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RENESAS

M16C/80 Group

Sensor's Output Impedance under A-D Conversion

1. Abstract

The following article introduces sensor's output impedance under A-D conversion.

2. Introduction

The explanation of this issue is M16C/80 Group.

3. Contents

3.1 Internal Equivalent Circuit of Analog Input

Figure 1 shows the internal equivalent circuit of analog input.

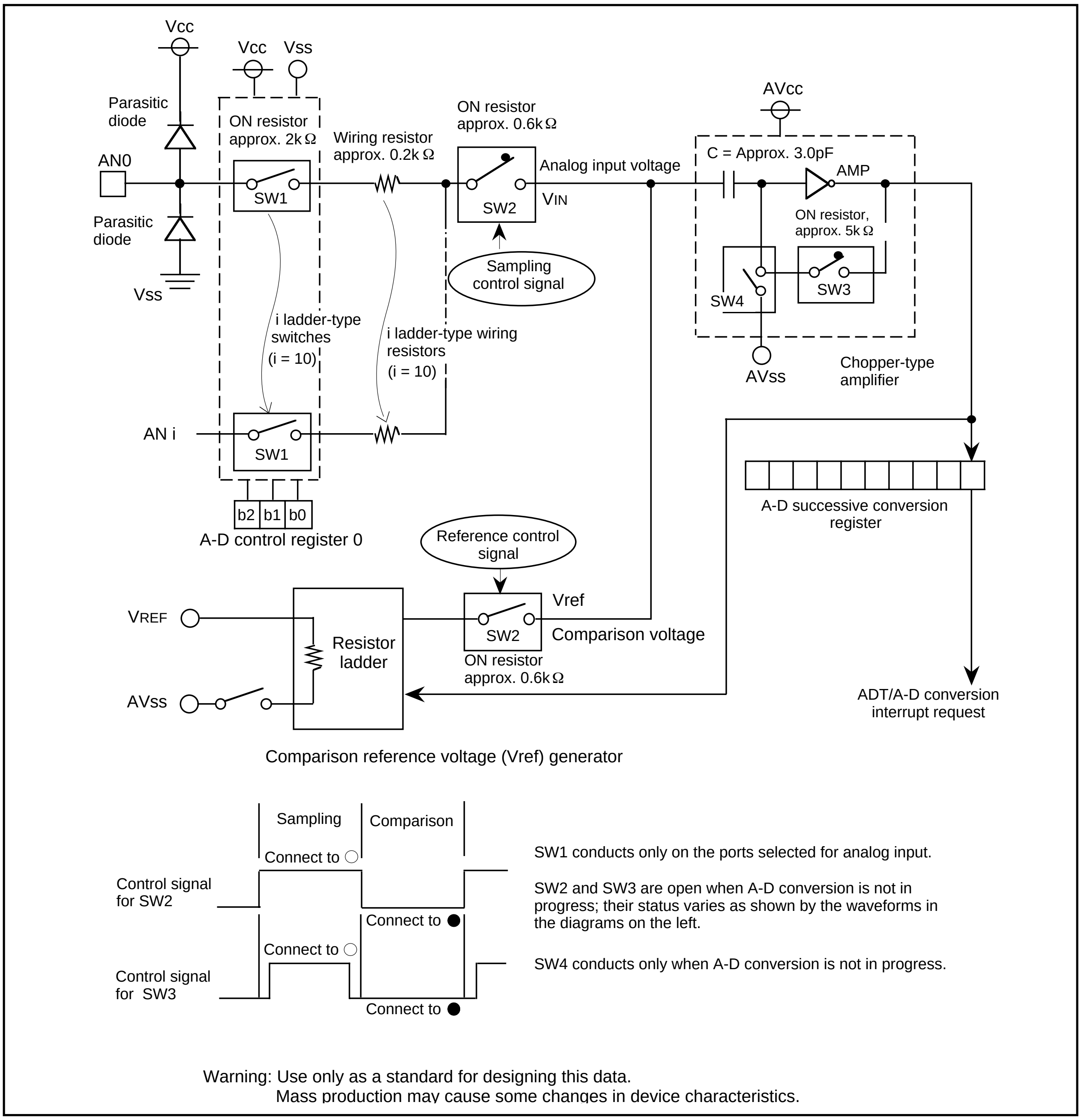

Figure 1. Internal equivalent circuit to analog input

3.2 Sensor’s Output Impedance under A-D Conversion

To carry out A-D conversion properly, charging the internal capacitor C shown in Figure 2 has to be completed within a specified period of time. With T as the specified time, time T is the time that switches SW2 and SW3 are connected to O in Figure 1. Let output impedance of sensor equivalent circuit be R0, microcomputer’s internal resistance be R, precision (error) of the A-D converter be X, and the A-D converter’s resolution be Y (Y is 1024 in the 10-bit mode, and 256 in the 8-bit mode).

Vc is generally $V_C = V_{IN}\{1 - e^{-\frac{t}{C(R0+R)}}\}$

And when t = T, $V_C = V_{IN} - \frac{X}{Y}V_{IN} = V_{IN}(1 - \frac{X}{Y})$

$$e^{-\frac{T}{C(R0+R)}} = \frac{X}{Y}$$

$$-\frac{T}{C(R0+R)} = \ln\frac{X}{Y}$$

Hence, $R0 = -\dfrac{T}{C \bullet \ln\frac{X}{Y}} - R$

With the model shown in Figure 2 as an example, when the difference between V_{IN} and V_C becomes 0.1LSB, we find impedance R0 when voltage between pins V_C changes from 0 to V_{IN}-(0.1/1024) V_{IN} in time T. (0.1/1024) means that A-D precision drop due to insufficient capacitor charge is held to 0.1LSB at time of A-D conversion in the 10-bit mode. Actual error however is the value of absolute precision added to 0.1LSB. When $f(X_{IN})$ = 10 MHz, T = 0.3 µs in the A-D conversion mode with sample & hold. Output impedance R0 for sufficiently charging capacitor C within time T is determined as follows.

T = 0.3 µs, R = 7.8 kΩ, C = 3 pF, X = 0.1, and Y = 1024 . Hence,

$$R0 = -\frac{0.3 \times 10^{-6}}{3.0 \times 10^{-12} \bullet \ln\frac{0.1}{1024}} - 7.8 \times 10^{3} \fallingdotseq 3.0 \times 10^{3}$$

Thus, the allowable output impedance of the sensor circuit capable of thoroughly driving the A-D converter turns out to be approximately 3.0 kΩ. Tables 1 and 2 show output impedance values based on the LSB values.

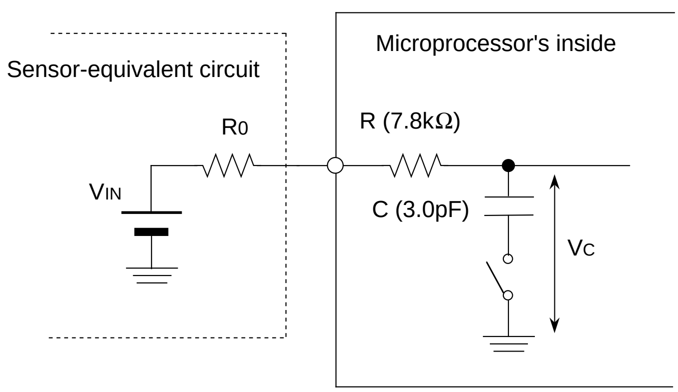

Figure 2 A circuit equivalent to the A-D conversion terminal

Table 1. Relation between output impedance and precision (error) of A-D converter (10-bit mode) Reference value

f(Xin) (MHz)	Cycle (µs)	Sampling time (µs)	R (kΩ)	C (pF)	Resolution (LSB)	R0 (kΩ)
10	0.1	0.3 (3 x cycle, Sample & hold bit is enabled)	7.8	3.0	0.1	3.0
					0.3	4.5
					0.5	5.3
					0.7	5.9
					0.9	6.4
					1.1	6.8
					1.3	7.2
					1.5	7.5
					1.7	7.8
					1.9	8.1
10	0.1	0.2 (2 x cycle, Sample & hold bit is disabled)	7.8	3.0	0.3	0.4
					0.5	0.9
					0.7	1.3
					0.9	1.7
					1.1	2.0
					1.3	2.2
					1.5	2.4
					1.7	2.6
					1.9	2.8

Table 2. Relation between output impedance and precision (error) of A-D converter (8-bit mode) Reference value

f(Xin) (MHz)	Cycle (µs)	Sampling time (µs)	R (kΩ)	C (pF)	Resolution (LSB)	R0 (kΩ)
10	0.1	0.3 (3 x cycle, Sample & hold bit is enabled)	7.8	3.0	0.1	4.9
					0.3	7.0
					0.5	8.2
					0.7	9.1
					0.9	9.9
					1.1	10.5
					1.3	11.1
					1.5	11.7
					1.7	12.1
					1.9	12.6
10	0.1	0.2 (2 x cycle, Sample & hold bit is disabled)	7.8	3.0	0.1	0.7
					0.3	2.1
					0.5	2.9
					0.7	3.5
					0.9	4.0
					1.1	4.4
					1.3	4.8
					1.5	5.2
					1.7	5.5
					1.9	5.8

REVISION HISTORY

Rev.	Date	Description	
		Page	Summary
1.00	Feb, 12, 2004	-	First edition issued

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