.*
- *Early life use (burn-in): The gas sensor performance and sensitivity will change during early life use. It is recommended to run the sensor for approximately 24 hours initially to ensure stable sensor performance. All values read in the first 24 hours must be ignored.*
- *For a sensor that is burned in, after a power down, the stabilization takes 20 minutes after power up.*

3.5 Signal Information

Table 2 and 3 provide the pin numbers, signal names and descriptions of the Customer Accessible pins on the AmbiMate. “I” designates input pins and “O” designates output pins.

Pin	Signal	I/O	Description
1	GND	I/O	Common Connection
2	EVENT_OUT	O	Motion detection
3	SCL	O	Clock signal for I^2C bus
4	SDA	O	Data signal for I^2C bus
5	Vdd	I	3.3 V dc Input

Table 2. 5 Pin Header I2C Signals

Pin	Signal	I/O	Description
1	Audio Output	O	Analog Audio Output Signal
2	GND	O	Common connection

Table 3. 2 Pin Header Audio Signals

3.6 I2C considerations

The host I^2C interface is addressable on address: 0x2A. The maximum practical baud rate is 100 kBaud. Please make sure the host device using is capable of clock stretching, otherwise a lower baud rate is recommended.[1] The host interface will ensure I^2C communication via Pin 3 (SCL) and Pin 4 (SDA), please be aware of considering a 3.3 V dc I^2C communication. Motion events are triggered on the Event_Out pin.

Data is delivered as raw data, therefore scaling and conversion is left to the host.

3.6.1 Module Registers (Read and write via I2C)

Sensor data is available in two register sets. Full resolution data consists of two registers (two bytes) for each sensor. Please make sure connection between the host and ground is established before 3.3 V dc connection is connected. Otherwise, sensors are not recognized correctly.
Table 4 shows the register address and data value for these registers. Temperature, Humidity, PIR, and Light are available on all modules. Audio and eCO_2 are optional and only fitted to some modules but registers are always available but will read maximum (0xFF, 0xFF) if the sensor is not fitted. The input is pulled up to 3.3 volts when a sensor is not fitted. During initialization, the AmbiMate ADC initially uses a 3.3 V reference to measure the optional sensors. If an optional register reads greater than 0x80, equivalent to 1.65 volts, the AmbiMate firmware determines that the sensor is not installed and not scan that sensor and will report it missing in the status byte.
The host computer can read all registers or can stop at any time with an I^2C NACK and Stop. For example, if the host knows that Audio and Gas sensors are not installed, and if the host is not concerned with the Battery voltage, it can read the status byte, temperature, humidity and light value and send a NACK on the Light Low Byte followed by an I^2C stop to minimize the communication time.

Register Address	Data Value
0x00	Status High Byte
0x01	Temperature High Byte
0x02	Temperature Low Byte
0x03	Humidity High Byte
0x04	Humidity Low Byte
0x05	Light High Byte
0x06	Light Low Byte

[1] For more information about host-devices and application software, please check 114-133115.

0x07	Audio High Byte
0x08	Audio Low Byte
0x09	Battery Volts High Byte
0x0A	Battery Volts Low Byte
0x0B	eCO_2 High Byte
0x0C	eCO_2 Low Byte
0x0D	VOC High Byte
0x0E	VOC Low Byte

Table 4. Sensor data registers.

In some cases, 8-bit resolution is adequate as shown in Table 5. A second set of registers is available with the high bytes in sequence to allow the host to read them with a single transaction.

Register Address	Data Value
0x40	Status High Byte
0x41	Temperature High Byte
0x42	Humidity High Byte
0x43	Light High Byte
0x44	Audio High Byte
0x45	Battery Volts High Byte
0x46	CO2 CO High Byte
0x47	VOC High Byte

Table 5. 8-bit Sensor data registers.

Other registers shown in Table 6.

Register Address	Data Value
0x80	Firmware version
0x81	Firmware sub-version
0X82	Optional Sensors

Table 6. Other registers.

Writeable registers are shown in Table 7.

Register Address	Data Value	Read/Write
0xC0	Scan Start Byte	W
0xC1	Audio Event Level	R/W
0xF0	0xA5 initiates a processor reset All other values ignored	

Table 7. Writeable registers.

3.6.2 Optional Sensors Byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	MIC	Reserved	CO2

Bit 0 CO_2 indicates that an optional CO_2 sensor is installed on the AmbiMate module when the bit is 1
Bit 2 MIC indicates that an optional Microphone audio sensor is installed when the bit is 1

3.6.3 Writeable Registers

Scan Start Byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	GAS	BATT	AUD	LIGHT	HUM	TEMP	STATUS

Bit 0 STATUS, when set, initiates a measurement.

Bit 1 TEMP, when set, initiates a measurement of the TEMPERATURE sensor.
Bit 2 HUM, when set, initiates a measurement of the HUMIDITY sensor.
Bit 3 LIGHT, when set, initiates a measurement of the LIGHT sensor.
Bit 4 AUD, when set, initiates a measurement of the AUDIO sensor if installed.
Bit 5 BATT, when set, initiates a measurement of the BATTERY voltage.
Bit 6 GAS, when set, initiates a measurement of the VOC sensor if installed.
Writing to this register initiates a one-time update of the internal measurements for each bit that is set. To update all internal measurements, write 0x7F to this register.

Note that writing to this register does not initiate communication of the updated values to the host. To update and read all data registers first write 0x7F to this register then read all data registers as described above and in the I²C communication section.

It is also possible to update one or more internal measurements by writing a single bit or multiple bits to this register. For example, if an EVENT occurs (the EVENT line goes high), it may be desirable to update and read the PIR motion sensor on a repeated basis to determine when the motion ends. Write 0x01 to this register, then read the STATUS byte (address 0x00) and repeat if needed.
Scanning all channels requires minimum 100 milliseconds. It is best to wait at least that time before reading the data to be sure to get the most recent data.
This register is clear when the measurement is complete. It is possible to poll this register to determine when it is OK to read the new values.

Reset Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

Writing the value 0xA5 to this register initiates an AmbiMate processor reset, which reinitializes all sensors. Any value other than 0xA5 will be ignored with no effect on the processor.

3.6.4 I²C Communication

This section describes the specific details of I²C communication with the AmbiMate module.
I²C address: 0x2A
I²C baud rate: 100 kBaud (100 kHz clock)
I²C write: indicate with bit 0 = 0
I²C read: indicate with bit 0 = 1

Before reading data registers, the host should assure that data is recent, this can be done by writing a value to the Scan Start register: see paragraph above.
To write to a register, send an I²C start, write the I²C address with the least significant bit clear to indicate a write, the write the register address and then write the new value for that register, followed by an I²C stop.
Write Sequence:

- I²C start
- Write to I²C address
- Write register address
- Write register value
- I²C stop

The table below is an indication of a typical write to the Start Scan register. Note that the first byte, the device I²C address is shifted left one bit so that 0x2A becomes 0x54 for a write. The second byte is the Scan Start Register address, 0xC0.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
S	0	1	0	1	0	1	0	0	ACK	1	1	0	0	0	0	0	0	ACK
	I2C address + write									Scan start register (0xC0)								→…

To read a register or sequence of registers, send an I²C start, write to the I²C address listed above with the second byte being the first register address to read. Send an I²C restart, then read to the I²C address and

then read the register value. To read multiple registers in sequence, ACK the first read byte and continue reading and ACKing until the last byte which should be NACKed followed by an I²C stop.
Read Sequence:

- I²C start
- Write to I²C address. (0x54 shifted left one bit with bit 0 = 0 to indicate a write)
- Write (first) register address
- I²C restart
- Read to I²C address. (0x54 shifted left one bit with bit 0 = 1 to indicate a read, thus 0x55)
- Read I²C byte with ACK (byte is value in register) Register automatically increments.
- Repeat until last register
- Read last I²C byte with NACK (byte is value in register)
- I²C stop

The table below is an indication of the start of a multi-byte read. First, the transmission is started by a write indication and pointer is set at first address 0x00. After reading address 0x00, other addresses will be read.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
S	0	1	0	1	0	1	0	0	ACK	0	0	0	0	0	0	0	0	ACK
	I2C address + write									Write to start at register 0x00								→…

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
S	0	1	0	1	0	1	0	1	ACK	x	x	x	x	x	x	x	x	ACK
	I2C address + read									Read at address 0x00								→…

3.7 Data Conversion

Data from the AmbiMate Module arrives as a series of bytes due to the inherent characteristics of the I²C bus. The host sends a “SCAN ALL” command to the AmbiMate. Alternately, the host could read individual addresses. In either case the data needs to be reassembled in the host (or PC) code. This discussion and examples assumes a “SCAN ALL” but the same principles apply to scanning individual addresses.

The first byte returned from a “SCAN ALL” command is the content of the status register. Since this register is 8 bits wide, no additional conversion is required.

Temperature from the sensor is the second value, communicated as two bytes which need to be assembled into a 16-bit integer, converted to a floating-point value then divided by 10.0 to get 0.1-degree resolution. If desired the temperature can be converted to degrees Fahrenheit. This C code snippet shows the conversion:

```
temperature_val_C = ((double)(read_data[1]*256 + read_data[2])) /
10.0;
temperature_val_F = 32.0 + ((9.0 / 5.0) * temperature_val_C);
```

Humidity from the HTU21 is the third value, communicated as two bytes which need to be assembled into a 16-bit integer, converted to a floating-point value then divided by 10 to get 0.1 percent resolution. This C code snippet shows the conversion:

```
humidity_val = ((double)(read_data[3]*256 +read_data[4])) / 10.0;
```

Light intensity is the fourth value, communicated as two bytes which need to be assembled into a 16-bit integer. This C code snippet shows the conversion:

```
light_val = (read_data[5]*256 + read_data[6]);
```

Sound intensity is the fifth value, communicated as two bytes which need to be assembled into a 16-bit integer.

The audio ranges from very low (20 in a perfectly quiet environment) to a max of 119. The reported value is the log of the value measured by the microphone so is in dB but may not exactly match an audio meter due to the low sampling rate available from this small processor and the necessary filtering to work at the low sample rate. At audio levels below 75 dB, quantization of the ADC will limit reported values to the following: 20, 58, 64, 67, 70, 72, 73, 75. Above 75 dB, the AmbiMate will report in 1 dB increments.

This C code snippet shows the conversion:

```
audio_dB = (read_data[7]*256 + read_data[8]);
```

Battery Voltage is the sixth value, communicated as two bytes which need to be assembled into a 16-bit integer. This C code snippet shows the conversion:

```
bat_val = ((double)(read_data[9]*256 +read_data[10]) / 1024.0) *
(3.3 / 0.330);
```

Gas (eCO_2) PPM is the seventh value, communicated as two bytes which need to be assembled into a 16-bit integer. This C code snippet shows the conversion:

```
gas_val = (read_data[11]*256 +read_data[12]);
```

VOC intensity if the eigth (and last) value, communicated as two bytes which need to be assembled into a 16-bit integer. This C code snippet shows the conversion:

```
voc_val= (read_data[13]*256 +read_data[14]);
```

When communicated from the byte stream is terminated with a Carriage Return (CR read_data[15]) and Line Feed (LF read_data[16]) bytes which can be ignored.

4 PHYSICAL LAYER DESIGN GUIDANCE

4.1 Environmental Sealing

The AmbiMate is a PCB assembly that is not environmentally sealed.

4.2 Mounting Location and Orientation

The AmbiMate can be mounted in any orientation and can be fit into multiple applications. Note that mounting the AmbiMate into any enclosure can alter the performance of the sensors on the AmbiMate. The enclosure design must be optimized to reduce undesired effects to the sensors' accuracy. It is important that the enclosure is designed to promote air circulation across the AmbiMate to improve the accuracy. TE offers options for creating two-piece separable connections and cable assemblies for connection to a remotely mounted AmbiMate. Please contact the TE Product Information Number on the 1st page of this document for further assistance.

4.3 Soldering

The AmbiMate may be soldered to the Host PCBA. See the customer drawings for the recommend pad layout.

Manual soldering

The through hole versions of the AmbiMate should be soldered using acceptable industry standard through hole soldering techniques via the installed connector headers. The castellated version of the AmbiMate can be soldered to a host PCBA using industry standard surface mount soldering techniques as described in IPC-J-STD-020 with a maximum temperature which should not exceed 260 °C following the guidelines of the Pb-Free Assembly. All solder joints should conform to the Workmanship Specification IPC-A-610, "Acceptability of Electronic Assemblies" and IPC J-STD-001, "Requirements for Soldering Electrical and Electronic Assemblies End Item Standards".

Reflow soldering profile

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)	3 °C/second max.	3° C/second max.
Preheat – Temperature Min (Ts_{min}) – Temperature Max (Ts_{max}) – Time (ts_{min} to ts_{max})	100 °C 150 °C 60-120 seconds	150 °C 200 °C 60-180 seconds
Time maintained above: – Temperature (T_L) – Time (t_L)	183 °C 60-150 seconds	217 °C 60-150 seconds
Peak/Classification Temperature (Tp)	See Table 4.1	See Table 4.2
Time within 5 °C of actual Peak Temperature (tp)	10-30 seconds	20-40 seconds
Ramp-Down Rate	6 °C/second max.	6 °C/second max.
Time 25 °C to Peak Temperature	6 minutes max.	8 minutes max.

Note 1: All temperatures refer to topside of the package, measured on the package body surface.

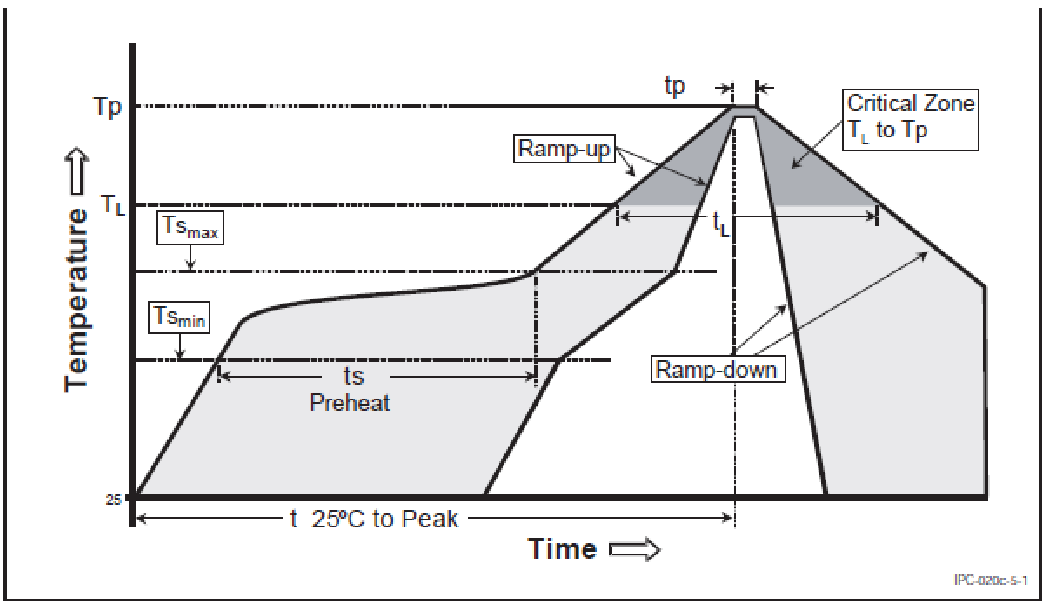

Figure 4: Reflow profile

4.4 Motion Event LED

When an event is detected by the AmbiMate, the motion event LED indicator illuminates on the lower right corner for the module (see Figure 1). If needed for the host application, a light pipe can be utilized to allow the motion event indicator to be visible in the final application.

5 QUALIFICATION

Please refer to 108-133092 for qualification data.