Development of an Instrument for Determination of Thermo-Electric Voltage of Fused Dissimilar Metallic Materials

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***Abstract-** Development of a device to determine the thermoelectric voltage of a fused dissimilar metallic material plays an importance role development of thermocouple sensor. The device consists of two thermocouple amplifiers ADS8495 and MAX 31855; analog -to- digital converter (16 bits); microcontroller; level-shifter; micro SD card; and intelligence liquid crystal display. The ADS8495 is a dc voltage output from 0 to 5 V with 42 µV/°C links to the terminal of fused material and MAX31855 has ability respond from -200 °C to 1370 °C of a step increment of 0.25 °C the input is connected to k-type thermocouple. The output dc voltage ranges from 0 V to 5 V with 42 µV/°C links to the terminal of fused material and the thermoelectric voltages ranges from -200 °C to 1370 °C of a step increment of 0.25 °C and the correlation when compared with Hg-in-glass thermometer is 0.997 and with mean deviation of 0.64 °C. The voltage developed by the fused point was compared with the thermocouple voltage for K-type from book of constant table IEC548-TMH gotten from IEEE. This result has correlation of 0.99 with the mean deviation of 46 µV. The performance evaluation shows that its continuous measurement can be used for determination of the thermoelectric voltage of different fussed dissimilar material to study the effect of alloying materials on thermoelectric voltage generated.*

***Indexed Terms-** Fused, Thermo-junction, Thermoelectric, Thermometer, Thermocouple Amplifier*

I. INTRODUCTION

In metal materials production are found their application in all area of life, most importantly in manufacturing of plane, automobile, electronic, in building, power system, and others. The metal alloy and fused dissimilar metal changed the initial and improve the physical, chemical and morphology of the constituents' metals. Many physical properties of such formulated material can be test for ductility using stress-strain instrument, electrical conductivity using modified Wheatstone bridge apparatus, thermal properties such as heat conduction of formulated materials using thermal conductivity of conductive material. Many researchers work on guideline for welding dissimilar metals considering many metallurgical factors but thermo-junction was not list among factors. One other major property is thermo-junction of the fused and welded point of dissimilar formulated metals.

Also, due to global crisis of energy need various energy source has been research into intensively include thermoelectric effect but much have not be achieve reason be that energy produce is too low with low efficiency. Any energy source must be environmental friendly. Since many researcher are interested in research more into thermoelectric energy production that will enhance the efficiency. Much work are not found on this subject except standard laboratory standardized fused dissimilar metal junction contain in book constant,On this paper an instrument was developed for determination of thermo electric voltage of a fused dissimilar metallic materials and the corresponding temperature from experimental result will be measured and data log it reduced difficult encounter in using analogue devices and reduced the cost to minima.

II. METHODOLOGY

i) Design Principle and Structure

The thermo electric voltage device consists of two thermocouple amplifiers for measuring seeback's voltage and the second used to measure the temperature at time, microcontroller, microSD card, intelligent liquid crystal display and power supply. The figure 1 below shows basic block diagram of the instrument.

When heat is applied to the fussed point of the two K-type thermocouple, the K-type thermocouples generated a proportional voltage and send the developed voltage to the input of the two thermocouple amplifiers. The thermocouple amplifiers (AD8495 and MAX31855) send a proportional analogue signal to the microcontroller, the A/D converter of the microcontroller converts the analogue signals to a digital signals and transform signals it into a raw data. The analysed data will be displayed on the Liquid Crystal Display and also be logged into the MicroSD Card for further application.

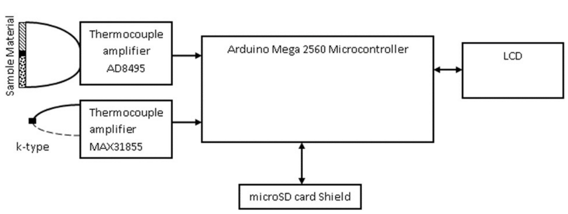

Figure 1: Basic Block Diagram of Instrument

ii) Thermocouple Amplifier Circuit Microcotroller, SD Card and LCD

a. Thermocouple Amplifier Use for Samples

Figure 2 shows the internal configuration of thermocouple amplifier. It is based on using the AD8495 thermocouple amplifier IC, which is designed specifically to measure K-type thermocouples. This analog solution is optimized for minimum design time: It has a straightforward signal chain and requires no software coding.

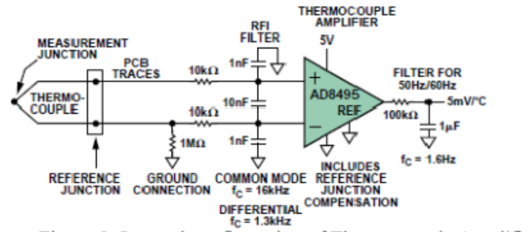

Figure 2: Internal configuration of Thermocouple Amplifier

- Gain and output scale factor: The small thermocouple signal is amplified by the AD8495's gain of 122, the actual voltage develop can be obtained from gain equation of an amplifier given by

$$V_{in} = \frac{V_{out}}{Gain} = \frac{V_{out}}{122} \quad (1)$$

- Noise reduction: High-frequency common-mode and differential noise are removed by the external RFI filter. Low frequency common mode noise is rejected by the AD8495's instrumentation amplifier. Any remaining noise is addressed by the external post filter.
- Reference junction compensation: The AD8495, which includes a temperature sensor to compensate for changes in ambient temperature, must be placed near the reference junction to maintain both at the same temperature for accurate reference junction compensation. (Analog Devices Application Note AN-1087)

b. Thermocouple Amplifier use with K type (MAX31855)

Electrically connection of the module is nothing more than what is provided as a sample circuit on the device on figure 3. The module require a level shifter before it can work well with arduino and any microcontroller ic shown on figure 4.

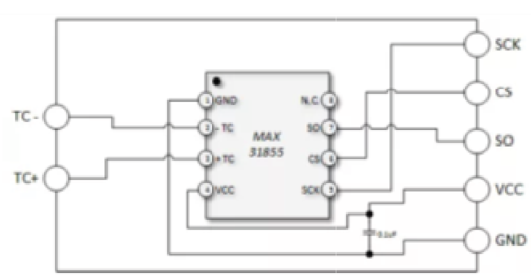

Figure 3: MAX31855 Circuit

c. Level Shifter

The level shifter consists of a transistor (BC548) and three resistors (two 10 kΩ and 4.7 kΩ) as shown the figure 3 below. The emitter and collector are connected to 3.3 V and 5.0 V via 10 kΩ each and 4.7 kΩ is connected between emitter and the base of the transistor. The emitters are connected to outputs CS, DO and SCK of the MAX31855 and collectors are linked to arduino three digital input/output pins. When output signal from MAX31855 is low the emitter is grounded make base emitter OFF the collector voltage will be closed to 5 V. Also, when output signal from MAX31855 is HIGH set base emitter in conduction, the current now flow through 10 k at collector the emitter, make voltage at collector to be closed to zero. The signal form MAX31855 changing from HIGH to LOW at emitter corresponding inverse signal is obtained at the collector (LOW to HIGH).

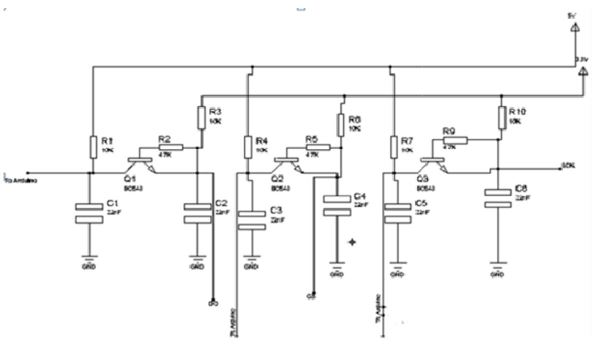

Figure 4: Circuit diagram of Level Shifter

a. Temperature Conversion for MAX31855

The device includes signal-conditioning hardware to convert the thermocouple's signal into a voltage compatible with the input channels of the ADC (see Figure 5). The T+ and T- inputs connect to internal circuitry that reduces the introduction of noise errors from the thermocouple wires. Before converting the thermoelectric voltages into equivalent temperature values, it is necessary to compensate for the difference between the thermocouple cold junction side (device ambient temperature) and a 0 °C virtual reference. For a K-type thermocouple, the voltage has increment of 41 µV/°C, this approximates the thermocouple characteristic with the following linear equation:

$V_{OUT1} = (41.276 \mu V/°C) \times (T_R - T_{AMB})$

Where V_{OUT1} is the thermocouple output voltage (µV), T_R is the temperature of the remote thermocouple junction (°C), and T_{AMB} is the temperature of the device (°C).

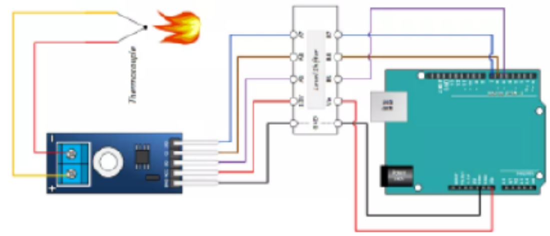

Figure 5: Connection between the Level Shifter and Arduino

b. ATmega328p Microcontroller

Microcontroller is small size computer on a single IC containing processor core, memory and programmable input-output peripheral. Microcontrollers are designed for the use of embedded applications, in contrast with microprocessor which are used for personal computers and other general purpose applications. Atmega328 is a low power, high performance; CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. Atmega328 provides 32 K bytes of in-system self-programmable memory with read while write capability and 1Kbyte EPROM.

c. Liquid Crystal Display

LCD is used to display the number tipping bucket count, rain depth, the current time and date at the instant. A Digchip make 20 character × 4 lines JHD162A liquid crystal display was used in the system developed. The display is a 16 pin which works with maximum power supply of 5.0 V and the data can be sent in either 4 bit, 2 operations or 8-bit, 1 operation so that it can be interfaced to 8-bit Microcontroller. Here we used 4 bits, 2 operation system.

III. TEST AND EXAMINATION

Performance test and examination was carried on the developed instrument for determination of thermoelectric voltage of fused dissimilar metallic materials. The Table 1 shows the comparison of the temperature measured with the thermocouple and Hg-in-glass thermometer. The performance evaluation of the thermocouple amplifier(MAX31855) has resolution of 0.25 °C, temperature ranges from -200 °C to 1350 °C, the correlation when compared with Hg-in-glass thermometer is 0.997 and with mean deviation of 0.64 °C was plotted on Figure 6.The Table 2 shows the result for K-type thermocouple obtained from thermocouple amplifier (AD8495). Usingequation 1K-type thermocouple gives the voltage developed at the fused point and it was compared with the thermocouple voltage for K-type from book of constant table IEC548-TMH gotten from IEEE. This result has correlation of 0.99 with the mean deviation of 46 μV.

IV. CONCLUSION

The thermoelectric voltage instrument developed shows good response and the performance was very good when compared with thermometer and with thermocouple voltage for K-type from book of constant table IEC548-TMH gotten from IEEE. The output dc voltage ranges from 0 V to 5 V with $42\mu V/℃$ links to the terminal of fused material and the thermoelectric voltagesranges from -200 ℃ to 1370 ℃ of a step increment of 0.25 ℃. The developed thermoelectric voltage of fussed dissimilar material instrument is inexpensive easy to maintain, service and repair if malfunctioning. The performance evaluation shows that its continuous measurement can be used for determination of the thermoelectric voltage of different fussed dissimilar material to study the effect of alloying materials on thermoelectric voltage generated.

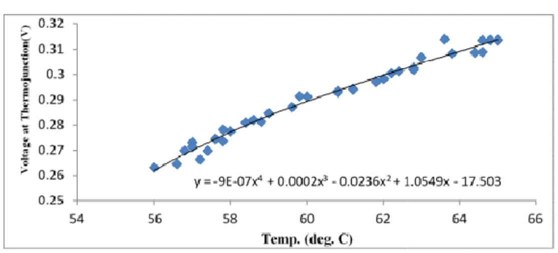

Figure 6: The Relationship of the Voltage at Thermo-junction and Temperature

Table 1: Standardization of Instrument for Determination of Thermo Electric Voltage of Fused Dissimilar Metallic Materials (Logged at 5 minuteInterval)

T_T°C	T_D°C	V_{Th} o (V)	Vin(computed)(mV)	Vsheet (mV)
65.25	65.00	0.3136	2.5707	2.6540
64.50	64.80	0.3135	2.5697	2.6230
64.25	64.60	0.3131	2.5664	2.6130
64.00	64.60	0.3090	2.5328	2.6020
63.25	64.40	0.3088	2.5307	2.5710
63.00	63.80	0.3085	2.5287	2.5610
63.75	63.60	0.3139	2.5727	2.5920
62.75	63.00	0.3068	2.5143	2.5920
62.50	62.80	0.3026	2.4805	2.5400
62.25	62.80	0.3019	2.4744	2.5300
62.00	62.40	0.3013	2.4693	2.5190
61.75	62.20	0.3005	2.4631	2.5090
61.50	62.00	0.2983	2.4447	2.4990
61.25	61.80	0.2970	2.4344	2.4880
	0.997			0.99
T_T°C is Thermometer Temperature Measurement				
T_D°C is Device Temperature Measurement				
V_{Th} o (V) is Thermoelectric amplifier output Voltage				
Vin (mV) computed is the real thermocouple voltage obtained from measure V_{Th} o(mV) using equation 1				
Vsheet (mV) is obtained from thermocouple table IEC584-TMH				

Table 2: Measured Thermoelectric Junction Voltage from Fused Metallic Material obtained from The Developed Instrument (Logged at 5 Minute Interval)

T_D°C	Volt (at fused point) (mV)
65.00	0.3136251
64.80	0.3136251
64.60	0.3135001
64.60	0.3090000
64.40	0.3087501
63.80	0.3085000
63.60	0.3138751
63.00	0.3067501
62.80	0.3026251
62.80	0.3018751
62.40	0.3012501
62.20	0.3005001
62.00	0.2982501
61.80	0.2970001
61.80	0.2972501

61.20	0.2941251
60.80	0.2931251
60.80	0.2935001
60.00	0.2912501
59.80	0.2915001
59.60	0.2870001
59.00	0.2846251
58.80	0.2812501
58.60	0.2820001
58.40	0.2808751
58.00	0.2775001
57.80	0.2781250
57.80	0.2736250
57.60	0.2745001
57.40	0.2697501
57.20	0.2162500
57.00	0.2731251
56.80	0.2700001
57.00	0.2713751
56.60	0.2645000
56.00	0.2631251
T_D°C is Device Temperature Measurement at fused point	
Volt (at fused point): The voltage developed at fused metallic material using equation 1 to derived from amplifier output	

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