Liquid Argon Evaporator

Goal:

The function of the DART prototype will be to measure the liquid argon (LAr) radiopure activity to be used in Darkside-20K. The cost of this argon I very high and require recovery from the DART chamber. It is therefore necessary to evaporate in the chamber for subsequent condensation in a storage cylinder. Evaporation is achieved by applying heat power through an electrical resistance. This paper describes the design of the circuit allows us to apply the vaporization power of the LAr. When the LAr has vaporized, the heat produced by the resistance must be automatically cut off.

The resistance:

IT is a platinum resistance with a temperature dependent value, at low temperature its ohmic value is low and as the temperature increase, the resistance increase proportionally.

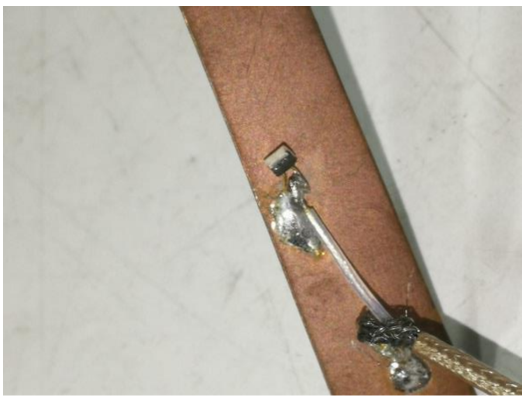
Model: P0K1.202.3FW.B.007

Charactreristics

- Fast response time
- Small dimensions
- Excellent long-term stability
- Resistant to vibration and thermal shock
- Simple interchangeability

Technical Data

- Nominal resistance: 100 Ohm at 0°C
- Temperature range: -200°C - +300°CCircuit
- Dimensions (LxAnxAl): 2 x 2 x 1.3 mm (LxAnxAl)
- Characteristic curve: 3850 ppm/K



The advantage of this resistance is its low mass, which preserves the radiopurity of DART.

Its operation is simple, as it only needs to apply a certain voltage to start working and dissipate heat. The resistor is epoxy bonded to a heatsink formed by a Teflon PCB (40x10mm).

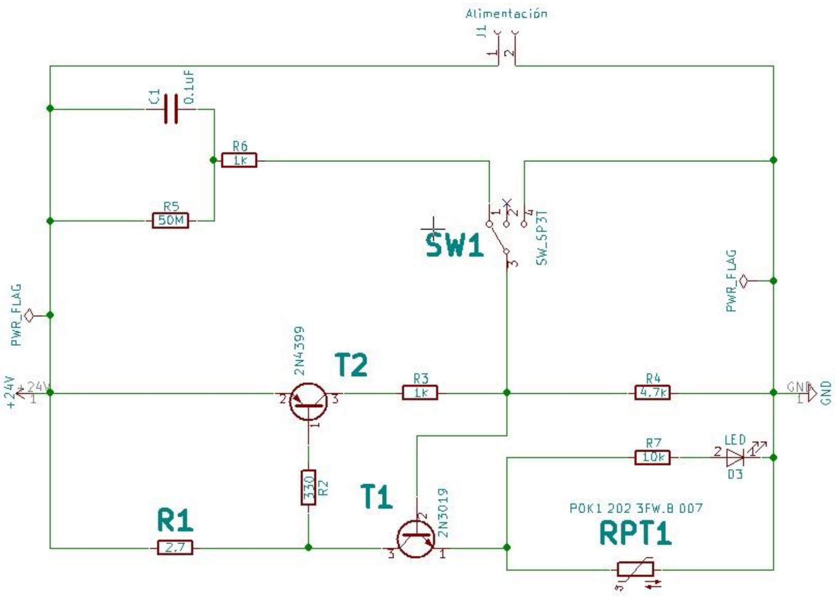
The circuit:

The circuit consists of 4 main components;

- Platinum resistance (RPT)
- Resistance 2.8 ohm (R1)
- Transistor NPN (T1)
- Transistor PNP (T2)

Operation:

The circuit works like a flip-flop, the transistor T1 can be in driving or cutting, depending on the voltage of its base. This, in turn, is determinate by state of T2 in cutting or driving. T2 will lead when there is a sufficient voltage drop at R1 due precisely to the fact that T1 is driving. That is, the conductive or cut-off state of both transistors feeds back into itself by making the system function as a flip-flop. The driving state is only possible with a current that produces a voltage drop at R1 sufficient to T2 conductive. This intensity is only possible is the RPT is very low, i.e. submerged in LAr. When the RPT value rises, the current R1 decreases and both T2 and T1 are cut off. The SW1 allows the circuit to be momentarily energized either to be driving or to be stopped.



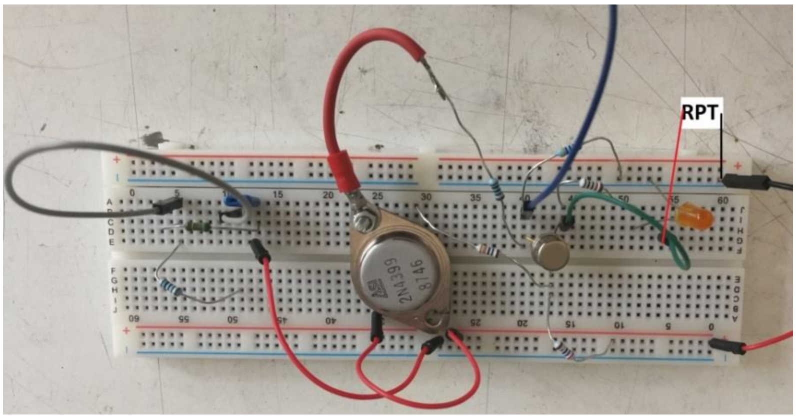


Figure 1. Mounting the circuit

Laboratory testing

With the resistor immersed in liquid argon (84ºK), the power dissipated in it is transmitted to the liquid in its entirety. Since the interface between the resistance and liquid is not perfect, a temperature increase in the resistance occurs due to non-infinite thermal conductivity.

$$P_d = L.\Delta ºK$$

When the resistance is discovered from the LAr, the value of L decreases and temperature in the resistor rises.

The relationship between the temperature and the ohmic value of the RPT is as allows:

$$ºC = ºK - 273 = \frac{R - 100}{0,3850}$$

The tests were performed using liquid nitrogen LN2 (77ºK)

The supply voltage (Vdc) is 24 volts and the value of R1 is 2.8 ohms.

In conduction, the RPT voltage is 17.57 V and the current is 0.2 A.

Figure 1 shows the constructed circuit and Figure 2 and 3 the assembly with the bistable deactivated and activated respectively.

Figure 2. Circuit at rest

Figure 3. Activated circuit

Under these conditions, the resistance value of RPT is:

$$R = \frac{V}{I} = \frac{17{,}57V}{0{,}2A} = 87{,}85\ \Omega$$

And the value of his temperature:

$$ºC = \frac{(87{,}85 - 100)}{0{,}385} = -31{,}5ºC = 241{,}5ºK$$

The power dissipated has a value of:

$$P_d = I.V = 3{,}5W$$

The value of conductivity is therefore:

$$L = \frac{P_d}{ºK - 77} = \frac{3{,}5}{241{,}5 - 77} = 0{,}021\ {}^{W}/_{ºK}$$

When LN2 is discovered the RPT resistance increases its temperature. Figure 4 shows the transient when the RPT is removed from the Dewar vessel. Channel 2 shows how the voltage increases to 24V after R, which cuts T2. From the voltage drop in R1 and from its ohmic value the current passing through the RPT can be deduced. Channel 3 shows the voltage drop to zero which feeds the RPT. From current and voltage values in the RPT the dissipated power transient is established as shown in figure 5. The temperature value is obtained from the value of the RPT (V/I) a transient is shown in figure 6. As I decrease, the temperature error increases until it loses its definition. The maximum value of the temperature reached in RPT is 80^{o}C.

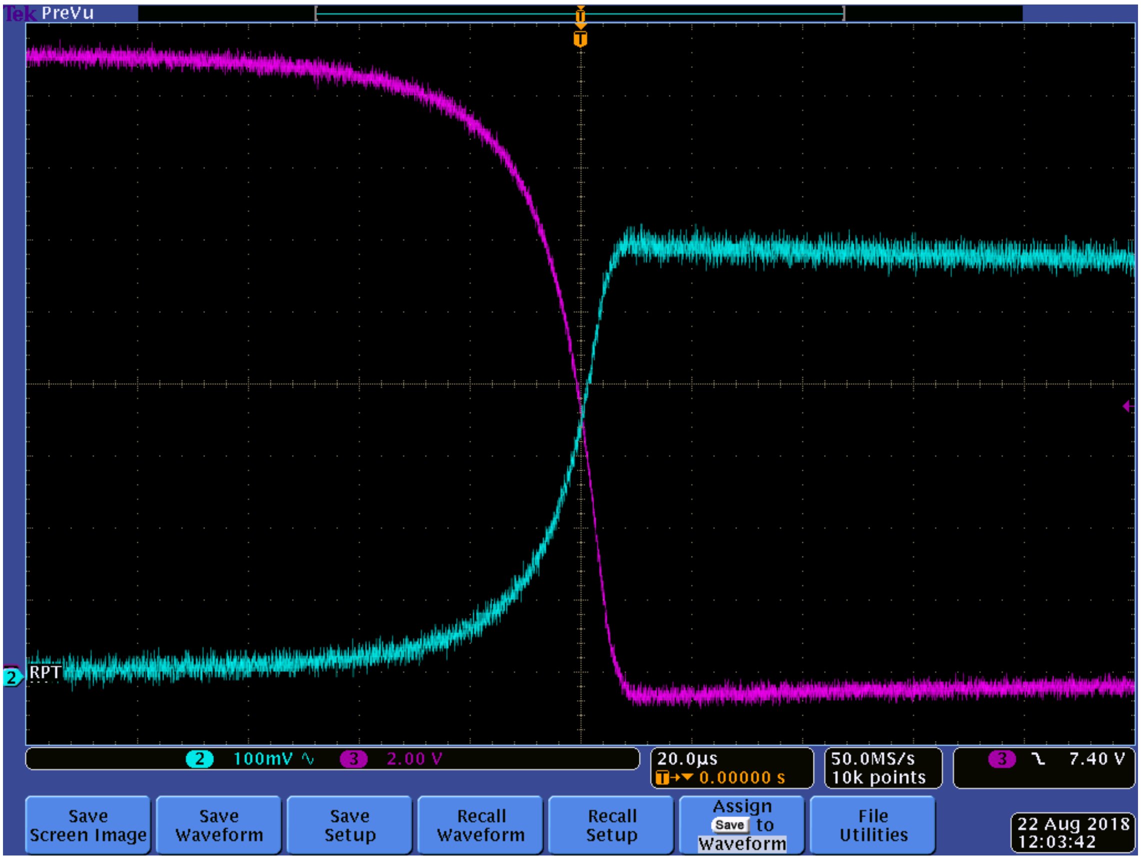


Figure 4. Cutting transient when RPT is removed from LN2. Channel 2 shows the 24V rise in voltage at R1. Channel 3 shows the voltage drop to zero that feeds the RPT.

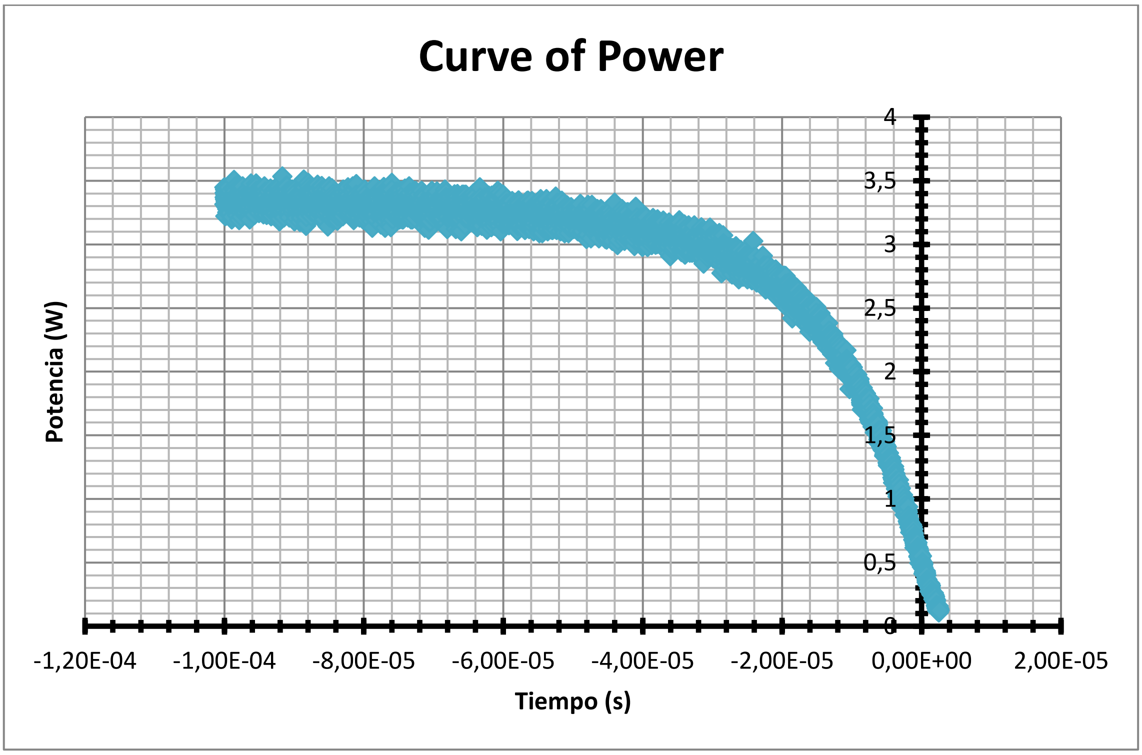


Figure 5. Curve of the power dissipated by RPT at the moment of cutting.

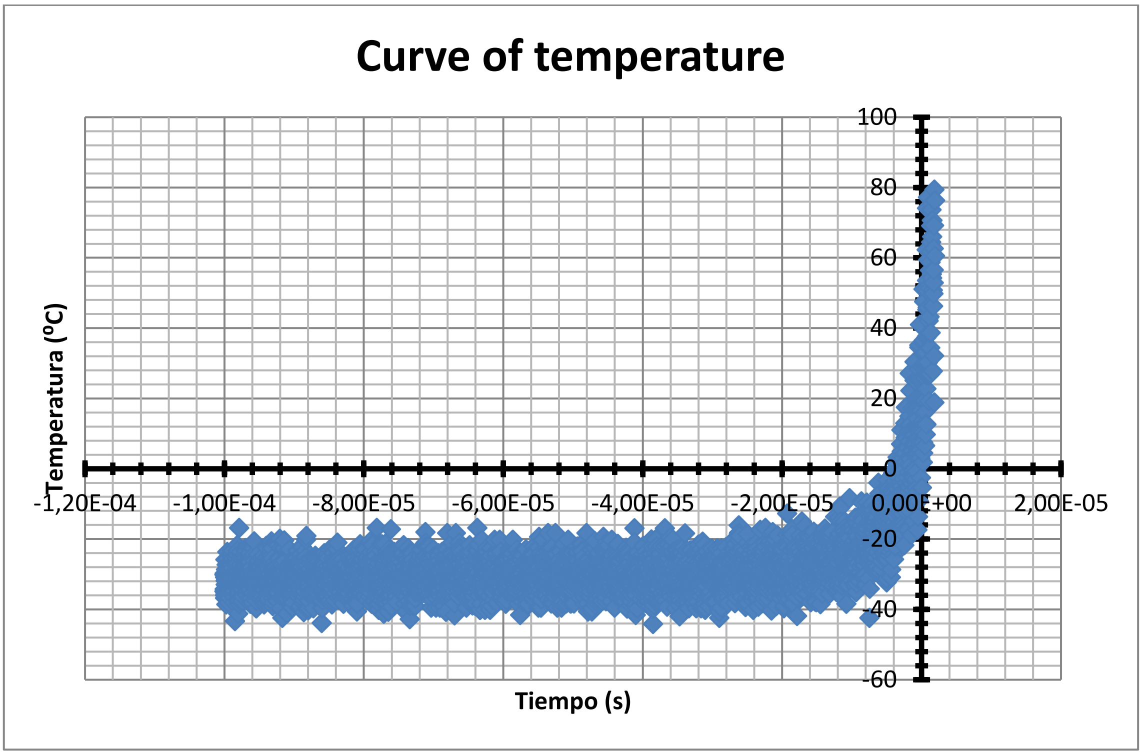


Figure 6. Curve of the temperature of RPT at the time of cutting.

Conclusions:

The estimated volume of DART is 1.1 liters, corresponding to a LAr weight of 1.54 kg. The heat of vaporization of LAr is 161.14kJ/kg. Therefore the work required to vaporize the DART LAr is 247kJ.

With 3.5W of power the time (t) required to empty the chamber is:

$$t = \frac{247kJ}{3{,}5W} = 70500\ seg$$

This value is reasonable as the LAr can be removed from DART in just under 20 hours.

If faster extraction is required, several RPT can be arranged in parallel, as the limited factor is a thermal conductivity between the resistor and the heatsink.

The shutdown temperature (30ºC) of the system is reasonably low.

The system is quiet immune to fluctuations that can lead to accidental shutdown. This immunity is determined by the temperature jump required to switch from the driving state to the off state (60ºC).