AN13905

ACMP Usage for LPC86x

Rev. 0 — 8 May 2023 Application note

Document Information

Information	Content
Keywords	LPC86x, ACMP, Voltage monitor, Pulse-width measurement
Abstract	This application note introduces and provides the usage note for the ACMP module of LPC86x.

1 Introduction

LPC86x series contain an ACMP (Analog Comparator) module. This application note introduces and provides the usage note for the ACMP module of LPC86x.

2 General function of ACMP

ACMP is a module that compares two analog input voltages and outputs a signal level indicating which of the inputs is greater or lesser.

Typically an analog comparator compares voltage levels on two inputs and gives digital output based on the comparison. When the voltage on the positive input (VA) is greater than the voltage on the negative input (VB), the output voltage (VOUT) is same as its positive supply (V+). Otherwise, the output is as its negative supply (V-). Usually, the ACMP module uses VDD as its positive supply, while GND as its negative supply.

Figure 1 shows an ideal behavior of ACMP.

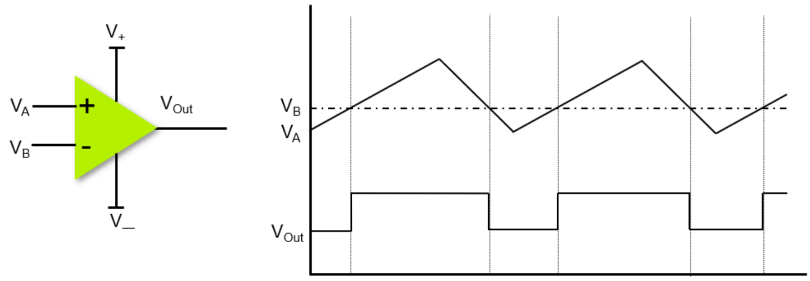


Figure 1. Ideal behavior of ACMP

3 LPC86x ACMP introduction and diagram

3.1 LPC86x ACMP introduction

LPC86x ACMP consists of four parts:

- Voltage ladder
- Input mux
- Analog comparator
- Output mux

3.1.1 ACMP voltage ladder

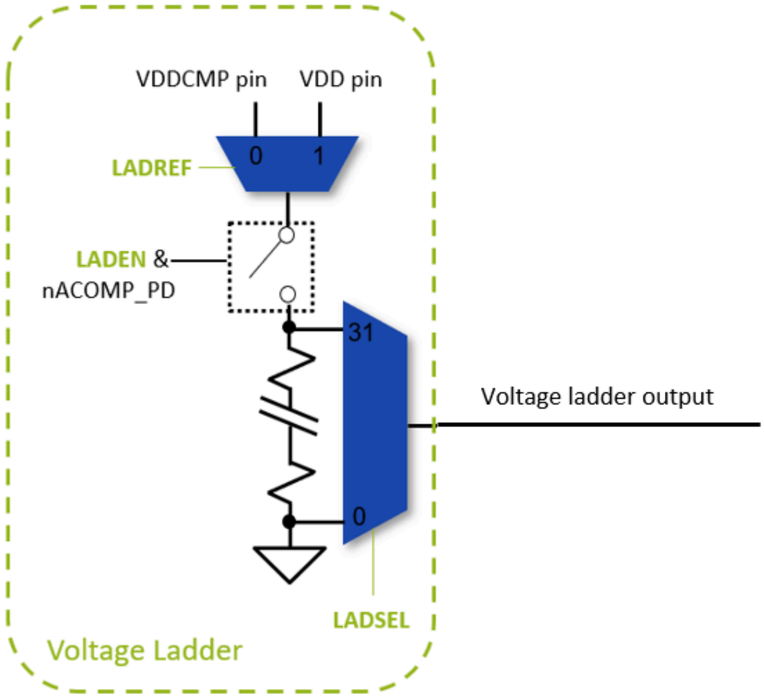


Figure 2. LPC86x ACMP voltage ladder

The ACMP voltage ladder can use two reference voltages, from the VDDCMP pin or the VDD pin. The voltage ladder selects one of 32 steps between the reference voltage and VSS inclusive. The voltage on VDDCMP must not exceed that on VDD.

Voltage ladder can be separately powered down for applications only requiring the comparator function to save the chip power consumption.

3.1.2 ACMP input mux

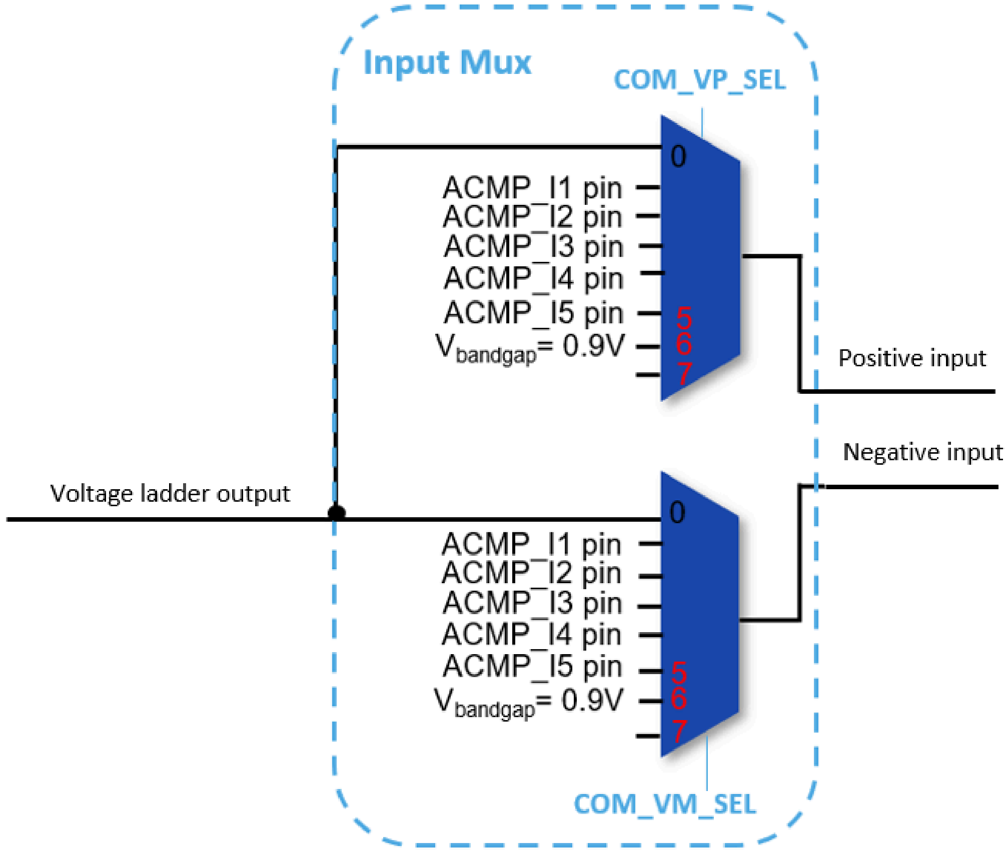


Figure 3. LPC86x ACMP input mux

LPC86x ACMP positive input and negative input can use seven input sources:

- Voltage ladder output
- ACMP_Ix (1 - 5)
- Band gap (Internal reference voltage 0.9 V)

3.1.3 ACMP analog comparator

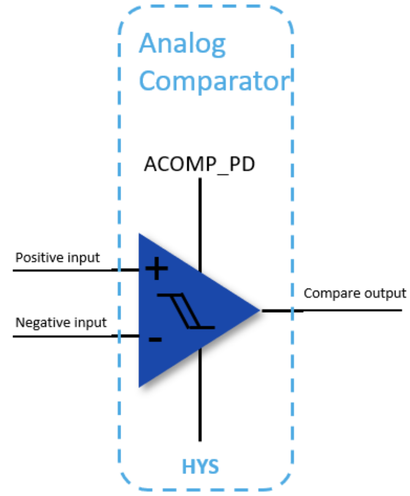


Figure 4. LPC86x ACMP analog comparator

The analog comparator compares the positive input and negative input, and gets the compare output.

User can enable or disable ACMP by controlling the PDRUNCFG register ACMP bit, and setting the different hysteresis voltage here.

3.1.4 ACMP output mux

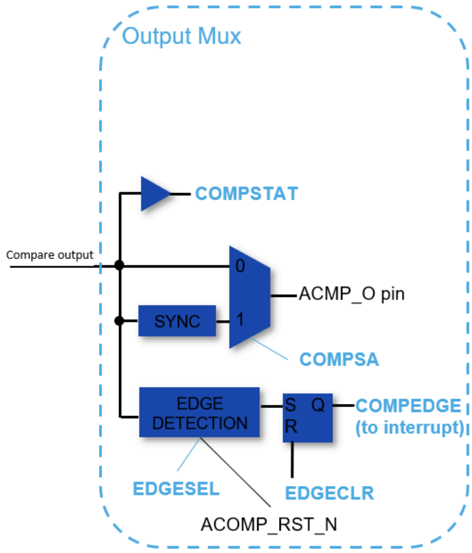


Figure 5. LPC86x ACMP output mux

The ACMP analog comparator output goes to a selected pin and causes an edge detected interrupt. The interrupt output is connected to NVIC.

One comparator output is internally collected to the ADC trigger input multiplexer.

Compare completed indicates that the ACMP status is completed.

3.2 LPC86x ACMP diagram

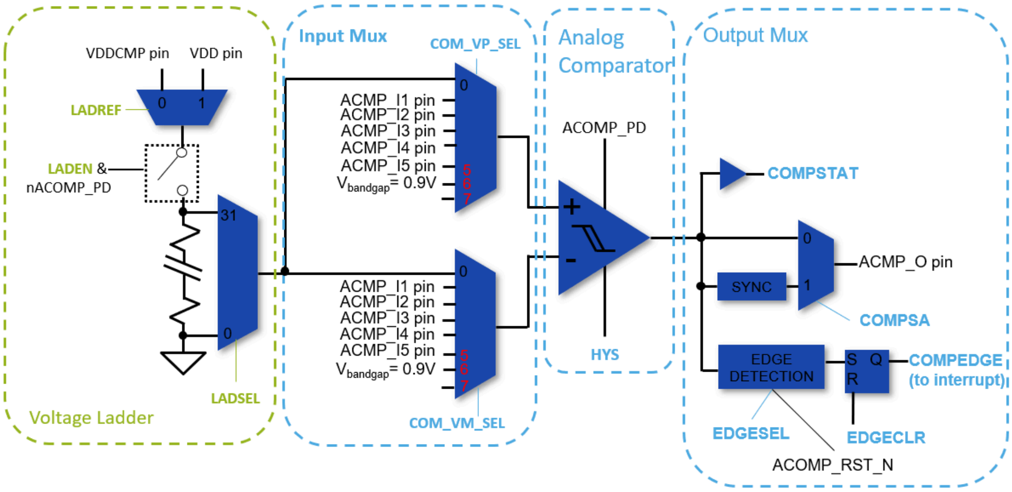


Figure 6. LPC86x ACMP diagram

The above four parts form the entire LPC86x ACMP diagram.

4 LPC86x ACMP pin description

LPC86x ACMP contains three kinds of pins:

- Input – ACMP_Ix
- Output – ACMP_O
- Reference voltage – VDDCMP

The input pins and reference voltage pins are fixed-pins. They must be enabled through the switch matrix and can only be assigned to special pins on the package.

The output pins are movable-pins. It can be assigned to any pin on the LPC86x package through the switch matrix.

Table 1 describes the ACMP pins.

Table 1. LPC86x ACMP pins description

Function	Type	Pin	Description	SWM register
ACMP_I1	I	PIO0_0	Comparator input 1	PINENABLE0
ACMP_I2	I	PIO0_1	Comparator input 2	PINENABLE0
ACMP_I3	I	PIO0_14	Comparator input 3	PINENABLE0
ACMP_I4	I	PIO0_23	Comparator input 4	PINENABLE0
ACMP_I5	I	PIO0_30	Comparator input 5	PINENABLE0
ACMP_O	O	any	Comparator output	PINASSIGN11
VDDCMP	I	PIO0_6	External reference voltage source for 32-stage Voltage Ladder.	PINENABLE0

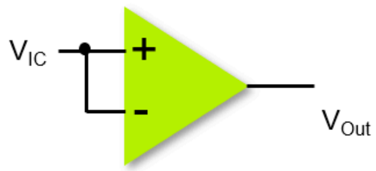
5 LPC86x ACMP non-ideal behavior characteristics

LPC86x ACMP has below non-ideal behavior characteristics:

- Offset voltage
- Propagation delay
- Hysteresis offset

5.1 Offset voltage

Offset voltage is the output voltage offset when both inputs are equal. The ideal behavior must be **0** when both inputs are equal. Figure 7 shows the LPC86x ACMP offset voltage.



VIC = (VA + VB) / 2

Symbol	Conditions	Min	Typ	Max
Voffset	V_{IC}=0.1V	-	3 mV	-
	V_{IC}=1.5V	-	3 mV	-
	V_{IC}=2.9V	-	6 mV	-

Figure 7. LPC86x ACMP Offset voltage characteristics

5.2 Propagation delay

Propagation delay is the time needed to establish the output. This delay is defined as the duration between the moment that the input signal crosses the threshold and the moment that the output state changes (usually when the output reaches 50 % of VDD). Figure 8 shows the example for the propagation delay.

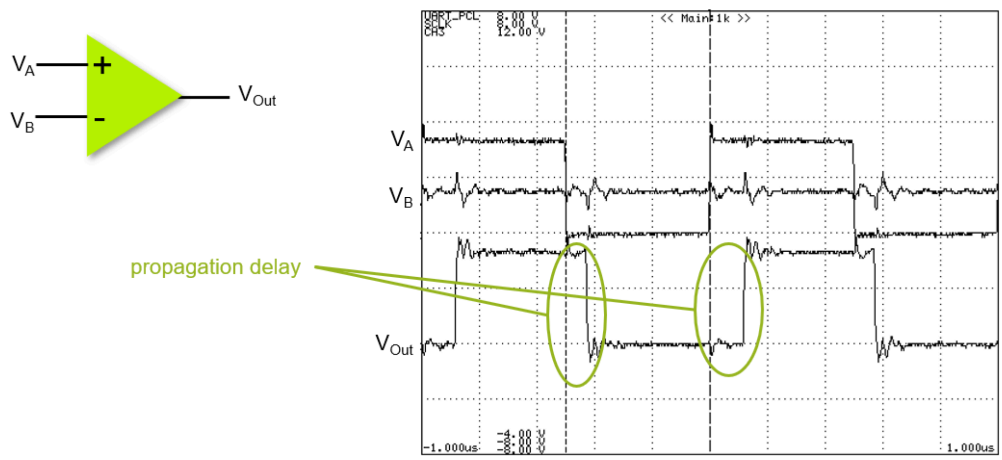


Figure 8. Propagation delay example

The Propagation delay time between rising and falling edge is unsymmetrical.

Figure 9 shows the LPC86x ACMP propagation delay characteristics.

Symbol	Conditions	Min	Typ	Max
t_{PD}	HIGH to LOW; VDD(3V3) = 3.0 V; VIC = 0.1 V; 100 mV overdrive input	-	150 ns	-
	VIC = 0.1 V; rail-to-rail input	-	250 ns	-
	VIC = 1.5 V; 100 mV overdrive input	-	150 ns	-
	VIC = 1.5 V; rail-to-rail input	-	170 ns	-
	VIC = 2.9 V; 100 mV overdrive input	-	180 ns	-
	VIC = 2.9 V; rail-to-rail input	-	70 ns	-

Symbol	Conditions	Min	Typ	Max
t_{PD}	LOW to HIGH; VDD(3V3) = 3.0 V; VIC = 0.1 V; 100 mV overdrive input	-	260 ns	-
	VIC = 0.1 V; rail-to-rail input	-	90 ns	-
	VIC = 1.5 V; 100 mV overdrive input	-	270 ns	-
	VIC = 1.5 V; rail-to-rail input	-	220 ns	-
	VIC = 2.9 V; 100 mV overdrive input	-	190 ns	-
	VIC = 2.9 V; rail-to-rail input	-	700 ns	-

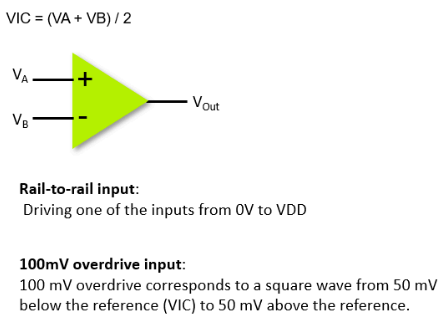


Figure 9. LPC86x ACMP propagation delay characteristics

5.3 Hysteresis offset

In ideal status, when the voltage on the positive input (VA) is greater or lesser than the voltage on the negative input (VB), the output voltage (VOUT) changes. In this case, the input signal crosses threshold cannot be set or the cross threshold equals to zero. While in some applications, the zero threshold causes system unstable, for example, the vibration existing around the zero threshold. Therefore, introducing hysteresis offset is an often-effective solution to these situations.

Figure 10 shows the example for the Hysteresis offset.

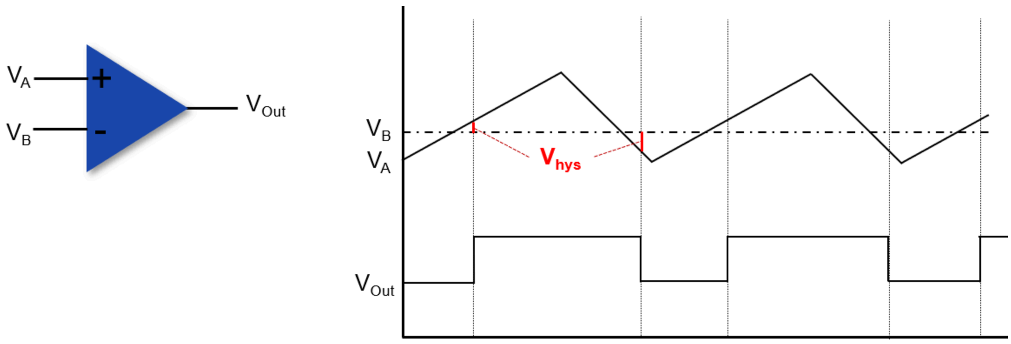


Figure 10. Hysteresis offset example

The LPC86x ACMP has four choices for ideal hysteresis offset: 5 mV, 10 mV, 20 mV, or none.

The measured hysteresis has a bit of offset voltage compared to the ideal one. The Positive hysteresis is a little different from the negative hysteresis.

Figure 11 shows LPC86x ACMP hysteresis offset characteristics.

Symbol	Conditions	Min	Typ	Max
V_{hys}	positive hysteresis; VDD(3V3) =3.0V; VIC=1.5V	-	6 mV, 12 mV, 22 Mv	-

Symbol	Conditions	Min	Typ	Max
V_{hys}	negative hysteresis; VDD(3V3) =3.0V; VIC=1.5V	-	7 mV, 13 mV, 23 mV	-

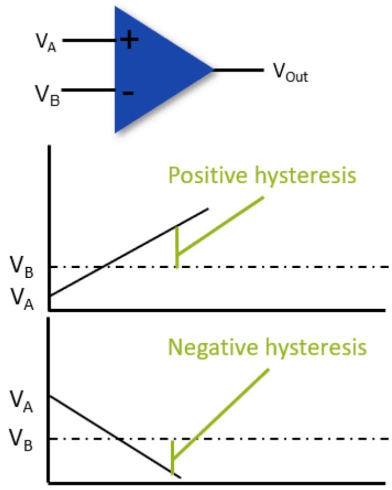


Figure 11. LPC86x ACMP Hysteresis offset characteristics

6 LPC86x ACMP basic configuration

To configure the LPC86x ACMP, perform the following steps:

- In the SYSAHBCLKCTRL register, set bit 19 to enable the clock to the register interface.
- Enable or disable the power to the analog comparator through the PDRUNCFG register.
- Clear the analog comparator peripheral reset using the PRESETCTRL register
- Connect the analog comparator interrupt to interrupt #11 in the NVIC.
- Configure the analog comparator pin functions through the switch matrix.

7 Application examples

7.1 Analog voltage monitoring

Using basic ACMP function, user can apply analog voltage monitoring, positive input as the monitored voltage and negative input as threshold voltage. When the voltage on the positive input (VA) is greater or lesser than the voltage on the negative input (VB), the output voltage (VOUT) is changed, and VOUT can connect to chip ADC or GPIO INT to take reaction from controller.

Figure 12 shows the circuit example.

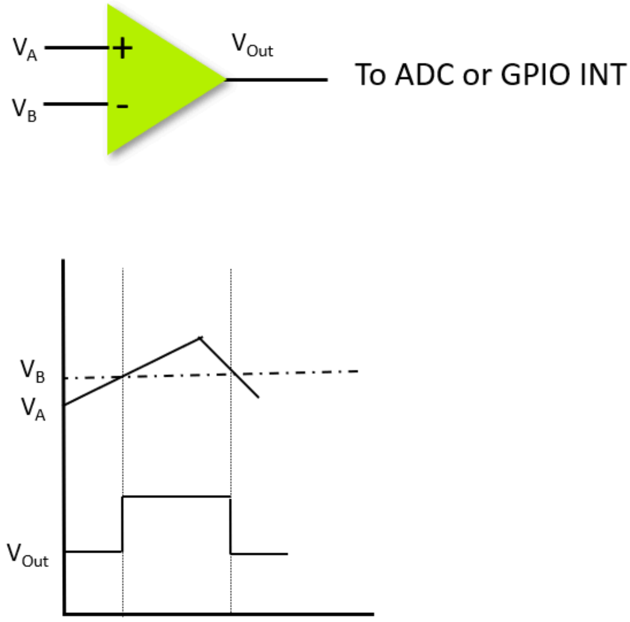


Figure 12. Analog voltage monitoring example

7.2 Pulse-width measurement

The width of a pulse can be measured using the comparator plus a timer. To implement this application, connect an external or internal reference voltage to the negative input (VB) and connect the pulse signal to the positive input (VA). When VA exceeds VB, the output becomes high and generates a rising edge on the timer input capture, triggering the timer start counting. The timer continues the counting until the output becomes low to generate a falling edge due to VA becomes less than VB. With this method, the time elapsed between the two consecutive captures represents the pulse width.

Figure 13 shows the circuit example.

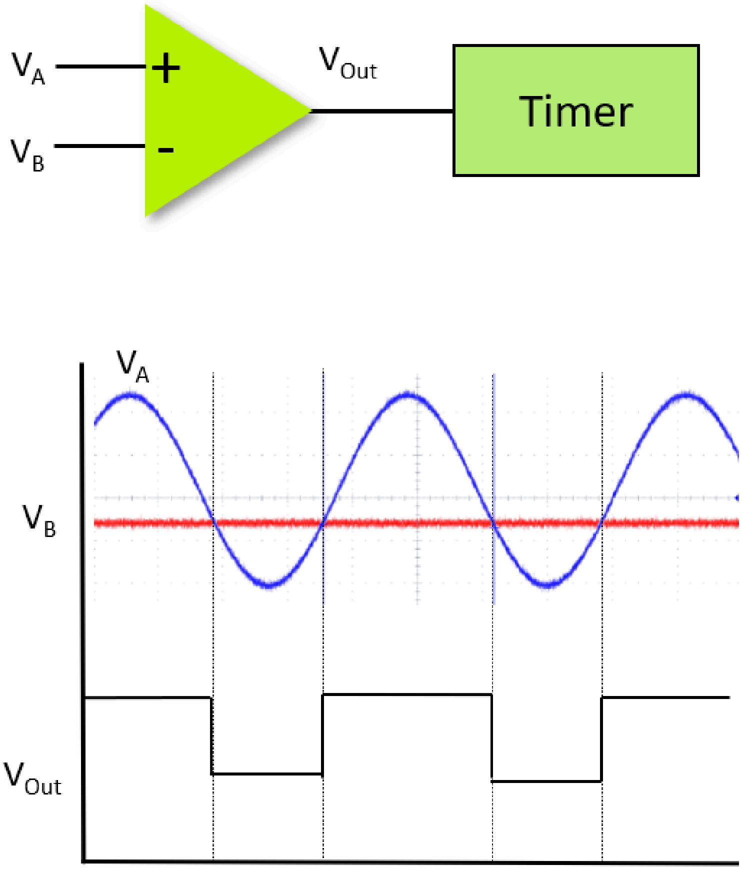


Figure 13. Pulse-Width measurement example

7.3 Using LPC86x ACMP as 5-bit ADC

When LPC86x is used in some applications which get LPC86x ADC resource limited, we can take advantage of the ACMP Voltage Ladder property and make one 5-bit ADC.

Figure 14 shows the circuit example.

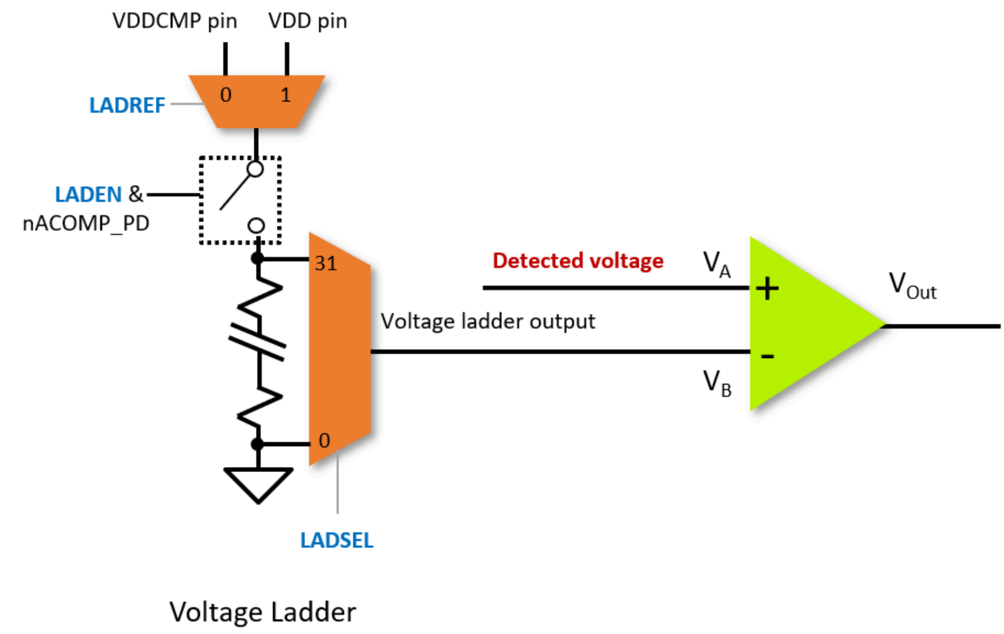


Figure 14. LPC86x ACMP work as 5-bits ADC

For example, using VDD = 3.1 V as Voltage Ladder Vref, considering voltage ladder value from 00000 to 11111, can get each step stands for 3.1 v/31 = 0.1 v. When the detected voltage equal to 0.15 v, using 11111 (3.1 v) to compare with it causes low ACMP output, and using 11110 (3.0 v) to compare with it also causes low ACMP output low. Try each step, and only using 00001 (0.1 v) to compare with it causes high ACMP output. Therefore, the detected voltage is judged between 0.1 v and 0.2 v. It makes the ACMP work as a 5-bit ADC.

Because this method uses each step to compare with detected voltage, the convert speed is limited and user can take some SW algorithm to raise the convert speed. For example, to speed up the comparison process, use the median algorithm of the software. Perform the first comparison with the middle step value of total steps, then the middle step value of the left steps, and so on.

8 Revision history

Table 2 summarizes the revisions to this document.

Table 2. Revision history

Revision number	Date	Substantive changes
0	08 May 2023	Initial release

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