Smart Pet Water Fountain

ECE 445 Design Document

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1 Introduction

We will build a smart pet water fountain for people that have pets at their homes. To help my customers better ensure the health conditions of the small pets and accommodate the water supply when he/she needs to leave home for several days, the smart pet water fountain is designed.

Our product solves my customer's problem by monitoring the water quality while maintaining a sufficient amount of freshwater in the freshwater tank.

1.1 Objective

Today, more people around the world have pets than ever before. According to American Pet Products Association's survey in 2020, 67% of U.S. households own a pet which is about 84.9 million homes. This proportion has been increased by 20% in thirty years [1]. Breakdown of the pet types, cats and dogs are the most popular animals, they contribute to about 80% of all pets. Same trend happens all over the world. On average, one in three households own a dog globally and about a quarter of households worldwide own a cat [2]. Both cats and dogs prefer flowing water. A source of fresh clean running water can encourage pets to drink. Drinking a certain amount of water daily plays an important role in long-term health for pets, especially cats. As a result, a water fountain is essential to most households having cats or dogs as pets. However, we can not ensure the water quality when we are away from home for several days. It can happen when pets have finished all remaining water in the water fountain, or water has been polluted somehow by the pet. These can cause the pet to be unwilling to drink water from the fountain.

Our goal is to design a smart water fountain that can monitor the water quality and automatically replace water when polluted(not healthy) or running out. We will use sensors to measure the water quality. Common water quality measurement factors include temperature, pH-value, conductance, turbidity and hardness [3]. Considering the pollution at home can only affect limited factors, we choose temperature, pH-value and conductance to be the three properties used for calculating water quality in our water fountain. These data will be collected, calculated, and reflected to the user in terms of "Good", "Average" and "Bad". The water fountain is also designed to self-filter the water every time when water is pumped through the submersible water pump.

1.2 Background

There have been quite a lot of water fountain products on the market[4], while most of them have only filtration as an extra function besides providing running water. [5] The size of the water fountain limits the capacity of the water source that most water fountains cannot store enough water for multiple pets to drink in several days.

Our water fountain can be connected to an extra water source that provides enough water for long-term usage. The link is adaptable to universal water bottles for convenience. The sufficient water source as well as automatic replacing and refilling function enable pet owners to leave home for several days without worrying about water supply for pets.

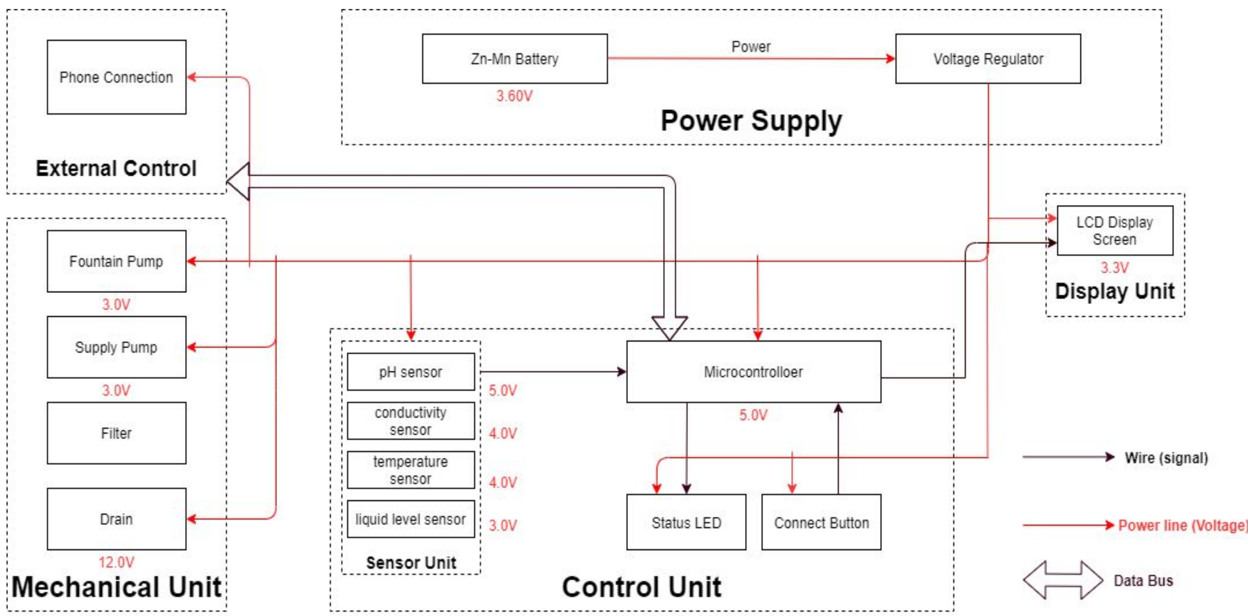
1.3 High Level Requirements

- Able to drain the polluted water and replace it with fresh water. Specifically, the polluted water will be drained by a motor-controlled valve to the “polluted water temporary storage tank” part. After completing the draining process, fresh water will be pumped from the general water supply(as described in the right down corner of the physical design, Figure 1).
- The fountain must accurately monitor the water quality, including measuring water temperature up to 48.89C and pH values between 6.5 and 8.5.
- Able to be connected to the users’ devices through WIFI. Prompt feedback from the smart water fountain to users’ interface with relevant information including the remaining water level and water quality index: ‘Good’, ‘Average’ and ‘Poor’.

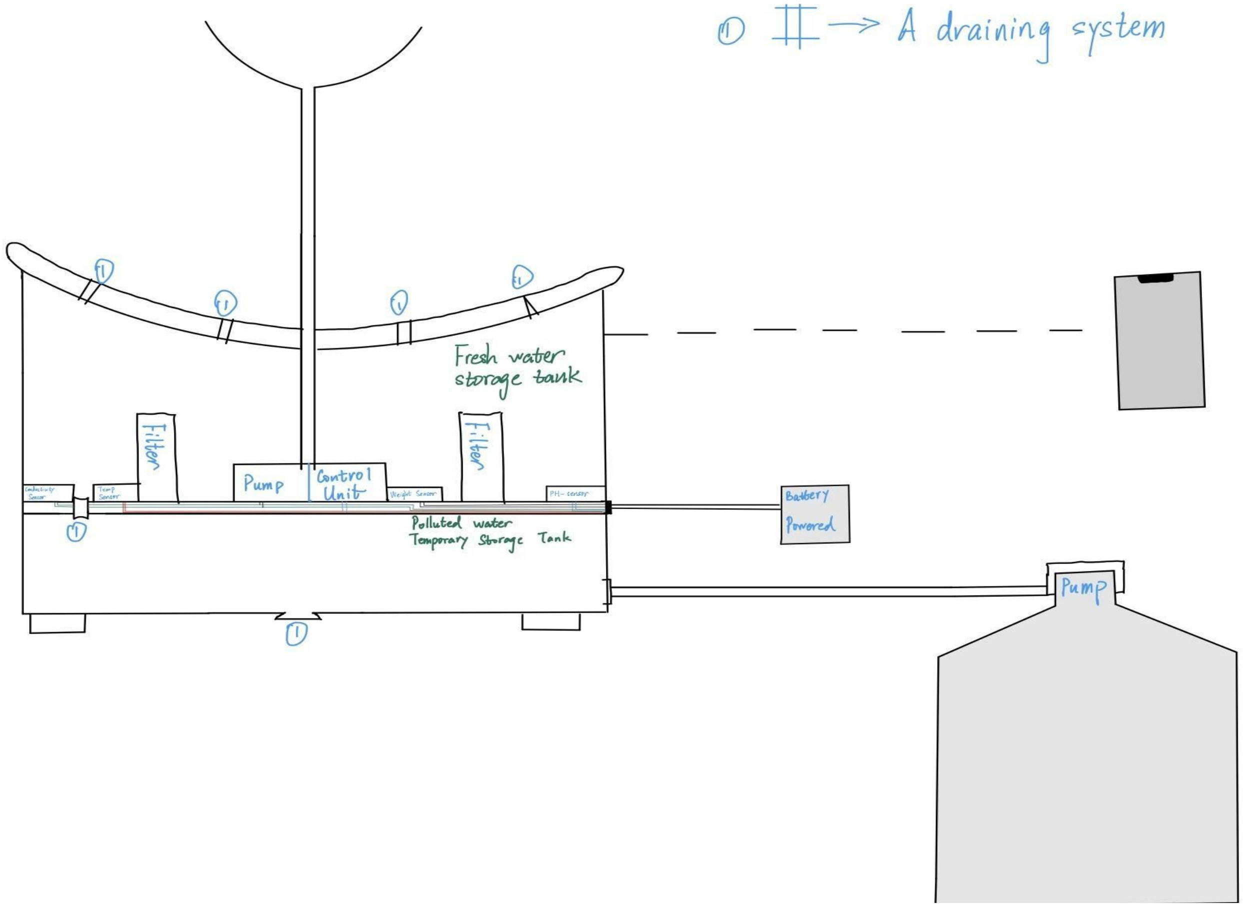
2 Design

To ensure the health of small pets while our customers are away from home, water quality is a critical point. The water quality monitor system embedded in the smart pet water fountain is the highlight of this project. Water quality will be determined according to three major factors: temperature, PH-value and conductivity. The results will then be demonstrated with three levels: poor, average and good. When the water quality is determined to be poor, then the polluted water will be drained and freshwater will be pumped into the freshwater tank. This leads to the second highlight of this project: the automatic water replacement mechanism. A universal connector will be designed to make it convenient for the customers to purchase big-bottled freshwater and connect to the pet water fountain easily.

2.1 Block Diagram



2.2 Physical Design



3 Requirements & Verification Tables

3.1 Sensor Unit

3.1.1 Temperature Sensor

Requirements	Verification
1. The accuracy of the Temperature sensor should be within +- 0.5 Celsius degrees 2. Should be able to work along with other sensors(blocks) which share the same power unit. The input voltage will be between 3.0V to 5.5V at all times and the sensor should be working under these conditions. 3. The frequency of 1 reading every 10 seconds is expected when the pet water fountain is fully functional.	1. Setting up 3 tanks of water each with different temperatures. Temperature will be measured using the sensor as well as a thermometer(a liquid-in-glass Hg thermometer with accuracy level of 0.5 Celsius degrees). The results will be compared and certain calibration will be made. 2. Various input voltages(3.0V, 3.5V, 4.0V, 4.5V, 5.0V and 5.5V) will be tested using power supply and test the working conditions for the sensor. 3. In each of the solutions, readings will be acquired every 10 seconds for 1 hour consecutively. The overall deviation between the sensor and the thermometer should be <= 0.5 Celsius degrees overall. And less than 1 outlier(data with relatively higher or lower value) should be reported in ten readings to ensure the overall accuracy.

3.1.2 pH-sensor

Requirements	Verification
1. The pH-sensor should be able to measure pH-values from 0-14. In addition, accurate measurement for solutions with pH-value between 5.0 to 8.5 needs to be achieved. Most daily use water has pH-value sitting in this range so an accuracy up to +-0.3 is sought for. 2. The pH-value claims a <=1 minute response time. When the pet water fountain is working fully-functional,	1. A digital pH meter will be used as a reference to verify the accuracy of the pH-sensor. Solutions will be used: lemon juice(pH~2), tomato juice(pH~4), black coffee(pH~5), water(pH~7), bleach(pH up to 13). These solutions are listed based on their pH-value from low to high. And pH values reported from the sensor and the digital pH meter will be compared and necessary calibration will be carried out. 2. pH-values for the 5 solutions mentioned above

pH-values are expected to be reported every minute.	will be obtained at the fastest possible rate(< 1min per reading). And the readings will be reported consecutively for 1 hour. After confirming the accuracy and the frequency of reading, calibrations will be made to make reading frequency stable.

3.1.3 Conductivity sensor

Requirements	**Verification**
1. The measurement range is expected to be accurate within 5% range from 0 to 10ms/cm. 2. A rate of 1 reading per minute is expected for this sensor.	1. Three different kinds of water will be prepared to verify the functions of this sensor: tap water, spring water and distilled water will be used. The result from the sensor will be compared with the results from a digital conductivity meter which has an accuracy of 2% for conductivity from 0 to 9990 us/cm. 2. The conductivity sensor will be programmed to measure for a reading at its fastest rate of 2 readings per minute for one hour for each of the solutions mentioned. After comparing the results with the digital conductivity meter, ensuring the accuracy of the readings, the sensor will then be calibrated to have stable reading frequency.

3.1.4 Liquid Level Sensor

Requirements	**Verification**
1. Alert when the water level is below 1 inch depth. 2. Regarding the overall dimension of the freshwater tank(depth around 4 inches). The accuracy of the sensor from depth of 1 inch to 4 inch should be controlled less than 1cm(a maximum error of 1% at maximum depth of 4 inches).	1. As this sensor is not sensitive when the water level is less than 1 inch, it will be tested with arbitrary water depth multiple times with proper calibration before finally being implemented onto the freshwater tank. 2. A yardstick shall be used to accurately measure the true depth of water. 10 arbitrary volumes of water will be added to the water tank and this sensor is going to be used to measure the water level. Comparing it with the

	actual reading from the yardstick, the accuracy can be determined.

3.2 Display Unit

3.2.1 Screen

Requirement	Verification
1. Display real time water quality level in the format of 'Water Quality: Good/Average/Poor' with at most 22 characters.	1. Use an LCD with an incoming buffer that stores at most 80 characters. 2. Program with arduino-compatible AVR ATMega328p chip to display real time water quality through I2C address.

3.3 Power Supply Unit

3.3.1 Voltage Regulator

Requirements	Verification
1. Can handle the maximum voltage supplied by the power outlet (110V±10V). 2. Can regulate the input voltage to voltage the range required by all the components. 3. Convert the supplied AC to DC. 4. Can operate under environment temperature 5-35°C.	1. Set the input voltage to the regulator to 100V, 110V, and 120V and check the functionality of the regulator. 2. Measure the output to each component on the integrated circuit through a voltmeter. The voltage should be regulated so that all the sensors would fully function and not be damaged. 3. Monitor the output to each component on the integrated circuit through an oscilloscope. All outputs should be direct current to prevent damage to sensors. 4. Test the system under 5°C, 25°C, and 35°C. Measure the output to each component on the integrated circuit through a voltmeter.

3.4 Mechanical Unit

3.4.1 Fountain Pump

Requirements	Verification
1. The fountain pump should have an operational condition around 3V, 200mA. 2. Can lift a cylindrical water stream of diameter 6mm for a height of 400mm. 3. The fountain pump must serve for a duration of 2 years without maintenance or replacement under heavy workload.	1. Power the pump with a 3V power supply. Measure the current through a multimeter to ensure a 200mA current in the system. 2. Attach a cylindrical pipe of 400mm to the water outlet of the pump. The pipe should be placed vertically upward. When powered with a 3V voltage source, water should be able to fill the pipe.

3.4.2 Supply Pump

Requirement	Verification
1. The supply pump should have an operational condition around 3V, 200mA. 2. must prevent water flow between the main supply and the fountain when no instruction is received.	1. Power the pump with a 3V power supply. Measure the current through a multimeter to ensure a 200mA current in the system. 2. Place the pump in the product and start filling the main supply. Water should not flow towards the fountain water container.

3.4.3 Filter

Requirement	Verification
Filtered water must have a quality level of “average” under the designed water quality algorithm.	Let water polluted with dust flow through the filter. Test the resultant water with the designed water quality algorithm. A test result of “average” should be emphasized.

3.5 Control Unit

3.5.1 Microcontroller

Requirement	Verification
1. Can transmit data over I2C to the LCD.	1. Connect microcontroller to LCD with SDA(PC4) and SCL(PC5) pins.

2. Can receive data from the temperature sensor, pH-value sensor and water conductivity sensor simultaneously. 3. Can output high/low signals directly to the supply pump and the draining system motor.	2. Connect each sensor to the microcontroller through Port A input pins. 3. Connect the two output port pins with the supply pump and the draining system motor respectively. High/low signals are transferred through each of the pins to control the devices.

4 Tolerance Analysis

The most important tolerance in our project is the evaluation of water quality. We determined the Poor, Average and Good ranges for the temperature, pH-value and water conductivity.

	Poor	Average	Good
Temperature (°C)	Temp < 5, Temp > 30	5 < Temp < 30	15 < Temp < 25
pH-Value	pH < 6.5, pH < 8.5	6.5 < pH < 7, 8 <pH < 8.5	7 < pH < 8
Conductivity (mS/cm)	Cond > 1mS/cm	Cond < 1ms/Cm	Cond < 0.5mS/cm

Another tolerance is about the water level measurement. We use a liquid level sensor that outputs resistance as an indicator of the water level. The output resistance is inversely proportional to the water level. According to the datasheet, the output resistance has ±10% tolerance. We set the alerting water level to 1 inch which corresponds to 1.5 Kohms. With the ±10% tolerance, the lower bound resistance at 1 inch can be $1500 \times (1 - 0.1) \ = 1350\Omega$. The resistance gradient is $140\Omega/inch\ (56\Omega/cm),\ \pm 10\%.$ Then the water level with 1350 Ohms is $\frac{1500\Omega - 1350\Omega}{140\Omega/inch} = 1.07\ inches$. So there is a buffering water level region up to 1.07 inches.

5 Ethics and Safety

5.1 IEEE Code of Ethics I-1

Quoted from IEEE Code of Ethics[11]: "To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment."

We will carefully choose the materials used to build the container. Non-toxic are sure to be used. We will prefer using reusable materials. In addition, the users can choose to buy reusable bottles of water for the freshwater supply for the pet water fountain. Those universal water bottles are safe and reusable. A special connector will be designed and the universal connection is planned. After the water in the bottle is used up, this reusable bottle can be recycled and reused. This is the most environmentally friendly solution and complies with the IEEE Code of Ethics #I-1. It not only improves the practicality, convenience, and reduces the future cost when using the pet water fountain.

5.2 IEEE Code Of Ethics II

Quoted from IEEE Code of Ethics: "II. To treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others."

As mentioned in the previous section, the mechanical unit involves electronic components that are physically placed in the water tank. The consequence can be serious if the leakproofing is not performed properly. To maintain a safe, convenient using experience, we will be responsible for testing and ensuring all containers meet the demand. These actions must be taken to ensure the safety of using the pet water fountain and protect the others.

5.3 IEEE Code Of Ethics I-6

Quoted from IEEE Code of Ethics: "to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations."

All team members involved in the development of the pet water fountain have completed "Laboratory Safety training" and have gained required and necessary knowledge in dealing with emergency situations. In case of accidents, proper reaction will be made to ensure the safety of people and property to the largest extent.

6 Citation

1. Pet industry market size & ownership statistics. (n.d.). Retrieved February 16, 2021, from https://www.americanpetproducts.org/press_industrytrends.asp

2. Man's best friend: Global pet ownership and feeding trends. (n.d.). Retrieved February 16, 2021, from https://www.gfk.com/insights/mans-best-friend-global-pet-ownership-and-feeding-trends

3. Water quality. (n.d.). Retrieved February 16, 2021, from https://www.michiganseagrant.org/lessons/lessons/by-broad-concept/earth-science/water-quality/#:~:text=Scientists%20measure%20a%20variety%20of,health%20of%20a%20water%20body.

4. Catit flower cat water fountain. (n.d.). Retrieved February 18, 2021, from https://www.petco.com/shop/en/petcostore/product/catit-flower-cat-water-fountain

5. Drink well 360 stainless steel pet fountain. (n.d.). Retrieved February 18, 2021, from https://www.chewy.com/drinkwell-360-stainless-steel-pet/dp/48106?utm_source=google-product&utm_medium=cpc&utm_campaign=hg&utm_content=Drinkwell&utm_term=&gclid=Cj0KCQiAvbiBBhD-ARIsAGM48bzKL43wvG8ec3qq2QHoStG2KFen7I5P6MeAI_4qu48WK0ZmWE-B6UwaAjMmEALw_wcB

6. Water-proof temperature sensor by Sparkfun. (n.d.). Retrieved February 16, 2021, from https://www.sparkfun.com/products/11050

7. Analog pH-sensor by Gravity. (n.d.). Retrieved February 16, 2021, from https://www.dfrobot.com/product-1110.html

8. Analog Electrical conductivity Sensor by gravity. (n.d.). Retrieved February 16, 2021, from https://www.dfrobot.com/product-1123.html

9. Liquid Level Sensor by Sparkfun. (n.d.). Retrieved February 16, 2021, from https://www.sparkfun.com/products/10221

10. 20 by 4 SerLCD-RGB Backlight Display. (n.d.). Retrieved February 16, 2021, from https://www.sparkfun.com/products/16398

11. IEEE - IEEE Code of Ethics. (n.d.). Retrieved February 18, 2021, from https://www.ieee.org/about/corporate/governance/p7-8.html

12. 5 Gallon Big Mouth BPA free reusable water dispenser bottle. (n.d.). Retrieved February 18, 2021, from https://www.walmart.com/ip/5-Gallon-Big-Mouth-BPA-FREE-Bubbler-Reusable-Water-Dispenser-Bottle-Made-in-USA/373334119?wmlspartner=wlpa&selectedSellerId=9760&&adid=22222222227243519745&wl0=&wl1=g&wl2=c&wl3=289667725800&wl4=pla-490445973980&wl5=9022198&wl6=&wl7=&wl8=&wl9=pla&wl10=117097115&wl11=online&wl12=373334119&veh=sem&gclid=Cj0KCQiAvbiBBhD-ARIsAGM48bxHxZ42ibLPJwrN28WIaNjlKS8gYUvFjUifIEGhHEIE_jLREPjeL5waAmaJEALw_wcB

13. Solenoid Valve by Digi-Key. (n.d.). Retrieved February 18, 2021, from https://www.digikey.com/en/products/detail/sparkfun-electronics/ROB-10456/5684378?utm_adgroup=Pneumatics%2C%20Hydraulics&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_Industrial%20Automation%20and%20Controls_NEW&utm_term=&utm_content=Pneumatics%2C%20Hydraulics&gclid=Cj0KCQiAvbiBBhD-ARIsAGM48by7oixywUkapOiOj9CouaJM79T05scTFRn8nsSx-EsOC6ChVVuSkxEaAoQrEALw_wcB

14. Submersible 3V DC Water Pump by adafruit. (n.d.). Retrieved February 18, 2021, from https://www.adafruit.com/product/4547?gclid=Cj0KCQiAvbiBBhD-ARIsAGM48bwvHlocyXSYt_5GAy6vpbUs5795IrBQNrXekEiWrd56o9lHqfyT8YYaAhpZEALw_wcB

15. Liquid-in-glass Laboratory Thermometer (n.d.). Retrieved February 28, 2021, from https://www.amazon.com/dp/B00551OFK0/ref=sspa_dk_detail_6?pd_rd_i=B00551OFK0&pd_rd_w=L9E4v&pf_rd_p=4269e1a0-a218-4fbd-9748-1cd337d2f2a5&pd_rd_wg=7AeGi&pf_rd_r=D38WP5CJ1AKT6BH02JWS&pd_rd_r=7c6b689e-1a2f-4da6-ae74-f28307caf007&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyMTJCRUdEU1FLTFdFJmVuY3J5cHRlZElkPUEwMzAzMzUxMVkyREIZQTFaQ0hMNiZlbmNyeXB0ZWRBZElkPUEwMTI2MTYxMjdNVDBFMjQ5S1ZaNyZ3aWRnZXROYW1lPXNwX2RldGFpbCZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU&th=1

16. Digital pH meter (n.d.). Retrieved February 28, 2021, fromhttps://www.amazon.com/High-Precision-Suitable-Accurate-Aquariums-Hydroponics/dp/B08S2T46SQ/ref=sr_1_4?_encoding=UTF8&c=ts&dchild=1&keywords=pH+Testing&qid=1614478193&s=industrial&sr=1-4&ts_id=4989325011

17. Digital Conductivity Meter (n.d.). Retrieved February 28, 2021, fromhttps://www.amazon.com/Upgraded%E3%80%91TDS-HASFINE-Conductivity-Temperature-Aquariums/dp/B088RFSQTL/ref=sr_1_6?_encoding=UTF8&c=ts&dchild=1&keywords=Conductivity+Meters+%26+Accessories&qid=1614479320&s=industrial&sr=1-6&ts_id=5088417011