## Long-Range Ultrasonic Time-of-Flight Range Sensor

CH201 HIGHLIGHTS

CH201 is a miniature, ultra-low power, long-range ultrasonic Time-of-Flight (ToF) range sensor. Based on Chirp's patented MEMS technology, the CH201 is a system-in-package that integrates a PMUT (Piezoelectric Micromachined Ultrasonic Transducer) together with an ultra-low power SoC (System on Chip) in a miniature, reflowable package. The SoC runs Chirp's advanced ultrasonic DSP algorithms and includes an integrated microcontroller that provides digital range readings over I^{2}C.

Complementing Chirp's CH101 ultrasonic ToF sensor product, CH201 provides accurate range measurements to targets at distances up to 5m. Based on ultrasonic pulse-echo measurements, the sensor works in any lighting condition, including full sunlight, and provides millimeter-accurate range measurements independent of the target's color and optical transparency. The sensor's Field-Of-View (FOV) can be customized and enables simultaneous range measurements to multiple objects in the FOV. Many algorithms can further process the range information for a variety of usage cases in a wide range of applications.
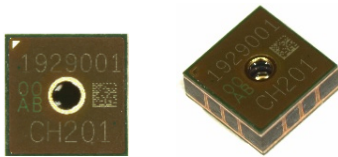
DEVICE INFORMATION

PART NUMBER	PACKAGE	LID OPENING
CH201-00ABR	3.5 x 3.5 x 1.26 mm LGA	1-Hole

RoHS and Green-Compliant Package

APPLICATIONS

- User presence in Home/Building Automation and Personal Electronics
- Obstacle avoidance
- Robotics and Drones
- Ultra-low power remote presence-sensing nodes
- Augmented/Virtual Reality and Gaming
- Gesture control
- Liquid level sensing & shelf inventory monitoring

FEATURES

- Fast, accurate range-finding
  - Operating range from 20 cm to 5m
  - Programmable modes optimized for long or short-range sensing applications
  - Customizable field of view (FoV) up to 180°
  - Multi-object detection
  - Works in any lighting condition, including full sunlight to complete darkness
  - Insensitive to object color, detects optically transparent surfaces (glass, clear plastics etc.)
- Easy to integrate
  - Single sensor for receive and transmit
  - Single 1.8V supply
  - I2C Fast Mode compatible interface, data-rates up to 400 kHz
  - Dedicated programmable range interrupt pin
  - Platform-independent software driver enables turnkey range-finding
- Miniature integrated package
  - 3.5 mmx 3.5mm x 1.26mm, 8-pin LGA package
  - Compatible with standard SMD reflow
  - Low-power SoC running advanced ultrasound firmware
  - Operating temperature range: -40°C to 85°C
- Ultra-low supply current
  - 1 sample/s:
    - 7.5 µA (1 m max range)
    - 13.5 µA (5 m max range)
  - 25 samples/s:
    - 63 µA (1 m max range)
    - 247 µA (5 m max range)

Table of Contents

1   SIMPLIFIED BLOCK DIAGRAM

Figure 1. Simplified Block Diagram

1.1   ABSOLUTE MAXIMUM RATINGS

PARAMETER	MIN.	TYP.	MAX.	UNIT
AVDD to VSS	-0.3		2.2	V
VDD to VSS	-0.3		2.2	V
SDA, SCL, PROG, RST_N to VSS	-0.3		2.2	V
Electrostatic Discharge (ESD)				
Human Body Model (HBM)[1]	-2		2	kV
Charge Device Model (CDM)[2]	-500		500	V
Latchup	-100		100	mA
Temperature, Operating	-40		85	°C
Relative Humidity, Storage			90	%RH
Continuous Input Current (Any Pin)	-20		20	mA
Soldering Temperature (reflow)			260	°C

1.   HBM Tests conducted in compliance with ANSI/ESDA/JEDEC JS-001-2014 Or JESD22-A114E
2.   CDM Tests conducted in compliance with JESD22-C101.

2   PACKAGE INFORMATION

2.1   8-PIN LGA

DESCRIPTION	DOCUMENT NUMBER
CH101 and CH201 Ultrasonic Transceiver Handling and Assembly Guidelines	AN-000159

2.2   PIN CONFIGURATION
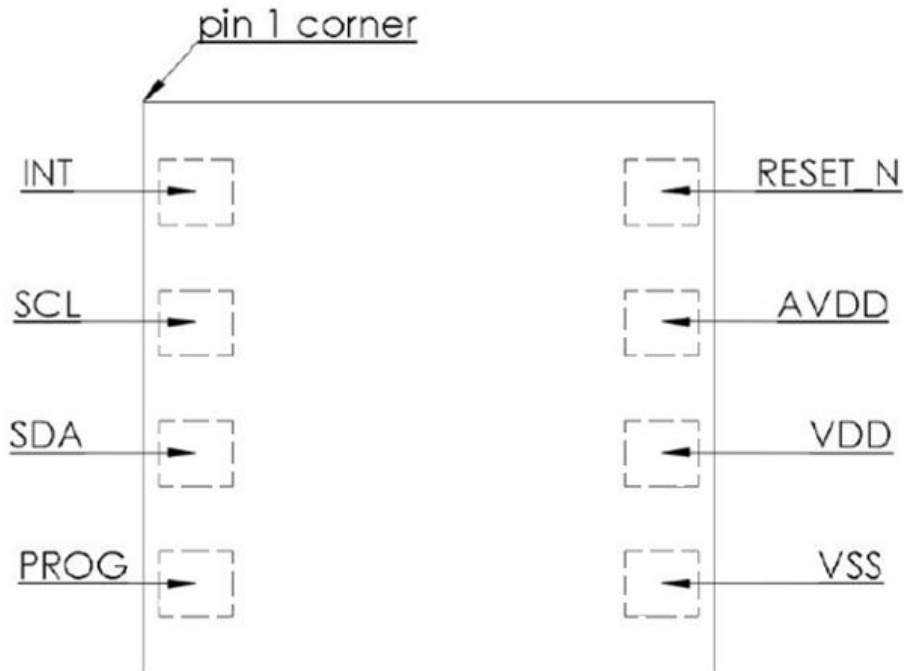
Figure 2. CH201 Package Top View

2.3   PIN DESCRIPTION

PIN	NAME	DESCRIPTION
1	INT	Interrupt output. Can be switched to input for triggering and calibration functions
2	SCL	SCL Input. I^{2}C clock input. This pin must be pulled up externally.
3	SDA	SDA Input/Output. I^{2}C data I/O. This pin must be pulled up externally.
4	PROG	Program Enable. Cannot be floating.
5	VSS	Power return.
6	VDD	Digital Logic Supply. Connect to externally regulated 1.8V supply. Suggest common connection to AVDD. If not connected locally to AVDD, bypass with a 0.1µF capacitor as close as possible to VDD I/O pad.
7	AVDD	Analog Power Supply. Connect to externally regulated supply. Bypass with a 0.1µF capacitor as close as possible to AVDD I/O pad.
8	RESET_N	Active-low reset. Cannot be floating.

Table 1. Pin Descriptions
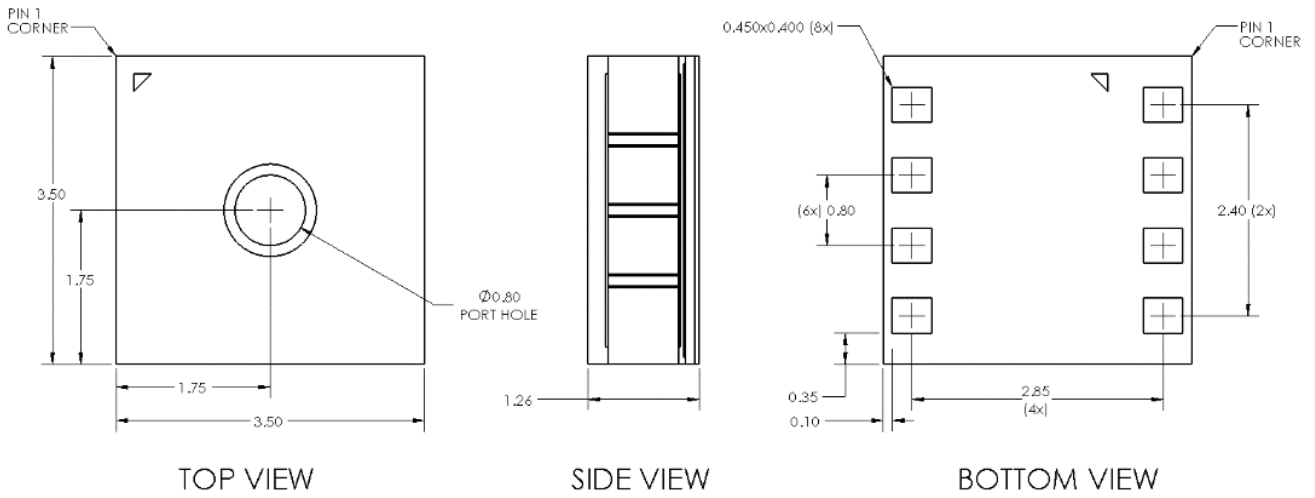
2.4 PACKAGE DIMENSIONS

Figure 3.Package dimensions

3 ELECTRICAL CHARACTERISTICS

AVDD = VDD = 1.8VDC, VSS = 0V, T$_A$ = +25°C, MIN/MAX ARE FROM T$_A$ = -40°C TO +85°C, UNLESS OTHERWISE SPECIFIED. PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY						
Analog Power Supply	AVDD		1.62	1.8	1.98	V
Digital Power Supply	VDD		1.62	1.8	1.98	V
ULTRASONIC TRANSMIT CHANNEL						
Operating Frequency				85		kHz
TxRx OPERATION (GPR FIRMWARE LOADED)						
Maximum Range	Max Range	Wall Target 58mm Diameter Post		5[1] 2.7[1]		m m
Minimum Range	Min Range		0.2[2]			m
Measuring Rate (Sample/sec)	SR	5m 1m			25 100	Sample/s Sample/s
Field of View	FoV		Configurable up to 180º			deg
Current Consumption (AVDD + VDD)	I$_S$	SR=1S/s, Range=1m SR=1S/s, Range=5m SR=25S/s, Range=1m SR=25S/s, Range=5m		8 14 63 247		µA µA µA µA
Measurement Time		5m max range		36		ms
Programming Time				60		ms

Table 2.

Notes:

1. Measurement tested using 45° FoV acoustic housing.
2. Tested with a stationary target. While objects closer than 20 cm can be detected, the range measurement is not ensured.

3.1 ELECTRICAL CHARACTERISTICS (CONT'D)

AVDD = VDD = 1.8VDC, VSS = 0V, T_A = +25°C, unless otherwise specified.

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGITAL I/O CHARACTERISTICS						
Output Low Voltage	V_{OL}	SDA, INT, I_{SINK}=XmA			0.4	V
Output High Voltage	V_{OH}	INT	$0.9*V_{VDD}$			V
I²C Input Voltage Low	V_{IL_I2C}	SDA, SCL			$0.3*V_{VDD}$	V
I²C Input Voltage High	V_{IH_I2C}	SDA, SCL	$0.7*V_{VDD}$			V
Pin Leakage Current	I_L	SDA,SCL, INT(Inactive), T_A=25°C			±1	µA
DIGITAL/I²C TIMING CHARACTERISTICS						
SCL Clock Frequency	f_{SCL}	I²C Fast Mode			400	kHz

Table 3. Electrical Characteristics Cont'd

4 TYPICAL OPERATING CHARACTERISTICS

AVDD = VDD = 1.8VDC, VSS = 0V, T_A = +25°C, unless otherwise specified.
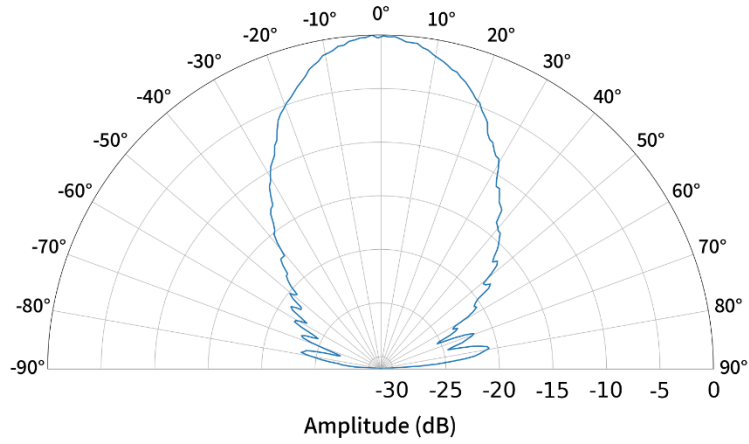
Figure 4. Typical Beam Pattern – MOD-CH201-00-01 45 deg FoV module

(Measured with a 1 m2 flat plate target at a 1m range)

5 DETAILED DESCRIPTION

5.1 THEORY OF OPERATION

The CH201 is an autonomous, digital output ultrasonic rangefinder. The Simplified Block Diagram in Figure 1 shows the main components at the package-level. The package includes a piezoelectric micro-machined ultrasonic transducer (PMUT) and system-on-chip (SoC). The SoC controls the PMUT to produce pulses of ultrasound that reflect off targets in the sensor's Field of View (FoV). The reflections are received by the same PMUT after a short time delay, amplified by sensitive electronics, digitized, and further processed to produce the range to the primary target. Many algorithms can further process the range information for a variety of usage cases in a wide range of applications.

The time it takes the ultrasound pulse to propagate from the PMUT to the target and back is called the time-of-flight (ToF). The distance to the target is found by multiplying the time-of-flight by the speed of sound and dividing by two (to account for the round-trip). The speed of sound in air is approximately 343 m/s. The speed of sound is not a constant but is generally stable enough to give measurement accuracies within a few percent error.

5.2 DEVICE CONFIGURATION

A CH201 program file must be loaded into the on-chip memory at initial power-on. The program, or firmware, is loaded through a special I^{2}C interface. Chirp provides a default general-purpose rangefinder (GPR) firmware that is suitable for a wide range of applications. This firmware enables autonomous range finding operation of the CH201. It also supports hardware-triggering of the CH201 for applications requiring multiple transceivers. Program files can also be tailored to the customer's application. Contact Chirp for more information.

CH201 has several features that allow for low power operation. An ultra-low-power, on-chip real-time clock (RTC) sets the sample rate and provides the reference for the time-of-flight measurement. The host processor does not need to provide any stimulus to the CH201 during normal operation, allowing the host processor to be shut down into its lowest power mode until the CH201 generates a wake-up interrupt. There is also a general-purpose input/output (INT) pin that is optimized to be used as a system wake-up source. The interrupt pin can be configured to trigger on motion or proximity.

6 APPLICATIONS

6.1 CHIRP CH201 DRIVER

Chirp provides a compiler- and microcontroller-independent C driver for the CH201 which greatly simplifies integration. The CH201 driver implements high-level control of one or more CH201s attached to one or more I^{2}C ports on the host processor. The CH201 driver allows the user to program, configure, trigger, and readout data from the CH201 through use of C function calls without direct interaction with the CH201 I^{2}C registers. The CH201 driver only requires the customer to implement an I/O layer which communicates with the host processor's I^{2}C hardware and GPIO hardware. Chirp highly recommends that all designs use the CH201 driver.

6.2 OBJECT DETECTION

Detecting the presence of objects or people can be optimized via software, by setting the sensor's full-scale range (FSR), and via hardware, using an acoustic housing to narrow or widen the sensor's field-of-view. The former means that the user may set the maximum distance at which the sensor will detect an object. FSR values refer to the one-way distance to a detected object.

In practice, the FSR setting controls the amount of time that the sensor spends in the listening (receiving) period during a measurement cycle. Therefore, the FSR setting affects the time required to complete a measurement. Longer full-scale range values will require more time for a measurement to complete.

Ultrasonic signal processing using the CH201's General Purpose Rangefinder (GPR) Firmware will detect echoes that bounce off the first target in the Field-of-View. The size, position, and material composition of the target will affect the maximum range at which the sensor can detect the target. Large targets, such as walls, are much easier to detect than smaller targets. Thus, the associated operating range for smaller targets will be shorter. The range to detect people will be affected by a variety of factors such as a person's size, clothing, orientation to the sensor and the sensor's field-of-view. In general, given these factors, people can be detected at a maximum distance of 3-4m away from the CH201 sensor.

For additional information, please refer to AN-000214 Presence Detection Application Note and associated Presence Detection S/W.

6.3 INTERFACING TO THE CH201 ULTRASONIC SENSOR

The CH201 communicates with a host processor over the 2-wire I^{2}C protocol. The CH201 operates as an I^{2}C slave and responds to commands issued by the I^{2}C master.

The CH201 contains two separate I^{2}C interfaces, running on two separate slave addresses. The first is for loading firmware into the on-chip program memory, and the second is for in-application communication with the CH201. The 7-bit programming address is 0x45, and the 7-bit application address default is 0x29. The application address can be reprogrammed to any valid 7-bit I^{2}C address.

The CH201 uses clock stretching to allow for enough time to respond to the I^{2}C master. The CH201 clock stretches before the acknowledge (ACK) bit on both transmit and receive. For example, when the CH201 transmits, it will hold SCL low after it transmits the 8th bit from the current byte while it loads the next byte into its internal transmit buffer. When the next byte is ready, it releases the SCL line, reads the master's ACK bit, and proceeds accordingly. When the CH201 is receiving, it holds the SCL line low after it receives the 8th bit in a byte. The CH201 then chooses whether to ACK or NACK depending on the received data and releases the SCL line.

Figure 5 shows an overview of the I^{2}C slave interface. In the diagram, 'S' indicates I^{2}C start, 'R/W' is the read/write bit, 'Sr' is a repeated start, 'A' is acknowledge, 'P' is the stop condition. Gray boxes indicate the I^{2}C master actions; white boxes indicate the I^{2}C slave actions.
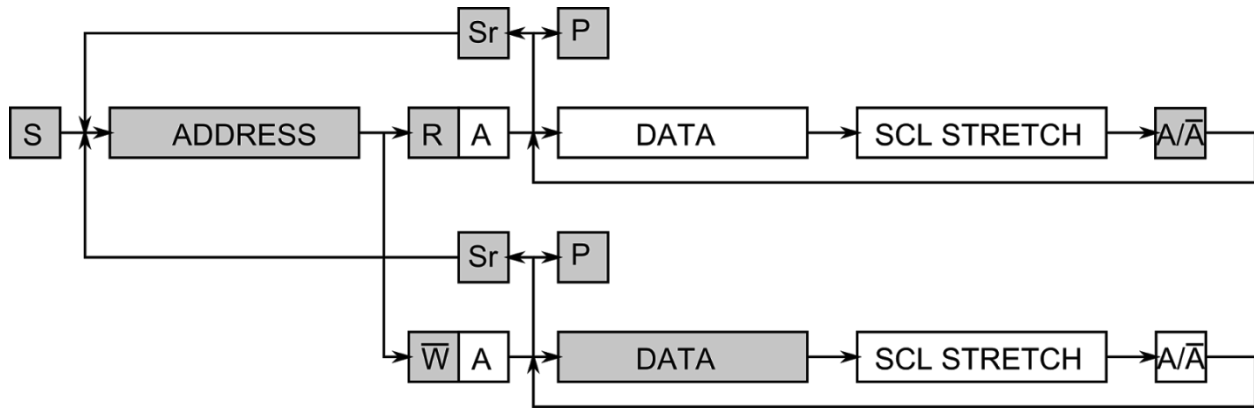
Figure 5. CH201 I²C Slave Interface Diagram

6.4 DEVICE MODES OF OPERATION

Free-Running Mode

In the free-running measurement mode, the CH201 runs autonomously at a user specified sample rate. In this mode, the INT pin is configured as an output. The CH201 pulses the INT pin high when a new range sample is available. At this point, the host processor may read the sample data from the CH201 over the I²C interface.

Hardware-Triggered Mode

In the hardware triggered mode, the INT pin is used bi-directionally. The CH201 remains in an idle condition until triggered by pulsing the INT pin. The measurement will start with deterministic latency relative to the rising edge on INT. This mode is most useful for synchronizing several CH201 transceivers. The host controller can use the individual INT pins of several transceivers to coordinate the exact timing.

CH201 Beam Patterns

The acoustic Field of View is easily customizable for the CH201 and is achieved by adding an acoustic housing to the transceiver that is profiled to realize the desired beam pattern. Symmetric, asymmetric, and omnidirectional (180° FoV) beam patterns are realizable.

An example beam pattern is shown in the Typical Operating Characteristics section of this document and several acoustic housing designs for various FoV's are available from Chirp.

6.5 LAYOUT RECOMMENDATIONS

Recommended PCB Footprint
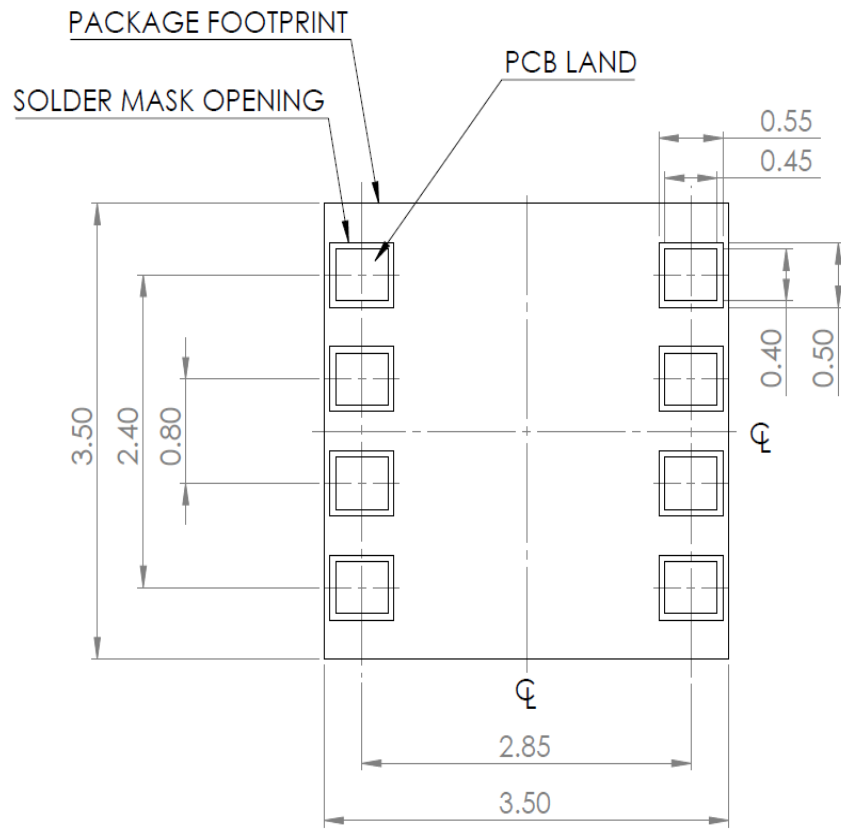
Dimensions in mm

Figure 6. Recommended PCB Footprint

6.6 PCB REFLOW RECOMMENDATIONS:

See App Note AN-000159 CH101 and CH201 Ultrasonic Transceiver Handling and Assembly Guidelines.

Use of Level Shifters

While the use of autosense level shifters for all the digital I/O signal signals is acceptable, special handling of the INT line while using a level shifter is required to ensure proper resetting of this line. As the circuit stage is neither a push-pull nor open-drain configuration (see representative circuit in Figure 7 below), it is recommended that level shifter with a manual direction control line be used. The TI SN74LVC2T45 Bus Transceiver is a recommended device for level shifting of the INT signal line.
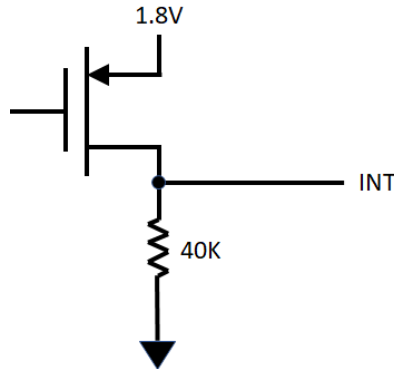
Figure 7. INT Line I/O Circuit Stage

6.7 TYPICAL OPERATING CIRCUITS
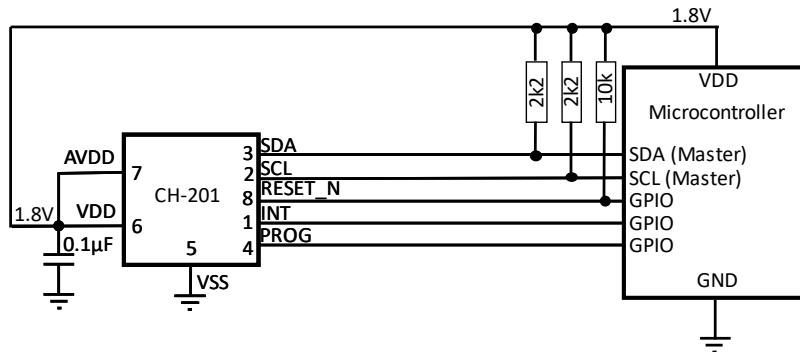
Figure 8. Single Transceiver Operation
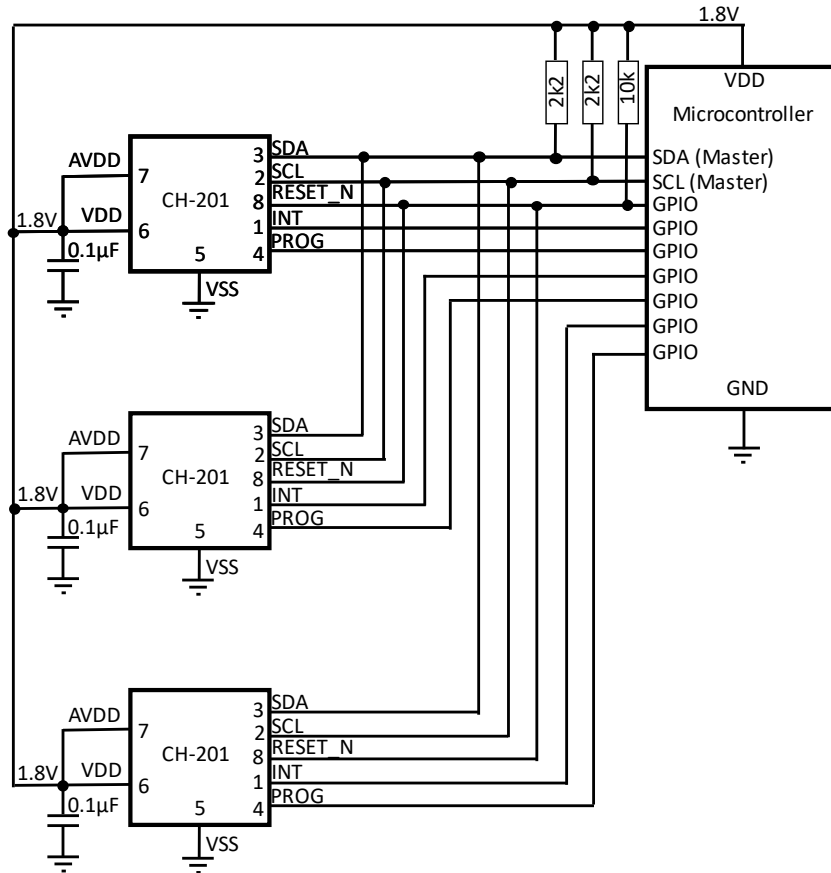
Figure 9. Multi-Transceiver Operation

7 ORDERING INFORMATION

7.1 PART NUMBER DESIGNATION

CH201-xxABx

Product Family

CH201 = Long-Range Ultrasonic ToF Sensor

Product Variant

00AB = Product Variant

Shipping Carrier

R = Tape & Reel
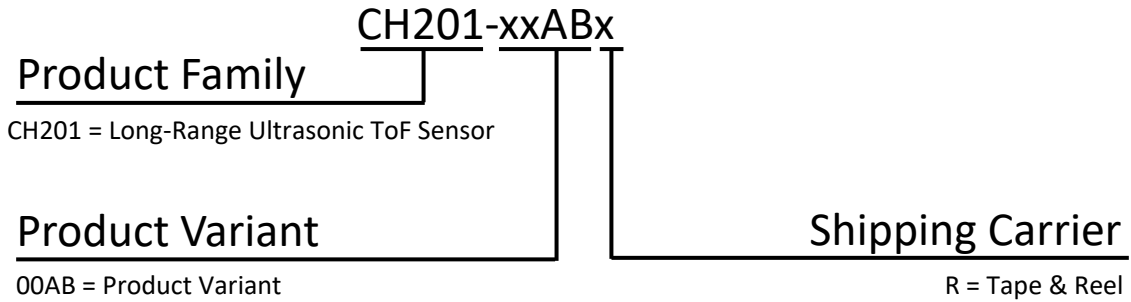
Figure 10. Part Number Designation

This datasheet specifies the following part numbers

PART NUMBER	PACKAGE BODY	QUANTITY	PACKAGING
CH201-00ABR	3.5 mm x 3.5 mm x 1.26 mm LGA-8L	1,000	7" Tape and Reel

Table 4. CH201 Part Number

7.2 PACKAGE MARKING

PRODUCT VARIANT MARK

YYWWTTT — DATE MARK

NN
AB
CHXXX

2D BARCODE

PRODUCT MARK
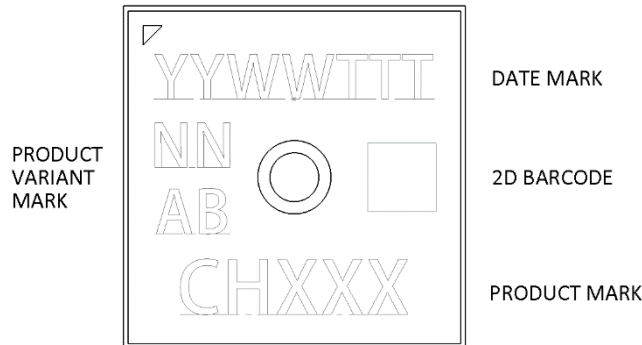
Figure 11. Packaging Marking

7.3 TAPE & REEL SPECIFICATION
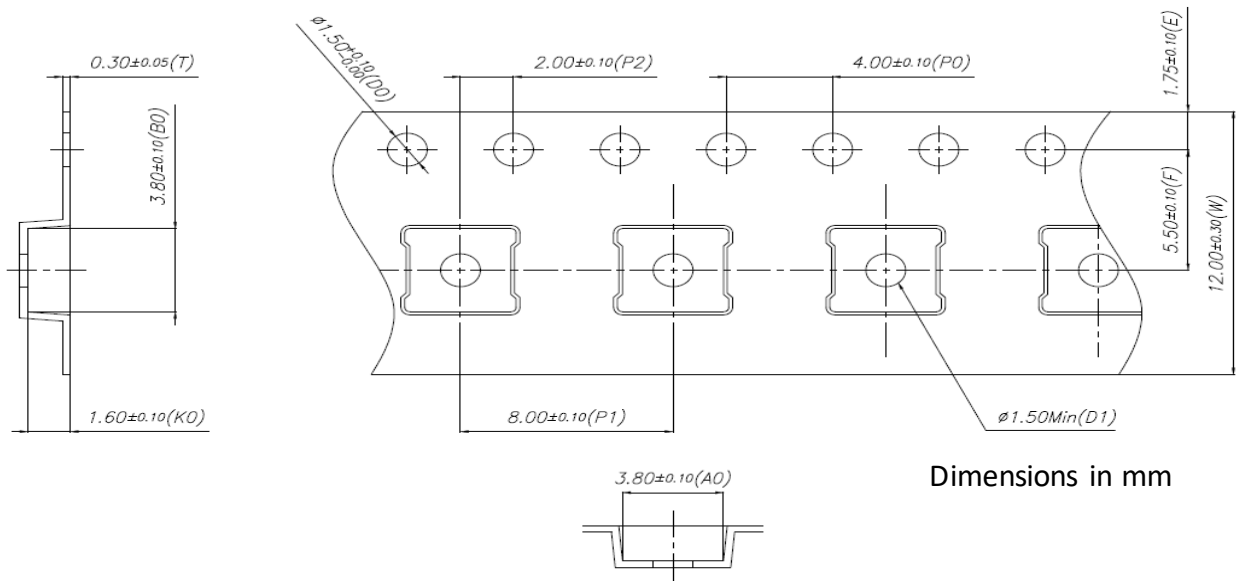
Dimensions in mm

Figure 12. Tape & Reel Specifications

7.4 SHIPPING LABEL

A Shipping Label will be attached to the reel, bag and box. The information provided on the label is as follows:

Device: This is the full part number

Lot Number: Chirp manufacturing lot number

Date Code: Date the lot was sealed in the moisture proof bag

Quantity: Number of components on the reel

2D Barcode: Contains Lot No., quantity and reel/bag/box number
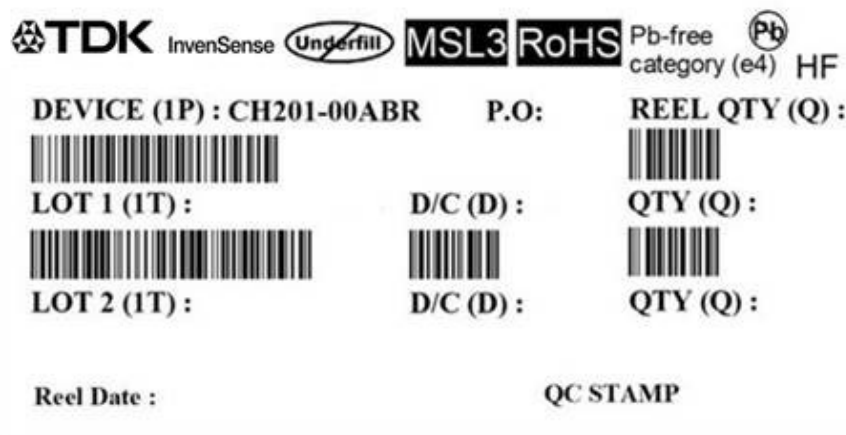
Figure 13. Shipping Label

8 REVISION HISTORY

DATE	REVISION	CHANGES
06/02/2020	1.0	Initial Release
9/22/2020	1.1	Fixed minor typos

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