

Fermi National Accelerator Laboratory

FN-410
2510.000

A FAIL SAFE CRYOGENIC LIQUID LEVEL CONTROLLER

T. Regan

October 1984



Operated by Universities Research Association Inc. under contract with the United States Department of Energy

A FAIL SAFE CRYOGENIC LIQUID LEVEL CONTROLLER

INTRODUCTION

Described herein is an instrument which will provide for the safe and automatic filling of dewars and other vessels with liquids of virtually any temperature and whose sensing element will be protected from overheating in a vacuum.

For the initial purpose the circuit was designed to work with cryogenic liquids, specifically argon and nitrogen. The circuit parameters however can be adjusted to work with any liquid, room temperature and below, with ease.

There are controlling devices in existence which will accomplish cryogenic liquid level detection. They all have limitations, chiefly the inability to evacuate the vessels to purify the contents without first turning off the level sensor to protect it from the effects of overheating. Additionally, they lack the fail-safe approach shown here in that redundancy is generally not employed in the critical power supply circuits and fault detection of the level sensing element.

Theory

The sensor, in this case an RTD platinum sensing resistor, has a temperature coefficient of $0.00385/^{\circ}\text{C}$ corresponding to $0.39 \pm 0.02 \Omega/^{\circ}\text{C}$ in the temperature range that this particular instrument is to be utilized. The RTD is considered to be an international standard as it meets certain established criteria¹.

In order to effectively determine when the liquid level is at that of the sensor, heat must be removed from the device. Otherwise it will act as a thermometer and will respond to the temperature of the atmosphere within the vessel, specifically the surface vapor. In operation at 77°K , the resistor has an approximate value of 25Ω while dissipating several hundred milliwatts in liquid nitrogen. The maximum dissipation must be held to $<0.5 \text{ watt/cm}^2$. Above this power level the film layer forms and it becomes insulated from the cooling effects of the liquid.

Further, since the surfaces of these liquids are often turbulent, the detector should be mechanically baffled so that waves and splashings do not affect it.

Operation

A $\mu\text{A759UIC}^2$ power operational amplifier is employed in a self excited system which can be viewed as a bridge. As used, the output has two stable states; full positive and zero volts. The amplifier has a D.C. gain of two when the bridge is balanced. With the RTD

connected to the non-inverting input and the reference resistor to ground, any change in the value of the RTD (above or below the reference) results in positive feedback. The diode placed in series with the feedback path insures that the output of the amplifier is, in this case, positive and cannot go negative. This guarantees that the RTD's power can be limited to a safe maximum value when immersed in the liquid and reduced to essentially zero when the resistance rises above the reference value. This feature renders the sensor safe in a vacuum.

Two voltage comparators follow the amplifier; one of these is used to test the integrity of the RTD loop, and the other provides drive for the solid state relay and discriminates against anything less than two thirds of the amplifiers full output voltage. This insures that the RTD is being driven hard and is submerged in the liquid.

The μ A759UIC can be replaced with a μ A741 driving an emitter follower if necessary. Circuit diagrams of the controller are shown in Fig. 1-4.

Since the input impedance of the module is quite low (less than 50 Ω) noise pickup has not been a problem. A low pass filter can be installed in series with the line to the reference input of the amplifier if necessary.

The remainder of the circuit is divided into two groups; filling logic and fault detection. They are by necessity interconnected so that if any fault which is tested for arises, the fill valve will close.

The tested items are:

- a) The integrity of the loop which comprises the RTD and its cabling to the controlling module.
- b) The supply voltages.
- c) The solid state relay.

The failure of any of the above will set the "Fault" flip flop which will clear the "Fill" flip flop, and remove the excitation voltage for the solid state relay. It also provides an audible signal to alert personnel involved. A switch is provided to defeat the audible signal, which admittedly can be annoying, however in that instance the "Fill" flip flop is held cleared. In the present version there is no provision to override this as the fault must be remedied in the interest of safety.

Since the control logic uses standard T²L logic, the +5 volt supply is derived from all the positive voltage sources commonly found in the NIM power supply. By "OR"ing these together, any two of the

three can fail and the circuit will perform its task. The failure of one will result in a fault condition. The ± 12 volt supplies are also sampled and the absence of either will result in a fault.

The integrity of the solid state relay is determined by waiting for two seconds after the excitation voltage is removed and testing for the absence of 120 vac at the output. If the voltage is still present the circuit will activate a relay which will cause the fuse in the "FILL" solenoid line to open and initiate a fault condition.

Defects in the RTD loop are detected by using a voltage comparator connected to the output of the amplifier. In a properly operating system the voltage at this point is approximately 600 millivolts, derived as a function of the diode and provides a very small operating bias for the resistor network. When the loop is opened this voltage falls, triggering the comparator which in turn sets the "Fault" flip flop.

Conclusion

One can imagine other versions of this where two sensors are used and the outputs of the amplifier logically combined to perform other tasks namely, a high and low limit sensor. The accompanying circuit utilizes one sensor and filling will commence as soon as the resistor is not surrounded by liquid. This keeps the liquid level within 1/16" of the full mark. Electronic hysteresis or delays can be incorporated to open this range up.

While safety was the primary concern in rendering this design, a secondary effort was to develop a circuit which will enable the RTD to be operated in a vacuum without damage from overheating.

I wish to thank R.D. Kephart, P. Mazur and W. Cooper for their informative conversations and suggestions, K. Kephart for her help in the preparation of this paper and M. Bennett for her patience in coping with the many iterations this paper underwent.

1. SAMA RC 21-4-1966 (USA)
British Standard, 1904:1964
DIN 43760
IEC 65B (proposed)
2. Fairchild Corp.
464 Ellis St.
Mountain View, CA 94042

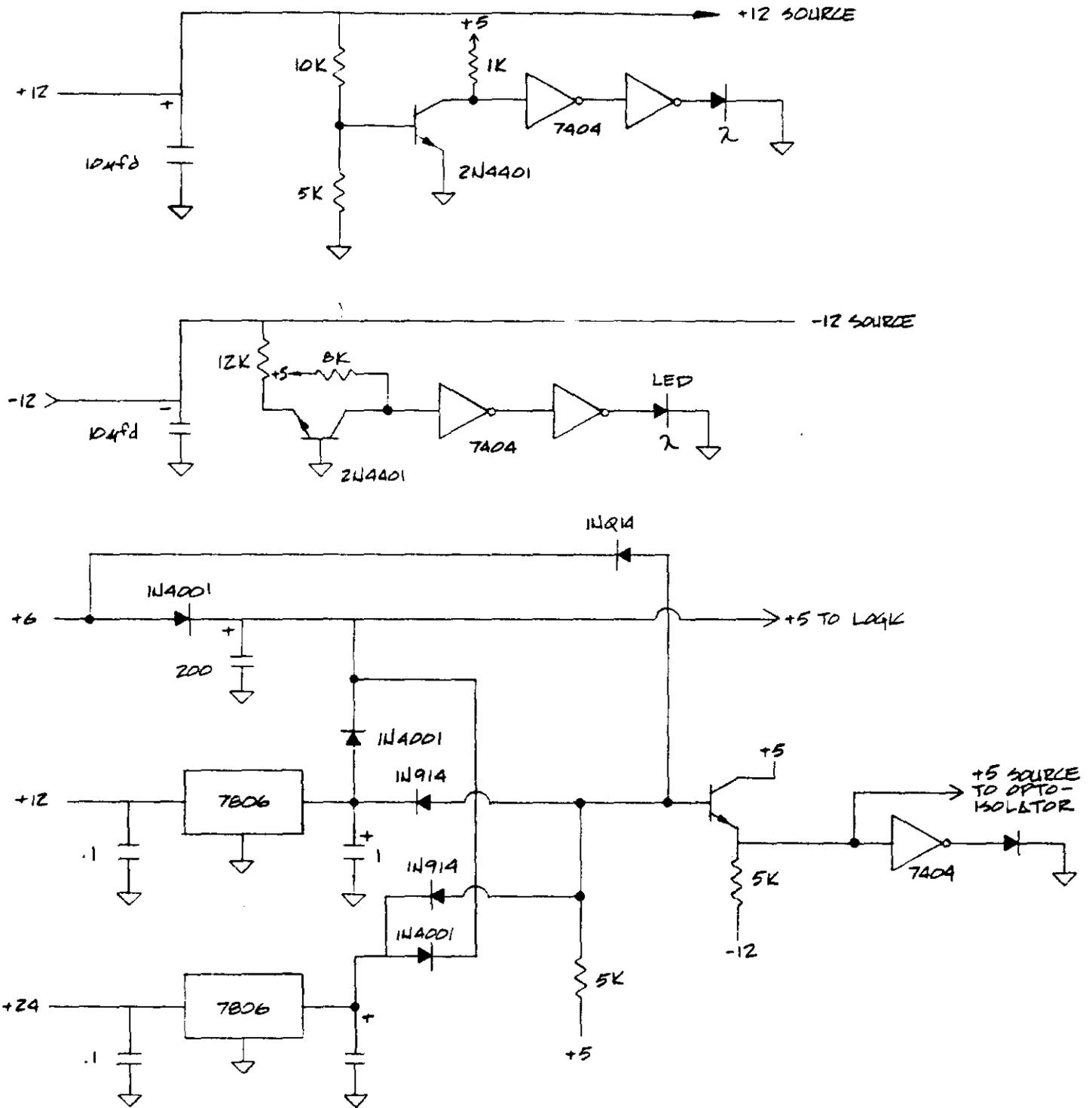


Figure 2

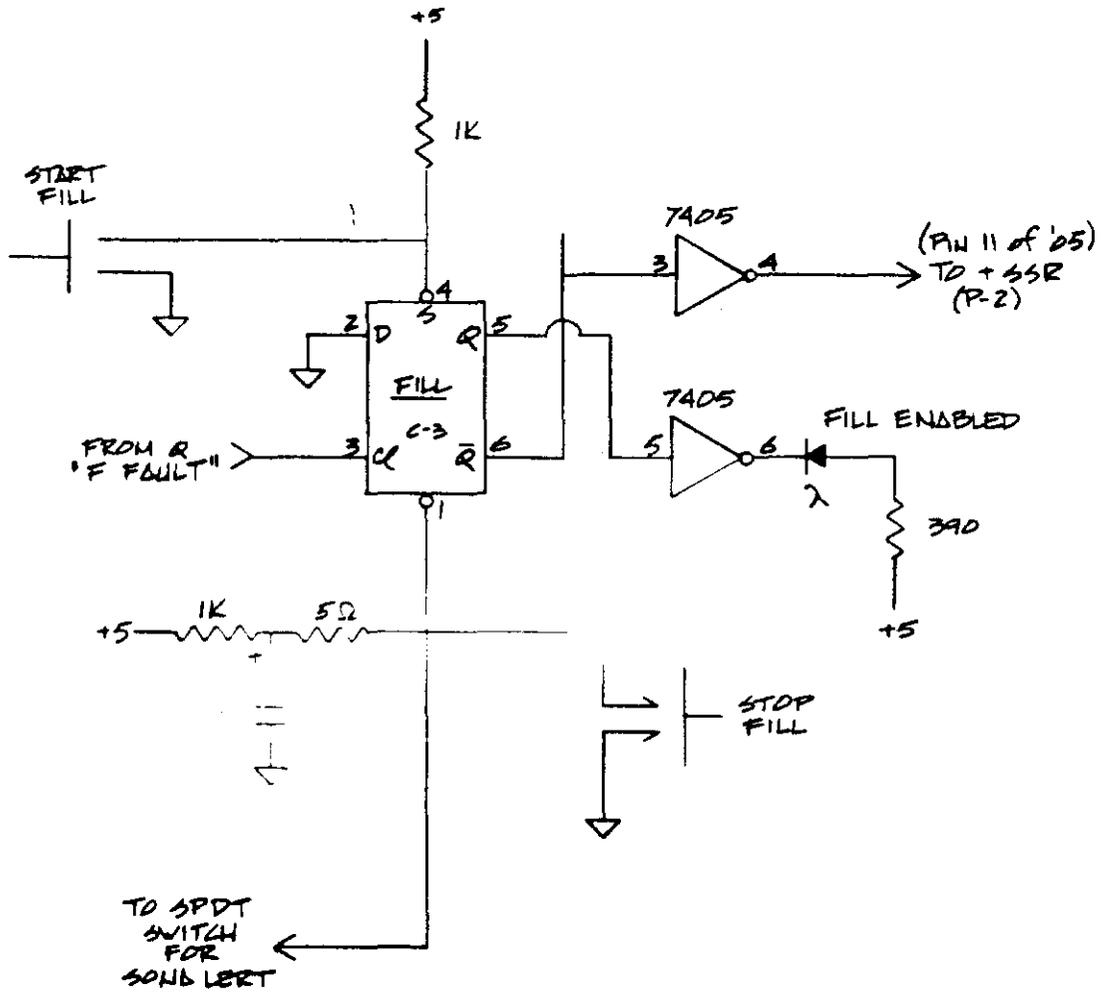


Figure 3

