# Technical Documentation

AC/DC Capacitive Sensor Unit

Model CSU-1011-H2U

User Manual

This page is intentionally left blank.

# AC/DC Capacitive Sensor Unit

# Type CSU-1011-H2U

From Serial No.103200

Rev 2.3 - July 2020


# SERVICE WARNING

The AC/DC Capacitive Sensor Unit contains no user-serviceable parts. It should be opened and serviced by qualified personnel only.

# Table of Contents



# Table of Figures

# 1. Getting Started

## Principle of Operation

The CSU-1011-H2U AC/DC Capacitive Sensor Unit (CSU) is a fully integrated analog synchronous modulation/demodulation system that provides the ability to measure mean and fluctuating quantities of interest, e.g., wall shear stress or pressure, using a differential capacitive sensor. The CSU provides low-noise power to the sensor head and conditions the analog voltage signal received from the sensor head for output to a data acquisition system. Capacitive sensing at DC is achieved by shifting the sensor baseband frequencies to a modulated signal and demodulating the returned signal from the sensor, enabling simultaneous real-time measurement of both mean and dynamic components.

(a) (b)

*Figure 1-1: DirectShear Capacitive Sensor Unit (a) and sensor head with cable (b).*

## Features and Benefits

- Ability to measure mean and fluctuating quantities using a variety of capacitive devices
- Integrated rechargeable lithium-ion battery system minimizes power line noise
- Two gain settings for measuring various size signals
- Auto Zero button for offset error correction
- Multi-pin LEMO push-pull connector provides supply voltages and carrier signals to sensor
- System status and battery voltage LED indicators

## Additional Required Equipment

The following additional components and specifications are recommended for AC and DC testing/calibration with the capacitive sensor control unit:

- CSU-compatible capacitive sensor head and cable
- RG58 coaxial cable with BNC connectors
- Data acquisition system (DAQ) – AC/DC measurement
    - Sensing Range: ±1, ±5, ±10V – sensor dependent (see datasheet)
    - Resolution: 18+ bits
    - Sampling frequency:
        - Sensor dependent w/ analog filter between sensor output and analog-to-digital converter (ADC)
        - 100+ kS/s w/o analog filter
- Digital multimeter – DC measurement only
    - 6.5 digits with power line cycle (PLC) integration
    - DAQ or PC connection (e.g., GPIB)

## Initial Setup

### Preparing the Capacitive Sensor Unit

The CSU should be powered for a minimum of one hour prior to testing to avoid undesirable start-up transients during measurement. Please refer to the Device Operation section for additional details regarding proper system operation.

### Charging the Capacitive Sensor Unit

Prior to using the system for the first time, the lithium ion batteries should be fully charged. Please refer to the Battery Charging section for details on the proper charging procedure. Initial charging of the system takes between 10-14 hours to achieve a full charge. Once fully charged, the system will operate for approximately 20 hours before requiring additional charging.

# 2. Description

The CSU-1011-H2U AC/DC Capacitive Sensor Unit is an integrated analog synchronous modulation/ demodulation system that provides the ability to measure mean and fluctuating quantities of interest using a capacitive sensor, e.g., wall shear stress or pressure. Capacitive sensing at DC is achieved by shifting the sensor baseband frequencies to a modulated signal and demodulating the returned signal from the sensor. The CSU provides low-noise power and carrier signals to the sensor head and conditions the returned analog voltage signal for output to a data acquisition system. Integrated rechargeable lithium ion batteries minimize noise due to EMI and provide up to 20 hours of continuous operation.

*Figure 2-1: CSU-1011-H2U*

## Low-Noise Power Circuit

The CSU power circuitry includes an AC/DC converter, two 10Ah lithium ion batteries, and a custom charging and power conditioning circuit. The CSU provides low noise ±12V power to the sensor and conditioning electronics via either AC line power or batteries that enable operation for up to 20 hours on a single charge.

## Signal Conditioning Electronics

The analog synchronous modulation/demodulation circuit provides two 180° phase-shifted 1 MHz carrier signals to the fixed sensor electrodes. Mean forces acting on the sensing element result in static changes in the nominal capacitance, thus changing the amplitude of the carrier wave. Demodulation of the amplitude-modulated sensor output voltage then provides baseband information in real time including both mean and dynamic components.

## EMI Shielding & Cabling

The CSU provides the sensor bias voltages and supply voltages via a shielded, multi-pin, twisted-pair cable, providing a continuous shield from the CSU to the face of the sensor head. Internal shielding of the signal conditioning electronics provides added immunity to EMI when operating on line power.

## Calibration

Each CSU is calibrated and paired via serial number with a specific sensor head and the pair should be used together for measurement. The results of each system calibration are presented in individual sensor calibration sheets.

## Front Panel at a Glance

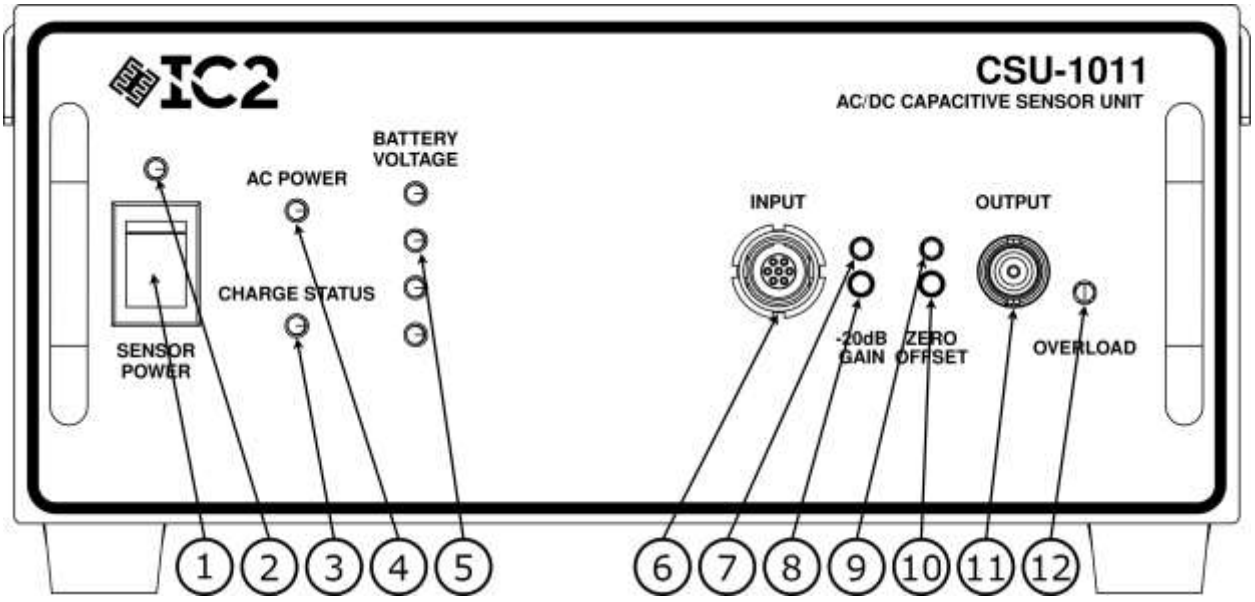



*Figure 2-2: The CSU front panel.*

| | Name | Description |
|---|---|---|
| 1 | Sensor Power Switch | Powers the signal conditioning electronics |
| 2 | Sensor Power LED | Indicates signal conditioning electronics status (on = powered) |
| 3 | Charge Status LED | Indicates battery charging status (on = charging) |
| 4 | AC Power LED | Indicates AC power status (on = AC line power) |
| 5 | Battery Voltage LEDs | Indicates battery voltage level |
| 6 | Sensor Input | Multi-pin LEMO push-pull connection to sensor |
| 7 | -20dB Gain LED | Indicates gain status (on = -20dB nominal gain) |
| 8 | -20dB Gain Button | Switches between -20dB gain and 0dB gain |
| 9 | Zero Offset LED | Indicates Zero Offset status (on = Zero Offset active) |
| 10 | Zero Offset Button | Switches between Zero Offset active and inactive |
| 11 | Sensor Output | BNC connection to DAQ |
| 12 | Overload LED | Indicates measured signal is clipped by signal conditioning circuit |

## Rear Panel at a Glance

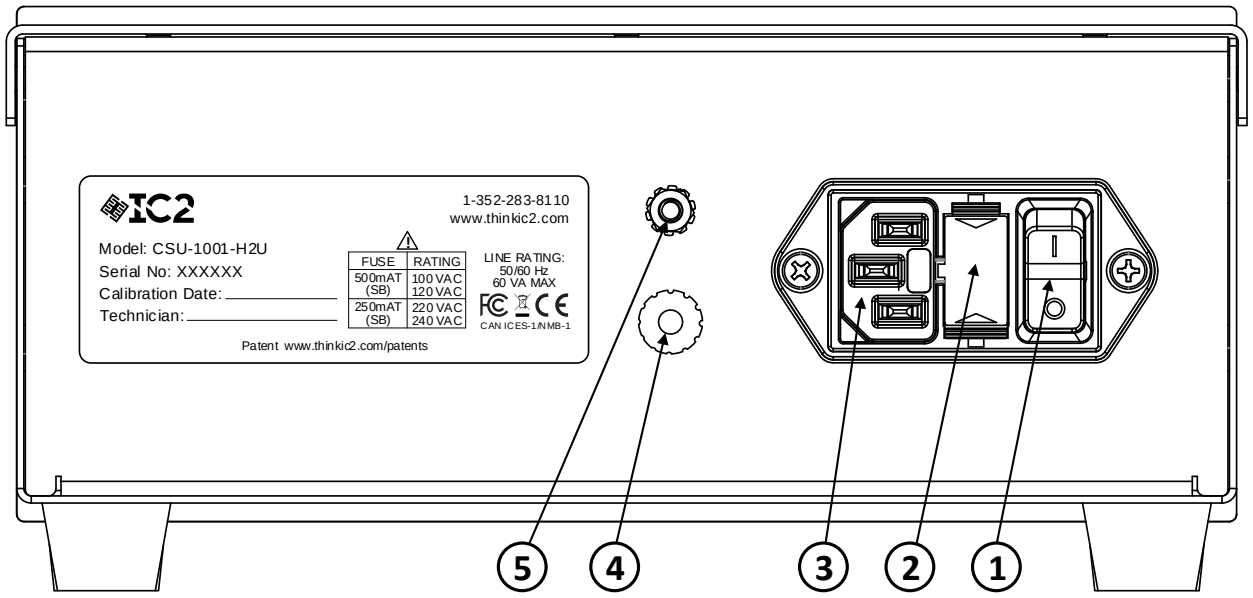



*Figure 2-3: The CSU rear panel.*

| | Name | Description |
|---|---|---|
| 1 | AC Power Switch | Enables AC power operation and battery charging |
| 2 | Fuse Block | Contains fuses for line and neutral conductors |
| 3 | AC Line Receptacle | Accepts power cable with female IEC 320 C13 connector |
| 4 | Common Terminal | Used for grounding sensor and signal conditioning electronics |
| 5 | Earth Ground Stud | Connected to earth ground via AC line receptacle |

# 3. Device Operation

## Powering the System

The CSU is powered through either an internal AC/DC converter or a pair of lithium ion batteries. The batteries provide a low-noise power source that enables continuous operation for approximately 20 hours on a single charge.

### Line Power Operation

The following procedure should be used to power the CSU for charging or operation on line power.

1. Check to see that the 120VAC line voltage is correct for the operating voltage in your area. The CSU comes with two 500mA slow-blow fuses installed for 120VAC operation. For operation at higher line voltages, refer to the Fuse Replacement section.

***CAUTION*** **Operating the instrument on a line voltage with incorrect fuses installed may cause damage to the instrument, possibly voiding the warranty.**

2. Before connecting the power cord, make sure that the rear panel AC Power Switch and the front panel Sensor Power Switch are in the “off” position.
3. Connect the female end of the provided power cord to the AC receptacle on the rear panel. Connect the other end to a grounded AC outlet.


**The power cord supplied with the CSU contains a separate ground wire for use with grounded outlets. When proper connections are made, the instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.**

4. Turn on the AC Power Switch located on the back panel. The AC Power, Charge Status, and Battery Voltage indicators on the front panel should all be illuminated.
5. Turn on the Sensor Power Switch located on the front panel. The green Sensor Power LED will illuminate, indicating power is being provided to the sensor head and the signal conditioning electronics.

### Battery Power Operation

1. If the provided power cord is connected, ensure that the AC Power Switch located on the back panel is in the “off” position.
2. Turn on the Sensor Power Switch located on the front panel. The green Sensor Power LED will illuminate, indicating power is being provided to the sensor head and signal conditioning electronics. In addition, the corresponding Battery Voltage LEDs will turn on based on the voltage level as discussed in the Battery Charging section.

### Fuse Replacement

A removable fuse holder located between the AC Line Receptacle and AC Power Switch protects the power line inputs of the instrument. If the line and/or neutral fuses need to be replaced, perform the following steps.


**Make sure the instrument is disconnected from the AC line and other equipment before replacing the fuse(s).**

1. Place the tip of a flat-blade screwdriver into the bottom of the fuse holder assembly. Gently push in and up until the bottom of the fuse block is released.
2. Place the tip of a flat-blade screwdriver into the top of the fuse holder assembly. Gently push in and down until the top of the fuse block is released, and pull the fuse holder out of the power module.
3. Remove the fuse(s) and replace with the appropriate type listed in Table 1.

***CAUTION*** **For continued protection against fire or instrument damage, only replace the fuse(s) with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse(s).**

4. Install the fuse holder assembly into the power module by pushing it in until it locks in place.

*Table 1: Fuse Ratings.*

| Line Voltage | Fuse Rating |
|---|---|
| 100/120V | 500mA slow-blow, 5×20mm |
| 220/240V | 250mA slow-blow, 5×20mm |

## Battery Charging

To charge the internal 4.2V lithium ion batteries, follow steps 1-4 in the Line Power Operation section, leaving the front panel Sensor Power Switch in the “off” position. The CSU will continue charging the batteries for a maximum duration of 14 hours, at which point the charger will switch into a low power state to prevent damage to the batteries. If a full charge has not been reached during this time, the charge timer can be reset by cycling the AC Power Switch.

***CAUTION*** **For protection against fire or instrument damage, do not repeatedly reset the battery charge timer. If the CSU is unable to provide a full charge to the batteries after two complete charging cycles, the system may need to be sent in for servicing.**

***NOTE*** **For best noise performance, avoid charging the batteries while the sensor head is powered, especially if the battery voltage level is 3.6V or lower.**

### Battery Voltage Level

To determine the charge level of the batteries, turn off the AC Power Switch and turn on the System Power Switch on the front panel. The four Battery Voltage indicator LEDs on the front correspond to the voltage levels listed in Figure 3-1.

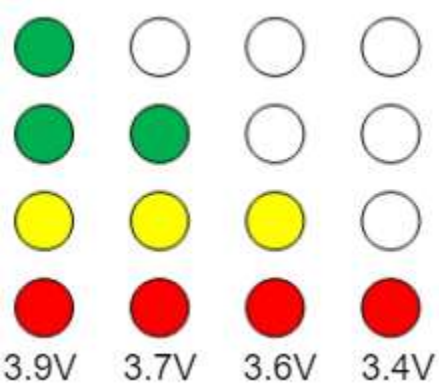



*Figure 3-1: Battery voltage indicator states and corresponding voltages.*

### Low Power Shutdown

If the battery voltage drops below ~3.3V, an internal switch will cut off power to the CSU to prevent damage to the batteries and the internal circuitry. At this point, all LEDs on the front panel will turn off, and the batteries should be recharged before further use.

***CAUTION*** **To avoid permanently damaging the batteries, the front panel Sensor Power Switch should immediately be turned off, and a full charging cycle should be completed before any additional use.**

## System Warmup

The CSU should be powered on with the sensor head connected and allowed to warm up for at least one hour to reach thermal equilibrium and mitigate undesirable start-up transients in the system response. If the system has been powered on for one hour but needs to be relocated the second warm-up duration can be reduced to fifteen minutes.

## Grounding

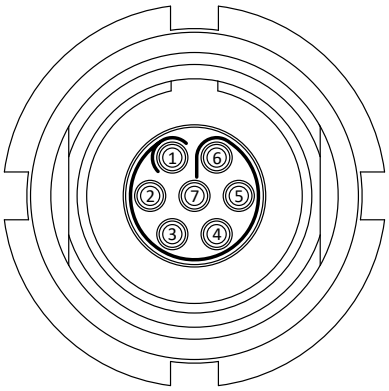
The chassis of the CSU is connected to earth ground through the AC Line Receptacle on the back panel. A separate internal ground (common) is used to tie the internal circuitry, sensor input, and DAQ output connections together, allowing the system ground to share a ground point with the DAQ system if desired. When using AC power, the Common Terminal and Earth Ground Stud located on the back panel of the system allow the internal ground to be connected to earth ground when no other ground connection is present in the system.

***NOTE*** **The Common Terminal should be disconnected from the Earth Ground Stud any time the system is operated using the internal batteries.**

## System Connection

The capacitive sensor head should be connected to the paired CSU using the included shielded multi-pin cable. The pinout for the CSU front panel and sensor head connector is shown in Figure 3-2. A user-provided shielded BNC cable should be used to connect the DAQ to the CSU output. The serial number for the CSU is located on the rear panel of the unit and is listed on the data sheet for the accompanying calibrated sensor.

***NOTE*** **To ensure the calibration data is valid, the sensor must be connected to the corresponding CSU.**




Pinout
1. +12V
2. COM
3. Signal
4. -12V
5. Neg Bias V
6. Pos Bias V
7. Signal Shield

*Figure 3-2: Pin configuration for the multi-pin Sensor Input connector on the CSU front panel.*

## Data Acquisition Settings

The output of the CSU should be connected to a data acquisition system via a BNC connection. The recommended minimum resolution is 100 nV. Typical AC-coupled signal outputs will not exceed 1 V in magnitude; however, mean output voltages can reach up to 6 V at full scale output without the Zero Offset engaged (see DC Offset Measurement below for Zero Offset operation). The minimum bandwidth of the data acquisition system should be at least twice the measurement bandwidth of interest to avoid temporally aliasing the sensor signal. For fluctuating shear stress or pressure measurements, the input to the data acquisition system should be AC coupled.

The CSU is equipped with two different gain settings and an overload warning LED. The -20 dB Gain Button switches between the two gain settings and resets the overload circuit. When the Gain LED is off, the gain is set to 0 dB. When the Gain LED is on, the gain is set to -20 dB nominal (see the calibration datasheet for the actual gain of the system). To switch between gain settings, press the -20 dB Gain Button. The Overload LED turns on when the signal measured is too large for the signal conditioning electronics. The overload circuit can be reset by pressing the -20 dB Gain Button. If the Overload LED is on and does not turn off after resetting the overload circuit, use the lower gain setting.

## DC Offset Measurement

Before and after data acquisition, the DC offset from the output of the circuit should be recorded. The DC offset provides information on whether sensor drift has occurred during operation. The DC offset of the sensor can be monitored at the CSU output by introducing a BNC tee to split off the signal. A digital

multimeter with at least 6.5 digits should be set to maximize dynamic range for determining the DC offset of the sensor.

The Zero Offset correction brings the DC offset to nominally 0V. To engage the Zero Offset, press and hold the Zero Offset Button for 3-5 seconds. When the Zero Offset LED comes on, the DC offset will drop. To disengage the Zero Offset, press the Zero Offset Button for less than 3 seconds. The Zero Offset LED will turn off and the DC offset voltage will return to normal.

***NOTE*** **Output drift can occur due to temperature and humidity fluctuations during the course of a test. Consult the sensor data sheet to determine the effect of changes in environmental conditions during testing.**

# 4. Service and Repair

The CSU-1011-H2U AC/DC Capacitive Sensor Unit has been designed to operate correctly for many years. However, if a fault occurs which prevents it from operating correctly, disconnect the AC power cord and any cables connected to the front panel Input and Output connectors to prevent the risk of further damage. Contact a service representative to schedule an appointment for service and recalibration.


**The sensor unit contains no user-serviceable parts. It should be opened and serviced by qualified personnel only.**

# 5. WARRANTY

Interdisciplinary Consulting Corp. (IC2) warrants this product free from defects in material and workmanship for a period of one (1) year from date of shipment.

Interdisciplinary Consulting Corp. warrants the following items for 90 days from the date of shipment: cables, rechargeable batteries, and documentation.

During the warranty period, IC2 will, at its option, either repair or replace any product that proves to be defective. To exercise this warranty, please contact IC2 headquarters in Gainesville, FL. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or a minimum of 90 days.

## LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without IC2's express written consent, or misuse of any product or part. This warranty also does not apply to problems arising from normal wear or failure to follow instructions.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE. THE REMEDIES PROVIDED HEREIN ARE THE BUYER'S SOLE AND EXCLUSIVE REMEDIES.

NEITHER INTERDISCIPLINARY CONSULTING CORP. NOR ANY OF ITS EMPLOYEES SHALL BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OF ITS INSTRUMENTS AND SOFTWARE, EVEN IF INTERDISCIPLINARY CONSULTING CORP. HAS BEEN ADVISED IN ADVANCE OF THE POSSIBILITY OF SUCH DAMAGES. SUCH EXCLUDED DAMAGES SHALL INCLUDE, BUT ARE NOT LIMITED TO: COST OF REMOVAL AND INSTALLATION, LOSSES SUSTAINED AS THE RESULT OF INJURY TO ANY PERSON, OR DAMAGE TO PROPERTY.

## 6. Corporate Contact

# Interdisciplinary Consulting Corporation (IC2)

**Address:**
4585 NW 6th St Suite C
Gainesville, FL 32609

**Website:** http://www.thinkic2.com/
**Phone:** 352-283-8110
**Technical Support:** support@thinkic2.com
**Sales:** sales@thinkic2.com

**Interdisciplinary Consulting Corporation · 4585 NW 6th St Suite C · Gainesville, FL 32609**
**Telephone: 352-283-8110 · www.thinkic2.com · info@thinkic2.com**