Voltmeter with 3-Digit, 7-Segment Indicator
SLG47011

This application note gives a step-by-step guide for creating a voltmeter using a 3-digit, 7-segment indicator. The unique set of ADC, MathCore, Memory Table, Width Converter, Data Buffers, and additional internal logic of the SLG47011 allows the creation of such a configurable and precise system.

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

Contents

Figures

Tables

© 2025 Renesas Electronics

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 GreenPAK Designer software [1] to open the .app files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Renesas 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 Designer Software, Software Download and User Guide, Renesas Electronics

[2] AN-CM-410 Voltmeter with 3-Digit 7-Segment Indicator.aap, Design file, Renesas Electronics

[2] GreenPAK Development Tools, GreenPAK Development Tools Webpage, Renesas Electronics

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

[4] SLG47011 Datasheet, Renesas Electronics

3. Introduction

In this application note, the AnalogPAK SLG47011 is used to create a voltmeter with a 3-digit, 7-segment dynamic display. The ADC with PGA is used for voltage measurement while the Memory Table and the Width Converter provide a dynamic display on a 3-digit, 7-segment indicator.

In this design, it is possible to use the voltmeter in two voltage ranges: up to 9.99 V and up to 99.9 V, depending on the switch position. The SLG47011 is highly configurable, so by changing the resistive divider and rewriting the Memory Table, the desired voltage range for the voltmeter measurement can be selected.

A 3-digit, 7-segment display is used for controlling multiple seven-segment displays in which the segments for each digit are dynamically activated one at a time, but is done so quickly that the human eye perceives this as the simultaneous illumination of all digits.

4. Operating Principle and GreenPAK Design

The circuit schematic of the voltmeter with a 3-digit, 7-segment display is shown in Figure 1.

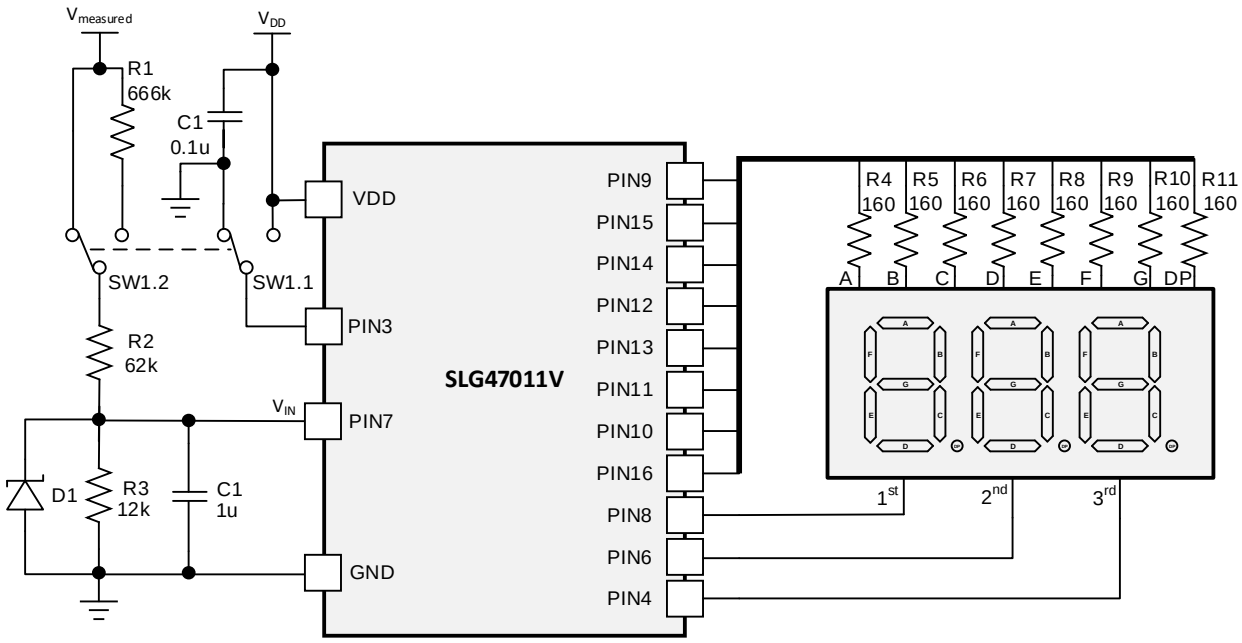

Figure 1. Circuit Schematic for Voltmeter with 3-Digit, 7-Segment Indicator

The V_{IN} voltage is applied to PIN 7 through a resistive divider 62 kΩ / 728 kΩ (666 kΩ + 62 kΩ) and 12 kΩ depending on the position of switch SW1. SW1 also affects the maximum allowable voltage ($V_{measured}$) and decimal point (DP) position. See Table 1.

Table 1. Switch Logic

SW1.1 position	PIN3 state	SW1.2 position	Max $V_{measured}$	DP active
GND	LOW (0)	62 kΩ	9.99 V	1st
V_{DD}	HIGH (1)	728 kΩ	99.9 V	2nd

PIN 8 activates the 1st digit and decimal point. PIN 6 activates the 2nd digit and decimal point. PIN 4 activates the 3rd digit.

The signal from PIN 7 then goes to the single-ended input of the PGA (buffer mode, mode #6) and then to ADC CH0 for further sampling. The maximum allowable voltage before the resistive divider, $V_{measured}$, is 9.99 V when the resistance of 62 kΩ is selected, and 99.9 V when 728 kΩ is selected.

The maximum voltage after the resistive divider is calculated by the following formulas:

$$Vmax1 = 9.99\ V\ \cdot \frac{12\ k\Omega}{62\ k\Omega + 12\ k\Omega} = 1.62\ V$$

$$Vmax2 = 99.9\ V\ \cdot \frac{12\ k\Omega}{728\ k\Omega + 12\ k\Omega} = 1.62\ V$$

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

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

where:

- V_{IN} (mV) is the voltage on PIN7,
- 1024 – 2^{10}, as the ADC has a 10-bit resolution.
- 1620 – internal Vref in mV,

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

The maximum value of V_{INdec} is 1024. The GreenPAK design is shown in Figure 2.

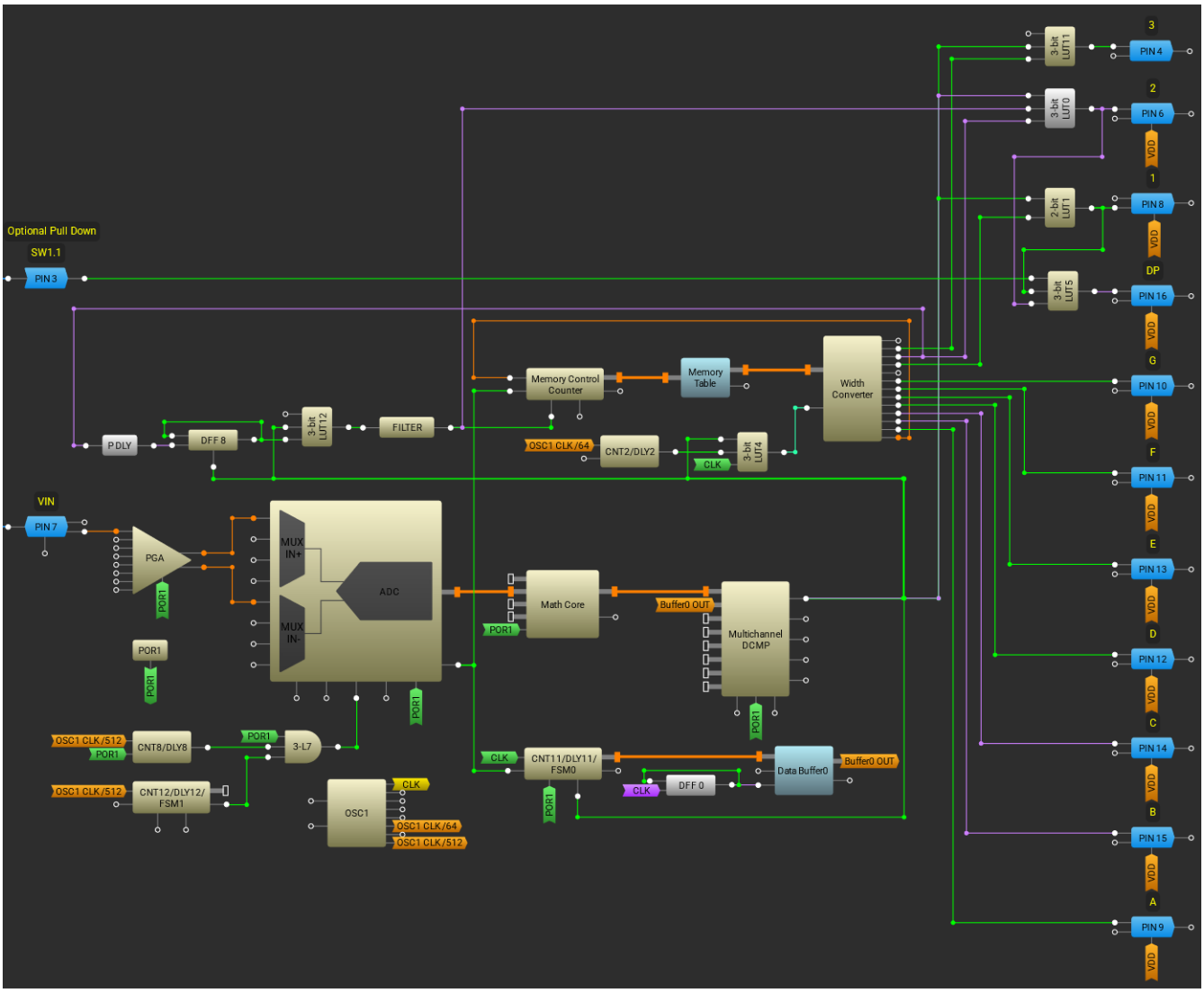

Figure 2. GreenPAK Design for Voltmeter with 3-Digit, 7-Segment Indicator

SLG47011 includes a Memory Table macrocell that can hold 4096 12-bit words. This space is enough to store the value of each of the three indicator digits for each V_{INdec} – 1024 x 3 = 3072 values in total. In other words, the "3n" word of the Memory Table corresponds to the 1st digit, the "3n + 1" word corresponds to the 2nd digit, and the "3n + 2" word corresponds to the 3rd digit of the corresponding $V_{measured}$. Where n = V_{INdec}.

The ADC output value arrives at the MathCore macrocell, where it is then multiplied by three. Then this value is used as an address in the Memory Table. Assuming that the ADC output is 1000, the MathCore output will be 3000. This means that the Memory Table values at the 3000, 3001, and 3002 addresses will be used and they 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 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 the 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 CNT11/DLY11/FSM0's current value is equal to the MathCore output value, the DCMP OUT0 is HIGH, and the Keep input of the 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. It sends the necessary address to the Memory Table.

Thus, when the ADC measures a certain voltage value, the described comparison will point to the corresponding voltage value stored in the Memory Table - 3 consecutively recorded digits, which will dynamically be displayed on the 7-segment display.

The stored data in the Memory Table goes to the Width Converter macrocell, which converts the serial 12-bit input into the parallel 12-bit output (Table 2).

Table 2. 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

3-bit LUT5 enables the decimal point (DP) through PIN 16 based on the states of PIN 3 (SW1.2), 2-bit LUT1 (1st digit), and 3-bit LUT0 (2nd digit).

Since the dynamic display method is used in this design, the digits will be ON sequentially with a period of 300 µs. This period is set by the CNT2/DLY2 (Reset Counter Mode) macrocell. 3-bit LUT4 sets the clock to the Width Converter based on synchronization with the CNT11/DLY11/FSM0 clock and the DCMP OUT0 state.

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 digit 2 (falling edge of the Width Converter OUT2).

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

CNT8/DLY8, CNT12/DLY12/FSM1, and 3-bit LUT7 are used to correctly turn on the ADC after the first turn-on when the POR signal arrives, as well as in further operations when turning the ADC off and on. CNT12/DLY12/FSM1 provides a period of 1.68 s, so the voltmeter value is updated every 1.68 s.

5. Memory Table Filling in Algorithm

The algorithm below is shown for a voltage of 9.99 V and a resistive divider of 62 kΩ and 12 kΩ. Since the second mode uses ten times the voltage and a ten times larger resistive divider, the memory table values will be similar, only the decimal point placement in the design is changed.

First, the value of $V_{measured}$ (V) for each V_{INdec} is calculated using the formula:

$$V_{measured} = \frac{V_{INdec}}{1024} \cdot 1.62\ V\ \cdot \frac{62\ k\Omega + 12\ k\Omega}{12\ k\Omega}$$

Then, the calculated $V_{measured}$ values are rounded to the second 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 the values of 3n, 3n + 1, and 3n + 2 should be created. They correspond to the 1st, 2nd, and 3rd digits of the indicator, respectively. The first column is assigned to the first digit of the rounded $V_{measured}$ 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 3).

Table 3. 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

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

In the case of a design where a decimal point is only needed after the first or second digit, the 8th bit (m4) "decimal point" value can be written and the corresponding Width Converter output which is connected to PIN 16. Since decimal point logic is currently activated using the logic based on the states of the 1st and the 2nd digits and the switch (PIN 3), this bit can be written 0 or 1 without any difference, since it is not connected.

The 9^{th} bit (m3) is responsible for turning on the first digit, the 10^{th} bit (m2) is responsible for turning on the second digit, and the 11^{th} 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 9^{th} bit (m3) will equal ‘0’, while the 10^{th} (m2) and the 11^{th} (m1) bits will equal ‘1’. For the second column with words of type 3n+1, the 10^{th} bit (m2) will be equal to ‘0’, while bits 9^{th} (m3) and 11^{th} (m1) will be equal to ‘1’. For the third column with words of type 3n+2, the 11^{th} (m1) will be equal to ‘0’, while bit 9 (m3) and bit 10 (m2) will be equal to ‘1’.

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

The resulting 3072 binary 12-bit values must 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 Figure 3.

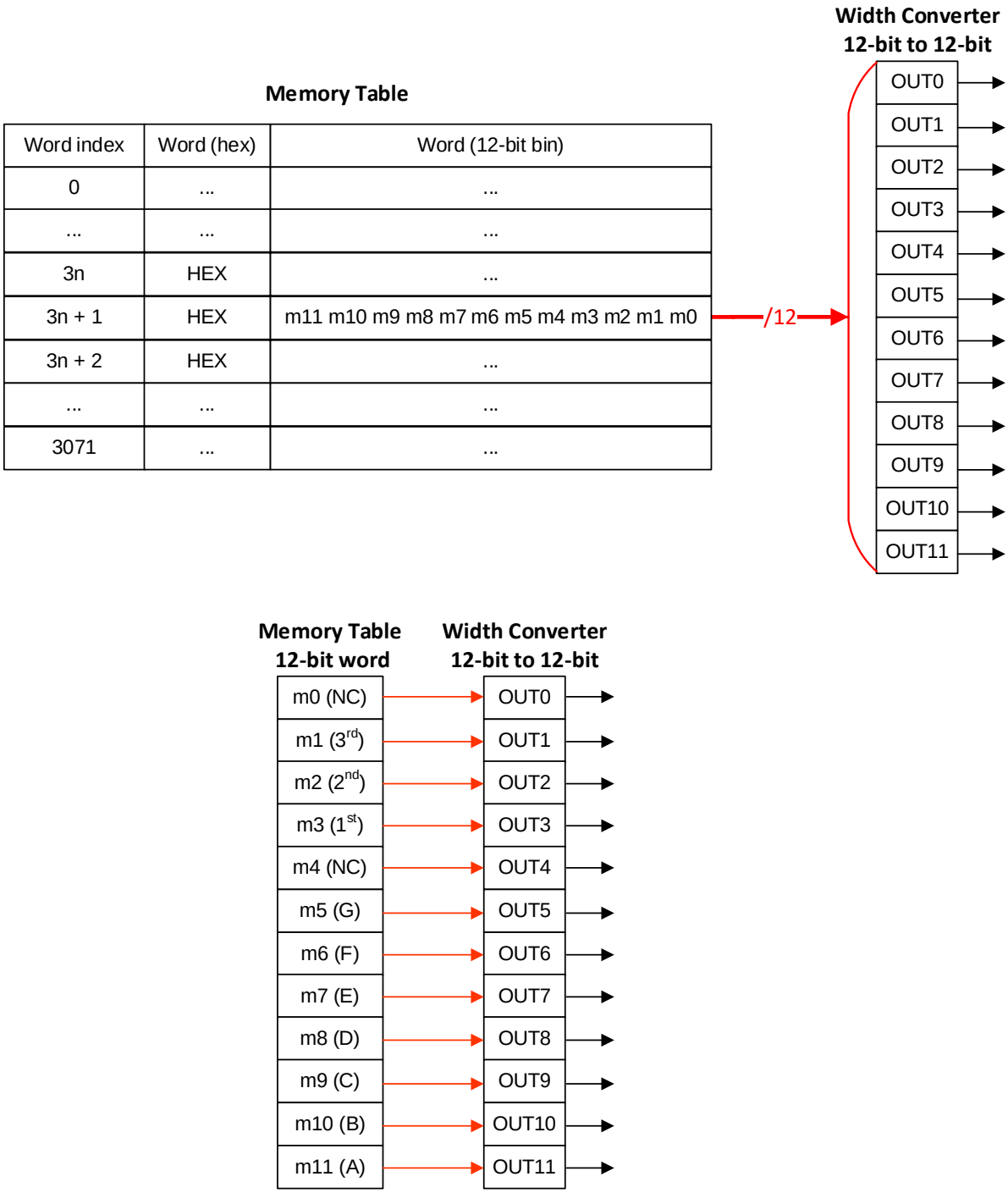

Figure 3. Bits Assignment for Memory Table to Width Converter

6. Testing Results

Figure 4 shows the result of measuring 7.77 V in 62 kΩ mode with 12 kΩ resistive divider (up to 9.99 V). The decimal point is active after the first digit.

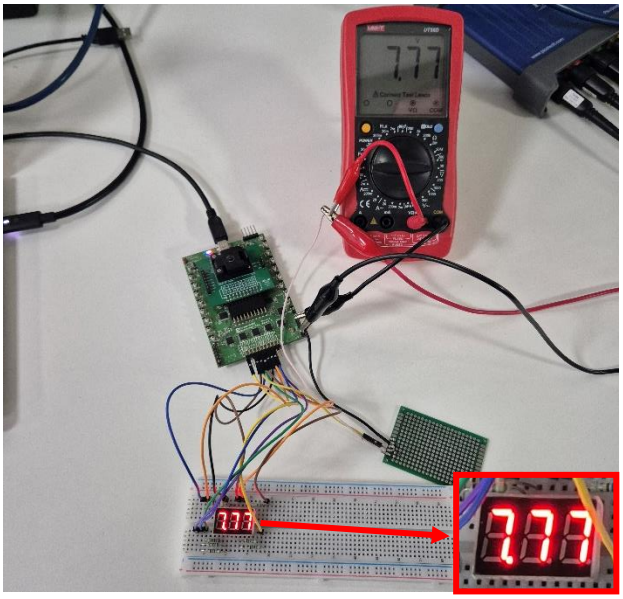

Figure 4. Voltage Range Up to 9.99 V: 7.77 V

Figure 5 shows the result of measuring the same 7.77 V but in 728 kΩ mode with 12 kΩ resistive divider (up to 99.9 V). The decimal point is now active after the second digit.

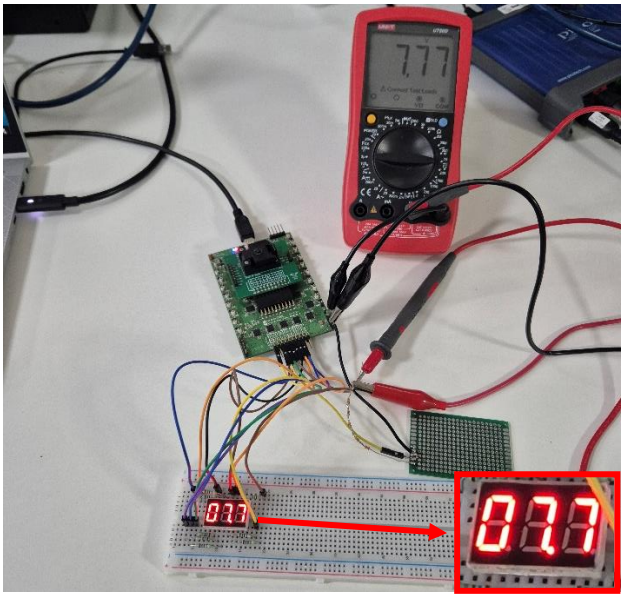

Figure 5. Voltage Range Up to 99.9 V: 7.7 V

Figure 6 shows the result of measuring 17.0 V in 728 kΩ mode with 12 kΩ resistive divider (up to 99.9 V). The decimal point is active after the second digit.

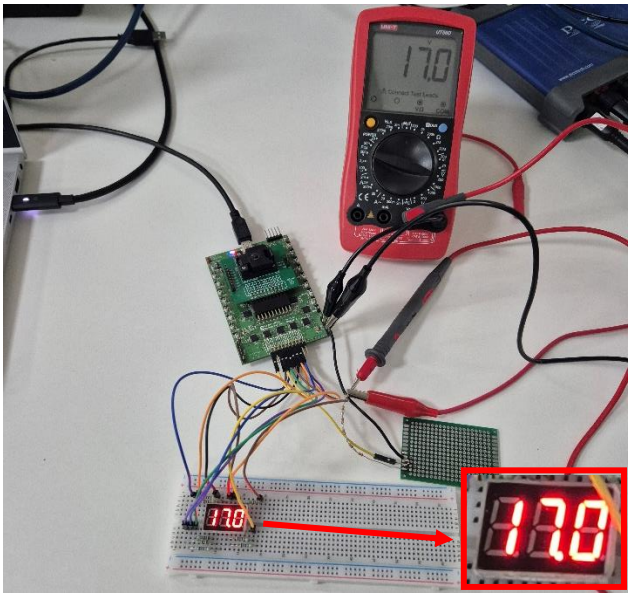

Figure 6. Voltage Range Up to 99.9 V: 17.0 V

7. Conclusion

This application note gives a step-by-step guide for creating a voltmeter with a 3-digit 7-segment indicator. The voltmeter has two modes with two voltage ranges: 9.99 V and 99.9 V.

The ADC with PGA is used for voltage measurement while the Memory Table and the Width Converter provide a dynamic display on a 3-digit, 7-segment indicator.

The SLG47011 is highly configurable, so by changing the resistive divider and rewriting the Memory Table, the desired voltage range for the voltmeter measurement can be adjusted as needed.

8. Revision History

Revision	Date	Description
1.00	April 8, 2025	Initial release.