1. General Description

The BoSL All-in-One probe combines a number of CotS sensors to provide a low-cost low-power avenue to depth, temperature and EC measurement of water in a small package.

By combining the MS5803, DS18B20, and EC measurement, it inherits the excellent characteristics of these sensors to deliver a high quality measurements.

The sensor itself requires little external circuitry to run and has been specifically designed for quick installation with the BoSL Board datalogger. It is compatible with Arduino-based boards or other microcontrollers.

The predominantly digital data interface reduces the impact of noise interfering with signal quality over longer cables.

Robust waterproofing enables the sensor to last in challenging environments for extended periods of time, while still being easy to install and adaptable for a wide range of installation scenarios.

The probes quick conversion time on all three measurement types allow it to quickly return to a low power sleep mode minimising battery use and enabling logging times of over a year when combined with appropriate dataloggers.

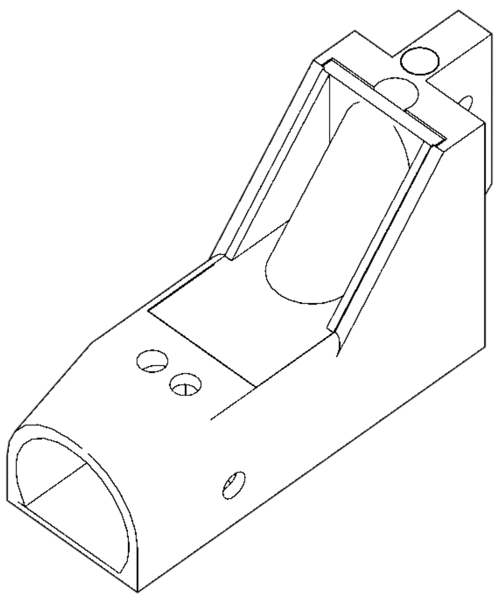
2. Applications

- Stormwater drains
- Water flows

3. Features

- Depth measurement
  - mm resolution
  - differential pressure
- Temperature measurement
  - 0.5°C accuracy
- EC measurement
  - ± 10% accuracy
- 1 µA sleep current
- 3.3V operation

4. Device Drawing



5. Pin Description

The BoSL All-in-One probe is terminated either with an RJ-45 T-586B wiring or a free CAT5 cable.

Pin		Description
Name	Colour	
ECP	white/orange	Power for EC measurement
VCC	orange	Input supply voltage
NC	white/green	No connect
SCL	blue	MS5803 I2C serial clock line
DQ	white/blue	DS18B20 1-wire data input/output
GND	green	Ground
ECD	white/brown	EC reading data output
SDA	brown	MS5803 I2C serial data

6.1 Absolute Maximum Ratings

Condition	Min	Max	Unit
Voltage on any pin relative to ground	-0.3	4.0	V
Water submersion depth		10	m

6.2 Recommended Operating Conditions

Parameter	Min	Typ	Max	Unit
VCC		3.3		V
Water submersion depth			10	m
EC voltage divider resistor resistance (R_D)		100		Ω
Voltage on ECP		3.3		V
ECD output ADC bit depth		10		bits
I2C clock frequency			400	kHz
Exterior cable length		10	30	m

6.3 Electrical Characteristics

Parameter	Min	Typ	Max	Unit
Active current (I_{Active})		1		mA
Sleep current (I_{Sleep})		1		μA
I2C address MS-5803		0x76		

7. Operation

Temperature Measurement

Temperature measurement is facilitated by the DS18B20 over the 1-wire interface. The DS8B20 is wired directly to the pins VCC, GND, DQ. A 4.7 kΩ resistor connected between DQ and VCC.

Communicating with the sensor requires a one-wire interface compatible device. A list of commands for the sensor can be found on the DS18B20 datasheet [1]. For connecting the device to an Arduino or Arduino compatible datalogger such as the BoSL board it is recommended that the Dallas Temperature Arduino Library is used [2].

Depth Measurement

The depth measurement is calculated from the pressure differential between an external known atmospheric pressure value, and the reading from the MS-5803. It is recommended that the BoSL Water Probe is located as close as possible to the bottom of the water flow for accurate depth measurements. The MS5803 is wired directly to the pins VCC, GND, SCL, SDA. It is set to I2C communication mode with device address 0x76. Pull up resistors with resistance 4.7 kΩ are connected to the SCL and SDA lines, eliminating the need for these to be added externally. The MS-5803 contains its own temperature sensor which can be read from however it is strongly recommended that the DS18B20 is used as it has much less thermal resistance to the surrounding water.

Communicating with the sensor requires a I2C interface compatible device. A list of commands for the sensor can be found on the MS5803 datasheet [3]. For connecting the device to an Arduino or Arduino compatible datalogger such as the BoSL board it is recommended that the SparkFun MS5803-14BA Breakout Arduino Library is used [4].

EC Measurement

The principal of measurement for delivering EC readings is measuring the resistance across a pair of submerged pins. The two pins are connected directly to ECP and ECD. This allows for end user flexibility on the resistance measurement technique.

A calibration curve is required to convert the resistance reading between the EC pins into a conductance measurement for the water, see 11. Sensor Calibration.

An implementation of EC measurement is shown in 10. Typical Application

8. Sleep Mode

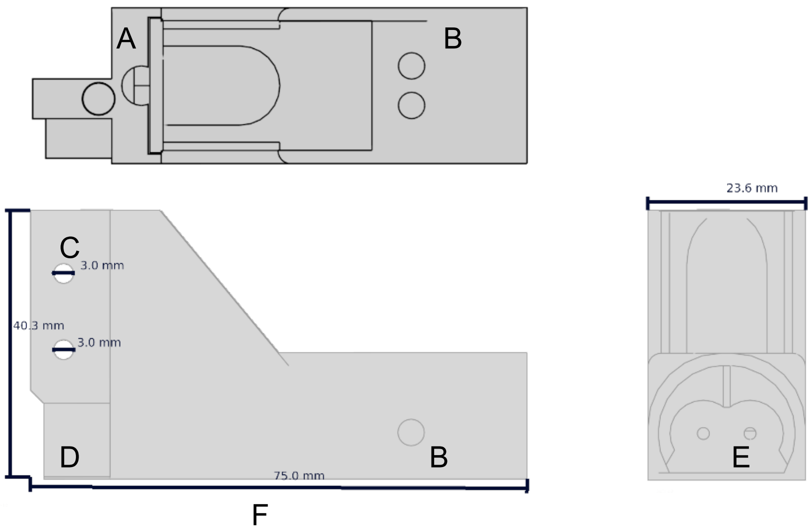
Sleep mode on the BoSL All-in-One probe greatly reduce the current consumption and allow the sensor to when paired with a suitable datalogger to log for periods of up to years without needing batteries to be replaced.

To enable sleep mode no commands should be sent to the DS18B20 or the MS5803. The ECP and ECD pins should be put into a high impedance state. If this is not possible then ECP should be pulled to ground.

To wake from sleep ECP and EDC should be returned to their normal state, commands can be sent to the DS18B20 or the MS5803 to wake them.

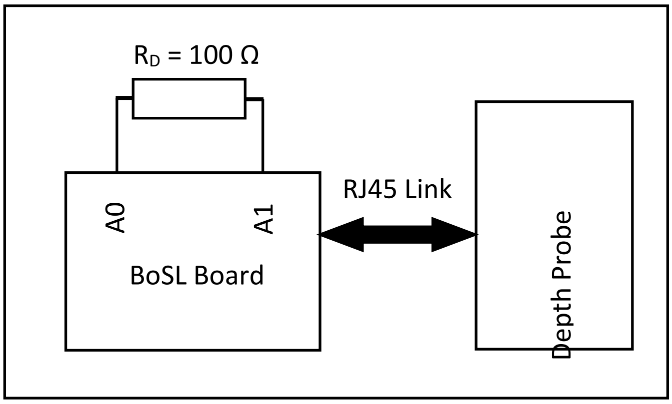
Each of the EC, DS18B20, and MS-5803 can be put to sleep independently.

9. Physical Overview



Letter	Description
A	CAT5 cable exit
B	EC shroud drain holes
C	M3 mounting holes
D	DS18B20 temperature sensor
E	EC probes
F	MS-5803

10. Typical Application



BoSL Board Integration

The wiring diagram and code snippets below can be used to achieve full functionality of the BoSL depth probe. Measurements of the water pressure, temperature, and EC can be called from functions in software, with their values returned for local logging or remote transmission.

In this design a MS-5803 located on the BoSL board is used to capture the current air pressure so water depth can be calculated via: $D = (P_{probe} – P_{air})/(\rho_{water}g)$. A voltage divider is used to measure the resistance between the EC pins. R_D is chosen to be 100 Ω for this as it makes the range of EC values commonly expected in water systems to be easily readable. The resistance between the EC pins is given by $R_{EC} = R_D (V_{ECD}/V_{CC} - 1)$.

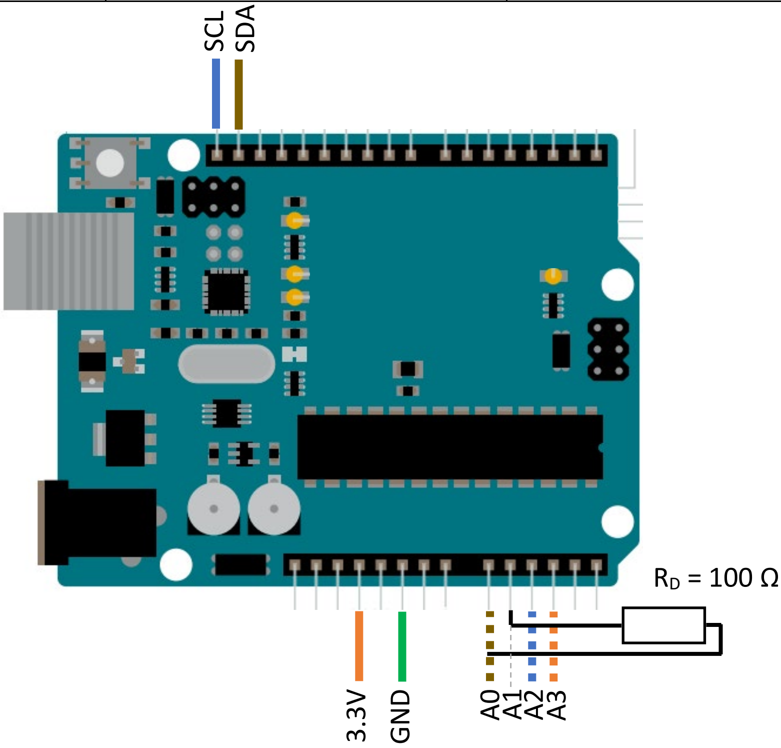
Code for BoSL board integration. Provides methods for reading temperature, pressure, and EC ADC reading which can be implemented into further logging code. For conversion between the EC ADC reading and electrical conductivity see 11. Sensor Calibration. The BoSL depth probe will return to sleep automatically after a measurement is taken. Please ensure that you have the latest versions of recommended libraries [2] [4].

```
//include libraries for DS18B20 and MS5803
#include <OneWire.h>
#include <DallasTemperature.h>
#include <SparkFun_MS5803_I2C.h>

MS5803 ProbeMS5803(ADDRESS_HIGH); //define depth probe MS5803 object
MS5803 AirMS5803(ADDRESS_LOW); //define bosl board MS5803 object

OneWire oneWire(A2); //define 1-wire object on A2 for DS18B20
DallasTemperature ProbeDS18B20(&oneWire); //define DS18B20 object

void setup() {
    pinMode(A0,INPUT);//configure pin to read from ECD
    pinMode(A1,OUTPUT);
    digitalWrite(A1,LOW);//ground one side of EC voltage divider
}
//function to return raw EC reading
int readECVoltage(){
    digitalWrite(A3,HIGH);//power ECP to take out of sleep mode
    analogRead(A0);
    int ecV = analogRead(A0); //read EDC twice to charge ADC capacitor
    digitalWrite(A3,LOW);//return EC to sleep mode
    return ecV;
}
//function to read water pressure from probe
float readProbePressure(){
    ProbeMS5803.reset();
    ProbeMS5803.begin(); //initialise MS5803
    return ProbeMS5803.getPressure(ADC_4096);//get and return pressure
}
//function to read air pressure from BoSL board
float readAirPressure(){
    AirMS5803.reset();
    AirMS5803.begin(); //initialise MS5803
    return AirMS5803.getPressure(ADC_4096);//get and return pressure
}
//function to read temperature from DS18B20
float readTemprature(){
    ProbeDS18B20.begin();
    ProbeDS18B20.requestTemperatures();// initialise DS18B20
    return ProbeDS18B20.getTempCByIndex(0);//get and return temperature
}
```

Arduino Uno Integration

For integration into an Arduino Uno similar code can be used as for the BoSL Board integration. A 100 Ω resistor should be placed between A1 and A0. The below wiring table should be used to connect the BoSL depth probe to the Arduino Uno.

Arduino Pin	BoSL Depth Probe Pin	
	Name	Colour
A3	ECP	white/orange
3.3V	VCC	orange
	NC	white/green
SCL	SCL	blue
A2	DQ	white/blue
GND	GND	green
A0	ECD	white/brown
SDA	SDA	brown



Source: https://content.arduino.cc/assets/Pinout-UNOrev3_latest.pdf

11. Sensor Calibration

To measure water depth, a one-point calibration needs to be done with another independent air pressure sensor before this product is installed in water. The calibration offset from this one-point calibration will correct the inherent difference between the sensor readings and the reference air pressure readings. To measure the water level with high accuracy, our initial results suggest that the sensor needs to be re-calibrated at least every two weeks. However the BoSL team have derived some automated calibration methods for this so please make contact if you would like to know more. We are also working on our BoSL probe 0.3, which is vented and stainless steel – we believe these should be available in Sept 2020.

For the EC sensor module, the following calculations can be used as a reference to convert the EC_ADC readings from you MCU to the actual EC readings (mS/cm):

The first step is to calculate the resistance across the EC probes based on the measured voltage drop when it is submerged in water:

$$R_{EC} = V_{in} \times \frac{ADC \times (R_0 + R_a)}{EC\_ADC \times V_{Ref}} - R_0 - 2R_a = \frac{(R_0 + R_a) \times (ADC - EC\_ADC)}{EC\_ADC} - R_a \qquad \text{Eq (1)}$$

where R_{EC} is the resistance across EC probes, V_{in} is the supply voltage from the MCU (for Arduino Uno's analog pins, this will be 5V, but can be 3.3V or other voltage level on other MCUs), EC_ADC is the ADC readings from the EC pin, ADC is the analog levels that the MCU can detect (for Arduino, 10-bit ADC of 1,024 discrete analog levels can be detected; other MCUs will result in different ADC detection levels), V_{Ref} is the reference voltage configuration of EC pin (by default, it will be same with V_{in} on Arduino, but users can choose a lower V_{Ref} to achieve higher resolution of voltage measurement, R_0 is the resistor between the ECD pin and the ground (flexible to change for achieving best sensor precision and measurement range), R_a is the estimated constant resistance of the digital/Analog pins of the MCU (for Arduino Uno, it is estimated to be 25Ω). When V_{in} is equal to V_{ref}, Eq.1 can be simplified:

$$R_{EC} = \frac{(R_0 + R_a) \times (ADC - EC\_ADC)}{EC\_ADC} - R_a \qquad \text{Eq (2)}$$

The second step is to calculate the specific electric conductivity (EC) based on the reciprocal relationship between the conductance (G) and the resistance across EC probe (R_{EC}):

$$EC = k \times G = k \times \frac{1}{R_{EC}} \qquad \text{Eq (3)}$$

where k is the cell constant (directly proportional to the distance separating the two conductive plates and inversely proportional to their surface area, for this sensor, assumed as 0.84), the unit of EC in Eq.3 is siemens (S).

The third step is to convert the specific EC readings into $EC_{@25°C}$, which is the standard way of reporting EC level in environmental water, by using the Eq.4:

$$EC_{@25°C} = \frac{EC}{(1 + 0.019 * (Temp - 25°C))} \qquad \text{Eq (4)}$$

where Temp is the water temperature measured by DS18B20 sensor through the DQ pin of the BoSL depth probe.

The final step is to determine calibration constants. Before the sensor installation, it is recommended that the user to do your own calibration with standard solutions of the measuring range you desired, to achieve the best sensor performance and sensing resolution, and adjust the above value using the following equation:

$$EC_{calibrated} = a \times EC_{@25°C} + b \qquad \text{Eq (5)}$$

where $EC_{calibrated}$ is the calibrated BoSL probe EC readings.

In absence of a unique calibration, the BoSL development team has created a general linear calibration curve (shown as Eq.6 below) by using 5 standard EC solutions ranging between

0.50 to 8.90 mS/cm (note we used 100ohm resistor and 3.3v supply). In total, 22 individual v0.2 BoSL depth probes were calibrated with standard solutions. The value was that a = 0.854 ± 0.0588 and b = -0.529 ± 0.118. The value of parameter a and b were calculated by averaging the values of 22 individual calibration, and their range was calculated by adopting one standard deviation.

12. Known Issues

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13. Ordering Information

Please contact David McCarthy, email: david.mccarthy@monash.edu

14. References

[1] MAXIM Intergrated, "DS18B20," June 2019. [Online]. Available: https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf.

[2] M. Burton, "Arduino Library for Maxim Temperature Integrated Circuits," Git Hub, [Online]. Available: https://github.com/milesburton/Arduino-Temperature-Control-Library. [Accessed 16 August 2020].

[3] TE Connectivity, "MS5803-14BA," August 2017. [Online]. Available: https://www.te.com/commerce/DocumentDelivery/DDEController?Action=srchrtrv&DocNm=MS5803-14BA&DocType=Data+Sheet&DocLang=English.

[4] SparkFun, "SparkFun_MS5803-14BA_Breakout_Arduino_Library," SparkFun, [Online]. Available: https://github.com/sparkfun/SparkFun_MS5803-14BA_Breakout_Arduino_Library. [Accessed 16 August 2020].

15. Revision Information

Revision Date	Description	Items Changed
16/08/2020	Initial draft	
21/08/2020	Released to SEW	