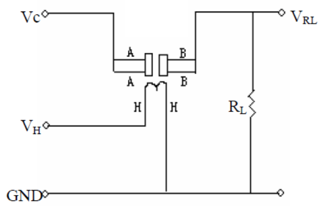
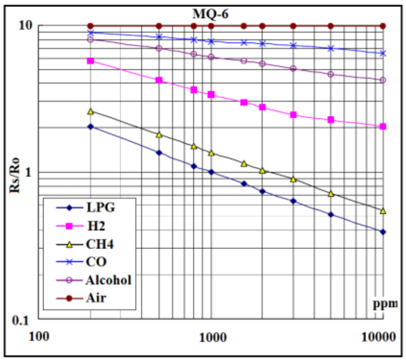
to calibrate the detector for 1000ppm of LPG concentration in air load resistance (RL) about 20KΩ. Figure 2 shows sensor wire connection, sensor sensitivity characteristics of MQ-6, and sensor electrical equivalent circuit.



(a)



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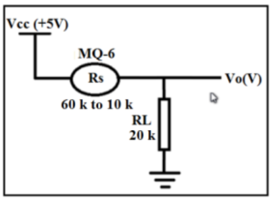


(c)

Figure 2. Sensitivity characteristics of the MQ-6 at Temp: 20℃, Humidity: 65%, O2 concentration 21%, RL=20kΩ, Ro: sensor resistance at 1000ppm of LPG in the clean air, Rs: sensor resistance at various concentrations of gases; (a) sensor wiring, (b) sensor sensitivity characteristics, (c) sensor electrical equivalent circuit.

Based on the sensor electrical equivalent circuit, the sensor output voltage can be calculated by (1);

9 5/ 9FF5 / 5 / 5 6 (1)

The value of the sensor output voltage will be varied depending on R_L value (20 kΩ), the instantaneous value of sensor resistance R_S (60 kΩ to 10 kΩ) based on LPG gas concentration and based on (1). Table1: Demonstrates the output voltages at different gas constrictions of same conditions of Figure 1.

Table 1: Output voltage of MQ-6 at different LPG gas concentrations

LPG Gas Concentration (ppm)	200	500	800	1000	2000	3000	5000	8000	10000
R_S/R_O	≈ 2.0	≈ 1.45	≈ 1.15	1.0	≈ 0.72	≈ 0.63	≈ 0.51	≈ 0.42	≈ 0.38
R_S (kΩ)	60.0	43.5	34.5	30.0	21.6	18.9	15.3	12.6	11.4
V_{RL} (V)	1.25	1.57	1.83	2.0	2.40	2.57	2.83	3.07	3.18

B. Adaptation Circuit

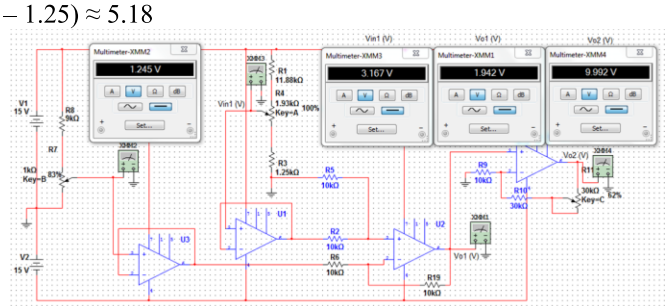
This circuit designed to receive the DC voltage from LPG gas sensor circuit with range 1.25 V to 3.18 V and works on modifying this range that to have longer range with modifying the starting point to make it starts from 0 V at 200 ppm gas concentration and increase the DC output voltage range that to end at 10 V at gas concentration 10000 ppm. Figure 3 represents the designed electronic circuit with simulation results that to demonstrate the function of the circuit. the circuit includes to op-amp sub-circuits; first on is a subtraction part that to subtract 1.25 V from the input DC voltage as shown in (2) below, while the second part is an amplifier with controlled voltage gain which set that to have 10 V when the input voltage 3.18 V, the equation of this part is explained in (3), and (4);

$$Vo1 = Vin1 - 1.25 \quad (2)$$

$$Vo2 = G * Vo1 \quad (3)$$

$$G = Vo2 / Vo1 \quad (4)$$

The desired value of the second part gain G equals 10 / (3.18 – 1.25) ≈ 5.18



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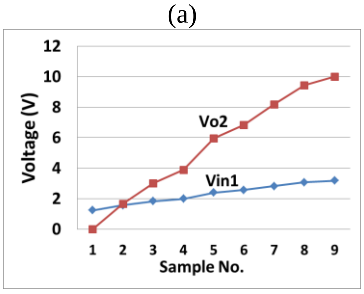
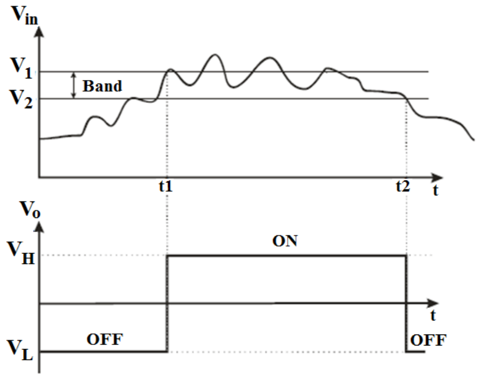


(b)

Figure 3. Adaptation circuit; (a) electronic design, (b) simulation results

C. Op-Amp Comparator with Hysteresis (Positive Feedback. Schmitt Trigger)

It is important to do the analog comparison by op-amp with not only one level but with two levels as a certain band that will immune from noise effect. in other word it is needed to avoid the switching around one comparison level. The suitable op-amp circuit for this request is positive feedback op-amp which is work as Schmitt trigger [32], as shown in Figure 4.



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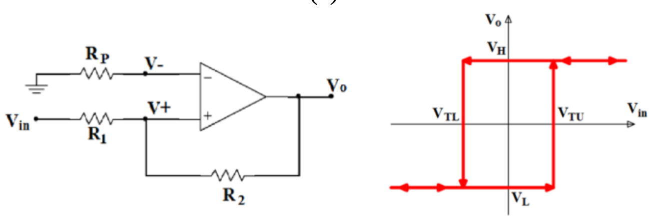


(b)

Figure 4. Positive feedback. Non-Inverting Schmitt Trigger; (a) hysteresis effect explanation, (b) op-amp circuit with hysteresis behavior

The desired upper and lower limits can be designed through;

$V_{TL} = - (R_1/R_2) \cdot V_H$ (5)

$V_{TH} = (R_1/R_2) \cdot V_L$ (6)

where V_H represents the positive saturated output voltage, and V_L represents the negative saturated output voltage, the hysteresis band can be shifted to any reference point as shown in Figure 5;

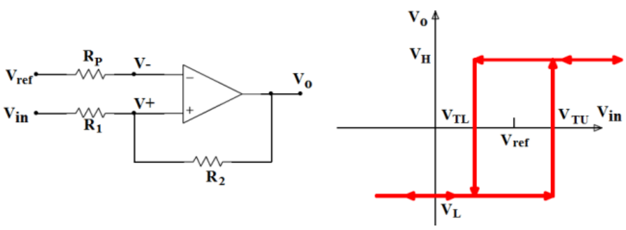
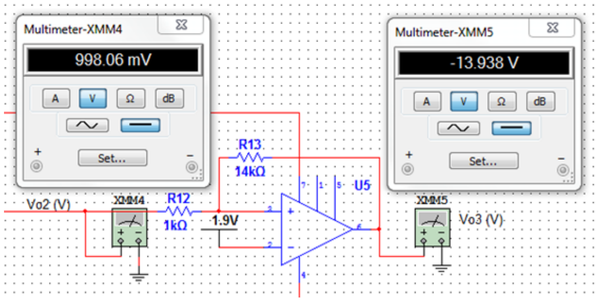
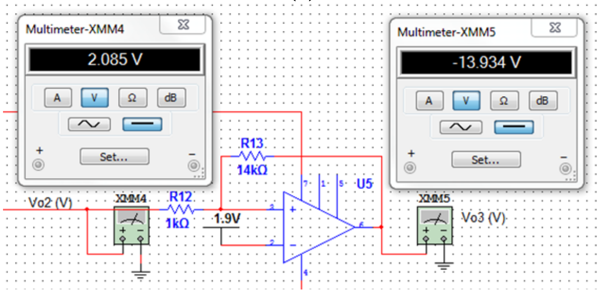


Figure 5. Positive feedback. Non-Inverting Schmitt Trigger with reference voltage and hysteresis behavior

The designed values for R_1 , and R_2 are 1 kΩ, 14 kΩ respectively, and the reference voltage is 1.9 V, the values of V_L , and V_H are -13.94 V, and + 13.95 V shown in Figure 6. The hysteresis function is proved through the simulation records of Figure 6, the desired voltages upper V_{TU} and lower V_{TL} limits of the voltage hysteresis band that are designed at Upper limit 3 V to sense LPG gas leakage 30% that to activate the alarm and protection parts, while the lower limit 1 V to remove the alarm in case there is no dangerous level of gas leakage and the case is only effect of other noise effects.



(a)



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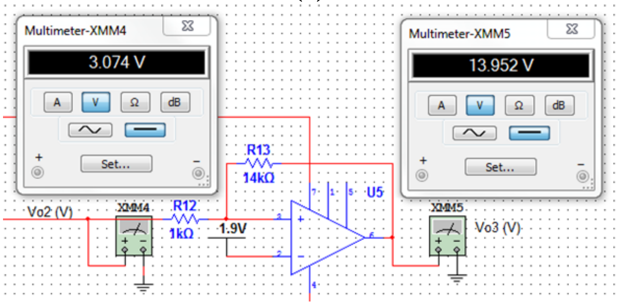

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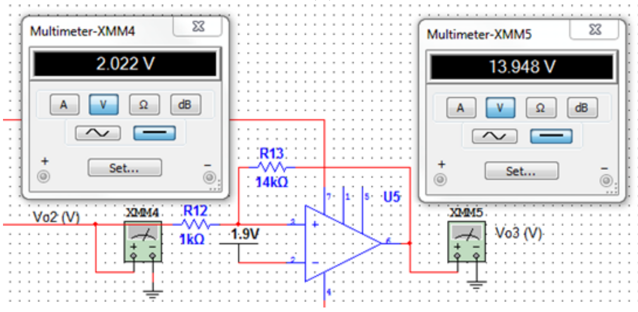
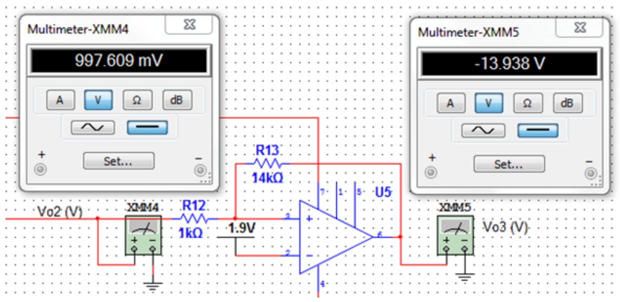


(d)

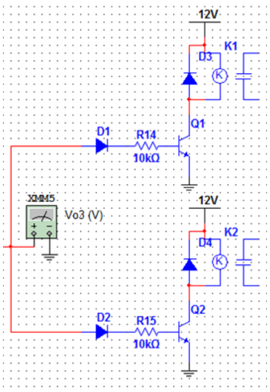


(e)

Figure 6. Electronic designed Non-Inverting Schmitt Trigger with reference voltage 1.9 V with hysteresis band, and simulation result

D. Drive Circuit

This circuit includes drives for the gas vale which is activated by DC 12 V, the drive circuit also activate 12 V red light lamp and buzzer sound alarm, the ventilation action is also important, the protection system include also part of ventilation which activated by drive circuit. Figure 7 shows the drive circuit which include two separated relays, first relay for alarm activity of light and sound while the second relay for protection activity of valve and ventilation activity.



Figue 7. Drive circuit

CONCLUSION

The introduced work in this paper presents an analog design with simulation results for a complete system alarm and protection system based on electronic discrete components as an alternative solution instead on micro controller based solutions that to avoid the complexity and high cost. the proposed system senses accurately the leakage state of LPG gas in home or industrial locations through continuous sensing to gas leakage level, and accurate protection function by big range of the designed adaptation circuit and the hysteresis function of the designed Schmitt trigger op-amp. Gas valve and ventilation parts can be controlled through the presented system that to avoid any dangerous case that may happen from the leakage of gas. The collected simulation results reflect the effectiveness of the proposed system and promise for an active prototype.

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