Principles of Measurement & Instrumentation I Laboratory

PHYS417

Laboratory Preliminary Report

Abdullah Burkan BEREKETOĞLU

Experiment 4 - Communication Protocols: I2C & SPI Compatible Sensors

Submitted By: Abdullah Burkan BEREKETOĞLU

Submitted to: Deniz Orhun BOZTEMUR & Enver BULUR

Student Id: 2355170

Experiment Date: 16.1.2022 (Make-up)

Submission Date: 19.1.2022

Question 1: Discuss the working principle of a digital potentiometer and its design:

A digital potentiometer which is also known as a digital resistor has the same functionality as a regular potentiometer, but instead of mechanical action, it has digital signals and switches. Most of the time this device works by making use of a resistor ladder system, which is a string of small resistors in series. At each step of the ladder, an electronic switch is present. At one time only one of the switches closed. From the closed switch “Wiper” position is determined also with the resistance ratio. We can give linear taper as an example of a resistive ladder digital potentiometer. The amount of steps in the ladder determines the resolution of the digital potentiometer.

Here is a figure showing the working principle of a digital potentiometer with 64 steps. These digital resistors in the potentiometer can be controlled by using simple up/down signals or by serial communication protocols such as I^2C (which is the one in our experiment) pr SPI.

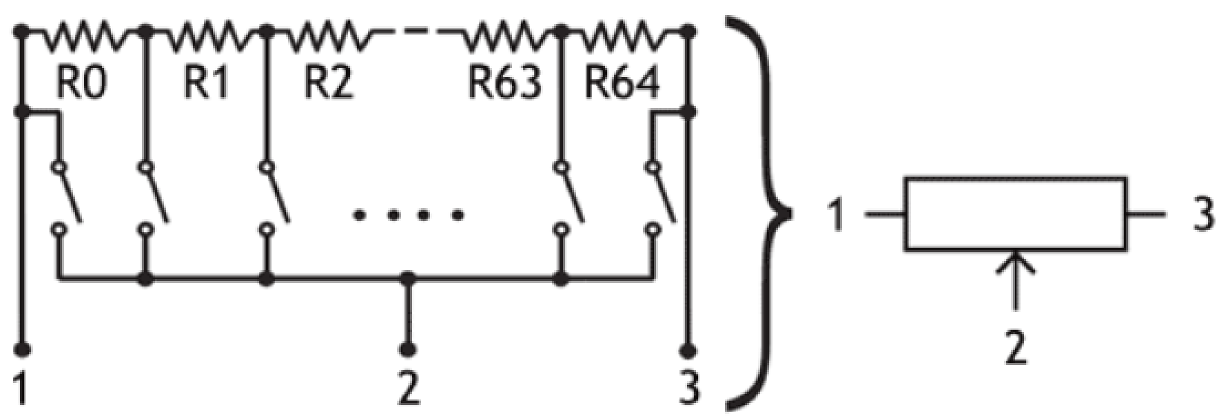

Figure 1 A design of digital pot with resistor ladder

Digital Potentiometer | Resistor Types | Resistor Guide (eepower.com)

Some properties of the digital potentiometers can be said since these are integrated circuit (ICs). Some of the variants have a nonvolatile memory (e.g., EEPROM or Flash) which shows the potentiometer remembers past resistance setting. When nothing on-board, wiper is at default at the middle position. Many ranges of resistances for digital resistors are available. These devices can be used at buttons, rotary encoders, up/down signals, etc.

Question 2: Discuss the thermoelectric effect and the pyroelectric effect:

The thermoelectric effect is caused by the charge carriers within the material (either e^-, or places where an e^- is missing, known as "holes") that diffuse from the hotter side to the cooler side. Measured in volts per Kelvin. The definition of thermoelectric effect is the direct conversion of the temperature differences to electric voltage and vice versa via a thermocouple.

The Pyroelectric effect can be said a change in surface charge (capacitance) in response to a change in temperature. These materials are usually crystalline and are coated with a black absorbing material. The thermal mass of these devices has to be kept small. The effect starts us to exhibit coupling between electrical polarization P and temperature T, such that a change in temperature results in a change in the electric dipole moment.

Question 3: Explore the datasheet of your digital potentiometer and describe its principle of operation and programming :

What we use in our experiment is X9C104 = 100K and the model ıs a solıd state nonvolatile potentiometer and is ideal for digitally controlled resistance trimming.

It has a resistor array composed of 99 resistive elements. Between each element and at either end are tap points accessible to the wiper element. The position of the wiper element is controlled by the CS_hat, U/d_hat, and INC_hat inputs. Wiper position can be stored in nonvolatile memory and can be recalled upon subsequent power-up operation.

The resolution of the X9C104 is equal to the maximum resistance value divided by the 99. So for our X9C104, it is 1010 ohm for each tap point.

Ponds Vh and Vl show us the terminals of high and low voltage which are equivalent to fixed terminals of a mechanical potentiometer. The minimum voltage is -5V and the max is +5V. It should be noted that the terminology of Vl and Vh references the relative position of the terminal with relation to wiper direction of movement with a selection from U/D_hat input and not the voltage potential on the terminal. Vw is the wiper terminal, it is equivalent to the movable terminal of a mechanical potentiometer. The position of the wiper within the array is determined by the control inputs. The wiper terminal series resistance for the X9C series is mostly typically 40 Ohm.

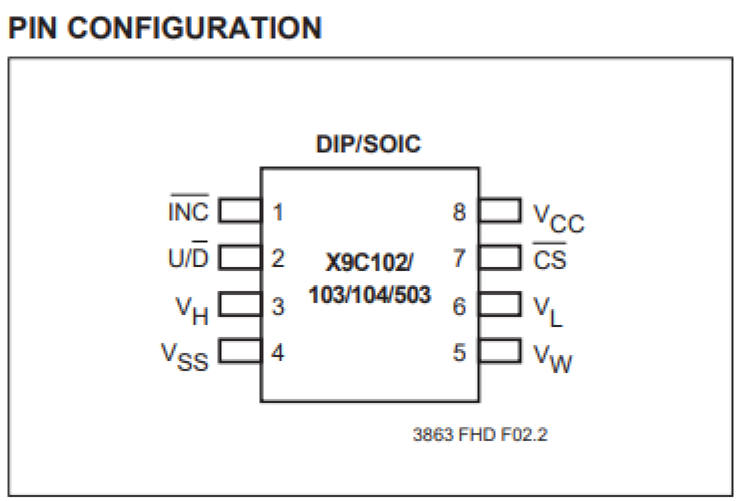

Figure 2 Pin Configuration X9C104

Elecrow X9C103S

PIN NAMES

Symbol	Description
V_H	High Terminal
V_W	Wiper Terminal
V_L	Low Terminal
V_{SS}	Ground
V_{CC}	Supply Voltage
$U/\overline{D}$	Up/Down Input
$\overline{INC}$	Increment Input
$\overline{CS}$	Chip Select Input
NC	No Connect

3863 PGM T01

Figure 3 Detailed names of Pin names of the IC.

Elecrow X9C103S

Question 4: Describe the working principle of a thermocouple and its types, advantages, and disadvantages. :

A thermocouple is a device to measure temperature. It comprises two dissimilar metallic wires joined together to form a junction. When the junction is heated or cooled, a small voltage is generated in the electrical circuit of the thermocouple which can be measured, and this corresponds to temperature. A thermocouple simply is a sensor to measure temperature. Here is the Type K Thermocouple which is the popular one and the one that is used in our experiment since it is reliable, accurate, and cheap. Most of them are made of Nickel-Chromium/Nickel-Alumel. Maximum continuous temperature is up to around 1100 Deg C.

Figure 4 Type K thermocouple

[What is a thermocouple? How do they work? (processparameters.co.uk)]

There is also a J-type Thermocouple which is also very common. It has a smaller temperature range than K-type thermocouples with a range of 0 to 600 Deg C. Type J is made up of two dissimilar metals which are Iron/Copper-Nickel → Constantin. Cost-wise this is also cheap as K type.

Mostly used in the plastics industry. Thermocouples with plugs or cables are identified by their colors coded. For this case type J is Black. If there is a cable, the black leg is positive and the white leg is negative.

Figure 5 Type J Thermocouple

What is a thermocouple? How do they work? (processparameters.co.uk)

Question 5: Explain how accelerometers measure acceleration:

The accelerometer is a device that detects the vibration or acceleration of the motion for the body. Due to the piezoelectric material, vibration or a change in motion causes the mass to have an effect on piezoelectric material which produces an electrical charge that is proportional to the force exerted upon it.

Question 6: Show the difference in the working principle between Thermostat, Thermistor, Resistive Temperature :

Unlike the RTD's thermistors can monitor a small range of temperature such as 600 to 130 compared. The cost for thermistors is much cheaper than RTDs. Thermistor in sensitivity context is more accurate since has resistance change by tens of ohm per degree compared to smaller changes of RTD.

If we compare the Thermistor with Thermostat we have these results, as mentioned above Thermistor is used for small temperature ranges. So maybe utilized up to 130 degrees Celsius. A thermostat, on the other hand, more robust and due to conductivity is by the mobility of electrons thermistor is more sensitive. The thermostat only allows metals to rise when the temperature fluctuates, but the thermistor is more complex and the reading is in conductivity changes.

Another difference between thermistors and thermostat is that even though they work at the same concept, they do it differently; a metallic oxide compound, such as cobalt or manganese, is used in thermistors. The conductivity of the metallic oxide oscillates with temperature, according to the principle. So from the oxide compound deployment, conductivity changes, and as a result, the gadget is calibrated to read variations in conductivity as a reflection of temperature changes.

Question 7: Detectors (RTD), Semiconductor-based temperature sensor:

The semiconductor temperature sensor is an electronic device fabricated in a similar way to other modern electronic devices such as microprocessors. These are typically hundreds or thousands of devices are formed on thin silicon wafers. Since wafer production is not in the context of this course will not talk about it.

There are widely available semiconductor temperature sensors are available from numerous manufacturers. There are no generic types as with thermocouple and RTDs, but still, a number of devices are made by more than one semiconductor.

There are 5 types of semiconductor temperature sensors

1- Voltage Output Temperature Sensors (LM94021, Programmable, SC80)

2- Current Output Temperature Sensors (LM134, Programmable, TO-46)

3- Digital Output Temperature Sensors (FM75, Fairchild, MSOP8)

4- Resistance Output Silicon Temperature Sensors (KYY10, Siemens, TO-92)

Silicon temperature sensor's resistance is given by the equation of =

$R = R_r(1 + a.(T-T_r) + b.(T-T_r)^2 - c.(T-T_i)^d)$ where R_r is the resistance at temperature T_r and a,b,c and d are constants. T_i is an inflection point temperature such that $c = 0$ for $T < T_i$

Lastly,

5- Diode Temperature Sensors (eq = $T = (V_1 - V_2) / (8.7248x10^{-5} \ln(I_1 / I_2))$)

Accuracy is due to the semiconductor nature for some sensors, be cautious and measure in small temperature changes which will be rewarding with very good measuring precision.

References

[Digital Potentiometer | Resistor Types | Resistor Guide (eepower.com)]

[Untitled Document (dducollegedu.ac.in)]

[Explained: Thermoelectricity | MIT News | Massachusetts Institute of Technology]

[Pyroelectricity - an overview | ScienceDirect Topics]

[Elecrow X9C103S]

[What is a thermocouple? How do they work? (processparameters.co.uk)]

[Accelerometer: What is it & How it Works | Omega]