Design of the measuring circuit for the content of crude oil in seawater

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Abstract. It has been demonstrated that there must be a linear relation between fluorescence intensity and concentration of crude oil in seawater. Since the fluorescence signal is strong weakness and is also affected by the ambient light & stray light, it must be extremely difficult or almost impossible to detect based on convention ways. In this paper, a new approach for the detection of the weak fluorescence signal by the programmable gain of digital lock-in amplifier (PG-DLIA). The proposed scheme which comprise of the 255 nm LED trigger to excite the seawater to produce fluorescent signal, and the high sensitivity photodiode as detector to perceive of the faint fluorescent signal. In particular, the feeble fluorescence signal is well detected through the circuit of PG-DLIA. In terms of the laboratory experiment and sea trial, the sensor of crude oil in seawater with this circuit has the advantages of simple structure, lower consumption, portable, modular, high precision, real time and continuity. It will have vast application prospects on the detection of weak signals.

1. Introduction
Crude oil pollution is more and more serious with the rapid development of our country industry. It has been seriously damage to the ecological environment, and seriously affect the health of human beings. Then, the concentration of crude oil in seawater directly reflects the activity and biomass of phytoplankton in seawater, become important parameters of seawater eutrophication evaluation and prediction of red tide disasters [1,2].

At present, the field sampling and laboratory analysis methods are also accepted for measuring the concentration of crude oil in seawater. These traditional detection methods exemplified the common drawbacks, which is cumbersome, time-consuming and difficult to determine the oil distribution. It indicated that the great incentives of devising effective strategies to replace these traditional detection methods. Therefore, it is reasonable to employ new detection schemes than those traditional schemes.

In the present work, the circuit of PG-DLIA is proposed for measuring the concentration of crude oil in seawater.

2. System design
The detection scheme proposed for content of crude oil in seawater is sketched in figure 1. Three parts are included, with one is trigger section, one is detection section, and the last is microprocessor section. The trigger section which is sketched in figure 1, consisting of the center wavelength of the 250 nm
LED used as excitation light source to produce the fluorescence signal. The detection section which is sketched in figure 1, consisting of the photodiode of S2386-18L and the circuit of PG-DLIA. The direct digital synthesizer (DDS) module and the processing module are included in this system microprocessor section which is sketched in figure 1 [3]. More specifically, first of all, the excitation light source of LED excited sea water to produce fluorescence signal and the fluorescent signal is accepted by detection photodiodes. Next, I/V circuit can convert the photodiode current to voltage, and through synchronous detection circuit to complete weak signal detection, and then after AD analog-to-digital conversion through a low-pass filter circuit after intervention in single-chip microcomputer for processing, finally, through digital filtering algorithm to smooth the noise reduction processing.

**Figure 1.** The system scheme proposed for the detection of the content of crude oil in seawater.

### 2.1. The design of the photoelectric detection circuit

Because of the excited fluorescence signal is weak signal relative to the ambient light noise signals. In the current work, an attempt new detection method of the circuit of PG-DLIA is made to extract the faint fluorescence signal in the design and detect of the system with the circuit of current-to-voltage (I/V) convention, the circuit of low-pass filter, the circuit of secondary programmable simplifier and the circuit of PG-DLIA.

#### 2.1.1. The design of the I/V convention and amplifying circuit.

As mentioned in section 2.1, the fluorescence signal is excited by the LED module and the exited current signal is output through the photodiode. Since the output current was already found to be weak signal, it must turn the current into the voltage signal, and then amplify the voltage signal. So, the offset voltage, input voltage noise and input bias current of the amplifier will affect the signal, and then the AD8618 amplifier was adopted with low input bias current and low voltage noise [4,5]. Figure 2 shows a typical I/V convention and amplifying circuit with a single feedback resistor, which mainly convert the weak current to the voltage signal. The capacitor C80 mainly used to restrain the high frequency voltage noise. The U30B of voltage follower is used for absorption, seclusion and improving the load capacity. The output voltage is calculated via the following equation, which is

\[ V_{out} = I_i \times \left( \frac{R_{81}}{R_{82}} \right) \]

**Figure 2.** The I/V convention and amplifying circuit.
2.1.2. The design of the LED modulator circuit. The design of the LED modulator circuit is shown in figure 3, which is proposed to drive the LED produce excitation light. In what follows, a clock set to a user-programmable frequency modulates LED with a constant current driver built around the MAX1916 drive circuit. The MAX1916 chip was adopted with low offset voltage, high conversion efficiency and low drop-out voltage. The cut-off frequency of the filter is basic equal to the frequency of the excitation light [6,7].

![Figure 3. The schematic of LED modulator circuit.](image)

The pin of SET is used as current input, whose current should adjust close relationships with the Resistance value of R2. The current of LED is calculated via the following equation, which is

\[ I_{LED} = 230 \times (V_{CTRL} - V_{SET}) \times (R_{SET})^{-1}. \]

The pin of EN is used as a square wave input, which control open and close for the chip of max1916. It is thus necessary to select an optimal resistance value for the determination of the current of the LED in process testing and design, whose purpose is not only to seek the most effective magnification but also to avoid the photodiode saturation problem possibly occurring in the case of the design of the LED modulator circuit.

2.1.3. The design of the circuit of PG-DLIA scheme. As shown in figure 4, fluorescence signal and the reference signal detection channels are included. They are in charge of the detect fluorescence light signal, reference light signal and background light signal, respectively. More specifically, in order to improve the ability of detecting fluorescent signal and completely avoid to the ambient light, a method of sampling integral of dual-channel is presented in this paper. The circuit of PG-DLIA scheme proposed for the design of the sensor is described in figure 4. Four detection circuits are included, with one is DDS module, one is phase sensitive detection (PSD) module, and one is programmable digital filter module. More specifically, The DDS module works to drive the LED in operation conditions to excitation seawater to produce the fluorescence signal and serve to PSD module as the reference signal. I/V circuit can convert the photodiode current to voltage, and through AD analog-to-digital conversion, and then after synchronous detection circuit to complete weak signal detection through a low-pass filter circuit after intervention in single-chip microcomputer for processing, finally, through digital filtering algorithm to smooth the noise reduction processing.

As mentioned in section 2.1, STM32F407 control module is used to convert a physical fluorescence signal into the content of crude oil in seawater, whose temperature detection unit is used to rectify the content of crude oil in seawater. Finally, the revised result is sent to the upper computer via RS485/RS232.
3. The experimental results and analysis

Figure 5 presents the results of linear correlation analysis for the sensor, which is based on the circuit of the programmable gain transimpedance amplifiers and synchronous detectors scheme. Then the 0 # diesel oil is added to the test vessel with gradient of 10 ug/L. When the concentration increased to 100 ug/l, the 0 # diesel oil will be added to 200 ug/L with gradient of 50 ug/L. During this time, stir the solution rapidly and continuously to prevent stratification of the 0# diesel. The obtained results is shown in the figure 5, and indicated that the relationship between the fluorescence intensity and the concentration of oil will coincidence with linear relation, which shows that the performance of the instrument is comparable with imported foreign instrument.
4. Conclusion
In this work, a new in situ oil detection scheme has been proposed. It is worth stressing here the great improvement in the detection of oil in water by the application of the circuit of PG-DLIA scheme to the sensor of crude oil in seawater. The experimental has been demonstrated that the sensor of crude oil in seawater based on the circuit of PG-DLIA behaves much better than the traditional detection methods. The great advantages of this detection technique justify the employment of the feeble fluorescence measurements from measured signal with noise as compared with the currently available signal detection technique. The measurement accuracy, battery life and stability had reached the highest level of the detection system.

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