4. Experiment contents

1) Understand and demonstrate the working principle of the mutual inductive liquid conductivity sensor; acquire the relationship between the sensor output voltage and liquid conductivity; and understand the important physical concepts and laws such as Faraday's law of electromagnetic induction, Ohm's law and the principle of the transformer.
2) Calibrate the mutual-inductive liquid conductivity sensor with precision standard resistors.
3) Measure the conductivity of the saturated saline solution at room temperature.
4) Acquire the relationship curve between the conductivity and temperature of the salt water solution (optional).

5. Precautions

1) After power turned on, please warm up for about 10 minutes before doing experiment.
2) To measure the conductivity of brine saturated solution at a certain temperature, the brine must be mixed and stirred to make the salt fully dissolved before measurement.
3) The sensor used in the experiment should be handled gently, do not drop or hit.
4) After the completion of experiment, the sensor must be cleaned and wiped dry with clean dry gauze.
5) The primary voltage of the sensor is usually 1.7 V-1.9 V during the experiment.

6. Experiment procedure

1) Figure 3 is the experiment wiring schematic for liquid conductivity measurement using LEEI-15 apparatus. In order to ensure the accuracy of the measurement, the apparatus uses a selection switch to rapidly switch voltage measurements between the input voltage (V_{in}) and output voltage (V_{out}) and displays on the same digital voltmeter.

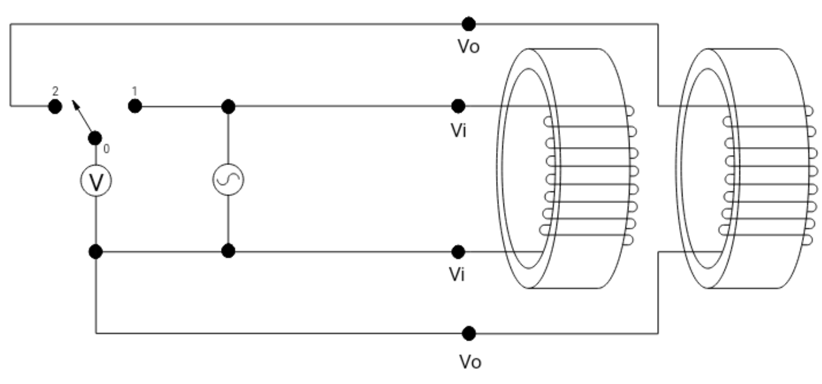


Fig. 3 Experiment wiring diagram for liquid conductivity measurement

During calibration, an external standard resistor is used instead of the standard liquid. As shown in Figure 4, a wire is passed through the hollow cylinder of the sensor and connected to the two ends of the standard resistor to form a resistance loop.

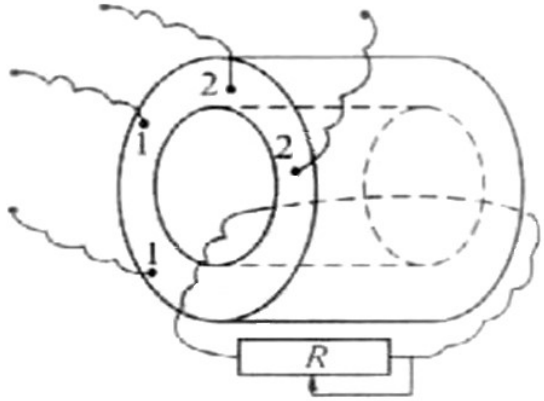


Figure 4 Schematic of the resistance loop for calibration

2) According to the range of "check standard", [0.00 — 9.50] Ω, measure the value (V_{out}/V_{in}) under different "check standard" (not less than 20 points) and record in the data table. During the measurements, pay attention to the input voltage V_{in}, adjust it at any time to remain V_{in} unchanged throughout the measurement process.

3) Measure the relevant dimensions of the sensor, calculate the value $K = \frac{1}{B}\frac{L}{S}$. Work out the calculation formula and the relative uncertainty formula for measuring liquid conductivity with this apparatus.

4) Take the voltage decay (V_{out}/V_{in}) as the ordinate and the reciprocal of the liquid column (1/*R*) as the abscissa to make the graph (not less than 20 points). It can be seen that the current induced by the sensor is linear within a certain range. Work out the linear relationship formula between (V_{out}/V_{in}) and (1/R). Calculate the average slope value (defined as $A_B = \frac{1}{2}(B\max + B\min)$), and the relative error of the slope (defined as $E_B = \frac{B\max - B\min}{B\max + B\min} \times 100\%$) (where B_{max} and B_{min} are the maximum and minimum possible values of the slope, respectively).

5) Measure the conductivity of saturated saline solution at room temperature and write the result.

7. Examples of Data Recording and Processing

* All experimental data are related to the parameters of individual apparatus, laboratory environment temperature, saline solution temperature, and other factors. They are for reference only.

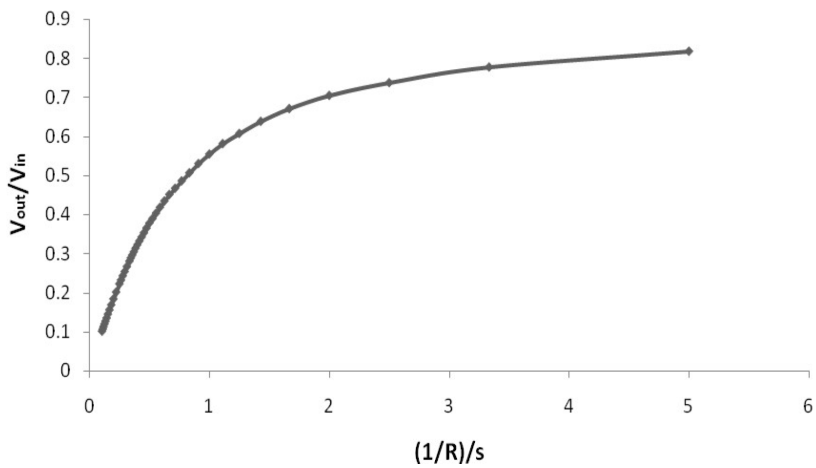
1) Data of V_{out}/V_{in} and 1/R (29 ℃)

R (Ω)	V_{in} (V)	V_{out} (V)	(1/R) (s)	V_{out}/V_{in}
0.20	1.805	1.476	5.000	0.818
0.30	1.805	1.403	3.333	0.777
0.40	1.805	1.331	2.500	0.737

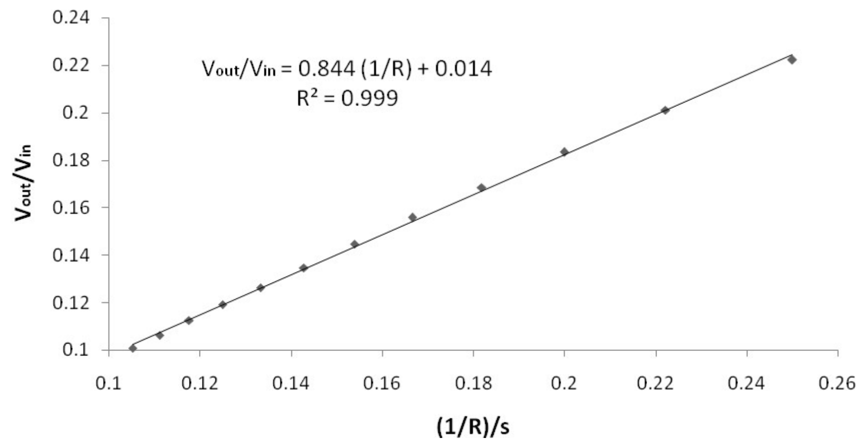
0.50	1.805	1.272	2.000	0.705
0.60	1.805	1.211	1.667	0.671
0.70	1.805	1.152	1.429	0.638
0.80	1.805	1.096	1.250	0.607
0.90	1.805	1.049	1.111	0.581
1.00	1.805	1.001	1.000	0.555
1.10	1.805	0.957	0.909	0.530
1.20	1.805	0.914	0.833	0.506
1.30	1.805	0.877	0.769	0.486
1.40	1.805	0.843	0.714	0.467
1.50	1.805	0.814	0.667	0.451
1.60	1.805	0.784	0.625	0.434
1.70	1.805	0.755	0.588	0.418
1.80	1.805	0.728	0.556	0.403
1.90	1.805	0.703	0.526	0.389
2.00	1.805	0.682	0.500	0.378
2.10	1.805	0.659	0.476	0.365
2.20	1.805	0.637	0.455	0.353
2.30	1.805	0.617	0.435	0.342
2.40	1.805	0.599	0.417	0.332
2.50	1.805	0.582	0.400	0.322
2.60	1.805	0.566	0.385	0.314
2.70	1.805	0.549	0.370	0.304
2.80	1.805	0.534	0.357	0.296
2.90	1.805	0.520	0.345	0.288
3.00	1.805	0.506	0.333	0.280
3.20	1.805	0.481	0.313	0.266
3.40	1.805	0.458	0.294	0.254
3.60	1.805	0.438	0.278	0.243
3.80	1.805	0.418	0.263	0.232
4.00	1.805	0.401	0.250	0.222
4.50	1.805	0.363	0.222	0.201

5.00	1.805	0.331	0.200	0.183
5.50	1.805	0.304	0.182	0.168
6.00	1.805	0.281	0.167	0.156
6.50	1.805	0.261	0.154	0.145
7.00	1.805	0.243	0.143	0.135
7.50	1.805	0.228	0.133	0.126
8.00	1.805	0.215	0.125	0.119
8.50	1.805	0.203	0.118	0.112
9.00	1.805	0.192	0.111	0.106
9.50	1.805	0.182	0.105	0.101

2) Draw V_{out} / V_{in} and 1/R relationship diagram (1/R ranges from 0 – 5 s)



3) Take out the linear region of V_{out} / V_{in} and 1/R relationship diagram to make a straight line graph (1/R range from 0 — 0.25 s)



4) K value calculation

   Measured sensor dimensions: L = 30.16 mm, d = 13.50 mm, so we got $S = \pi(\frac{1}{2}d)^2$ = 143.07 mm^2. With B = 0.844 Ω, we have K=L/(BS) = 0.250 s/mm.

5) Measure the conductivity of saturated brine (V_{in} = 1.805 V)

   a) Brine temperature 35.6 ℃; V_{out} = 0.125 V

      $\sigma = K*V_{out}/V_{in}$ = 0.250 * 0.125 / 1.805 = 0.0173 s/mm = 17.3 s/m

   b) Brine temperature 40 ℃； V_{out} = 0.141 V

      $\sigma = K*V_{out}/V_{in}$ = 0.250*0.141/1.805 = 0.0195 s/mm = 19.5 s/m

   c) Brine temperature 45 ℃； $V_{ou\ t}$ = 0.149 V

      $\sigma = K*V_{out}/V_{in}$ = 0.250*0.149/1.80 5 = 0.0206 s/mm = 20.6 s/m

   d) Brine temperature 50 ℃； $V_{ou\ t}$ = 0.159 V

      $\sigma = K*V_{out}/V_{in}$ = 0.250*0.159/1.805 = 0.0220 s/mm = 22.0 s/m

   e) Brine temperature 55 ℃； $V_{ou\ t}$ = 0.175 V

      $\sigma = K*V_{out}/V_{in}$ = 0.250*0.175/1.805 = 0.0242 s/mm = 24.2 s/m