AirChip3000

Description and Main Functions

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Applicability:

This manual applies to all devices based on the AirChip3000 with firmware version 3.1 or higher and hardware version 7.0.

1 OVERVIEW

The AirChip3000 is a programmable, custom designed integrated circuit developed by ROTRONIC and is at the core of the following humidity-temperature measuring devices:

- o HygroClip2 (HC2) probes
- o HF3 transmitters and thermo-hygrostats
- o HF4 transmitters
- o HF7 transmitter
- o HL20 data loggers
- o HP21 hand-held indicators
- o Custom designed OEM products

The purpose of this technical note is to briefly describe the ROTRONIC AirChip3000 digital technology and its main functions. The functions provided by the AirChip3000 are common to all devices that are based on the AirChip3000 and are not described again in the individual device instruction manuals.

1.1 *Introducing the AirChip3000*

The AirChip3000 consists of an ASIC, a microcontroller and an E-PROM memory, all in a single chip. This gives the AirChip3000 the functionality of a small specialized computer. The basic function of the AirChip3000 is to condition and process the signals from two external sensors: a humidity sensor and a temperature sensor, and to provide both digital and analog output signals. In addition, the AirChip3000 offers a wide range of functions such as dew / frost point calculation, sensor calibration and adjustment, alarms, sensor diagnostics and even data recording.

AirChip3000 installed on its small companion PCB

An important feature of the AirChip3000 is the ability for the user to easily update the firmware and keep the AirChip3000 up-to-date regarding any future functionality improvement.

1.2 *Function overview*

The AirChip3000 functions fall into two main categories:

a) Internal functions

- Temperature sensor signal conditioning
- Humidity sensor signal conditioning
- Sensor failure digital alarm

b) User functions

- User configurable settings
- Psychrometric calculations
- Out-of-limit values
- Simulator mode
- Automatic humidity sensor test and drift compensation
- Sensor failure mode
- Data recording
- Humidity-temperature calibration and adjustment

1.3 *Relevance of the AirChip3000 functions*

The practical relevance of some of the AirChip3000 functions depends on the type of device that uses the AirChip3000. Using the example of a transmitter, the data recording function has practical relevance primarily when the transmitter has a digital interface that is permanently connected to a PC or to a network.

1.4 *Access to the AirChip3000 configuration and user functions*

Access to the user configurable settings and to the user functions described in this note requires connecting the AirChip3000 device to a PC running the ROTRONIC HW4 software (version 2.1.0 or higher). Some of the user functions can also be accessed by connecting the AirChip3000 device to a compatible ROTRONIC device such as the HP23 hand-held calibrator.

Instructions for using the AirChip3000 functions are provided either in the HW4 instruction manual (Device Manager) or in the instruction manual of each specific device.

1.5 *Digital communication with the AirChip3000*

Starting with firmware version 1.3, the AirChip3000 accepts several communication protocols that allow users to read the measurement data without the HW4 software. When using the standard RO-ASCII protocol, access to some of the AirChip3000 functions is also possible without HW4. For details, see document **E-M-AC3000-CP**.

2 USER CONFIGURABLE SETTINGS

A list of the settings that can be configured by the user is provided in the individual hardware and software instruction manuals for the devices based on the AirChip3000. This list varies depending on the type of device. Each instruction manual also provides a list of the default factory settings.

3 INTERNAL FUNCTIONS

3.1 *Temperature sensor signal conditioning*

The resistance [Ohm] of an RTD is a non-linear function of temperature [˚C]. The AirChip3000 uses a 4th degree polynomial to change the temperature signal from the RTD to a linear signal. The default factory values for the polynomial coefficients conform to generally accepted standards (IEC 751 – ASTM E1137) and are shown below:

$$R = R_0(1 + At + Bt^2 + C(t-100)t^3)$$

Default values:

R_0 = 100 Ω
A = $3.9083\ 10^{-3}$
B = $-5.7750\ 10^{-7}$
C = $-4.1830\ 10^{-12}$ Note: at temperature values ≥ 0˚C, the coefficient C is set to zero.
t = temperature in ˚C

The default factory coefficients are retained in the AirChip3000 memory. This allows returning the AirChip3000 to its original factory settings at any time.

3.2 *Humidity sensor signal conditioning*

The capacitance of the humidity sensor used in conjunction with the AirChip3000 is a non-linear function of relative humidity (%RH). The AirChip3000 changes the raw values read from the humidity sensor to linear values and also compensates these values for the effect of temperature on the humidity sensor.

Humidity sensor linearization

The AirChip3000 keeps in memory a set of two tables (A1% and A2%) consisting of corrections (linearization) to be applied at 23 °C ± 5 °C to the raw humidity data generated by the humidity sensor. Each table holds 101 values (from 0 to 100 %RH, in steps of 1 %RH) to achieve a very precise linearization of the humidity sensor. Table A1% holds the factory default values. Table A2% holds the additional corrections generated during adjustments made by the user. The linear humidity value is obtained by adding to the raw humidity value the corresponding corrective values from both tables. An interpolation is used for intermediate raw values.

Table A1% cannot be modified by the user. This table is used to return the AirChip3000 to its original factory settings at any time after zeroing the values generated by the user in table A2%.

Humidity sensor temperature compensation

Practically every make of relative humidity sensor requires a compensation for the effect of temperature on the humidity output signal in order to maintain accurate measurements over a wide range of temperature conditions. In the specific case of a capacitive sensor, compensation is required because the dielectric characteristics of both the water molecule and the hygroscopic polymer used in the sensor vary with temperature.

The AirChip3000 holds in memory a set of 31 tables corresponding to temperature values within the range of -100 to +200˚C (see note below). Each table holds compensation data between 0 and 100 %RH in steps of 10 %RH. A temperature of 23˚C is used as the reference.

Based on the humidity and temperature data provided by the sensors, the AirChip3000 uses the values from the tables to apply a correction for the effect of temperature on the humidity sensor. Intermediate correction values are interpolated.

Note: Devices based on the AirChip3000 are compensated only within the temperature limits at the sensors specified by the factory for each type of device (see device instruction manual > Technical Data).

3.3 *Sensor failure digital alarm*

The AirChip3000 will automatically detect a major failure of the humidity and temperature sensors such as an open circuit or a short circuit and will trigger a digital alarm. This condition will be indicated when the AirChip3000 device has its own display or is connected to a PC running the ROTRONIC HW4 software.

4 USER FUNCTIONS

4.1 *Psychrometric calculations*

The AirChip3000 can be configured to calculate either the dew point or the frost point. The dew point and frost point calculations differ at values below freezing. Below the freezing point of water, the dew point calculation is the temperature at which water vapor condenses as a liquid (overcooled water as may be encountered at values down to -40˚C). By contrast, the frost point calculation is the temperature at which water vapor condenses as a solid (ice). Above freezing both calculations give the same numerical result.

The AirChip3000 can also be configured not to calculate any parameter.

4.2 *Out-of-limit values*

The AirChip3000 can be configured to trigger a digital alarm whenever humidity, temperature or the calculated parameter are outside of limits defined by the user. This condition will be indicated when the AirChip3000 device has its own display or is connected to a PC running the ROTRONIC HW4 software. The out-of-limits alarm indication is not available on the AirChip3000 analog outputs.

4.3 *Simulator mode*

The AirChip3000 can be configured to temporarily generate user defined fixed digital and analog signals for both temperature and humidity. Fixed signals can be used to verify both the proper transmission of the signals after completing an installation (loop validation).

4.4 *Automatic humidity sensor test and drift compensation*

The AirChip3000 can be set to test the condition of the humidity sensor at regular intervals of time and to compensate excessive sensor drift.

Any humidity sensor can drift progressively due to the chemical effect of contaminants present in the environment. The correction to be applied to compensate for sensor drift was established based on an analysis of defective ROTRONIC Hygromer® sensors collected from the field. This analysis shows that a contaminated sensor typically exhibits drift primarily at humidity conditions above 50 %RH

Sensor test

The condition of the sensor is evaluated by measuring the current value of humidity in a special test mode. In the case of a good sensor, the %RH value measured in the test mode should agree with the value measured in the normal measuring mode. The test returns a sensor error which is defined as the difference between the two values.

The sensor error returned by the test is evaluated against two threshold values that can be set by the user:

- **Correction Threshold**: When the sensor error is less than this value, the humidity sensor is considered to be good and does not require a correction
- **Defective Threshold**: When the sensor error equals or exceeds this value, the humidity sensor is considered to be defective and a digital alarm is triggered (see Sensor Failure Mode).

The sensor test is not designed to be meaningful at humidity values of 50%RH or lower and the test is subject to a lower limit that can be set by the user. The default value set by the factory is 60 %RH

Correction method

When the function is enabled, and provided that the test returns a sensor error that is between the correction threshold and the defective threshold, a correction (**SQ**) is added to the humidity value measured by the sensor.

- When the sensor measures a humidity value (**RH**) of 47.7 %RH or higher:

$$SQ = A * RH^2 + B * RH + C$$

- SQ is equal to zero for any humidity value (**RH**) that is less than 47.7 %RH. Whenever the sensor test returns an error that is less than the correction threshold, the value of SQ is automatically set to zero for the entire humidity range.

Configuration settings of the function

Function Configuration Settings	Factory default
Function enabled	N
Lower limit for sensor test	60 %RH
Test Mode	4 (see note below)
Coefficient A	0.0038 (see note below)
Coefficient B	-0.2004 (see note below)
Coefficient C	0.9077 (see note below)
CT: Correction Threshold	2 (see note below)
DT: Defective Threshold	5 (see note below)

NOTE:

- All default values are subject to future change by the factory. Do not change the current default settings without consulting the factory as this could negatively affect measurement accuracy.
- To test the condition of the humidity sensor without applying any correction to the measurements, set the value of coefficients A, B and C to zero.

Action table

SE: Sensor Error (Test)	Test Result	Correction	Alarm
SE < CT	Good	N	N
CT ≤ SE < DT	SQ-Tuned	Y	N
SE ≥ DT	Bad	-	Y (see note below)

Note: The AirChip3000 issues a “Bad” sensor digital alarm only when both of the following conditions are met: (a) the %RH measured prior to the test is at least equal to the lower limit set for the sensor test and (b) the humidity sensor test returns the result “Bad”.

4.5 *Fail safe mode*

The fail safe mode can be used to prevent an undesirable action by a humidity or temperature control device that relies on the analog or digital signals of the AirChip3000.

The AirChip3000 can be configured to generate a fixed humidity or temperature value (both digital and analog) in the event of a major failure of the humidity or temperature sensor (shorted or open sensor). This mode is also triggered when the AirChip3000 issues a “Bad” sensor alarm as previously defined. The fixed values generated by the AirChip3000 are pre-defined by the user.

Note: The calculated dew or frost point takes a fixed value whenever the value of both temperature and humidity is fixed.

4.6 *Data recording*

The AirChip3000 can be programmed to record both the humidity and temperature measurement data. The calculated parameter cannot be recorded. The recorded data are retained in the AirChip3000 non-volatile memory. The main characteristics of this function are as follows:

- Relative humidity values are recorded with a resolution of 0.1 %RH
- Temperature values are recorded with a resolution of 0.05°C / 0.05°F
- Memory capacity: 2000 pairs of humidity and temperature values
- Adjustable log interval (multiples of 5 seconds, up to 23 h 59 m 55 s)

Note: Any recorded data present in the AirChip3000 is automatically erased whenever a new recording session is started. Data recording is paused when the AirChip3000 is not powered and resumes automatically as soon as power is re-established (see also Data Recording Modes).

4.6.1 Data recording modes

The AirChip3000 features two different data recording modes:

Loop: When the memory is full the AirChip3000 dumps the oldest data sample and keeps recording. The memory retains the most recent 2000 pair of values.

Start-Stop: The AirChip3000 stops recording data as soon as the memory is full (no recorded data is lost)

Any of the two modes can be stopped at any time by sending a command to the AirChip3000.

4.6.2 Date and time

The AirChip3000 does not have an internal real time clock and does not keep track of the date and time. An internal time counter ensures that data is recorded at fixed intervals of time as configured by the user. The log interval must be entered as a multiple of 5 seconds. The value of the log interval is retained in the AirChip3000 non-volatile memory.

When using the ROTRONIC HW4 software to download recorded data to a PC, the date and time associated with each individual pair of recorded values can be reconstructed by the HW4 software provided that the user has made a note of the following:

Data recorded in the Start-Stop mode: Date and time when the recording was started by the user.

Data recorded in the Loop mode: Date and time when the recording was ended by the user.

The date and time information can be entered using the HW4 “Fine Tuning” function prior to downloading the recorded data from the AirChip3000 (see HW4 manual E-M-HW4v2.1-DR).

There is a tolerance on the accuracy of the AirChip3000 internal clock. As a result, the actual log interval may differ slightly from the value specified by the user and this may cause an error on the time and date calculations when data is downloaded to a PC. Prior to using HW4 to download the recorded data, this error can be reduced by using the HW4 “Fine Tuning” function.

4.7 *Calibration and adjustment*

Note: for detailed instructions, please consult the ROTRONIC HW4 software instruction manual or the individual instrument manuals.

For both humidity and temperature, adjusting the AirChip3000 is a 2-step process. Please note that the two steps do not have to be carried out at the same time or on the same day.

● **Step 1: Calibration**

Calibration consists in capturing humidity and / or temperature values measured by an instrument at a number of known reference conditions without making any changes to the instrument. As-Found data is the result of a calibration.

Temperature: the AirChip3000 can retain in memory up to 2 calibration points, each consisting of: measured temperature value and reference temperature value. In principle, the calibration points can be saved in any order. The calibration points are retained in memory until erased by the user or until the probe is adjusted by the user.

Humidity: the AirChip3000 can retain in memory up to 100 calibration points, each consisting of: measured humidity value, reference humidity value and temperature at the time of calibration. In principle, the calibration points can be generated at any temperature and saved in any order. The calibration points are retained in memory until erased by the user or until the AirChip3000 is adjusted by the user.

Note: HW4 offers the possibility of using the dew or frost point measured by a chilled mirror instrument as the source for the reference humidity value. HW4 converts the dew or frost point into relative humidity based on the temperature measured by the AirChip3000.

● **Step 2: Adjustment (with the HW4 software)**

Adjustment consists in making the humidity and / or temperature values measured by an instrument agree as closely as possible with a number of known reference conditions. As-Left data is the result of an adjustment.

Temperature: the temperature signal of the AirChip3000 is adjusted based on the calibration points present in memory. The type of adjustment depends on the number of calibration points:

- 1 calibration point: offset adjustment (equivalent to a 1-point adjustment)
- 2 calibration points: offset and slope adjustment

The AirChip3000 uses a 4th degree polynomial to change the raw data generated by the temperature sensor to a linear response. For details, see document **E-T-AC3000-DF-V1**.

o A 1-point adjustment changes the offset used by the temperature A/D converter. This is equivalent to changing the value R_0 (resistance value of the RTD at 0˚C) in the 4th degree polynomial used by the AirChip3000.

o A two-point adjustment changes both the offset used by the temperature A/D converter and the coefficient A (slope) of the 4th degree polynomial used by the AirChip3000.

In addition to the user generated values, the AirChip3000 retains in memory the factory defaults for the value R_0 and the coefficients of the 4th degree polynomial. The factory defaults cannot be changed by the user and are always available to return the AirChip3000 device to its original condition.

Adjustment accuracy depends both on the number and on the distribution of the calibration points over the temperature range to be measured.

As an alternative method, the temperature signal of the AirChip3000 can be adjusted by doing a 1-point adjustment at 0˚C and entering a new set of coefficients for the 4th degree polynomial. In this case temperature calibration points are not required.

Humidity: the AirChip3000 adjusts the raw humidity data provided by the sensor so as to agree with the calibration points present in memory. The type of adjustment depends on the number of calibration points:

- 1 calibration point: general offset adjustment (equivalent to a 1-point adjustment)
- 2 calibration points: offset and slope adjustment
- 3 or more calibration points: offset, slope and linearization adjustment

The AirChip3000 retains in memory two sets of tables. The combined data from both tables is used to change the humidity sensor raw data to a linear signal (see Measurement Model). Table A1% holds the factory default values and table A2% holds the values generated as a result of the most recent humidity adjustment by the user. Initially all values in table A2% are set to zero.

The values in both tables A1% and A2% are valid when the humidity sensor is at a temperature of 23 ˚C. Regardless of the actual temperature associated with each humidity calibration point, the values in table A2% are automatically brought back to the 23 ˚C reference temperature. This conversion relies on the sensor temperature compensation data that is programmed by the factory in the AirChip3000 memory.

The accuracy of the user adjustments depends both on the number and on the distribution of the calibration points. The most accurate adjustment results are obtained by using 4 or more calibration points, equally distributed over the humidity range to be measured.

The factory values A1% cannot be changed by the user and are always available to return the AirChip3000 to its original condition.

Note: When using the ROTRONIC HW4 software, user adjustment data and adjustment results can be saved to a file for trouble-shooting purposes.

5 ERES CONFORMANCE (FDA, GAMP)

When used in conjunction with the ROTRONIC HW4 software, products based on the AirChip3000 conform to the requirements of FDA and GAMP for electronic records and electronic signatures (ERES). The AirChip3000 retains in memory important data such as the date of the last configuration, the date of the last adjustment, last adjustment values, etc. The AirChip3000 can be password protected against unauthorized access to the main user functions (configuration, humidity and temperature adjustment, etc.).

6 FIRMWARE UPDATES

The ROTRONIC HW4 software includes a tool that can be used to easily update the AirChip3000 firmware after connecting the AirChip3000 device to a PC.

Firmware updates serve the purpose of keeping the AirChip3000 up-to-date regarding any future functionality improvement. Firmware updates will be available on the ROTRONIC website for downloading. Firmware files are given a name that shows both to which device the file applies and the version number of the firmware. All firmware files have the extension ROF.

7 SPECIFICATIONS (AirChip3000)

Main Functions	
Measurement	Relative humidity and temperature
Psychrometric calculations	Dew or frost point (digital and analog signals)
Temperature compensation	Maintains the accuracy of humidity measurement over the temperature range of the humidity sensor based on more than 30,000 reference points
Humidity adjustment	Against reference environment: 1-point (offset) or up to 100 points
Temperature adjustment	Against reference environment 1-point (offset) or up to 2 points
Data logging	Loop recording (retains latest values) Up to 2000 value pairs (%RH and °C / °F) Retains the log start time Each value pair is numbered (counter)
Humidity sensor test and drift compensation	Automatic, configurable
Defective humidity sensor alarm	Digital and analog signals, configurable
Out-of-limits value alarm	Digital signal only, configurable
Firmware update	via UART interface

Humidity measurement	
Humidity sensor	Depends on application
Measuring range	0…100 %RH

Temperature measurement	
Temperature sensor	Pt100 RTD, IEC 751 class A
Measuring range	-100…200 °C (expanded range: 600 °C)
Sensor excitation current	300 µA (30 µA)
Sensor linearization	4th degree polynomial (IEC 751 / ASTM E1137)
Sensor wiring type	4-wire

Configurable analog outputs (D/A converters)		
Output 1		Can be made to correspond to any parameter
	Default parameter	Relative humidity
	Scaling limits	-999.99…9999.99 engineering units
	Output signal range	0...1 V
Output 2		Can be made to correspond to any parameter
	Default parameter	Temperature
	Scaling limits	-999.99…9999.99 engineering units
	Output signal range	0...1 V
Output 1 and Output 2		
	D/A resolution	16 Bit / 15 µV
	Offset at 0 V	<10 mV
	Analog signal deviation from digital signal	±1 mV
	Minimum external load	1000Ω
	Internal resistance	<10 Ω

Digital interface	
Interface type	UART (Universal Asynchronous Receiver Transmitter)
Organization	Dialog, duplex
Default configuration	Baud rate : 19,200 Parity : none Data bits : 8 Stop bits : 1 Flow Control : none
Tolerance	3 %
Baud rate configuration:	No
Logical levels	Logical 0: <= 0.3V * VDD Logical 1: >= 0.8V * VDD
Maximum cable length	5 m (16.4 ft) w/o signal booster

Start-up time and data refresh rate	
Start-up time	1.5 s (typical)
Data refresh rate	1.0 s (typical) – when not calculating any parameter

8 DOCUMENT RELEASES

Doc. Release	Date	Notes
_10	Sep. 23, 2008	Original release
_11	Oct. 18, 2008	Added digital communication with the AirChip3000 Renamed Sensor failure Mode to Fail Safe Mode
_12	August 22, 2014	Update for latest hardware (7.0) and firmware (3.1) version. Technical specification adapted: - Pt100, class A - Offset of analog output