DESY Summer Student Program

A Report on the Slow Control System of ALPS-II

Concentrating on the temperature observation

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Introduction:

Any Light Particle Search (ALPS-II):

Weakly Interacting Slim Particles (WISPs for short), often predicted by extensions of the Standard Model, if exist, would tremendously change our understanding of physics. A number of experiments are searching for these particles to investigate physics beyond the standard model (Baker *et al*). One of these experiments is Any Light Particle Search (ALPS) at DESY, which runs a Light Shining through a Wall (LSW) experiment. The main principle behind such experiment can be described in (J. Redondo and A. Ringwald)'s words:

"*We could say that the obstacle to achieve light shining through walls is that the electromagnetic interactions are too strong. However, this is not the end of the story. There are in nature other forms of radiation which are far less strongly interacting. If one could convert photons into quanta of these other forms of radiation, the latter would do the dirty work of traversing the wall, and all one has to do is to revert the conversion process at the end of the wall."*

The first stage of the experiment (ALPS-I) set the world wide best laboratory limits for WISPs by improving the previous results by a factor of ten. The next stage of the experiment (ALPS-II) is designed to achieve three orders of magnitude higher sensitivities in WISPs searches than the existing ones in laboratory experiments (Bahre *et al*).

The Slow Control System of ALPS-II:

The Slow Control System (SCS) of any particle physics' experiment is the system which monitors and controls the system variables and conditions that can influence the data signal, in order to insure the detector's stability and integrity. The SCS is also responsible of the safety management of the delicate parts of the experimental setup (E. Aprile *et al*).

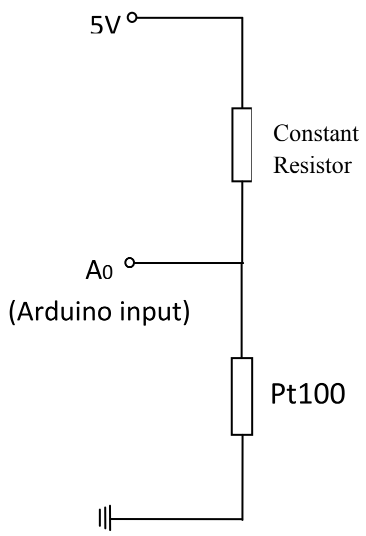
The Technical Design Report of ALPS-II (TDR in the following) suggests two parts of the control system: The control of the magnet, which includes parameters like temperature and pressure. And the safety loop for the laser, which controls the doors for the gray rooms...etc (Bahre *et al*). However, we are excluding the safety loop in this report. Then the other system variables of the SCS can be described as follows:

- **General variables**: These are variables needed for the whole set of the experiment. They include:
    - Temperature,
    - Pressure,
    - Vibrations of the laser and the cavity,
    - Laser Status,
    - Shutter status,
    - Laser power,
    - Magnet current

- **Variables needed for the optical setup:** The suggested setting of variables to be observed and controlled by the SCS needed for the optics set is as follows:
    - Observation of temperature inside the vacuum chamber.
    - Observation of temperature of the production cavity end mirror.
    - Observation of temperature of the ALPLAN (can be measured under the mirror and on the three legs)
    - Vacuum pressure controlling.

      The temperature is considerably crucial variable in the whole setup of ALPS-II. Extra heat injection to the ALPLAN can cause it to deform, which might perturb the optical setup. A simulation made by Martin Lemke showed that if 300 mW are absorbed in the PC end mirror, the temperature in the mirror rises by only 0.7 K and the ALPLAN deforms by 1 micrometer. Pressure difference between the cavities can lead to destroy the mirror inside the shutter-box if the shutter-box is closed.

- **Variables needed for the detector system:** It is important to observe all the variables that can influence the sensitivity of the Transition Edge Sensor (TES). That includes:
    - Temperature observation inside and outside cryostat,
    - Pressure observation inside cryostat,
    - Magnetic field observation inside and outside the cryostsat,
    - Observation of the ambient light,
    - Observation of the TES conditions
    - And observation of the SQUID conditions.



Temperature Observation in ALPS-II:

As mentioned earlier temperature observation is important for almost all parts of the experiment. In the following we propose the temperature observation technique.

- **Measuring temperature:** A simple, vacuum proof and available at DESY device that can be used for measuring temperature is the Resistance Temperature Detector (RTD) Pt100. Pt100 is a sensor whose resistance is correlated to its temperature. It has a resistance of 100 Ohm at zero Celsius, and the R Vs T has linear-like behavior (Wolfgang Ranke), (Wikipedia).
- **Temperature Readout:** The TDR suggests a microcontroller such as Arduino for taking the readouts. Arduino is a microcontroller and a software creation environment that can create programs that can interact with the physical world to sense and respond to touch, sound, position, heat and sound (Michael Margolis).

A voltage dividing circuit was used with simple software (developed from an Arduino built-in one) that can measure the resistance of Pt100. The corresponding temperature can be read by improving this program to include fit function excluded from the data table of Pt100 (T Vs R).

- Hardware description: The voltage dividing circuit is shown in the figure above. It had 5V input supplied from the Arduino built-in power supply. Arduino divides this voltage into 1023 steps for the readout (Analog to Digital conversion).
- Software description: The program used for measuring the resistance is found below.

```
/*
 resistance_ino
 Reads an analog input from the pt100 circuit on pin 0, converts it to voltage and then
calculate the resistance,
 and prints the result to the serial monitor.
 Attach one pin of pt100 to the constant resistor and attach both to pin A0, attach the other
pin of pt100 to ground
 and the other pin of the resistor to +5V.

 This example code is developed from ReadAnalogVoltage by Amel S. A. Alhassan
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 */
```

```
  // defining the source voltage
 const double involtage = 5.0;
  // defining the external resistance (set this value to the resistance of  your voltage divider)
 const double exresistance = 20000.0;


// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
}

// the loop routine runs over and over again forever:
void loop() {

   // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
  double voltage = sensorValue * (5.0 / 1023.0);
  // calcuate the resistance of pt100
  float resistance = (voltage * exresistance) / (involtage - voltage);
  // print out the value you read:
  Serial.println(resistance);
}
```

Results:

The table below compares the resistance measures made using the voltage division circuit shown beside with Arduino UNO for different resistors including Pt100 with measurements made by Digital Multimeter (DMM) and the color code. The constant resistor in this table was set to 20K Ohm. Pt100 in the diagram was replaced by R1 and R2 to measure their resistance.

Resistor	Color Code	Multimeter	Arduino
R1	10K Ohm +/- 1%	9930 Ohm	9937.31 Ohm
R2	20K Ohm +/- 1%	1980 Ohm	19938.73 Ohm
Pt100	-	111.3 Ohm	58.82 Ohm

Table1: Testing the Arduino UNO resistance measuring.

The crucial element about using voltage divider circuit with Arduino is that the constant resistor has to have a resistance that minimizes the current so it does not heat Pt100 up. At the same time, it has to divide the voltage in an effective way that does not influence Arduino's readout precision. The table below shows the Arduino reads for Pt100 resistance with different voltage dividers. The Pt100 resistance with the circuit unconnected was found to be 111.0 (using DMM). This resistance is equivalent to 28 degrees Celsius. The temperature measurement taken by the thermometer was 23 +/- 1 degree Celsius.

Voltage divider resistance	Pt100 resistance given by Arduino	Equivalent temperatures
200 Ohm	112.84 Ohm	33
270 Ohm	110.45 Ohm	27
330 Ohm	111.29 Ohm	29
510 Ohm	108.90 Ohm	23
1000 Ohm	107.14 Ohm	18
10K Ohm	88.76 Ohm	-29
20K Ohm	58.82 Ohm	-36

Table 2: Pt100 resistance measurements obtained by using Arduino with different constant resistors and their equivalent temperatures.

Discussion:

- Noticed temperature difference between measurement made using Pt100 via the DMM and the thermometer measurement.
- Using constant resistor with high value gives wrong measurement.
- Measurements made using constant resistors of values between 270 and 300 gave similar results to the DMM. While measurement made using 510 Ohm resistor was identical to the thermometer measurement.
- Further investigations need to be made with different temperatures.

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