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Progress of the Hard-wired Instrumentation and Control Works for the Neutral Beam Test Stand

Korea Atomic Energy Research Institute

To the president of the Korea Atomic Energy Research Institute;

We submit this report on “Progress of the Hard-wired Instrumentation and Control Works for the Neutral Beam Test Stand” as a technical report

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Abstract

Progress of the hard-wired instrumentation and control works for the neutral beam test stand(NB-TS) has been existed for the past one year period. Details of the installed arc detector circuit are explained. LN_2 level and temperature control during the cryosorption pumping operation are explained with an emphasis on its control circuit. With an expectation of more accurate and sensitive measurement of temperatures than the thermocouple utilization during the calorimeter operation, PT-100 resistance temperature detector(RTD) utilization is initiated and the results are described. During the ion beam experiment, physical measurements are made with some delayed time than the beam extraction, and thus a delayed trigger pulse generator was fabricated and installed to the system. Underlying principles of the electronic circuits for the interlock implementation and optical signal transmission are introduced. These are basically the application of operational amplifier circuits. A cautious aspect of the SMPS(switch mode power supply) utilization is also given.

Contents

1. Introduction

After the submission of the technical report on the hard-wired instrumentation and control for the Neutral Beam Test Stand(NB-TS)[1], the extracted beam power has become much higher(60 kV, 18A for 200 seconds with JAERI’s ion source), and hard-wired instrumentation and control (I&C) of the NB-TS has also been progressed with the construction schedule. First of all, vacuum system of the NB-TS has been enhanced of its performance by the expansion of the LN_2 supply system for the cryosorption pumps from a mere 150L supply reservoir to a 5000L field tank installed outside the facility building. The accompanying control system also was fabricated and installed to comply with the control needs of the expanded LN_2 supply system. The newer LN_2 supply system with the accompanying control functions now works satisfactorily for the operation of the cryosorption pumps of the NB beam line.

Measuring the temperatures at the coolant water supply line at the inlet and outlet locations during beam extraction is very important because this will result in the estimation of the absolute heat absorbed by the calorimeter itself. Thus the inlet flow and outlet flow of coolant had to be measured of their temperatures. For the temperature measurement purposes, PT-100 sensing elements were introduced to the system. We anticipated that the PT-100 sensor would result in more accurate readings for the temperature of the coolant water than utilizing thermocouples, and the preliminary results are described. Other works that are covered in this report are: description of the arc detector circuit, detailed explanation of the circuit operations of the DA converter for the optical receiver circuit, and flow rate signal treatment circuit. It is expected that these works will be applicable to the upcoming construction of the main NBI heating system for the KSTAR project.

2. Progress of the hard-wired NB-TS I&C works

2.1. Arc detector circuit

During the ion source operation, there exist the possibilities of abnormal situations that could hamper the normal operation or even deterioration of the ion source. Three possible abnormal cases are supposed to exist in the operation of the ion source: 1) Arc current abnormality, 2) Arc voltage abnormality, and 3) Langmuir probe signal abnormality. Occurance of any one of the above abnormalities and the anticipated abnormal signal outputs are schematically shown in Figure 1. An appropriate processing circuit had to be fabricated that can detect any of the abnormalities and process them to generate the notch signals for the temporary shutdown of the ion source operations. Figure 2 shows the circuit producing the ARC_I_Pulse signal. This circuit also produces the ARC_I_ON signal which will act as the basis for the timing.

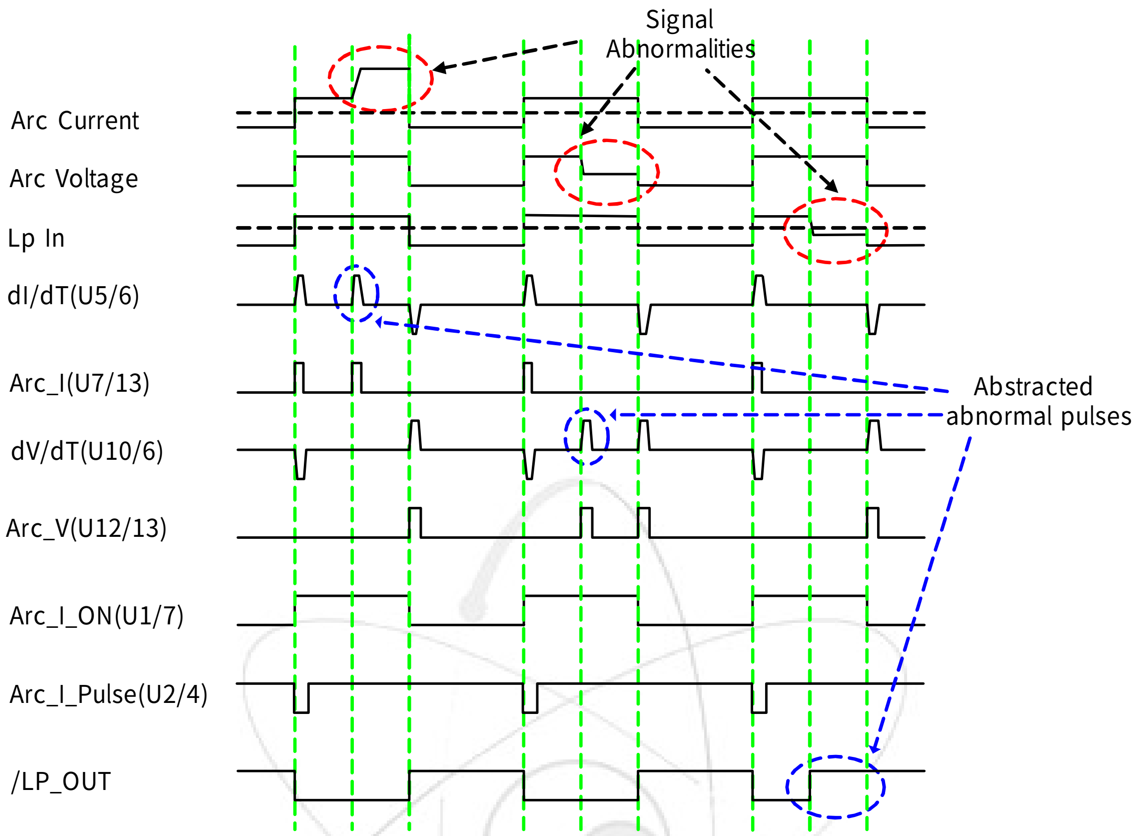


Figure 1. Modeled timing diagram for the various arcing pulses and the corresponding derived pulses for the ion source operation.

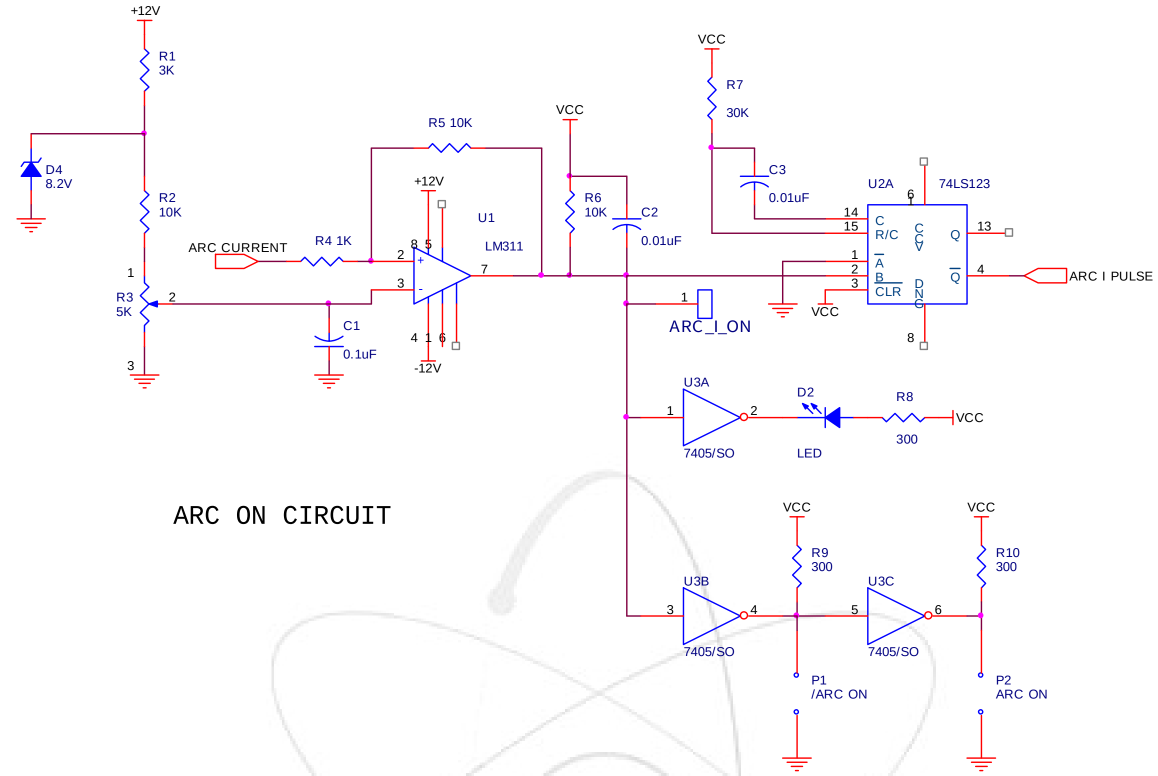


Figure 2. Arc_I_Pulse section of the arc detector circuit

Figure 3 shows the dI/dT signal generating circuit which had been passed to the comparator to obtain only the positive going pulses. The first op amp is for the differentiation of the signal.

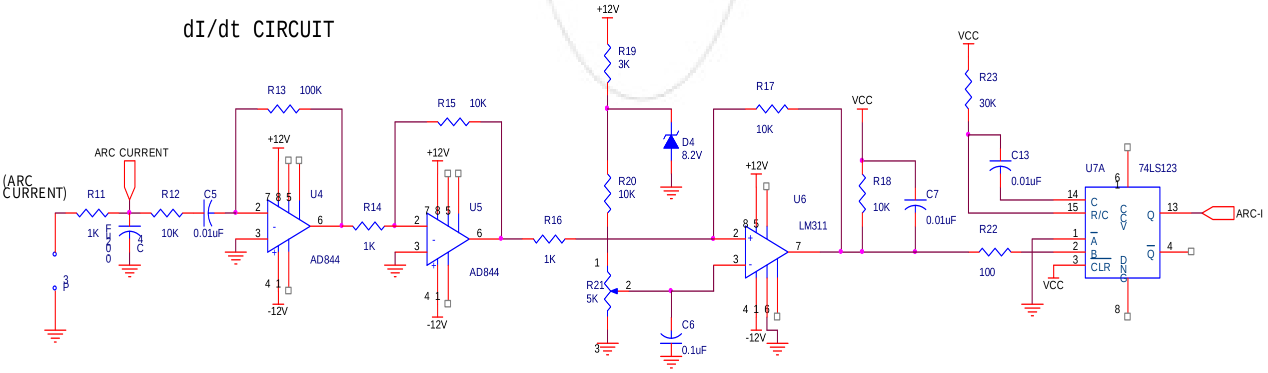


Figure 3. ARC_I section of the arc detector circuit

ARC_V signal shown in Figure 4 comes from the dV/dT signal which was also compared to generate positive pulses. Here also the first op amp is for the differentiation of the input signals.

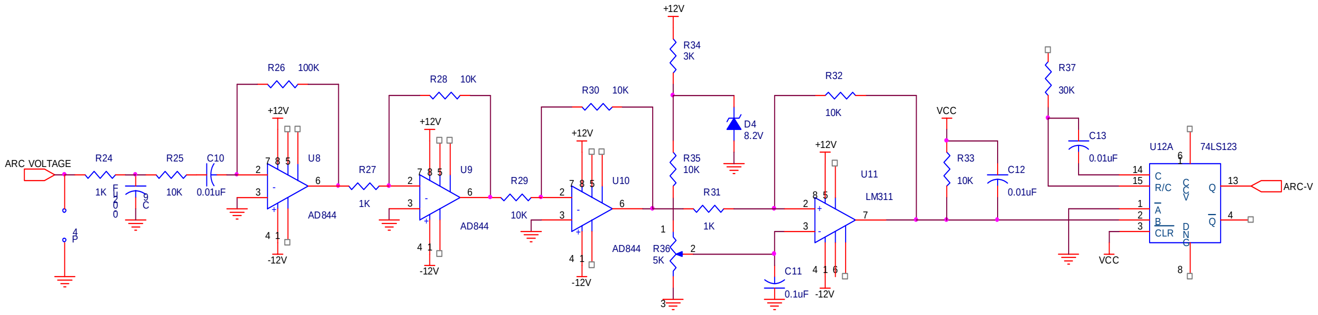


Figure 4. ARC_V section of the arc detector circuit.

Comparator output of the Lp_IN results in the /LP_OUT signal as shown in Figure 5.

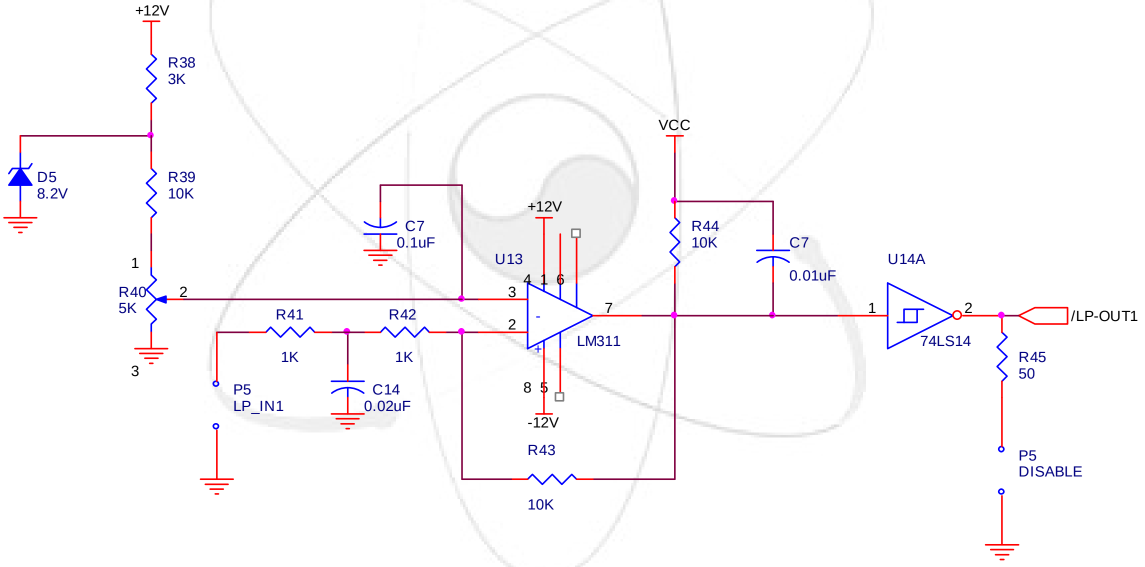


Figure 5. LP1 section of the arc detector circuit

All the above signals were sent to the multiple input NOR gate 74LS54(figure 6) of which logic diagram is shown in Figure 7.

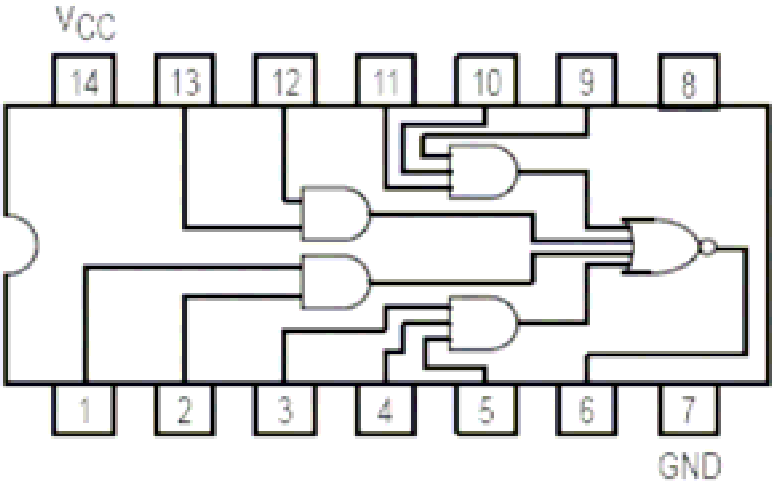


Figure 6. Pin configuration of the 74LS54.

To extract the ARC_I signal, ARC_I_PULSE signal is made to remove the normal-shaped pulses and these two pulses are ANDed as shown in the first AND gate of Figure 7. This process is rather tricky; the ARC_I_PULSE should be wide enough to remove the normal part of the ARC_I signal. The other three part extracting the ARC_V and LP_OUT pulses are self-explanatory. There are two LP sensors installed for the LP signal abnormalities and thus two logic gate circuits are there for the LP signal processing. In conclusion, any of the abnormal signals can be detected and come out as an output from 74LS54.

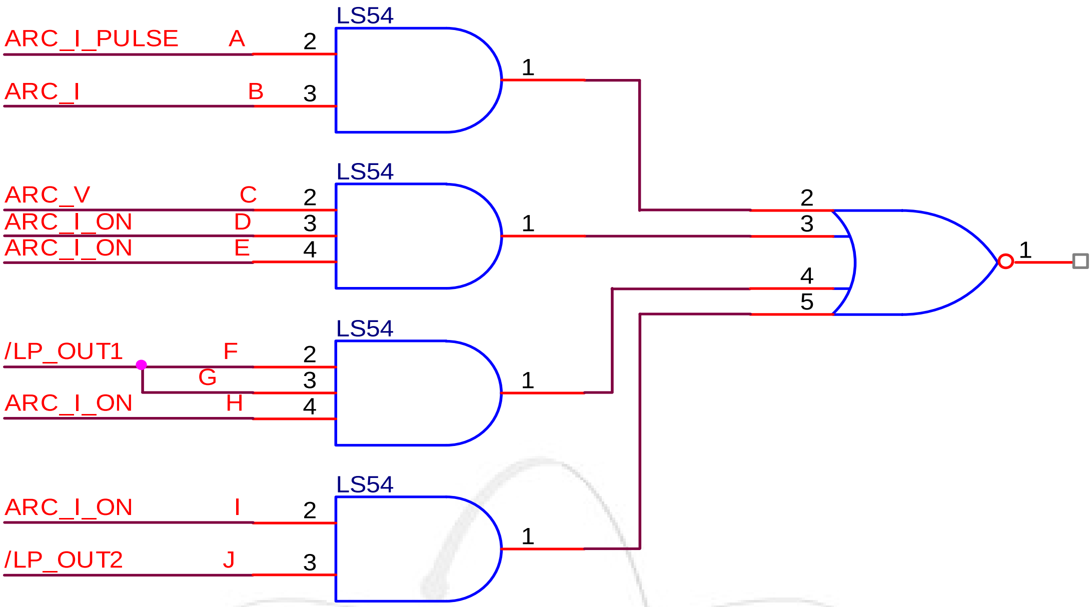


Figure 7. Logic diagram for the related arc pulses for the generation of the notch signals.

2.2. Liquid nitrogen level control

2.2.1. General description of the cryosorption pumping

The principle of the cryosorption pumping can be well described as shown in Fig. 8. High pressure, cooled helium gas from the compressor functions as a coolant when its pressure is decreased at the cold head of the Giford-McMahon cooler. The temperature of the coolant head can go to 10K[4]. Based on this principle, cryosorption panels were constructed as shown in Figure 9. Four sets of cryosorption panel are installed inside the NB chamber. As can be seen in the figure, the cryopanel surfaces are protected by the cooled baffles which are about 80K(or -193℃). 150 L of LN_2 was consumed to cool down the baffles from ambient temperature to 80K in 3 hours and to sustain the temperature for another 2 hours. Another 150 L of LN_2 was consumed for sustaining the temperature for 6 hours[5]. Cryosorption panels cooled down from ambient temperature to 20K within 6 hours with an LN_2 consumption rate of about 35L/min. The driving forces for the cryopumps are supplied by the four accompanying compressors(two Coolpak 4200s and two Ulvac C40s) installed on top of the chamber.

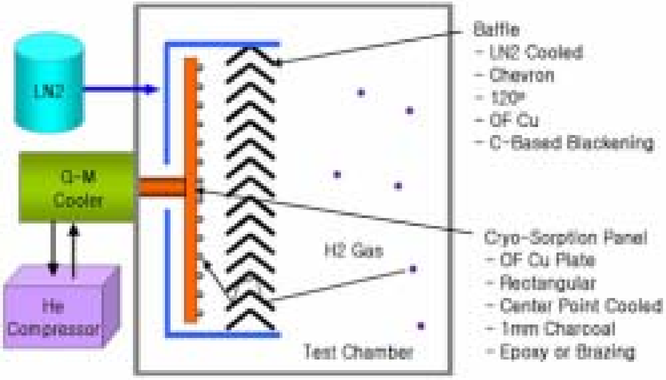


Fig. 8. Schematic diagram showing the operation of the cryosorption pump in action.

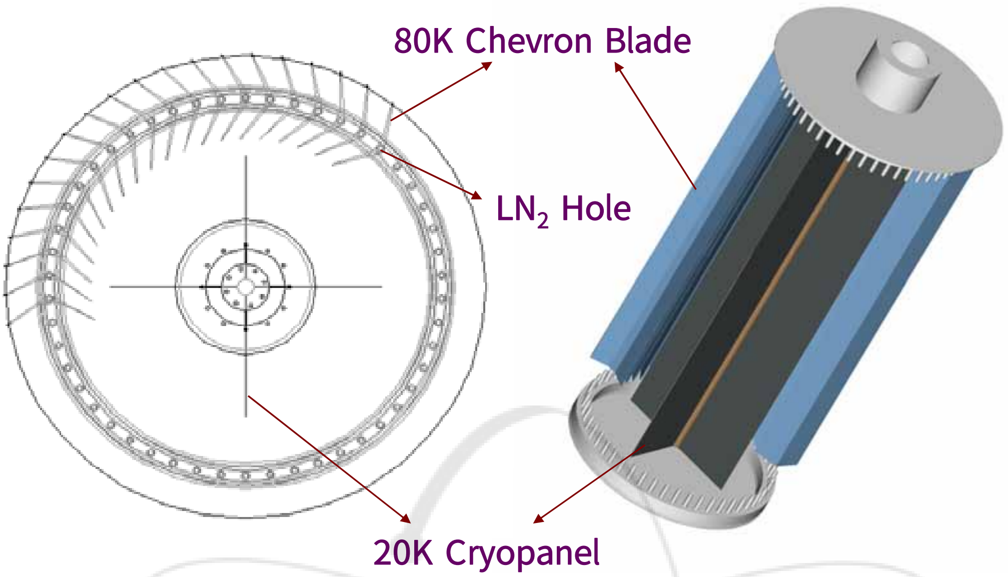


Figure 9. Structure of Cryosorption Pump

2.2.2. Construction of the new LN_2 supply lines and its control circuits

Needs for keeping the baffle temperature and the LN_2 level to be consistent with the controlling parameters existed, and a specific valve system with a temperature controller(EC-5500S, supplied by Ohkura Co.) was adopted for this purpose[6]. However, after some usage of this control system, some inconveniences became apparent; i.e., the system is supplied of its LN_2 only from a small bottle of 150L capacity, thus necessitating the operator's attendance for the exchange of the bottles all through the cooling period which would have extended up to many hours. For example, cryosorption panel cooled down to 20K after 6hours of LN_2 supply with consumption rate of 35L/hr[5]. Further operator's attendance was inevitable for the replenishing the LN_2 because the reservoir was equipped only with a manual valve. Original controller measured temperature only at the baffle and there were two valves each at the baffle LN_2 outlet and at the upper side of reservoir; the two valves were operating with a complementary action with the baffle temperature signal changes. The closure of the valve on top of the reservoir will make the nitrogen gas pressure of the reservoir become higher with time, thus resulting in a thrusting action for the LN_2 flow to the baffle area. This kind of indirect baffle temperature control apparently resulted in an unsatisfactory baffle temperature control, as well as the consumption of LN_2 larger than needed.

Thus necessity of a larger LN_2 supply tank with more refined controlling mode of the LN_2 temperatures and levels through many controlling valves became apparent, resulting in a construction of a newer LN_2 supply system schematically shown in Figure 10. Compared to the original supply system, the newer one is supplied of its LN_2 from much larger LN_2 supply tank(5000L vs. 150L), thus eliminating the inconvenience of frequent bottle exchanges. Besides of measuring temperatures at each of the baffle, each reservoir had been installed with two thermocouples at upper level and at lower level of the reservoirs, respectively. This configuration enabled independent control of the distribution valves for the reservoir bottles in a more refined manner.

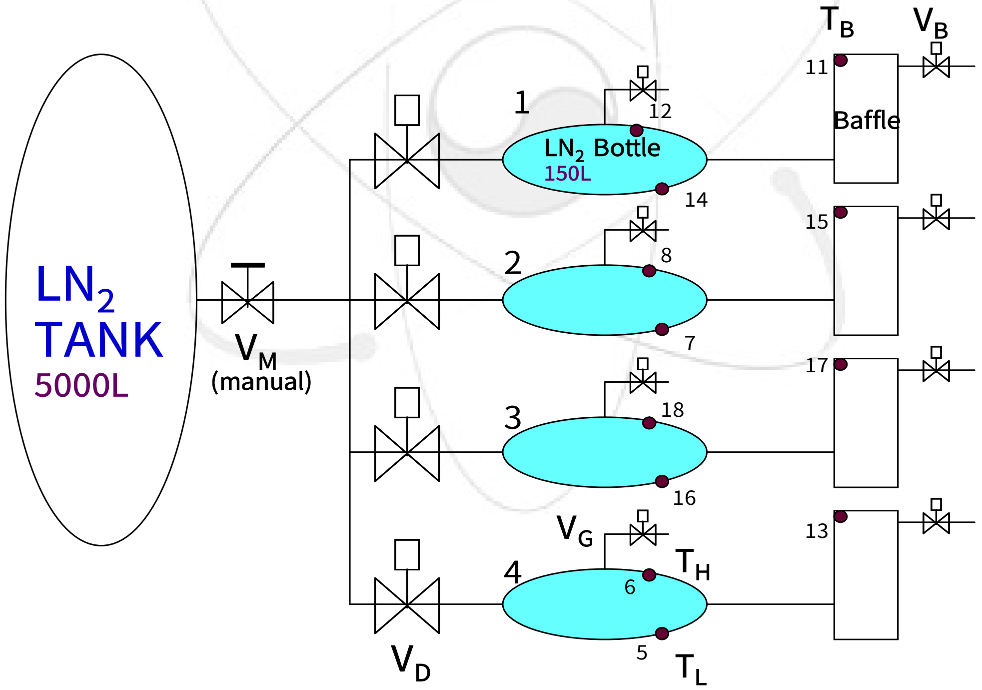
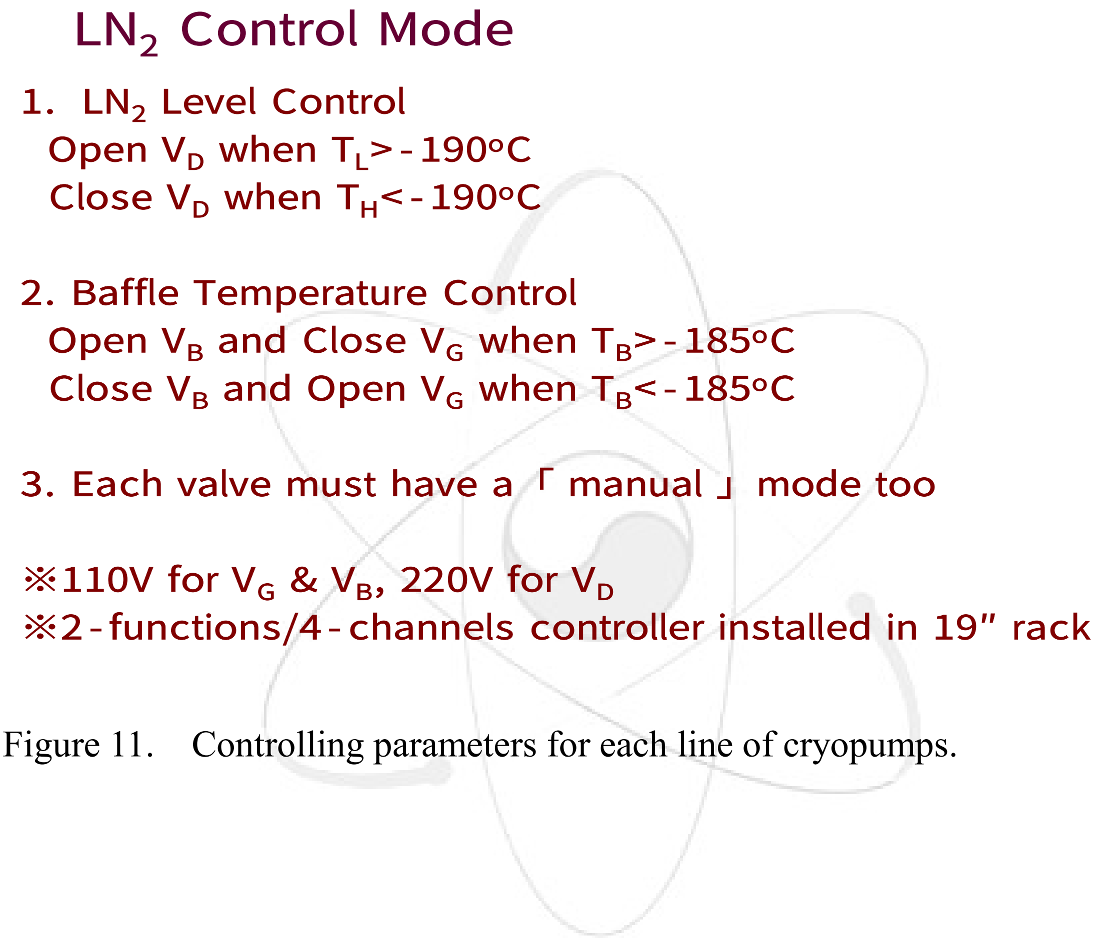


Figure 10. Schematic diagram of the newly constructed LN2 supply system.

As there were many temperature measurements and level controls for each supply line, controlling parameters was more complex as described in

Figure 11. One conspicuous aspect of the described parameters is that the reservoir bottle has two points of temperature measurement for the level controlling action of the reservoir bottle itself, thus refilling conditions shown in Figure 11 enables more refined refilling of LN_2. Refilling process is temporally shown in Figure 12.



LN_2 Control Mode

1. LN_2 Level Control
   Open V_D when $T_L > -190$°C
   Close V_D when $T_H < -190$°C

2. Baffle Temperature Control
   Open V_B and Close V_G when $T_B > -185$°C
   Close V_B and Open V_G when $T_B < -185$°C

3. Each valve must have a 「manual」 mode too

※110V for V_G & V_B, 220V for V_D
※2-functions/4-channels controller installed in 19" rack

Figure 11. Controlling parameters for each line of cryopumps.

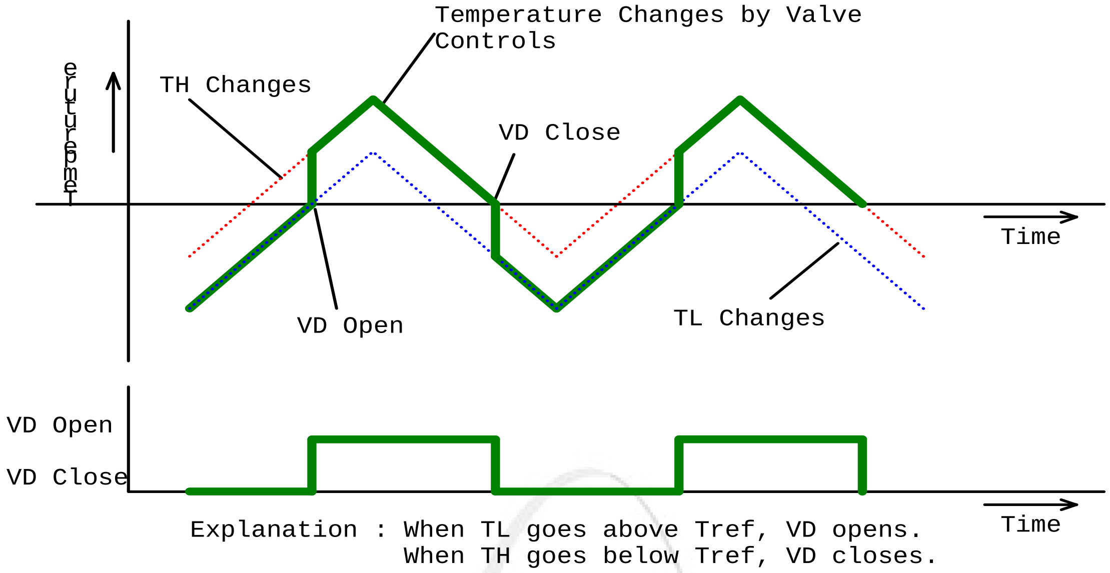


Figure 12. Sequential diagram showing the level control of the LN2 reservoir.

According to Figure 11, complementary aspect of valve operation is still inherited onto the newer LN$_2$ controller from the original one through the measurement of the baffle temperature(T_B); when T_B is higher than -185℃, the V_B will be opened to make the LN$_2$ evaporation possible with the resultant cool-down of the baffle whereas V_G will complementarily be closed to make the N$_2$ pressure piling in the reservoir drive LN$_2$ into the baffle region. Opposite action will take place when T_B becomes lower than -185℃; V_B will be closed and no more cooling takes place at the baffle region, whereas V_G will complementarily be opened for the nitrogen pressure not to accumulate. Resultant controlling circuit has been designed as shown in Figures 13 and 14.

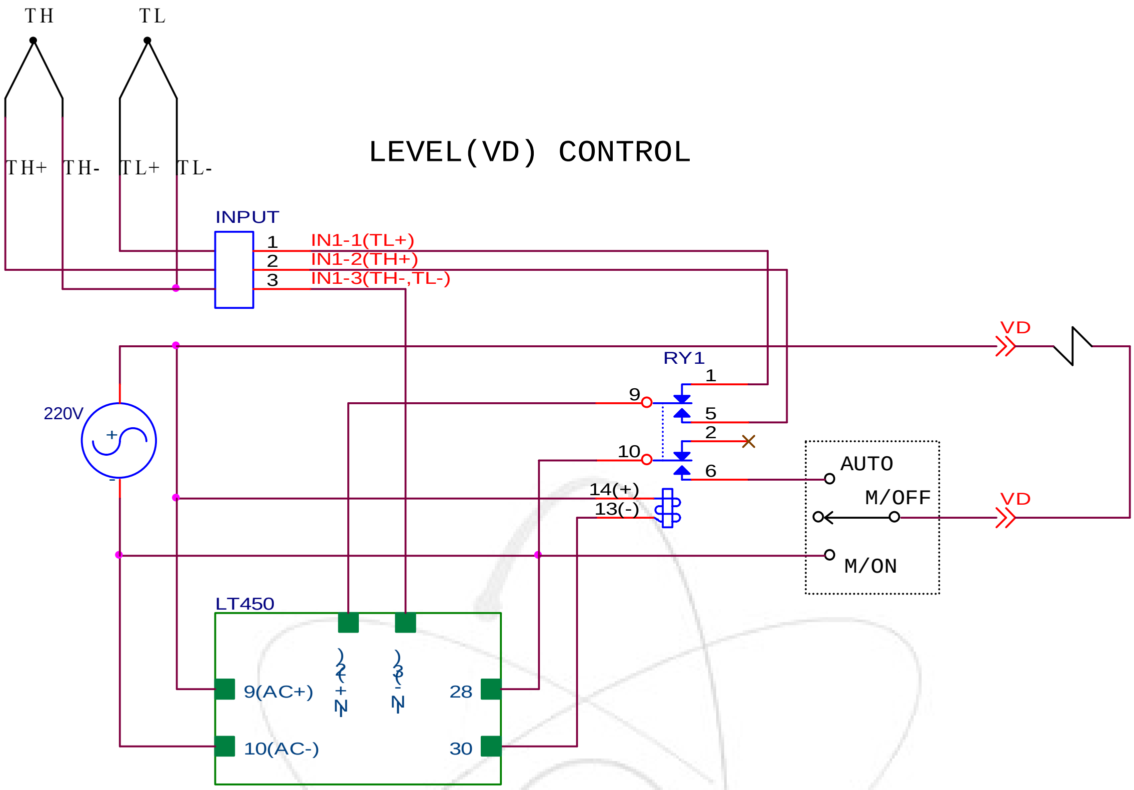


Figure 13. LN2 level control circuit diagram.

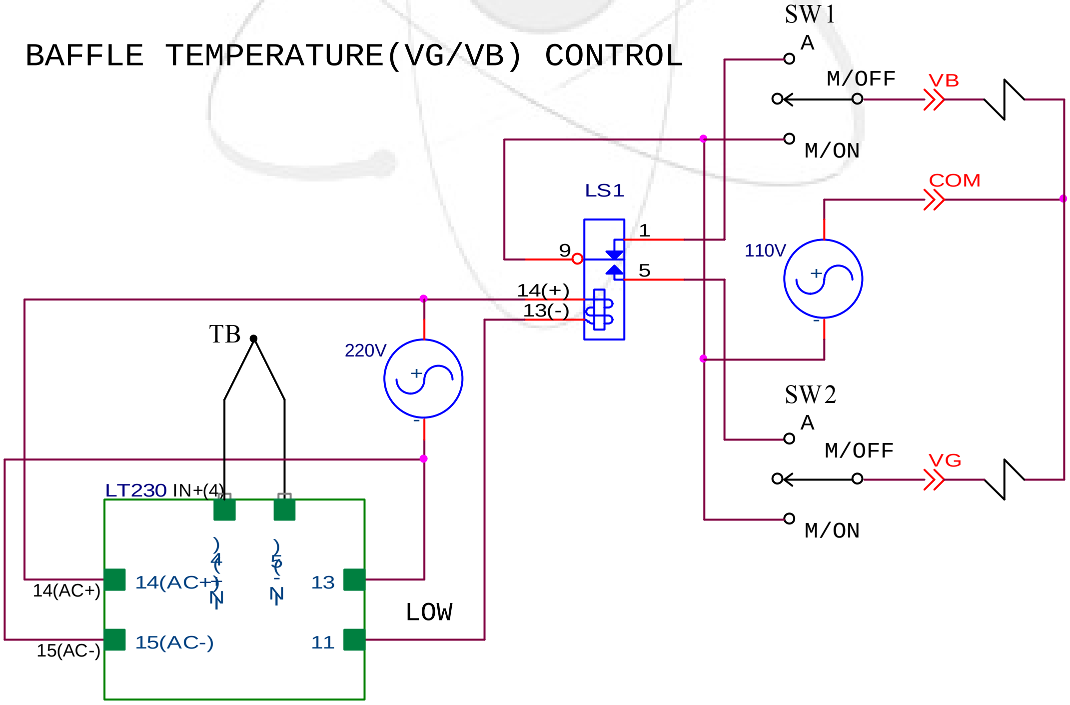


Figure 14. Baffle temperature control circuit diagram.

Care should be taken in operating the baffle temperature control circuit. That is, when LN_2 is inside the reservoir, there should never be a chance when both of the two valves are closed; and this possibility exists when one of the switch is in AUTO position and the other switch is in MANUAL position or when both of the switches are on the OFF position with the liquid nitrogen in the reservoir. In this state the nitrogen gas pressure in the reservoir-baffle path can pile up. The front panel appearance of the finally constructed LN_2 supply control module is shown in Picture 1.

Picture 1. The front view of the LN2 controlling module.

2.3. Temperature measurements and calorimetry

2.3.1. Necessities of the temperature measurement and calorimetry in the NB-TF

One of the important task in the neutral beam experiment is the beam power measurement(7). The ratio of the injected neutral beam power into the Tokamak torus over the power consumed in the acceleration stage is the ultimate efficiency parameter for the neutral beam injection facility. However, the installation of the calorimeter in the torus is not possible, and thus the direct measurement of the beam power has also been impossible. An alternative to this task is the installation of the movable calorimeter in the beam line where cooling water flow is utilized for the calorimetry.

The diagnosis utilizing this water flow calorimetry(WFC) is very important, but not so easy to attain the desired accuracy and sensitivity.

Usually temperature difference(delta T) between the inlet and outlet of the coolant water is measured for the calorimetry of the NB beam line. However, thermocouples are not so sensitive, and thus usually thermistor blocks are utilized for the delta T measurement in the NB experiments. Other than the coolant water, there are some paths that the absorbed heat at the calorimeter is dissipated: they are the thermal radiation to the cryosorption panels, conductive loss to the flanges, convective loss to the air, etc. Heaters can be used beforehand to measure these losses and the resultant data can be used as a correction factor.

2.3.2. Utilization of the Thermocouples for the Temperature Measurements

Until now, needs for the temperature measurements during the operation at various locations of the neutral beam test facility have been met by the exclusive adoption of the K-type thermocouples. The locations of the temperature measurements were detailed in the previous report(1). Thermocouple utilizations were mainly implemented by: (1) Utilization of the SCXI module supplied by the National Instruments; (2) Utilization of the dedicated integrated chip(IC) designated as AD595; (3) Individual cases in which the TC signals were sent to any indicator/controllers.

Compared to the K-type thermocouple which has a wide range of temperature measurement(-200~1300℃), T- type thermocouple has narrower range of measurement(-200–500℃). We started to utilize the T-type thermocouple to the colorimeter outlet temperature measurement. That is, to the outlet of the calorimeter outlet pipe, we installed three sensors that are the K-type thermocouple, PT-100 resistance temperature sensor, and the T-type thermocouple(Figure 15).

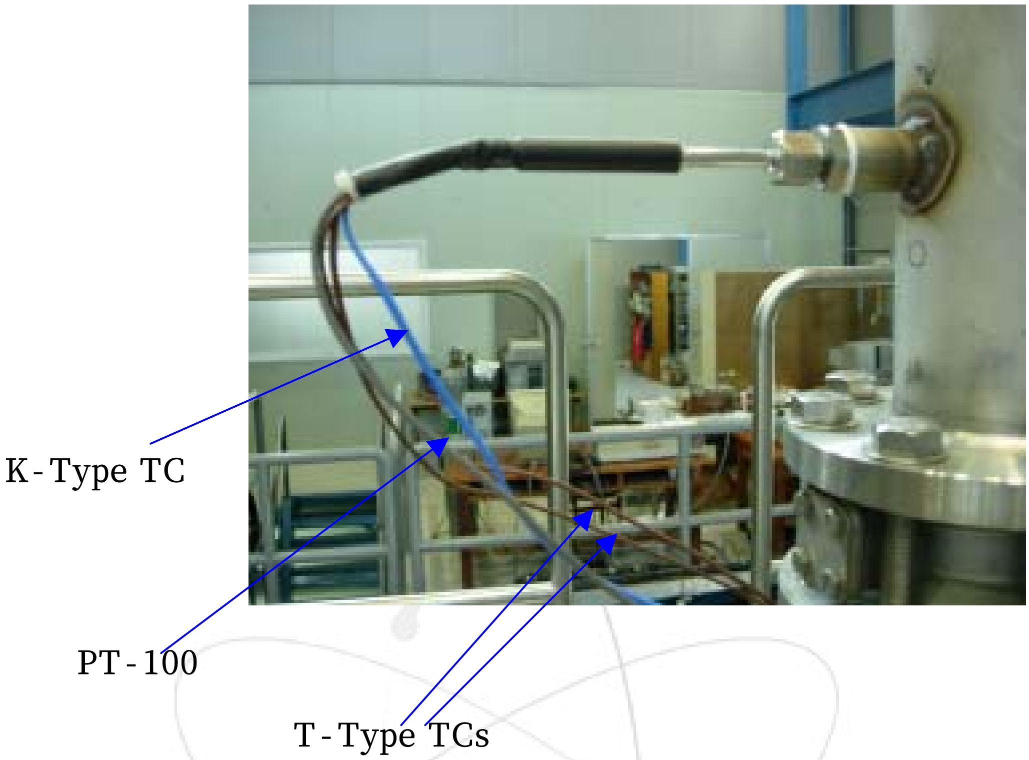


Figure 15. Temperature Sensors installed onto the Calorimeter Outlet Pipeline

A. Utilization of the SCXI module

For this case, TC signals from ion dump, neutralizer, bending magnet, and calorimeter were sent to the dedicated SCXI module located on top of the NB chamber. The signals were then sent to the control room through the fiber optic line and then processed to be displayed or archived.

B. Utilization of the AD595

A thermocouple signal processing component known as AD595 has been utilized for a few years in the NBI group, and it has been found that this chip should be used with appropriate caution to get the satisfactory temperature readout. It is apparent that the two differential input signals should be ground-referenced if the differential amplifier action should be effective. Incidentally, ***Databook of AD595 suggests the connection of +input terminal(Pin 1) to the circuit ground(Pin 7).*** Figure 16 should help understand this situation. The ISO122P after the AD595 is for the signal isolation. If there is no need for the signal isolation, any general purpose op amp can be used. The output signal of AD595 is not so strong that the amplification stage as shown here is necessary.

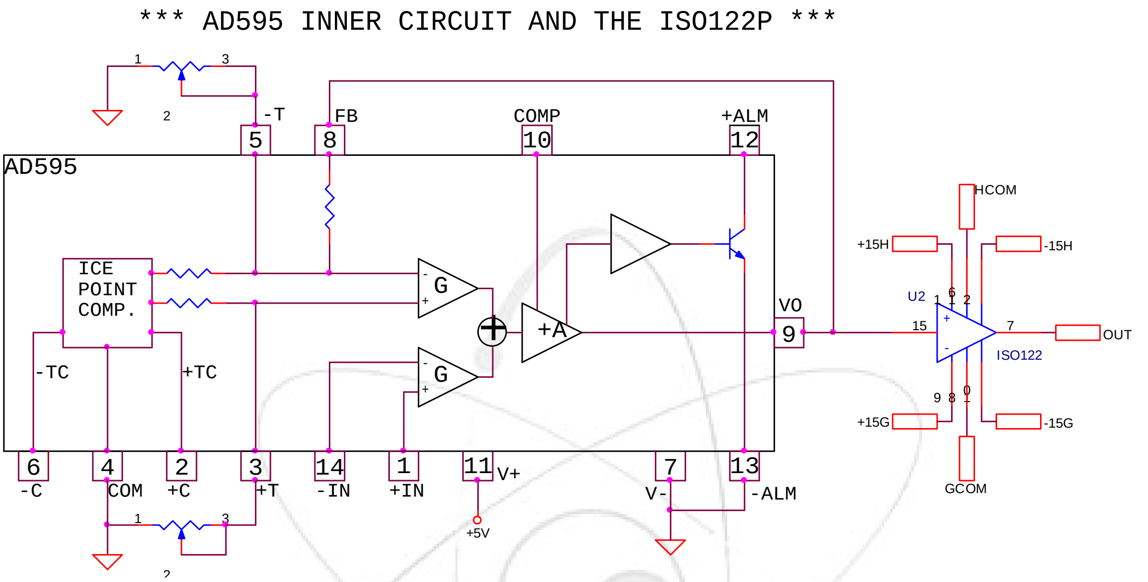


Figure 16. Inner circuit of the AD595 and the ISO122P. Here ISO122P is for the signal isolation

C. *Individual cases in which the TC signals were sent to any controllers.*

Examples of these cases were those of accepting the TC signals and sending appropriate controlling signals to any other locations. A typical example of this case is the control of liquid nitrogen level and the baffle temperature for the cryosorption pump operations as described above.

2.3.3. Utilization of Pt-100 for the Temperature Measurements

A. *Temperature measurement and the calorimeter*

It is expected that if we measure the temperatures both at the inlet and the outlet of the calorimeter, the difference of the two temperatures would yield the quantitative measure of the neutral beam power. The following general relationship holds for the absorbed energy by the coolant water per unit time[8];

$$Q = mc\int_{0}^{\infty} \Delta T(t)dt \qquad (1)$$

Where Q is the absorbed energy(cal), m is the mass flow rate(l/sec), c is the specific heat(1 cal/g°C), $\Delta T(t)$ is the temperature difference between the inlet and outlet of the coolant flow, and dt is the time increment. If we neglect the compressibility of water at pressures lower than 10 atm, we can safely say that the specific heat of water could be the same as that at 1 atm.

B. Mr Kawai's Summary of the Pt-100 utilization at JAERI

Presently, KAERI and JAERI(Japan Atomic Energy Research Institute) are cooperating in their research activities. According to Mr Kawai of JAERI, their temperature measurement, especially for the case of coolant temperature monitoring, relies on RTD method utilizing the Pt-100(9). This section reproduces Kawai's summary of the Pt100 utilization at JAERI(Figure 17).

Sensor : Pt-100(100Ω at 0°C, 138.51Ω at 100°C → 0.385 Ω/°C)

Passing constant current of 2mA → 770.2 X 10^{-6} V/°C

(For the K-thermocouple : ~40 X 10^{-6}V/°C)

Resistance variation : Pt-100(dR) is directly proportional to dT

Advantage :

Cold junction is not necessary

High stability and wide linearity

Disadvantage :

Mechanical strength is not enough(mechanical shock or vibration)

Constant current power supply and (differential amplifier) are required

"Pt100 is better than a thermocouple for temperature measurements around room temperature"

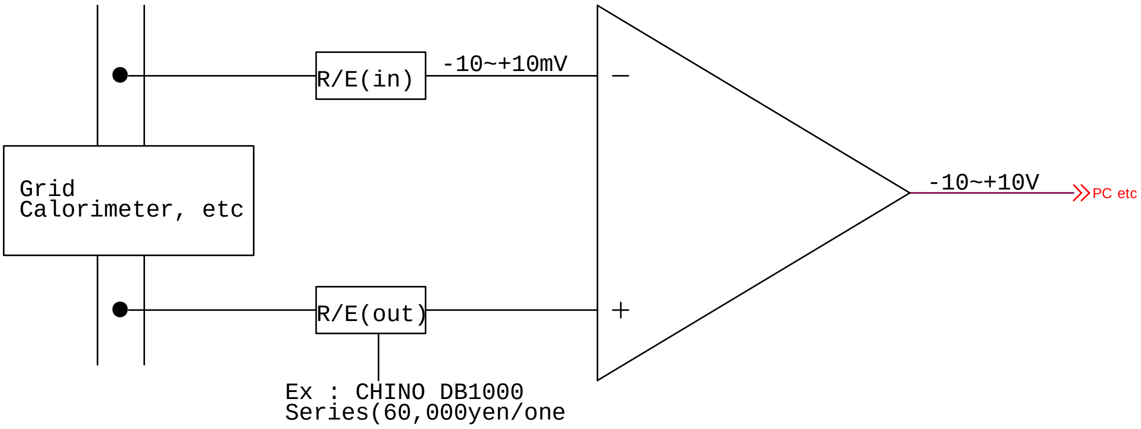


Figure 17. Circuit that Mr Kawai introduced about the PT-100 utilization at JAERI.

Accepting the above summaries presented by Mr. Kawai of JAERI, we started implementing the Pt-100 to our temperature measurement needs.

C. Temperature measurement with RTD

Resistance temperature detectors(RTDs) are temperature-sensing devices whose resistance increase with temperature[10]. According to the Application Note 046 from National Instruments[11], the relationship between the resistance and the temperature is very linear and follows the equation :

For >0℃,

$$R_T = R_0[1 + \alpha T + \beta T^2] \qquad (2)$$

Where

R_T = resistance at temperature T

R_0 = nominal resistance

α and β are constants used to scale the RTD.

RTDs require current excitation to produce a measurable voltage. RTDs are available in 2-wire, 3-wire, or 4-wire configuration. The lead wires in the 4-wire configuration are resistance-matched. 2-wire and 3-

wire RTDs are unmatched. Resistance in the lead wires that connect the RTD to the measuring system will add error to the readings. The most common type RTD is platinum.

D. Testing a commercial module for Pt-100 sensor and readout fabrication

To comply with the suggestions given by Mr. Kawai, we decided to adopt a temperature measuring module which can output 4-20mA for the temperature signal by Pt-100; and a temperature measuring module "TZ4ST-R4C" supplied by "Autonics" was considered fitting to our purpose. As we should supply the temperature signals to a differential amplifier, we obtained signal voltage – temperature characteristics of the modules when we connected a 250Ω resistor across the output of the module to find out the performance characteristics. A typical result of this test is shown in Figure 18.

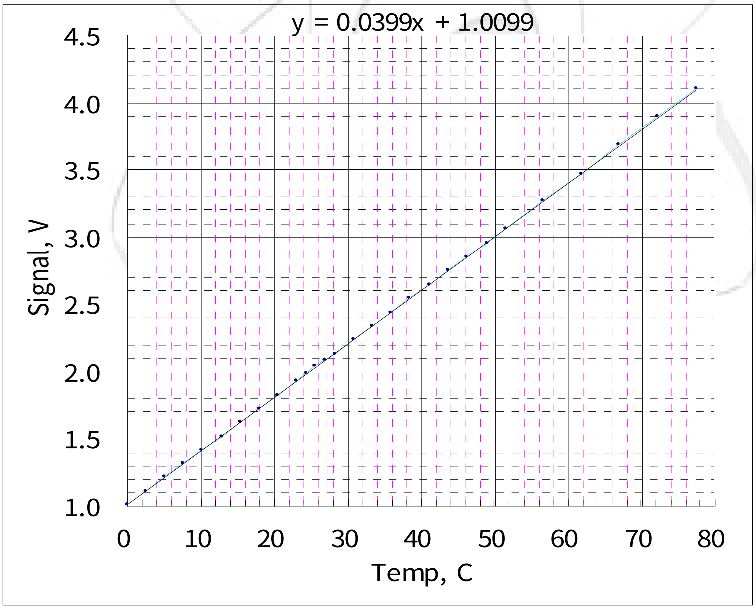


Figure 18. A typical result of the characterization of the temperature measuring module "TZ4ST-R4C" supplied by "Autonics"

The result shows that the relationship between the voltage signal across the resistor and the temperature is given by the following relationship:

$y = 0.0399x + 1.0099$

Where y is the voltage signal and x is the temperature values. Considering the tolerance of the resistor values, it can be clearly said that the module is manufactured so that the following relationship holds when we attach an exactly 250 Ω resistor across the output terminals:

$Y = 0.04x + 1.000$

Thus, a 1 volt difference would correspond to 25℃ in temperature difference. We applied the temperature signal voltage to the A/D converter of the National Instruments' PXI system and then sent the signal to the control room through the fiber optic cable; the received signal could then be processed to display the temperatures and the absorbed beam powers. Autonics says that they flow 5V to (20kΩ + Pt100), thus the current is 0.25mA. This current is amplified to make 40mV/℃ signal.

The fabricated readout module for the PT-100 sensors have 4-20mA output signals. These current signals were converted to voltage signals by connecting 250 ohm resistors each corresponding to the inlet temperature sensor and outlet temperature sensor. Exact values of the resistors were 250.02 ohm(for inlet) and 249.9 ohm(for outlet). These values corresponds to 0.008 % and 0.04% of relative errors each; otherwise said, the inserted 250 ohm resistors can be considered to be quite accurate enough.

Resistance of the lead wires could lead to serious error to the temperature readout. For example, when we made connections from the PT-100 sensors to the readout module with certain wires, the results were :

1) inlet temperature sensor wire was 1.1 ohm for the 11.4 meter length,
2) outlet temperature sensor wire was 0.7 ohm for the 10.7 meter length,
3) V-out wire was only 0.1 ohm for the 11.0 meter length.

Wire for number 3) is very low in its resistance and it can be said that the wire quality is very good. Anyhow, if the lead wire resistance is 1 ohm and the temperature was 0℃, the measured resistance would result in 101 ohm and this value would result an erroneous result. In an incident with similar situation as above, we got about -1.0℃ for the ice-water medium, which result should not be obtained. Final comments for this circumstance are that the lengths of the lead wires for the PT-100 sensor should be as short as possible and the wires should be of high quality with low resistance per length specifications.

2.4. Delay circuit fabrication

2.4.1. Background

In the NB experiments, arc current flows after some time delay from the issuance of the start-up command. Accordingly the experimental procedures such as the CCD camera operation should start with some delay from the start-up command. The delay time should be determined operationally, and the experimental issuance of the delayed signal would have to be made through a fabricated circuit which satisfies these operational requirements. The general schematic of the experiment time schedule is shown in Figure 19. The timer used was Model H5BR-B from OMRON. The waveform for the input and output are shown in Figure 20.

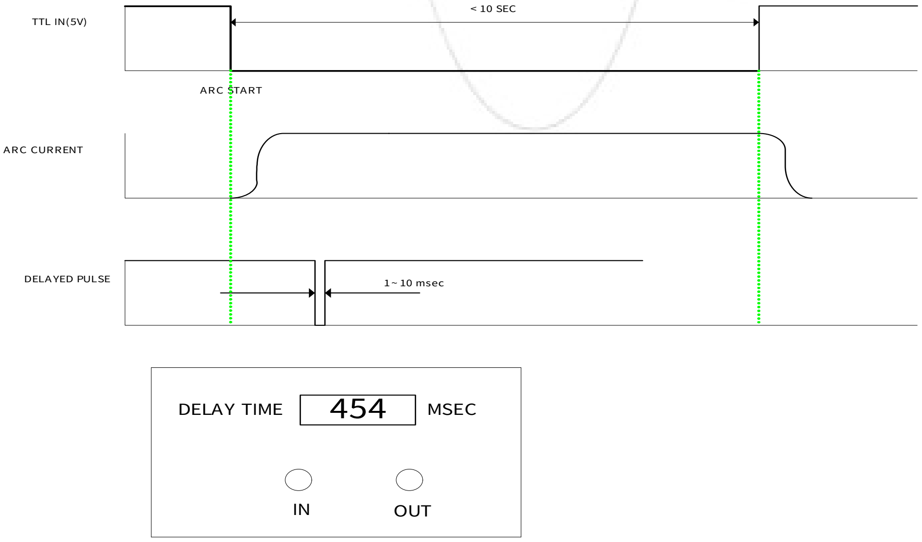


Figure 19. Schematic explanation of the delayed trigger circuit

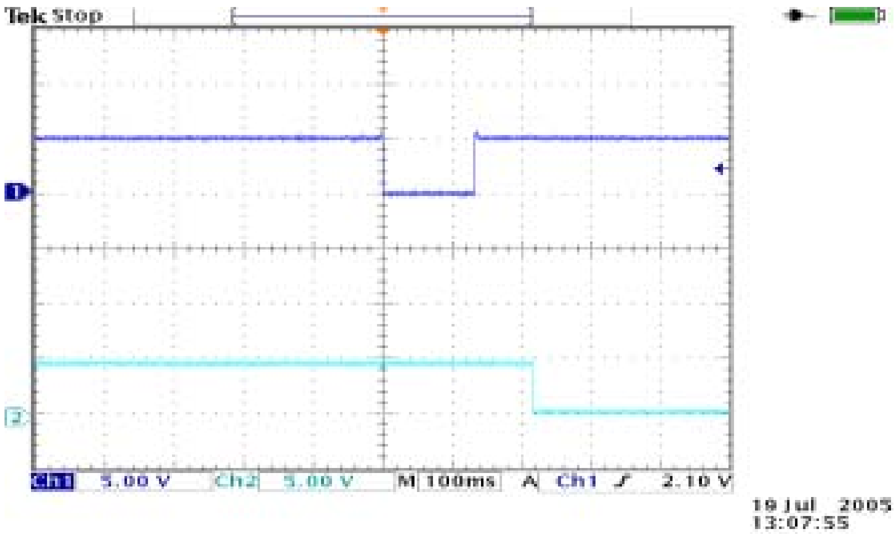


Figure 20. Upper waveform is for the input signal, whereas lower waveform is for the output signal. Timer was set to send 200 msec delayed signal.

3. Miscellaneous works

3.1. Differential amplifier and the flow interlock circuit

As we described in the previous report(1), we designed an interlock circuit protecting the calorimeter from any inadvertent coolant shutdown. The relationship between flow rate and the voltage output was

$$V = 2.40F + 1, \tag{3}$$

or

$$F = 0.417(V - 1) \tag{4}$$

where F = flow rate in kL/minute and V = output in volt. Designing a circuit satisfying equation (4) can be implemented using the differential amplifier circuit; i.e., differential amplifier circuit shown in Figure 21 can be utilized for the implementation of our purpose(Franco, Ref.3).

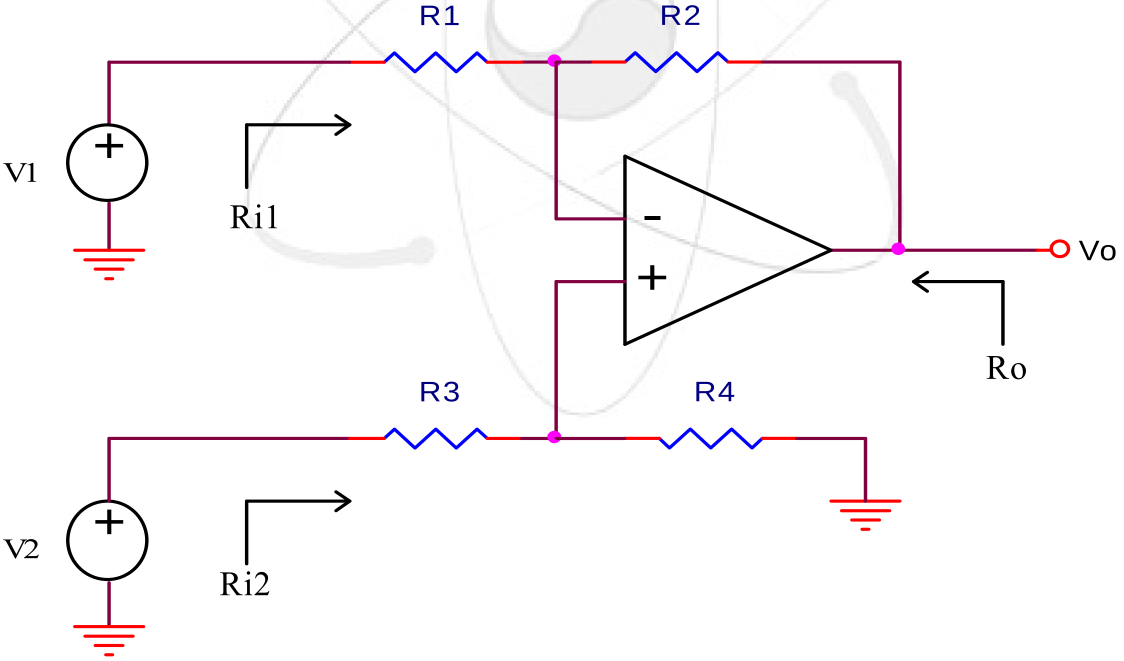


Figure 21. The general case of the differential amplifier(Franco, p.20, Ref. 3)

For the circuit of Figure 21, the following relationship can be written:

$$v_o = \frac{R_2}{R_1}\left(\frac{1 + R_1 / R_2}{1 + R_3 / R_4} v_2 - v_1\right) \tag{5}$$

If the resistance pairs are in equal ratios:

$$\frac{R_3}{R_4} = \frac{R_1}{R_2} \tag{6}$$

Then equation (5) simplifies to

$$v_o = \frac{R_2}{R_1}(v_2 - v_1) \tag{7}$$

Equation (7) shows that if condition (6) holds a differential amplifier circuit with R_2 / R_1 and R_4 / R_3 equal to 0.417 and v_1 equal to 1 volt will make the desired circuit. The resulting circuit diagram is shown in Figure 22. In this figure, flow signal in volt comes into U2 whereas U1 makes the 1 volt. Resistors R3, R4, R5 and R6 make the necessary ratio values as equation 4 necessitates.

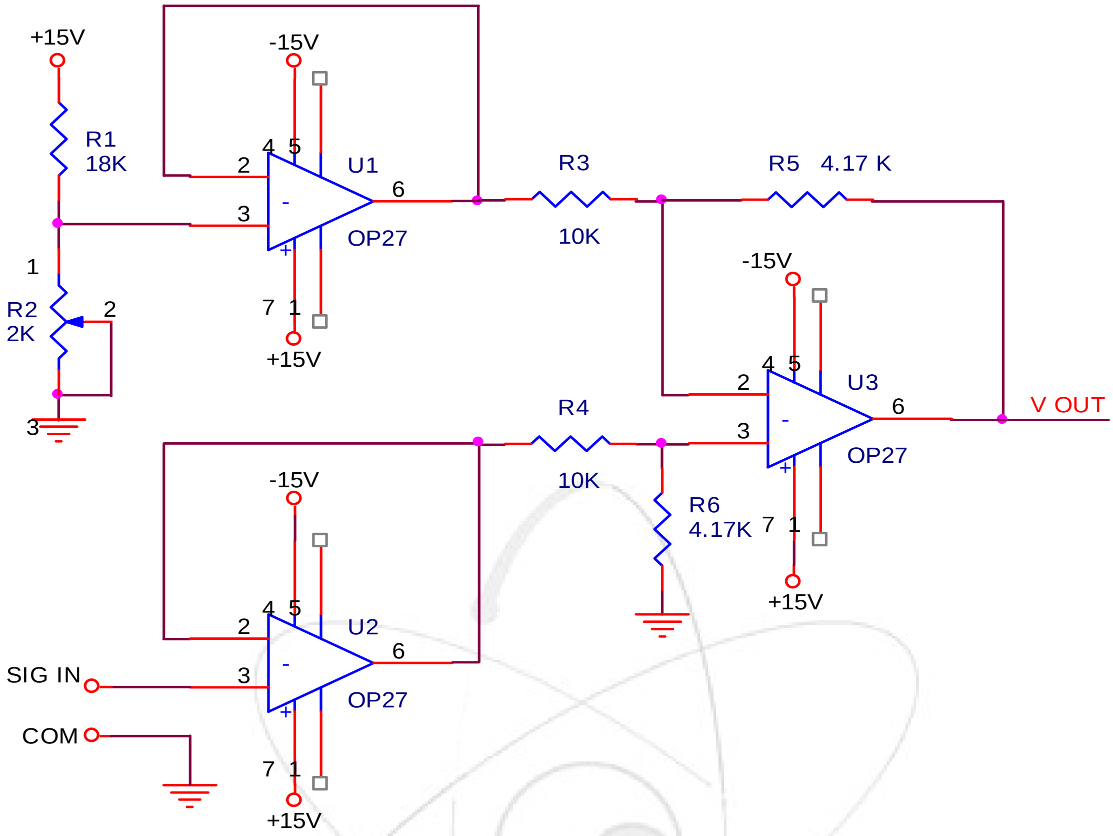


Figure 22. Electronic circuit utilizing the flow rate signal for the interlock signal generation.

3.2. Optical Signal Transmission

3.2.1. Summing amplifier and the AD667 Calibration

According to Johnson and Malki(2), a typical summing amplifier can be represented as Figure 23.

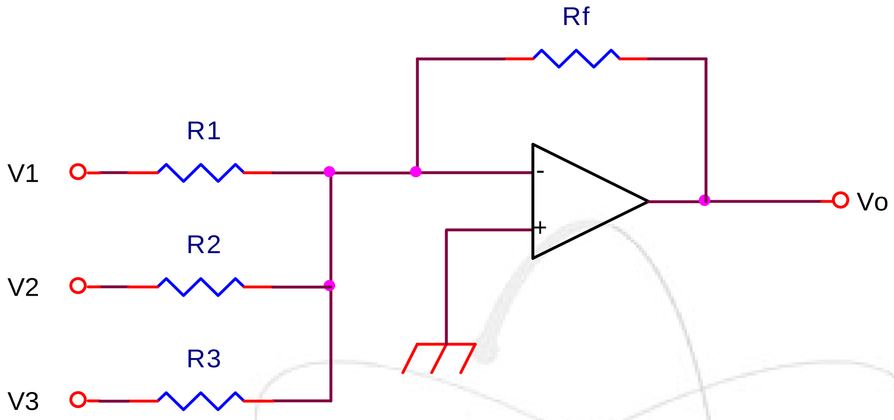


Figure 23. A summing amplifier according to Johnson and Malki(2)

Voltage output of this circuit can be shown as

$$v_o(t) = -(\frac{1}{R_1}v_1 + \frac{1}{R_2}v_2 + \frac{1}{R_3}v_3)R_f \tag{8}$$

This relationship can be utilized to rationalize the process of AD667 output calibration. In the previous report(1), description was made on the reproducibility enhancement and offset calibration of the optical signal transmission. That is, at the receiver module of the optical transmission, output from the D/A converter AD667 was made to be as close as possible to the input voltage at the transmitter board by the insertion of two variable resistors around the output stage of AD667. The corresponding circuit is redrawn in a simplified form as shown in Figure 24.

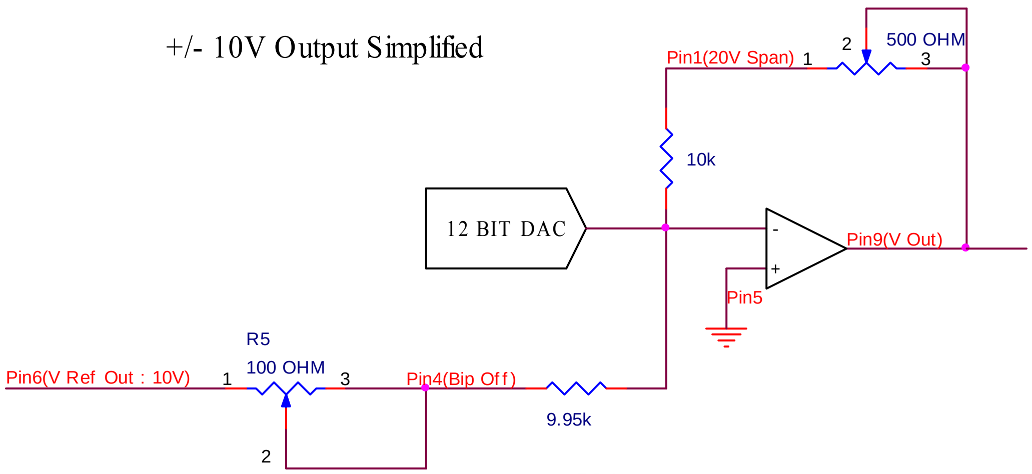


Figure 24. Two variable resistors inserted around the output and the related pins of AD667 for the refinement of reproducibility and offset calibration.

Close look at Figure 24 soon reveals that the circuit is a kind of summing amplifier circuit. Databook for the AD667 says that the 10 volt bipolar offset is applied at pin 4. Thus if we designate the internal DA signal as V_{DA} and the accompanying ladder resistor value R_{DA}, V_o can now be written as follows:

$$v_o = -\left(\frac{V_{DA}}{R_{DA}} + \frac{V_{offset}}{R_{offset}}\right)R_f = -\left(\frac{V_{DA}}{R_{DA}} + \frac{10}{10}\right)\times 10 = -\left(\frac{V_{DA}}{R_{DA}} + 1\right)\times 10 \qquad (9)$$

The above reasoning apparently implies the range of V_{DA}/R_{DA} to be from 0 to -2 for the output to be from -10 volt and +10 volt. If R_{DA} is 10k Ohm, V_{DA} would have to be 0 to -20V. Reproducibility calibration will be possible if we vary R_f to make the output voltage equal to input voltage.

3.2.2. Design of a new optical transceiver circuit

In the last report[1], we described the two types of optical signal transceiver circuit. The one is based on the V/F conversion as well as F/V conversion for the signal transmission through the optical cables. The other is based on the A/D conversion of the signals by the AD7891 followed by the serialization at a programmed Altera CPLD chip for the signal transmission through the optical cable and the signal reproduction at the receiver board where the signals were cooked at another differently programmed chip for the D/A conversion at AD667. The plastic optical fibers(POFs) were found to be sending the optical signals very short distance(barely 40 meters). Thus after an earlier utilization of the POFs we switched to the hard clad silica(HCS) cables for the longer signal transmissions when we completed the control room where various sensing signals as well as the controlling ones should have to be received or sent through the optical fibers for about 40 meters between the control room and the NBI facilities.

When there is availability of the inlet power for driving the optical signal transceiver circuits, there is no problem in the utilization of the AD7891 based optical transceiver circuits. However, for the case of the G2 current measurement where there is no availability of inlet power for the optical transceiver circuit, batteries had to be used for driving the optical transceiver circuits. As we described before, the AD7891-based optical transceiver circuit draws the necessary power to make the regulated +5V from the +15V input into the board for the transceiver boards. For the TX board, 250mA/+15V flows whereas 190mA/+15V flows for the RX board. For the battery powered circuit which receives the +15V from the regulator that is also receiving powers from the attached batteries, this power consumption is an intolerable waste of the battery power. Experience shows that as far as we adopt the power-wasting AD7891-based transceiver circuit the frequency of battery exchanges was too frequent to be tolerable.

Thus a newer, refined optical transceiver circuit has been devised; this circuit would utilize advantageous features of the ADVFC32-based circuit which does not waste the precious regulated power as the AD7891-based circuit does. First of all, as the G2 current signal can both be negative as well as positive, the transceiver circuit should accommodate this bipolar signal at the input stage; however, as the ADVFC32 processes only the positive signal at the input stage, some voltage offsetting measure should be included to the circuit. This necessity can easily be met; we just add some positive voltage to the input signal to make the possible negative signal to be positive at the input stage. Then the resultant transmitted signal will again be made to be the original one only by deleting the same amount of voltage at the final stage. As the G2 current is sensed as a voltage signal and its absolute value is almost always within 5V, the offsetting voltage would have to be +5V in the input stage.

The other consideration is the reaching distance. As the POF-based optical signal cannot go far enough as our facility necessitates, the one alternative is of course the HCS-based fiber cables. Making the reaching distance longer is simple to implement; at both the transmitter stage and receiver stage we only adopt optical transmitter components accommodating the HCS fiber. Through this way the resulting circuit would be expected to assure the longer battery lifetime between battery exchanges.

3.3. Interrupt indicator circuit

Various interrupt occurs during the power supply operations. These interrupt signals were made to sent to the control room to acknowledge the operators of the interrupt occurrences. The signals are sent to the control room via the optical cable. In a normal state, optical signal with lights lit is sent through the cable, whereas during interrupt period the light is turned off in the cable. The minimum interrupt period is 300 microsecond. An “ST” type optical connector and cable is utilized.

According to the above prerequisite conditions, an Agilent HFBR-2412 receiver is used for the circuit. Surrounding circuit for the HFBR-2412 is shown in Figure 25. However, fabrication of the final module for the interrupt indication was stopped as the working situation has changed.

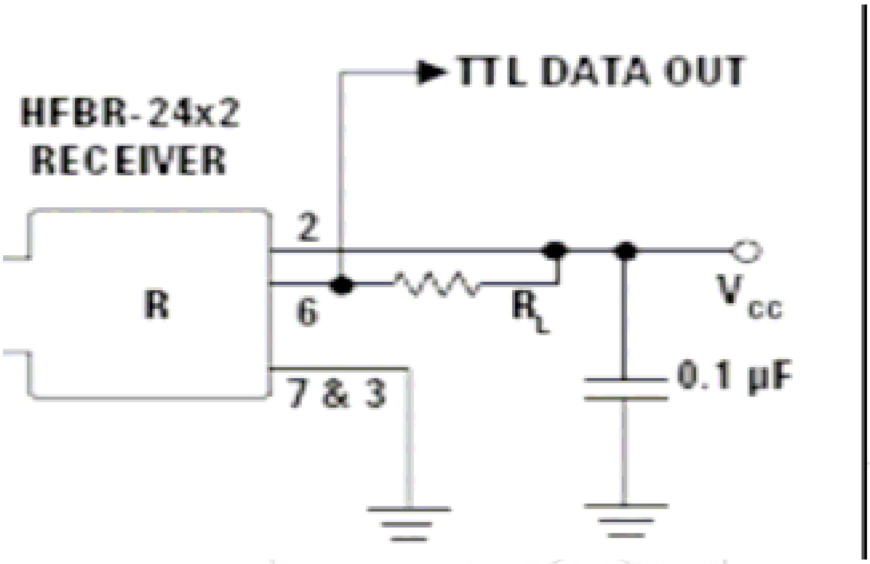


Figure 25. The HFBR-2412 optical receiver and its related cicuit

3.4 Comments on the SMPS utilization

3.4.1. Phenomena detected when using an SMPS

During the fabrication of the flow rate and temperature measurement module for the electron dump, there arose some difficulty when we installed the switching mode power supply in the module. That is, when we tried to supply +15V to the various circuits inside the module, the “+15V” became much lower than the nominal voltage. The SMPS was a model “VSF50-EE”, with nominal output of +15V(1.4A), -15V(0.3A), and +5V(0.5A - 5.0A) that was supplied by the “Fine-Suntronics” Co., Korea. According to our estimation, our module necessitates about 0.75A(+15V) from the SMPS, and thus the SMPS was thought to be enough for our purpose; thus this kind of “voltage dropping” was somewhat mysterious.

When we asked the SMPS manufacturer(82-2-461-1524-ex521, 이동찬) for the solution of this unwanted results, their response was that some current(0.5A, in our case) should be flown(from the +5V terminal) for the +15V output function normally. Their SMPS product does not clearly stipulate this operational precaution. They just shows the current range of the +5V output(0.5A – 5.0A), and this is their only indication of the above operational precautions. According to their comments, +5V output functions as a feedback for the primary coil of the output transformer(operated at 170kHz) of the SMPS. ***In the next time users of the SMPS should be aware of flowing the necessary currents from the other channel in wiring their circuits.***

3.4.2 Explanation of the phenomena given by the SMPS manufacturer

We received explanation of the SMPS operational behavior from the manufacturer; the operational behavior is that there should be some current flowing in the +5V channel if we want the +15V channel work properly. Below is the original content which we received in Korean. For the contents clearly preserved, we archive the letter as in the original Korean.

A. The original explaining transcription of the operational behavior for the SMPS

품명 : VSF50-EE 작성 : 이동찬
CH1(V1) : +5V/0.5A~5A
CH2(V2) : +15V/0~1.4A
CH3(V3) : -15V/0~0.3A

"본 제품은 절연형 AC/DC power supply 이며 기본적인 동작은 AC 입력을 전파정류④한 DC 전압을 FET 로 switching 시켜 2 차측으로 펄스형태로 에너지를 전달함(Figure 26). 2 차측에 전달된 펄스형 전압은 ⑦,⑨,⑪Block(정류회로)를 거쳐서 DC 전압으로 정류됩니다. V_1, V_2, V_3 의 출력전압은 각각 사용부하전류에 따라 출력전압이 낮아지므로 출력전압을 안정되게 해주기 위해서는 ⑧과 같이 출력전압상태를 검지하여 Photo-coupler 를 통해서 1 차측 FET Switching 의 ON/OFF Time 을

제어해야만 합니다. 따라서 ⑧과 같이 출력전압을 검지하는 출력(V_1 (+5V))은 V_2,V_3 출력부하에 영향을 받지 않습니다. 하지만 V_2,V_3 는 ⑧과 같이 출력을 검지하여 제어하는 회로가 없습니다. 따라서 V_2, V_3 는 V_1 출력부하상태에 따라 변하게 되어 있습니다. 그래서 V_1 최소부하전류조건이 필요하게 됩니다.

※ V_2, V_3 출력단자에 검지회로를 추가하지 못한 이유는 추가하게 되면 FET, ⑤, ⑥, ⑧을 V_2, V_3 에도 각각 추가해야 되므로 회로가 복잡해지고, Size 가 커지게 되며, 가격이 상승하게 됩니다.”

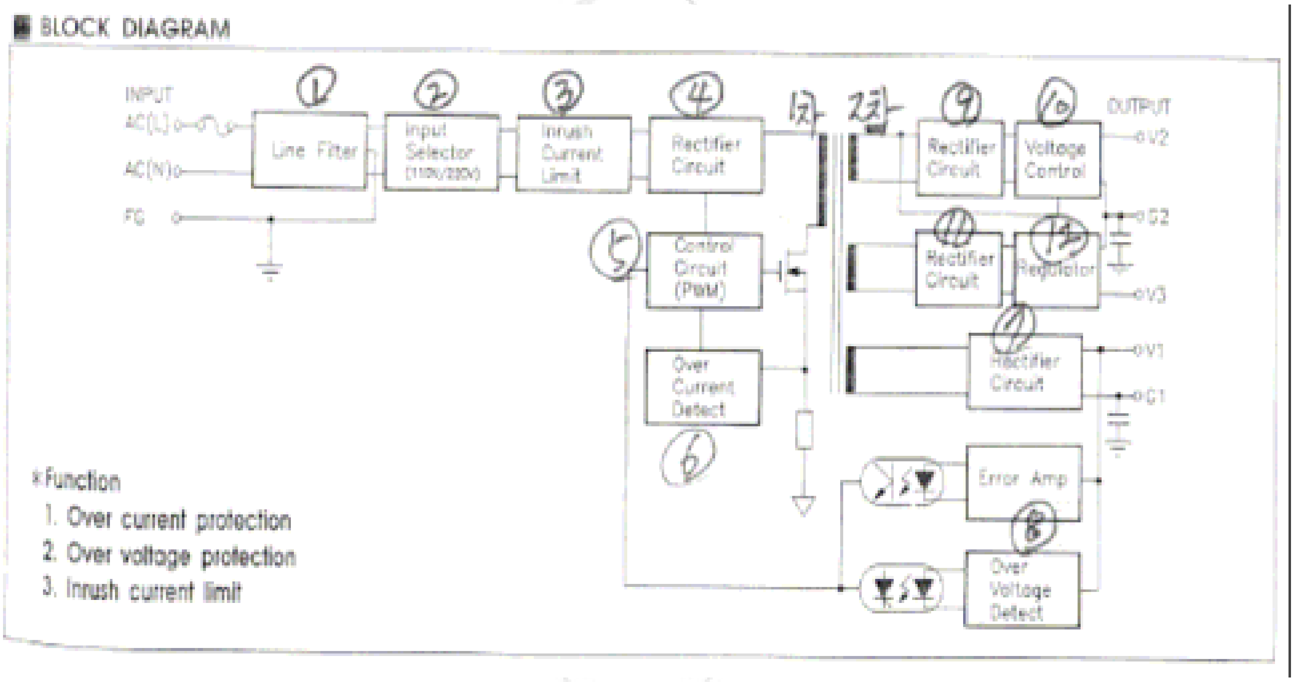


Figure 26. The SMPS circuit

B. English Translation of the original explaining transcription of the operational behavior for the SMPS

“This product is an isolated AC/DC power supply. The operational principle is that the AC input is rectified at ④ and the resultant DC is switched by FET to a pulsed form, and then fed to the secondary winding of transformer. The pulsed voltage came to the secondary winding is then fed to the rectifier circuit of comprised of ⑦,⑨ and ⑪, thus becoming DC voltage.

V1, V2, V3 will decrease as the currents become higher. Thus voltages are sensed at ⑧, and this signal is fed to the photo-coupler to control the switching of FET. Thus V_1 will not depend on the output voltage of V_2,V_3. However, V_2,V_3 does not have the control circuit that senses the output voltage, and V_2, V_3 will change as V_1 will change. Thus V_1 needs the minimum current for the whole circuit to work properly.

Elements similar to FET, ⑤, ⑥, ⑧ have to be added to the circuit if we want to regulate V_2 and V_3; this would make the total circuit more complex and the cost will become higher."

3.5. Arrangement of the beam line power inlet wiring

There has been working for the rearrangement of the wiring of the power lines to the beam line. Of the many power lines to the beam line, power lines for the heater lamps should also had to be rearranged for the neatness of the wiring. There are two power needs for the heating as follows:

1. Three lamps each with 110V/100W power needs(Total : 300W)
2. Eight lamps each with 220V/1200W power needs(Total : 9600W)

Power lines for the above lamps are now rearranged for the wiring neatness and safe considerations. Other power lines such as for the compressor are also made to be rearranged for the neatness as well as more safety.

4. Conclusion

In relation to the operation of the neutral beam test facility at KAERI, further hard-wired instrument and control functions have been constructed after the first report on the same subject has been published. Arc detector circuit for the ion source operation has been constructed and its circuit details are shown with explanation of its functioning. After the liquid nitrogen supply system was expanded of its volume capacity, the accompanying circuit for the reservoir replenishing and the temperature control of the baffles were constructed. This circuit can replenish the reservoir with LN_2 in an automated manner, thus relieving the operator from the continued attendance near the system. Some reasoning of the existing circuits for the NB-TS has been given; e.g. the summing amplifier for the AD667 calibration and the differential amplifier for the flow interlock circuit. Most of the works described in this report would well be applied to the upcoming construction of the KSTAR-NBI heating system.

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서지정보양식

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초록 (15-20줄내외)

지난 1년간 중성빔 시험장치의 기기장치 현장작업의 진행상황을 기술하였다. 설치한 아크검출회로의 동작을 상세히 기술하였다. 크라이오 흡착펌프작동을 위한 액체질소 액면 및 온도조절회로에 대하여 설명하였다. 열량계 운전시, 온도측정을 보다 더 정확히, 정밀하게 측정하기 위한 목적으로 PT-100측온저항체에 의한 온도측정장치를 제작하여 이를 현장에 설치하였다. 이온빔 실험중에, 물리적실험이 이온빔 발생신호보다 지연되어 이루어지도록 지연펄스발생회로를 제작하여 이를 현장에 설치하였다. 설치한 인터록회로 및 광통신회로들과 관련한 전자회로적 원리를 설명하였다. 이들은 기본적으로 연산증폭기회로이다. 스위칭전원을 사용할 때에 주의할 점을 기술하였다.

주제명키워드 (10단어내외)	중성빔가열, 기기장치제어, 아크검출회로, 크라이오 흡착펌프, PT-100측온저항체, 지연펄스발생회로, 인터록회로, 광통신회로, 스위칭전원

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<tr><td>Sponsoring Org.</td><td colspan="2"></td><td>Contract No.</td><td colspan="2"></td></tr>
<tr><td colspan="2">Abstract (15-20 Lines)</td><td colspan="4">Progress of the hard-wired instrumentation and control works for the neutral beam test stand(NB-TS) has been existed for the past one year period. Details of the installed arc detector circuit are explained. LN$_2$ level and temperature control during the cryosorption pumping operation are explained with an emphasis on its control circuit. With an expectation of more accurate and sensitive measurement of temperatures than the thermocouple utilization during the calorimeter operation, PT-100 resistance temperature detector(RTD) utilization is initiated and the results are described. During the ion beam experiment, physical measurements are made with some delayed time than the beam extraction, and thus a delayed trigger pulse generator was fabricated and installed to the system. Underlying principles of the electronic circuits for the interlock implementation and optical signal transmission are introduced. These are basically the application of operational amplifier circuits. A cautious aspect of the SMPS(switch mode power supply) utilization is also given.</td></tr>
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