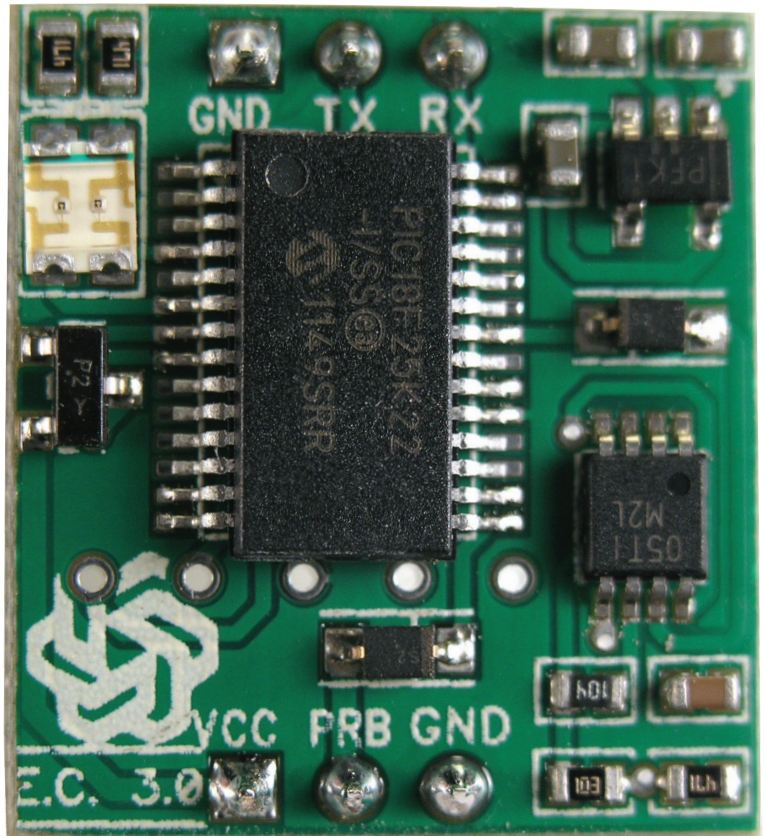


# Micro footprint electrical conductivity / total dissolved solids / salinity monitoring subsystem

## Features

- E.C. readings +/- 5 $\mu$ s
- Full E.C. capability from 11 $\mu$ s to 92,000 $\mu$ s
- Temperature dependent or temperature independent readings
- Total dissolved solids (TDS) referenced to KCL
- Salinity is derived from the Practical Salinity Scale (PSS-78)
- Data output is a comma separated string:  $\mu$ s, TDS, Salinity
- Single reading or continuous reading modes
- Simple asynchronous serial connectivity **(voltage swing 0-5v)**
- Simple instruction set consisting of only 6 (not including calibration) commands
- Micro footprint circuitry
- Debugging LED's
- 5V operational voltage



4.2 mA in active mode\*  
3.8 mA in quiescent mode\*  
\*LED's off

## Description

Reading the E.C, TDS and salinity of water is an extremely complicated task, frustrating many embedded systems engineers. Atlas Scientific has taken the complexity out of water quality analysis with respect to E.C/TDS/Salinity with the Atlas Scientific E.C Circuit .

The E.C. Circuit is a highly compact electrical conductivity monitoring system that fits into any breadboard. This design configuration allows the user to accurately monitor E.C./TDS/Salinity without having to add any additional circuitry or components to your design. The E.C. Circuit can take readings from 3 different types of conductivity probes (K 0.1/ K 1.0/K 10); giving the E.C. Circuit a range of 11 $\mu$ s to 92,000 $\mu$ s. Communication with the E.C. Circuit is done using only 6 simple commands. The E.C Circuit provides scientific grade readings to any embedded system that has a UART asynchronous serial connection interface.



# Contents

System Overview .....	3
Pin Out .....	4
Absolute Maximum Ratings .....	4
Device operation .....	5
L1 .....	6
L0 .....	7
R .....	7
TT.TT[C] .....	8
C .....	9
E .....	9
X .....	9
I .....	9
Calibration instructions .....	10

# System Overview

The E.C. Circuit is easy to connect to your micro-controller, requiring only two data lines. 6 simple commands are used to control the E.C. Circuit. It is necessary to connect the E.C. Circuit to a conductivity probe with a K constant of 0.1, 1.0 or 10.0 for the E.C. Circuit to work properly. The E.C. Circuit has been designed to operate at 5.0V. Care should be taken to make sure that the power supplied to the E.C. Circuit is as close to 5 volts as possible for accurate readings.

## Sensor type

Three different types of conductivity probes can be connected to the E.C. Circuit

Each probe will provide high resolution if it is used in the correct type of water.

Probe type	Type of water to be analyzed	Probe range
K 0.1	Pure water and drinking water	11 $\mu$ s to 3,000 $\mu$ s
K 1.0	Fresh water to brackish water	1,300 $\mu$ s to 40,000 $\mu$ s
K 10	Salt water	36,000 $\mu$ s to 92,000 $\mu$ s

Using a K 0.1 probe in brackish or salt water will return "--" indicating the reading is out of range. Conversely using a K 10 probe in drinking water with a conductivity of 100  $\mu$ s would read "0"; as the probe would not be able to detect anything in the water.

## Pin Out

**GND** Return for the DC power supply. GND (& Vcc) must be ripple and noise free for best operation.

**Vcc** Operates at 5.0V

**TX** TX output delivers asynchronous serial data in TTL RS-232 format, except voltages are 0-5v. The output is (up to 17) ASCII digits representing the E.C. in Microsiemens/TDS(in PPM)/Salinity(PSS-78) and ending with a carriage return (ASCII 13).

Example: 50000,32800,32.7<CR>

50,000µs 32,800ppm 32.7 salinity

The baud rate is: 38400, 8 bits, no parity, with one stop bit.

If standard voltage level RS232 is desired, connect an RS232 converter such as a MAX232.

## Absolute Maximum Ratings\*

Parameter	MIN	TYP	MAX	UNITS
Storage temperature (Micro-E.C. controller)	-40		125	C°
Storage temperature (E.C. probe)	-20	25	125	C°
VCC	5.0	5.0	5.0	V

**\*Note:** Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to maximum rating conditions for extended periods may affect device reliability

## Device operation

When the E.C. Circuit is connected to a power supply (5.0v) the **green** "power on" indicator LED will be lit. The device will immediately enter standby mode and wait for a command.

There are a total of 8 different commands that can be given to the Micro-E.C. system. (These are operational commands and not calibration commands)

**All commands must be followed by a carriage return <CR>.**  
**Commands are not case sensitive.**

## Operational commands: Quick Reference

Command	Function	Output
L1	Enables debugging LEDs	Enabled (default state)
L0	Disables debugging LEDs	Disabled
R	Returns a single E.C./TDS/salinity reading. Where the temperature is set to 23 ° Celsius.	50000,32800,32.7
TT.T,[C]	Returns a temperature compensated conductivity reading. Adding the optional "C" (25.0,c<CR>) Will return continues readings Q 1000MS	50000,32800,32.7
C	Returns continues readings Q 1000ms at the temperature previously used (if temp temperature was not set 23° C is used)	50000,32800,32.7
E	Stops all readings. Enter standby/quiescent mode	N/A
X	Instructs the E.C. Circuit to do a factory reset	N/A
I	Returns device info	N/A

## Calibration Command: Quick Reference

Command	Function	Output
P,[1,2,3]	Sets the probe type being used by the circuit	k0.1, k1.0, k10.0
Z0	Dry probe calibration	"Dry Cal"
	<b>K0.1 probe calibration</b>	
Z2	Calibrate for 220 $\mu$ s	"220 $\mu$ s cal"
Z30	Calibrate for 3,000 $\mu$ s	"3,000 $\mu$ s cal"
	<b>K1.0 probe calibration</b>	
Z10	Calibrate for 10,500 $\mu$ s	"10,500 $\mu$ s cal"
Z40	Calibrate for 40,000 $\mu$ s	"40,000 $\mu$ s cal"
	<b>K10.0 probe calibration</b>	
Z62	Calibrate for 62,000 $\mu$ s	"62,000 $\mu$ s cal"
Z90	Calibrate for 90,000 $\mu$ s	"90,000 $\mu$ s cal"

## Command Definitions

**L1** This will enable both debugging LED's.

The E.C. Circuit has two LED's

**Green LED** .....Power indicator

**Red LED** .....Instruction received/E.C. transmit

By default, the LED's are enabled.

These LED's are designed to help the user determine that the E.C. Circuit is operating properly.

Changes to this setting are written to EEPROM memory and therefore will be retained even if the power is cut.

*\*Keeping the LEDs on will consume an additional 30 mA\**

**Full proper syntax: I1<cr> or L1<CR>**

**L0** This will disable both debugging LED's.

Changes to this setting are written to EEPROM memory and therefore will be retained even if the power is cut.

**Full proper syntax: I0<cr> or L0<CR>**

**R** Instructs the E.C. Circuit to return a single E.C. reading.

Taking a single reading is not considered scientifically accurate. The E.C. Circuits readings will become accurate after ~ 15-25 continues readings. A single reading will only give you an estimate of the conductivity.

\*This instruction takes 1000 milliseconds to complete

When using the "R" command the temperature is defaulted to 23° C if no temperature data has been entered. If temperature data has been entered then the last temperature entered is used.

**Full proper syntax: r<cr> or R<CR>**

The E.C. Circuit will respond: EC,TDS,SAL<CR>

**Where:**

**EC is the electrical conductivity in  $\mu$ s**

**TDS is Total Dissolved Solids (referenced to Kcl)**

**SAL is Salinity (Practical Salinity scale 1978)**

If the probe responds with "--" the E.C, TDS or salinity is out of range.

Such as:  
70000,43000,--

This is because the PSS (practical salinity scale) only goes to 42; which is reached at a conductivity of 62,290  $\mu$ s

--" can also be seen when using a probe that is not designed for the type of water it is immersed in. Using a K.01 probe in saltwater would produce that type of reading.

**TT.TT[,C]** Instructs the E.C. Circuit to return a single temperature compensated E.C. reading.

Inputting a temperature value to the E.C. Circuit will change the circuits default temperature. All new readings will be based off of that new temperature until system reboot.

A temperature can be entered one time or each time a new reading is taken. Placing a ",c" after the temperature instructs the E.C. Circuit to take continues readings after the temperature has been entered

**Temperature is always in Celsius**

**Full proper syntax: 17.8<CR> or 17.8,C<CR>**

**(Where 17.8 is a representation of any Celsius temperature you wish to enter)**

The E.C. Circuit will respond: EC,TDS,SAL<CR>

**Where:**

**EC is the electrical conductivity in  $\mu\text{s}$**

**TDS is Total Dissolved Solids (referenced to Kcl)**

**SAL is Salinity (Practical Salinity scale 1978)**

**If 17.8,C<CR> was entered the readings would be transmitted from the E.C. Circuit every 1000ms**

If the probe responds with "--" the E.C, TDS or salinity is out of range.  
Such as: 65000,35100,--

This is because the PSS (practical salinity scale) only goes to 42; which is reached at a conductivity of 62,290  $\mu\text{s}$

--" can also be seen when using a probe that is not designed for the type of water it is immersed in. Using a K.01 probe in saltwater would produce that type of reading



**C** Instructs the E.C. Circuit to take continues reading every 1000ms.

The E.C. Circuits reading will become accurate after ~ 15-25 continues readings.

**Full proper syntax:** **c<cr> or C<CR>**

The E.C. Circuit will respond: EC,TDS,SAL<CR>

**Where:**

**EC is the electrical conductivity in  $\mu$ s**

**TDS is Total Dissolved Solids (referenced to Kcl)**

**SAL is Salinity (Practical Salinity scale 1978)**

**E** Instructs the E.C. Circuit to End continuous mode and enter standby/quiescent mode

Delivering this instruction when not in continuous mode will have no effect on the E.C. Circuit

**Full proper syntax:** **e<cr> or E<CR>**

The E.C. Circuit will respond by ceasing data transmission.  
There is no ASCII response to this instruction

**X** Instructs the E.C. Circuit to do a factory reset

Delivering this instruction will clear all calibration data and temperature setting.  
The E.C. Circuit then will enter standby mode

**Full proper syntax:** **x<cr> or X<CR>**

The E.C. Circuit will respond: **Factory reset<CR>**

**I** Returns device info

Delivering this instruction will instruct the E.C. Circuit to transmit it device info.

**Full proper syntax:** **i<cr> or I<CR>**

The E.C. Circuit will respond: **E,V3.0,4/11<CR>**

**Where:**

**E =E.C. Circuit**

**V3.0= Firmware version**

**4/12= Date firmware was written**

# Calibration Instructions

In order to provide the engineer with the greatest possible accuracy E.C. Circuits now ship uncalibrated. This is because micro voltage changes in your circuit design cannot be compensated for at the factory.

**The E.C. stamp must be calibrated in the following order:**

- **Set probe type**
- **Calibrate for a dry probe**
- **Calibrate for high side  $\mu$ s reading**
- **Calibrate for low side  $\mu$ s reading**

**All calibration data is stored in the EEPROM memory and will not be lost during power down.**

## Step 1: Set probe type

Connect the E.C. probe to your E.C. Circuit through the BNC connector. The E.C. Circuit needs to know what type of probe it is connected to; there are 3 possible probe types to choose from.

K0.1  
K1.0  
K10.0

The E.C. Circuit will permanently change its configuration settings to the probe type that has been specified. Anytime a new probe type is connected to the stamp it must be configured to read from that probe.

The command to set the probe type is:

"P,1" for a K0.1 E.C probe  
"P,2" for a K1.0 E.C probe  
"P,3" for a K10.0 E.C probe

**P,[1] [2] [3]** Informs the E.C. Circuit what type of probe it is connected to.

The E.C. Circuit is defaulted to probe type#2

## Probe command table

<b>P,[1][2][3] command</b>	<b>Probe type</b>	<b>E.C.-Stamp response</b>
P,1<cr>	K 0.1	K0.1<cr>
P,2<cr>	K1.0	K1.0<cr>
P,3<cr>	K10.0	K10.0<cr>

## Probe type table

<b>Probe type</b>	<b>Type of water to be analyzed</b>	<b>Probe range</b>
K 0.1	Pure water and drinking water	11µs to 3,000µs
K 1.0	Fresh water to brackish water	1,300 µs to 40,000µs
K 10	Salt water	36,000 µs to 92,000µs

## Full proper syntax:

(In this example we will set the E.C. to a K0.1 probe type)

**p,1<cr> or P,1<CR>**

The E.C. Circuit will respond: **k0.1<CR>**

## Step 2: Dry Calibration

Do not put the probe in any liquid. You are going to calibrate your E.C. Circuit for a dry condition. This is much like setting the TARE on a scale.

**Z0** Informs the E.C. Circuit to calibrate for a dry probe.

**Full proper syntax: z0<CR> or Z0<CR>**

The E.C. Circuit will respond: **Dry Cal<CR>**

### Step 3: Calibrate the E.C. stamp for high side $\mu\text{S}$ readings

Each E.C. probe type is calibrated against 2 different E.C. solutions. One E.C. calibration solution is on the low side of the probes E.C. range and the other calibration solution is on the high side.

Probe type	Low side calibration solution	High side calibration solution
K 0.1	220 $\mu\text{S}$	3,000 $\mu\text{S}$
K 1.0	10,500 $\mu\text{S}$	40,000 $\mu\text{S}$
K 10	62,000 $\mu\text{S}$	90,000 $\mu\text{S}$



## Calibration is first done on the high end.

K0.1 first calibration: 3,000 $\mu\text{S}$   
 K1.0 first calibration: 40,000 $\mu\text{S}$   
 K10.0 first calibration: 90,000 $\mu\text{S}$

- Place the E.C. probe in the high side calibration solution.
- Put your E.C. Circuit in continues mode by transmitting the "C" command.
- Let the E.C. Circuit run in continues mode for 3-5 minutes. The readings will start to stabilize after 3-5 minutes.
- Transmit high side calibration command

Probe type	High side calibration solution	High side calibration command
K 0.1	3,000 $\mu$ s	Z30<CR>
K 1.0	40,000 $\mu$ s	Z40<CR>
K 10	90,000 $\mu$ s	Z90<CR>

### Example:

(Here we calibrate an E.C. Circuit connected to a K10 probe.)

**Full proper syntax:**    **z90<CR> or Z90<CR>**

The E.C. Circuit will respond:    **90,000  $\mu$ s cal**

### Step 4: Calibrate the E.C. stamp for low side $\mu$ s readings

Now that the E.C. Circuit has been calibrated for the high side, now calibrate it to the low side.

The second calibration event is done on the low side.  
Do not do low side calibration first.

K0.1    Second calibration: 220 $\mu$ s  
K1.0    Second calibration: 10,500 $\mu$ s  
K10.0    Second calibration: 62,000 $\mu$ s

- Place the E.C. probe in the low side calibration solution.
- Put your E.C. Circuit in continues mode by transmitting the "C" command.
- Let the E.C. Circuit run in continues mode for 3-5 minutes. The readings will start to stabilize after 3-5 minutes.
- Transmit high side calibration command

Probe type	Low side calibration solution	Low side calibration command
K 0.1	220µs	Z2<CR>
K 1.0	10,500µs	Z10<CR>
K 10	62,000µs	Z62<CR>

### Example:

(Here we calibrate an E.C. Circuit connected to a K10 probe.)

**Full proper syntax: z62<CR> or Z62<CR>**

The E.C. Circuit will respond: **62,000 µs cal**

## Calibration is now complete

Salinity is derived using: The Practical Salinity Scale 1978 (PSS-78)

$$S = a_0 + a_1 R_T^{1/2} + a_2 R_T + a_3 R_T^{3/2} + a_4 R_T^2 + a_5 R_T^{5/2} + \frac{(T-15)}{1+k(T-15)} \{ b_0 + b_1 R_T^{1/2} + b_2 R_T + b_3 R_T^{3/2} + b_4 R_T^2 + b_5 R_T^{5/2} \}$$

$$\text{Where: } R = \frac{C(S, T_{68}, P)}{C(35, 15_{68}, 0)}$$

$$\text{Where: } R_T = \frac{R}{r_T R_P}$$

$$\text{Where: } R_P = 1 + \frac{A_1 p + A_2 p^2 + A_3 p^3}{1 + B_1 T + B_2 T^2 + B_3 R + B_4 TR}$$

