Thermometer with 3-Digit 7-Segment Indicator
SLG47011

The application note gives step-by-step guidelines for creating a thermometer with a 3-digit 7-segment indicator. The unique set of features available in the SLG47011, which include the ADC, MathCore, Memory Table, Width Converter, Data Buffers, and additional internal logic, are what makes it possible to create this type of configurable and precise system.

The application note comes complete with design files which can be found in the Reference section.

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1. Terms and Definitions

ADC	Analog-to-Digital Converter
CH	Channel
DCMP	Digital Comparator
DFF	D Flip-Flop
LUT	Look-up Table
MF	Multi-Function
OSC	Oscillator
PGA	Programmable Gain Amplifier

2. References

For related documents and software, please visit: AnalogPAK | Renesas

Download our free Go Configure Software Hub [1] to open the .aap file [2] and view the proposed circuit design. Use the AnalogPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Renesas Electronics provides a complete library of application notes [4] featuring design examples, as well as explanations of features and blocks within the Renesas IC.

[1] GreenPAK Go Configure Software Hub, Software Download and User Guide, Renesas Electronics

[2] AN-CM-421 Thermometer with 3-Digit 7-segment Indicator.aap, AnalogPAK Design File, Renesas Electronics

[3] GreenPAK Development Tools, AnalogPAK Development Tools Webpage, Renesas Electronics

[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage, Renesas Electronics

[5] SLG47011 Datasheet, Renesas Electronics

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3. Introduction

In this application note, the AnalogPAK SLG47011 is used to create a thermometer using a 3-digit 7-segment dynamic display (NTC thermistor NTCC 10k). The SLG47011's ADC with PGA is used for voltage measurement while the Memory Table and the Width Converter are used to dynamically display the temperature on a 3-digit 7-segment indicator.

In this design, the thermometer can display a temperature ranging from 0.1 °C to 99.9 °C.

The dynamic 3-digit 7-segment display consists of using multiple (three) 7-segment displays in which the segments of each digit are activated sequentially, but fast enough that the human eye perceives this as the seamless illumination of all display segments at once.

4. Operating Principle and GreenPAK Design

The circuit schematic of the thermometer with a 3-digit 7-segment indicator is shown in Figure 1.

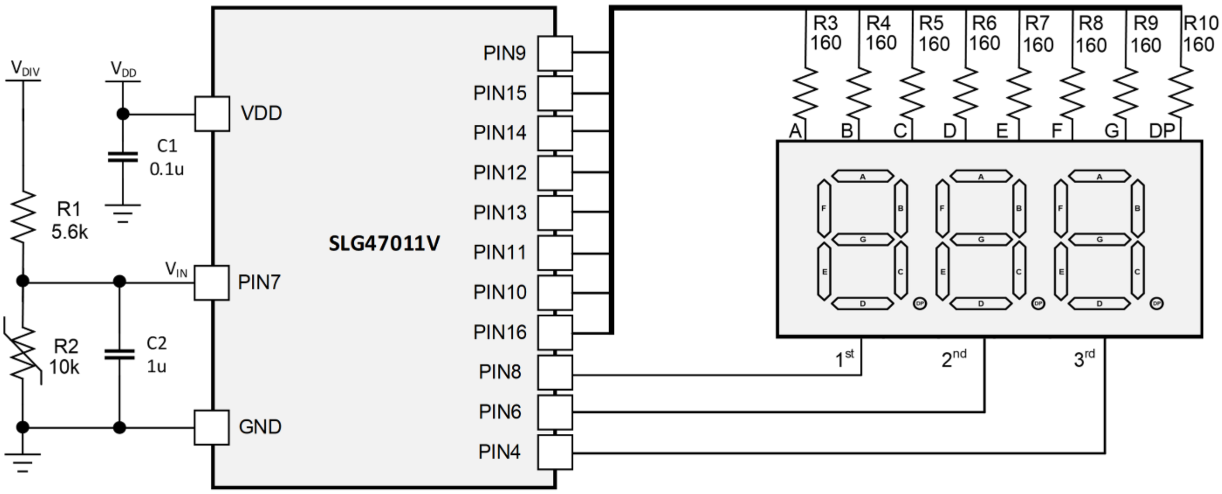


Figure 1. Thermometer with 3-Digit 7-Segment Indicator Circuit Schematic

The V_{DIV} = 1.8 V voltage is applied to PIN 7 through a resistive divider R_T / (R + R_T), where R = 5.6 kΩ. PIN 8 activates the 1st digit, while PIN 6 activates the 2nd digit and decimal point. PIN 4 activates the 3rd digit.

The signal from PIN 7 goes to the single-ended input of the PGA (buffer mode, mode #6) and then to ADC CH0 for further sampling. The allowable temperature range measured by the thermometer is 0.1 °C to 99.9 °C (or 273.25 K to 373.05 K).

The voltage (V_{IN}) after the resistive divider is equal to:

$$V_{IN} = V_{DIV} \cdot \frac{R_T}{R_T + R}.$$

The ADC converts this voltage to a 10-bit code using the formula:

$$V_{INdec} = \frac{V_{IN} \cdot 1024}{1620}.$$

Where:

- R_T is the resistance of the NTC thermistor: $R_T = R_0 exp\left[B\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$.
- R_0 = 10000 Ω is the resistance at ambient temperature T_0 (25 °C or 285.15 K),
- B = 4050 K is a constant of the thermistor,
- V_{IN} is the voltage on PIN7,
- 1024 represents the 10-bit resolution of the ADC (2^{10}).
- 1620 represents the internal Vref in mV,

- V_{INdec} is V_{IN} in 10-bit decimal format

The maximum value of V_{INdec} is 1023.

The NTC thermistor resistances for the minimum and maximum value of the temperature are calculated by:

$$R_{Tmin} = 10000\Omega \exp\left[4050K\left(\frac{1}{273.25K} - \frac{1}{285.15K}\right)\right] = 34481\Omega,$$

$$R_{Tmax} = 10000\Omega \exp\left[4050K\left(\frac{1}{373.05K} - \frac{1}{285.15K}\right)\right] = 653.9\Omega.$$

The maximum voltage after the resistive divider is equal to: $Vmax = 1.8\,V\frac{34481\,\Omega}{34481\,\Omega + 5600} = 1.55\,V$,

The minimum voltage after the resistive divider is equal to: $Vmin = 1.8\,V\frac{653.9\,\Omega}{653.9\,\Omega + 5600} = 0.188\,V$.

The relationship between the measured temperature and V_{IN} for the applied parameters of the circuit is shown in Figure 2.

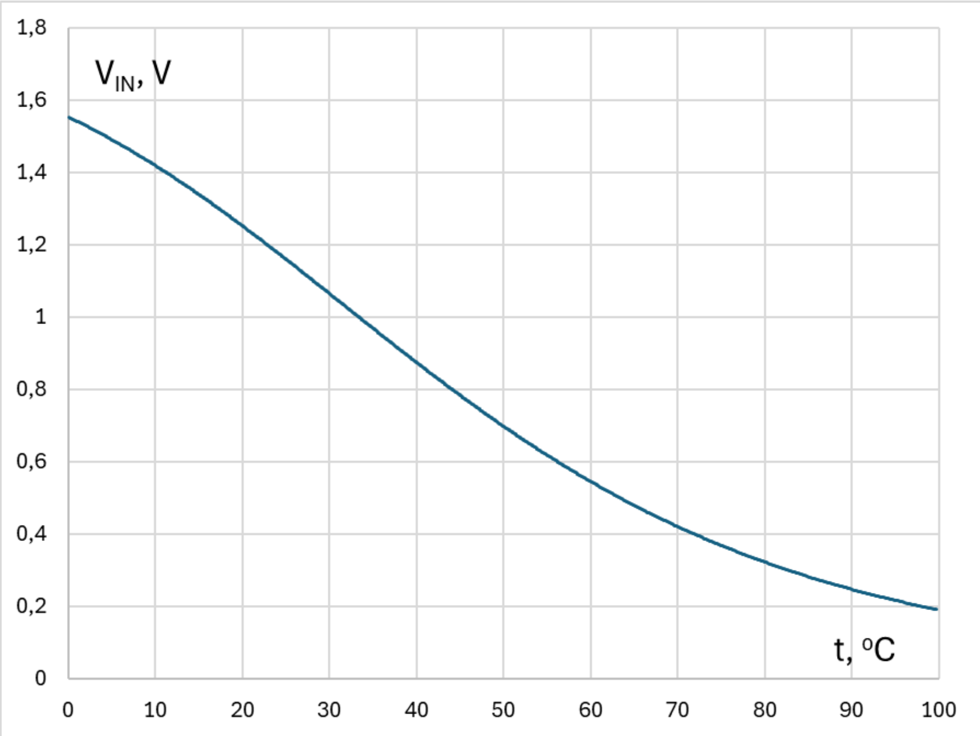


Figure 2. Graph showing the relationship between temperature and V_{IN}

5. GreenPAK Design

The GreenPAK design is shown in Figure 3.

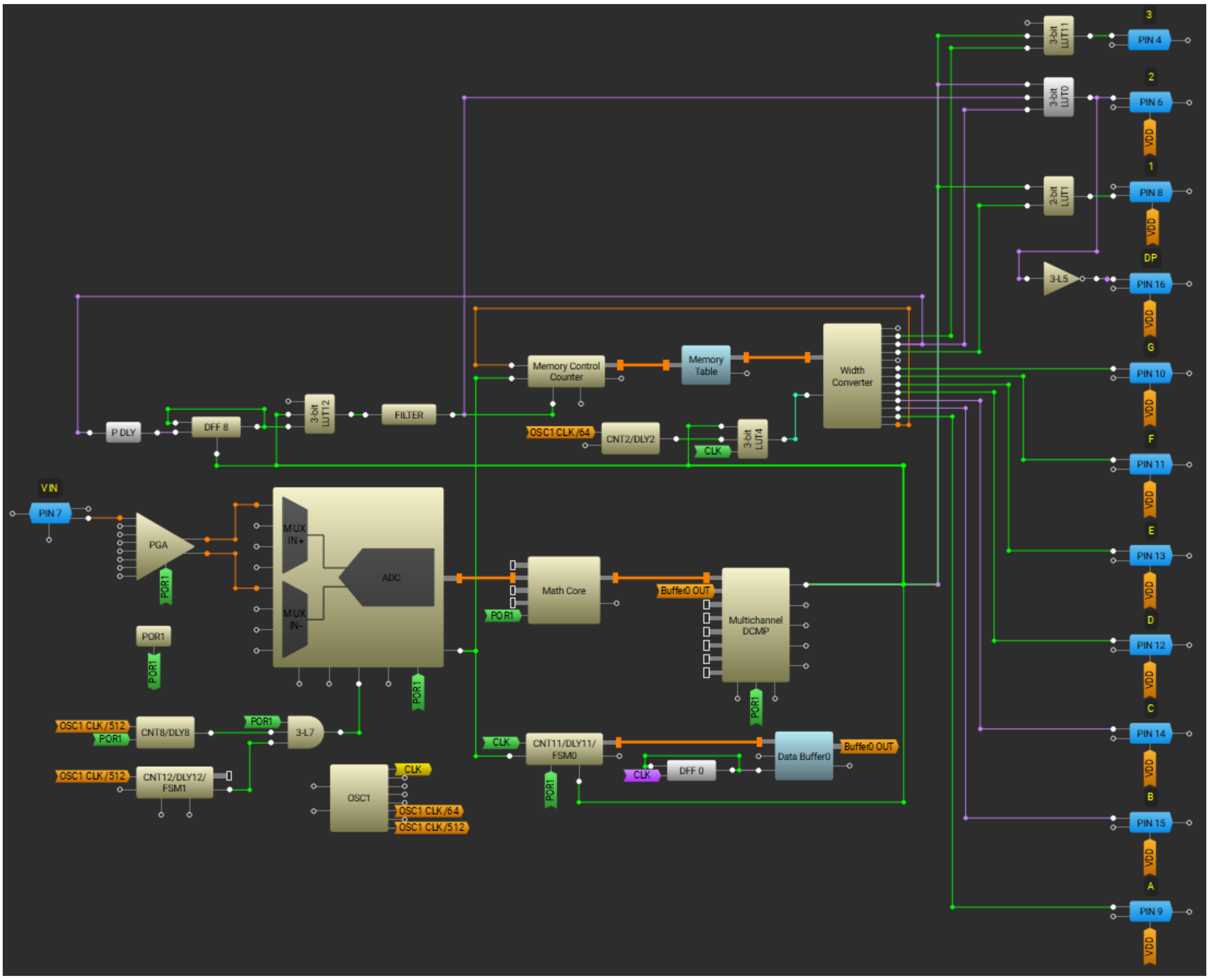


Figure 3. Thermometer with 3-Digit 7-Segment Indicator GreenPAK Design

The SLG47011 contains a Memory Table macrocell that can hold 4096 12-bit words. This space is enough to store the values of each of the three indicator digits for each VINdec (1024 * 3 = 3072 values in total). In other words, the 3n word of the Memory Table corresponds to the 1st digit, the 3n + 1 to the 2nd digit, and the 3n + 2 to the 3rd digit of each corresponding T, where n = V_{INdec}.

The ADC output value is sent to the MathCore macrocell, where it is multiplied by three. This value is then used as a Memory Table address. Assuming that the ADC output is 1000, then the MathCore output is 3000. This means that the Memory Table values at the 3000, 3001, and 3002 addresses will be used and will correspond to the indicator's 1st, 2nd, and 3rd digits accordingly.

Data from the MathCore output goes to the IN+ CH0 input of the Multichannel DCMP macrocell. This data is compared with the data on the IN- CH0 input, which is taken from the Data Buffer0 output. Data Buffer0 stores the data from the CNT11/DLY11/FSM0 macrocell, which operates in Counter/FSM mode.

The Counter/FSM is reset to "1" when a HIGH signal from the ADC Data ready output arrives and starts counting upward. The Multichannel DCMP OUT0 output is connected to the Keep input of CNT11/DLY11/FSM0. This means that when the CNT11/DLY11/FSM0 current value is equal to the MathCore output value, the DCMP

OUT0 output is HIGH, and the Keep input of CNT11/DLY11/FSM0 is also HIGH, keeping the counted value for further addressing to the Memory Table.

At the same time, together with CNT11/DLY11/FSM0, the Memory Control Counter is counting upward from 0 and sets the Memory Table address.

Thus, when the ADC measures a certain voltage value, the previously described comparison operation will point to the corresponding voltage value stored in the memory table - three consecutively recorded digits, which are then dynamically displayed on the 7-segment display.

The Memory Table’s stored data then goes to the Width Converter macrocell, which converts the serial 12-bit input into a parallel 12-bit output (Table 1).

Table 1. Width Converter Connections

Width Converter OUT	SLG47011 PIN	Function
OUT0	NC	not connected
OUT1	3-bit LUT11 IN0 -> PIN 4	3rd digit cathode
OUT2	3-bit LUT0 IN0 -> PIN 6	2nd digit cathode
OUT3	2-bit LUT1 IN0 -> PIN 8	1st digit cathode
OUT4	NC	not connected
OUT5	PIN 10	G
OUT6	PIN 11	F
OUT7	PIN 13	E
OUT8	PIN 12	D
OUT9	PIN 14	C
OUT10	PIN 15	B
OUT11	PIN 9	A

The inverter enables the decimal point (DP) through PIN 16 based on state of 3-bit LUT0 (2nd digit).

To dynamically display the temperature, the digits will be ON sequentially with a period of 300 µs. The period is set by the CNT2/DLY2 macrocell (in Reset Counter Mode). 3-bit LUT4 sets the clock of the Width Converter based on its synchronization with the CNT11/DLY11/FSM0 clock and the state of DCMP OUT0.

The P DLY, DFF8, and 3-bit LUT12 macrocells form a state counter for the Up/Down input of the Memory Control Counter macrocell based on the state of the 2nd digit (falling edge on OUT2 of the Width Converter).

When the first digit is ON, the Memory Control Counter counts upward by 1, when the 2nd digit is first set ON, the state counter is set to LOW, forcing the Memory Control Counter to count down, but it has already activated the 3rd number. Therefore, the 2nd number is activated again, and the state counter goes HIGH forcing the Memory Control Counter count upward, but it has already activated the first digit. Thus, all three digits will be sequentially activated until there is a new measured value from the ADC macrocell.

CNT8/DLY8, CNT12/DLY12/FSM1, and 3-bit LUT7 are used to properly turn on the ADC after the first turn-on when POR arrives, as well as during further operation when the ADC is turned on and off. CNT12/DLY12/FSM1 provides a period of 1.68 s, which results in the thermometer value being updated every 1.68 s.

6. Memory Table Filling Algorithm

The algorithm below is shown for a V_{DIV} voltage of 1.8 V and a resistive divider of 5.6 kΩ and R_T.

First, the resistance value of R_T (Ω) at ambient temperature T is calculated using the formula:

$$R_T\ \Omega = \frac{V_{INdec} \cdot 5600\ \Omega}{1.8\ V \cdot 1024/1.62\ V - V_{INdec}}.$$

Second, the value of the temperature t (℃) for a determined R_T value is calculated by:

$$t\ ℃ = \left(\frac{1}{287.15\ K} + \frac{1}{4050} ln \frac{R_T\ \Omega}{10000\ \Omega}\right)^{-1} - 273.15.$$

Then, the calculated t (℃) values are rounded to the first decimal point.

For each V_{INdec} value, three values are assigned in the memory table as follows: each V_{INdec} corresponds to three consecutive values in the memory table 3n, 3n + 1, and 3n + 2, where n = V_{INdec}.

Three separate columns for each of the values of 3n, 3n + 1, and 3n + 2 should be created. They each correspond to the 1st, 2nd, and 3rd digits of the indicator, respectively. The first column is assigned to the first digit of the rounded t value. The second column is assigned to the second digit, and the third column is assigned to the third digit.

For each digit of each column, a 7-bit binary value is found (m11 - m5), corresponding to the activation of the corresponding digit of the seven-segment display (Table 2).

Table 2. 7-Segment Code

Digit	7-bit Code for 7-Segment Indicator ABCDEFG
0	1111110
1	0110000
2	1101101
3	1111001
4	0110011
5	1011011
6	1011111
7	1110000
8	1111111
9	1111011
L	0001110

When the measured t_{meas} temperature is in range 0.1 °C > t_{meas} > 99.9 °C the 0 - L symbols should be displayed on the indicator. The 3rd digit is not activated in this case.

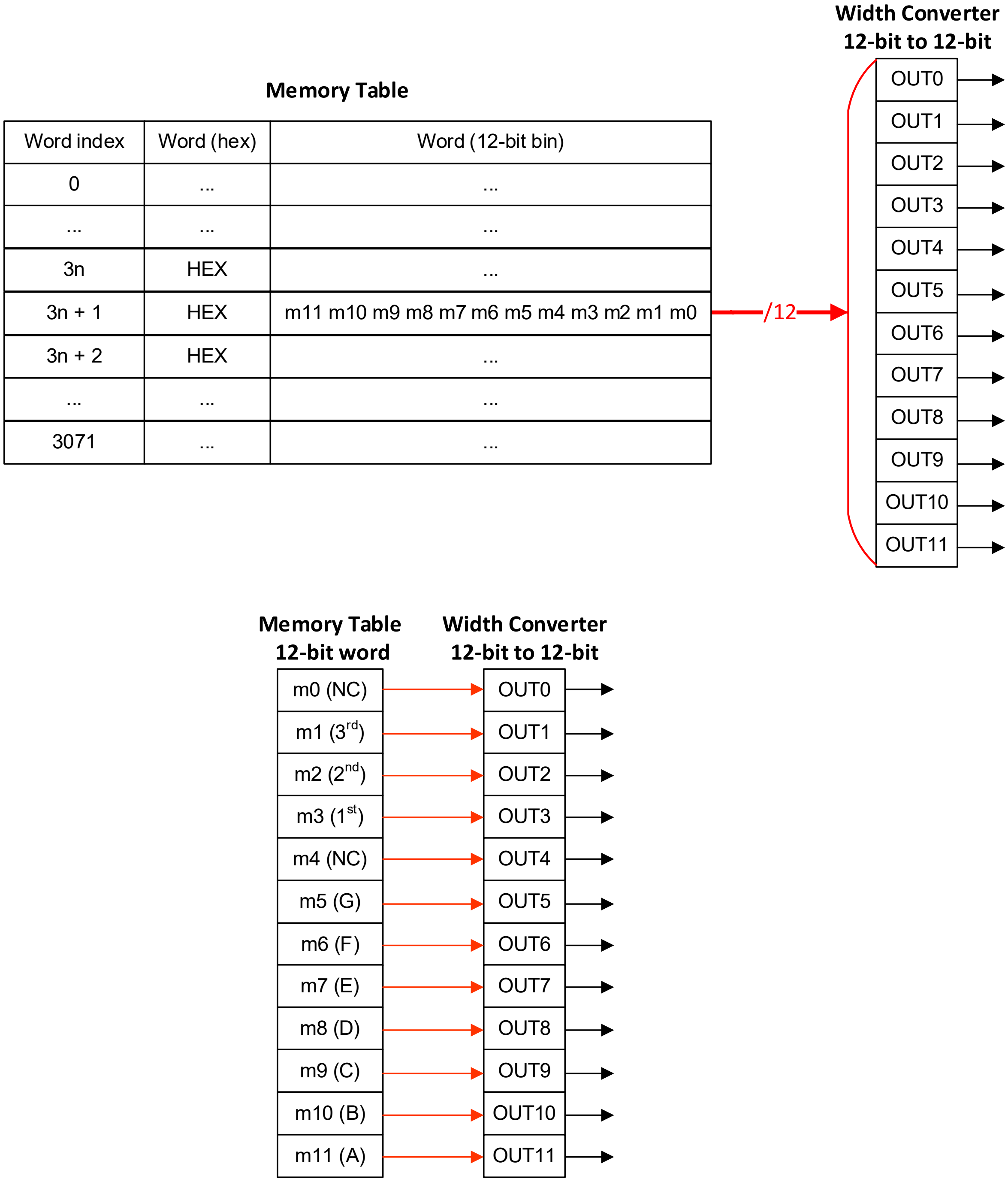
The next step is to add 5 more bits (m4 - m0) to the right of this value to get a 12-bit number.

The 9th bit (m3) is responsible for turning on the first digit, the 10th bit (m2) is responsible for turning on the second digit, and the 11th bit (m1) for the 3rd digit. Since a 7-segment indicator with a common cathode is used, turning on the digit is done with a LOW level (0). Therefore, for the first column (with words of type 3n), the 9th bit (m3) will equal 0, while the 10th (m2) and the 11th (m1) bits will equal 1. For the second column (with words of type 3n + 1), the 10th bit (m2) will be equal to 0, while the 9th (m3) and 11th (m1) bits will be equal to 1. For the third column (with words of type 3n + 2), the 11th (m1) bit will be equal to 0, while the 9th (m3) and 10th (m2) bits will be equal to 1.

The 12th bit (m0) is not used, so its value does not affect the design.

The resulting 3072 binary 12-bit values must then be converted to hex.

The required values for the Memory Table are already determined, now they need to be sorted in ascending order of the Word index and inserted into the appropriate location in the software. For a better understanding of the connections between the Memory Table and the Width Converter, see the Figure 4.



Word index	Word (hex)	Word (12-bit bin)
0	...	...
...	...	...
3n	HEX	...
3n + 1	HEX	m11 m10 m9 m8 m7 m6 m5 m4 m3 m2 m1 m0
3n + 2	HEX	...
...	...	...
3071	...	...

Figure 4. Memory Table to Width Converter Bit Assignments

7. Testing Results

Figure 5 shows the result of measuring a temperature of around 17 °C with respect to data obtained by a multimeter thermocouple.

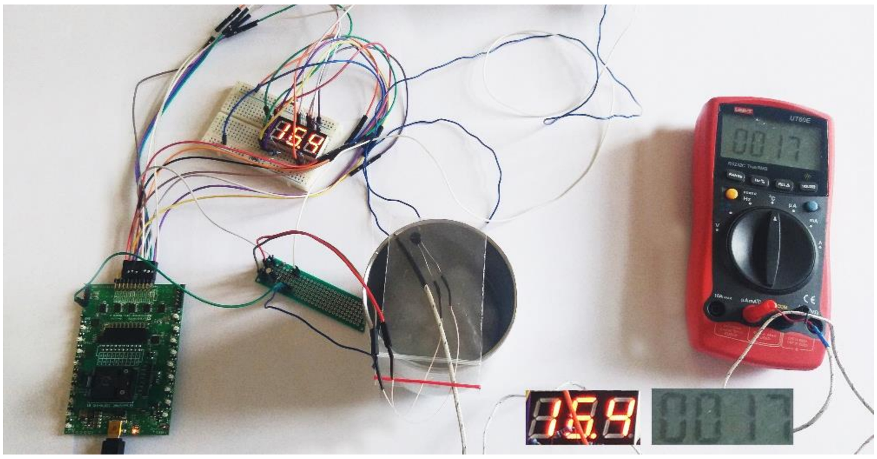


Figure 5. Temperature Range Up to room temperature: 17 °C

Figure 6 shows the result of measuring a temperature of around 59 °C with respect to data obtained by a multimeter thermocouple.

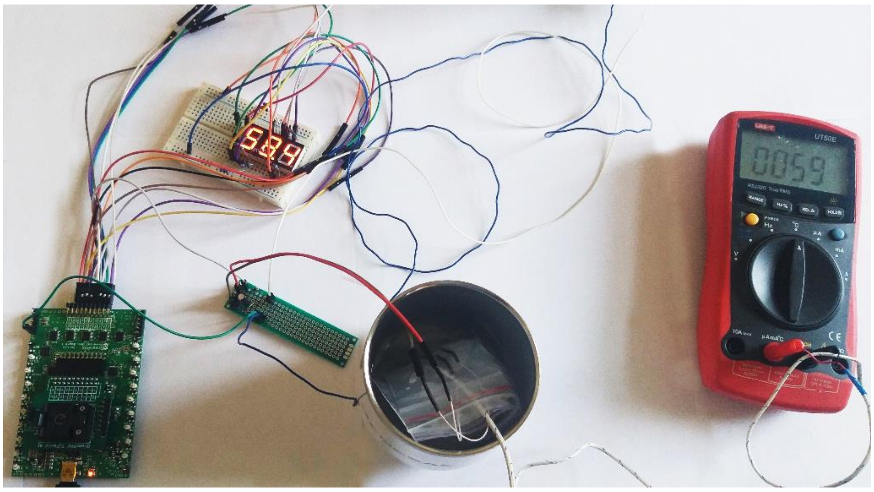


Figure 6. Temperature Range Up to 99.9 °C: 59 °C

Figure 7 shows the result of measuring a temperature of around 70 °C with respect to data obtained by multimeter thermocouple.

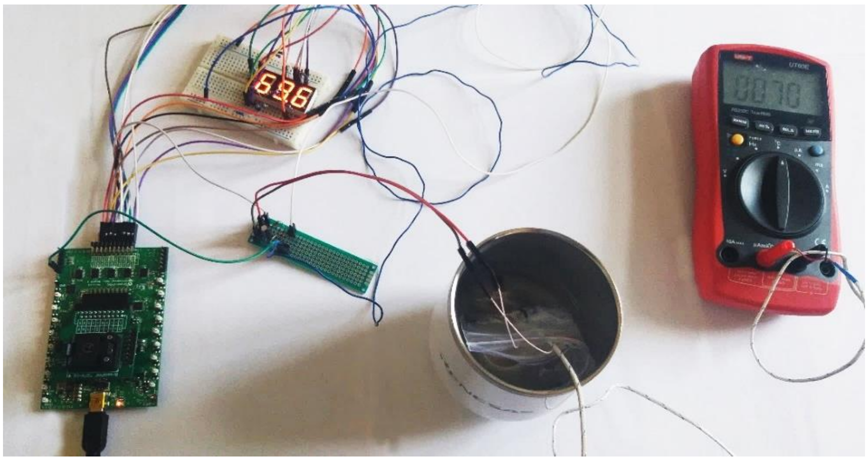


Figure 7. Temperature Range Up to 99.9 °C: 70 °C

8. Conclusion

This application note gives step-by-step guidelines for creating a thermometer with a 3-digit 7-segment indicator.

The ADC with PGA is used for indirect temperature measurement while the Memory Table and the Width Converter provide the data to dynamically display the result on a 3-digit 7-segment indicator.

The SLG47011 is highly configurable, and by changing the resistive divider and rewriting the Memory Table, different desired temperature ranges for the thermometer measurement can be configured.

9. Revision History

Revision	Date	Description
1.00	Dec 19, 2025	Initial release.

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