LAPIS SEMICONDUCTOR

SQ003116E005

ML610Q400 Series

Sample Program AP Notes

For
Barometer Application

2nd Edition
Issue Date: April 16, 2010

Table of Contents

1. Overview

This document describes the application programming notes (hereafter called the AP notes) arranged to help customers develop software that, by using the Successive Approximation Type AD Converter, which is hardware that the ML610Q400 Series MCU (hereafter called the MCU) has, performs air pressure measurement as the barometer.

APIs are provided for each function module. The AP notes describe the functions and operating conditions of each API and samples of use of those APIs.

In connection with the AP notes, a sample program is provided that actually operates using APIs on ML610Q400 Series Demo Kit.

◆ Related Documents
The following are the related documents. Read them as required.

- ML610Q400 Series Sample Program AP Notes For Sensor/Mesurement Application
- ML610Q400 Series Sample Program API Manual
- ML610Q431/ML610Q432 User's Manual
- ML610Q435/ML610Q436 User's Manual
- ML610Q411/ML610Q412/ML610Q415 User's Manual
- ML610Q421/ML610Q422 User's Manual
- ML610Q482 User's Manual
- ML610Q400 Series Demo kit Hardware User's Manual
- nX-U8/100 Core Instruction Manual
- MACU8 Assembler Package User's Manual
- CCU8 User's Manual
- CCU8 Programming Guide
- CCU8 Language Reference
- DTU8 User's Manual
- IDEU8 User's Manual
- uEASE User's Manual
- uEASE Connection Manual ML610Qxxx
- FWuEASE Flash Writer Host Program User's Manual
- LCD Image Tool User's Manual

2. System Configuration

2.1. Hardware Configuration

The following figure shows the hardware configuration on which the sample software runs.

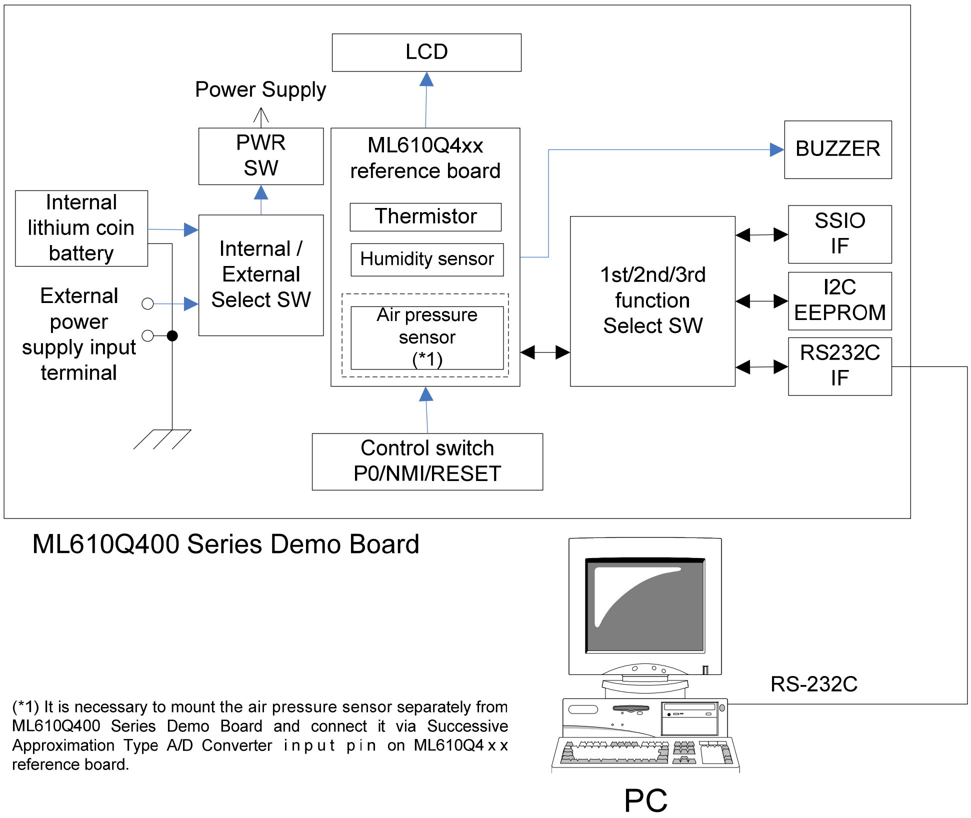


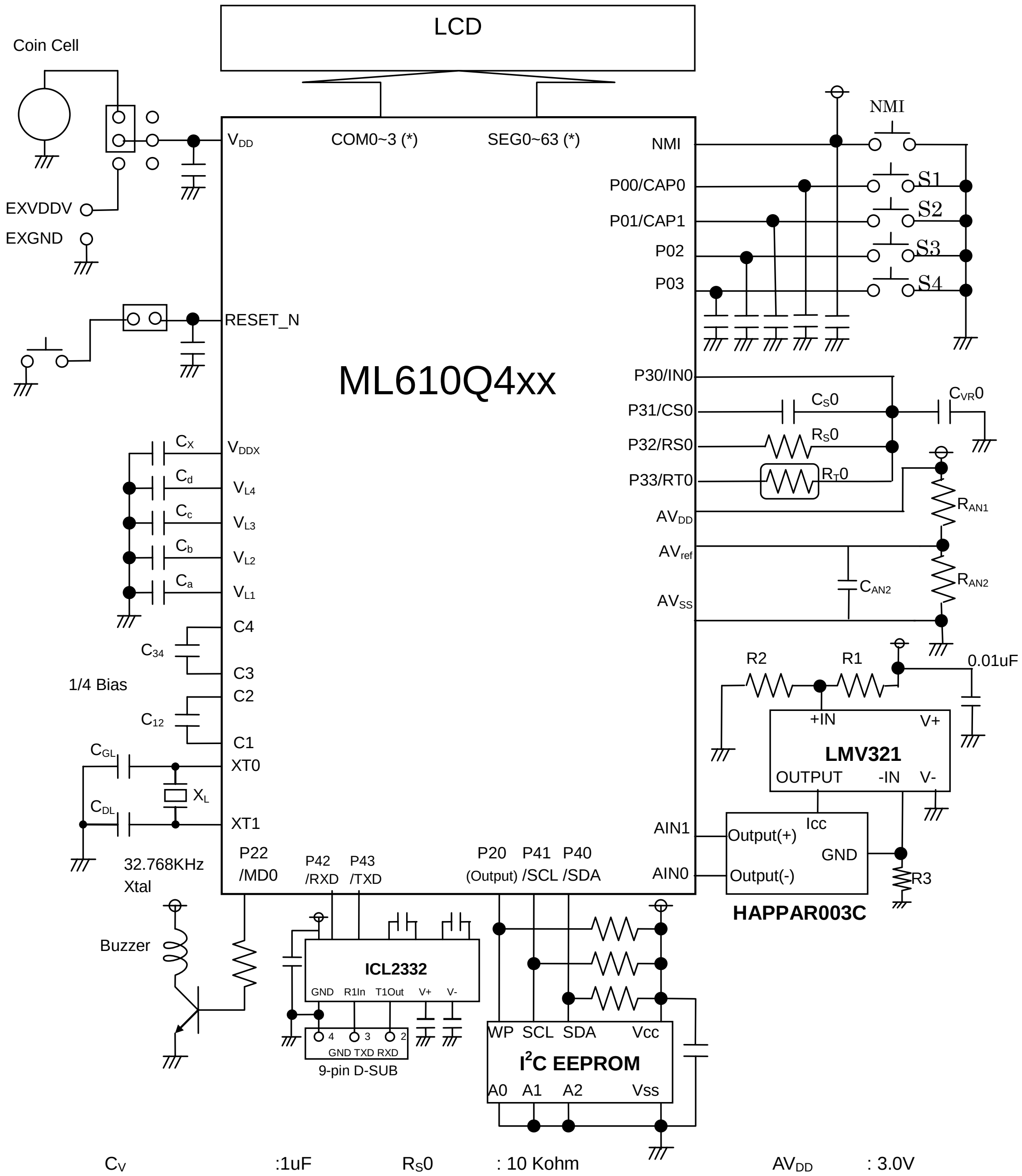
Figure 2-1 Hardware Configuration

In the above hardware configuration, the peripheral parts which are necessary for running the sample software are shown below.

Peripheral parts	The number of peripheral parts	Descriptions
Control switch	4	The switch S1, S2, S3 and S4 are used to change mode or control the application.
Thermistor	1	It is used for the temperature measurement by using RC-ADC.
Air pressure sensor	1	It is used for the air pressure measurement by using SA-ADC.
EEPROM	1	It saves the measured air pressure data.
LCD panel	1	It displays the mode and result of operation.
RS-232C interface	1	It is used for data communication with PC. The communication condition is as follows. Baud rate : 9600bps, Data : 8bit, Parity bit : none, Stop bit : 1 bit

2.2. Peripheral Circuit Diagram

The circuit of MCU circumference is connected as shown in the following figures. (Please be careful that it is different from the default connection on the reference board of ML610Q431 attached to ML610Q400 Series Demo Kit.) Please see "3.1.2.2 Range of A/D Conversion" about the details of the composition of the reference voltage (AVref) terminal portion of SA-ADC. In order to use the output of an air pressure sensor in the differential amplification input of SA-ADC, both AIN0 pin and AIN1 pin are connected to an air pressure sensor. Please see "3.1.2.1.3 Peripheral Circuit Composition of Sensor" about the circuit composition of the air pressure sensor circumference.

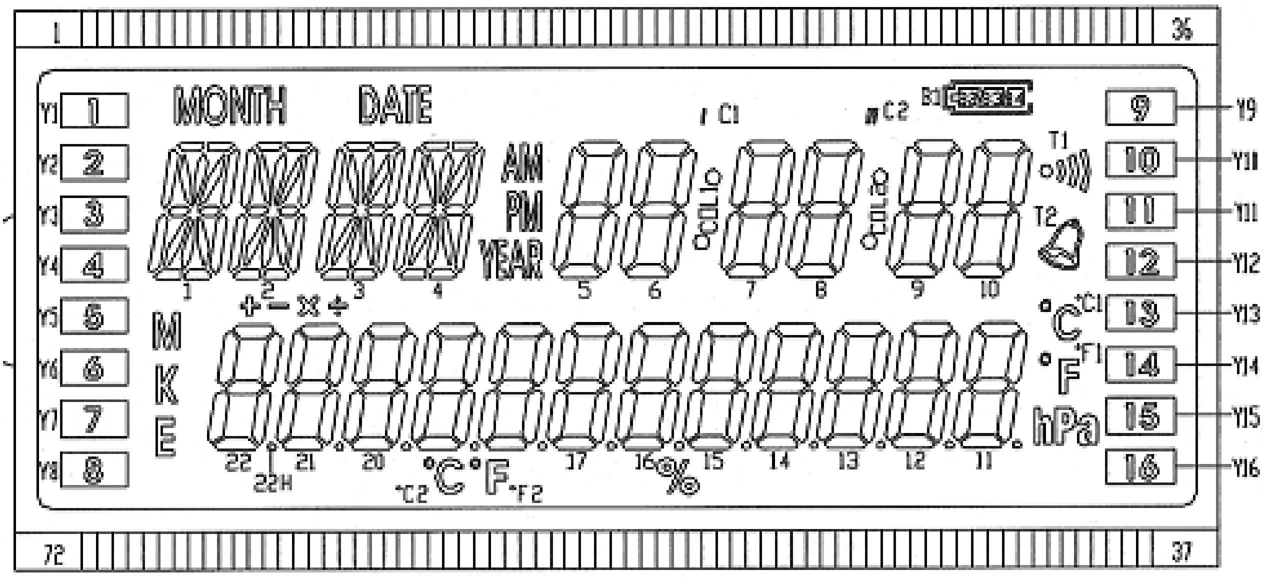


C_V	:1uF	R_S0	: 10 Kohm	AV_{DD}	: 3.0V
C_{L0}	:1uF	C_S0	: 560 pF	V_{ref}	: 2.3V
C_{L1}	:0.1uF	$C_{VR}0$	: 820 pF		
C_1	:1uF	R_T0	: 103AT (Semitec) thermister	R_{AN1}	: 10 Kohm
C_X	:0.1uF			R_{AN2}	: 33 Kohm
Ca,Cb,Cc,Cd	:1uF			C_{AN2}	: 100 uF
C_{12},C_{34}	:1uF			R1	: 15 Kohm
C_{GL}	: No (0 pF)			R2	: 1 Kohm
C_{DL}	: No (0 pF)			R3	: 470 ohm

Figure 2-2 Peripheral Circuit Diagram

(*) The number of COM/SEG pin that can be connected to LCD panel depends on the type of the LCD driver built into the MCU. Please see the chapter "LCD Driver" of the User's Manual for your target MCU.

2.3. LCD Panel Specifications



16-segment characters:	The 4 digits on the upper part of the panel
7-segment characters:	The 6 digits on the upper part of the panel
8-segment characters:	The 12 digits on the lower part of the panel
Marks for hand-held calculator:	7
Other marks:	32

Figure 2-3 Layout of the LCD Panel

Table 2-1 Pin Assignments (COM/SEG)

PIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
COM1				COM1	Y1	1H	1A	1B	1C	MONTH	2H	2A	2B	2C	3H	3A	3B	3C	4H	4A	4B	4C	AM	5F
COM2			COM2		Y2	1I	1J	1K	1L	DATE	2I	2J	2K	2L	3I	3J	3K	3L	4I	4J	4K	4L	PM	5G
COM3		COM3			Y3	1P	1O	1N	1M		2P	2O	2N	2M	3P	3O	3N	3M	4P	4O	4N	4M	YEAR	5E
COM4	COM4				Y4	1G	1F	1E	1D		2G	2F	2E	2D	3G	3F	3E	3D	4G	4F	4E	4D		5D
PIN	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
COM1	5A	6F	6A	7F	7A	8F	8A	9F	9A	10F	10A	B3		Y9	Y13	T2	11A	11F	12A	12F	13A	13F	14A	14F
COM2	5B	6G	6B	7G	7B	8G	8B	9G	9B	10G	10B	B4		Y10	Y14	°C1	11B	11G	12B	12G	13B	13G	14B	14G
COM3	5C	6E	6C	7E	7C	8E	8C	9E	9C	10E	10C	B2		Y11	Y15	°F1	11C	11E	12C	12E	13C	13E	14C	14E
COM4		6D	COL1	7D	C1	8D	COL2	9D	C2	10D	T1	B1		Y12	Y16	hpa	11H	11D	12H	12D	13H	13D	14H	14D
PIN	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
COM1	15A	15F	16A	16F	17A	17F	18A	18F		19A	19F	20A	20F	21A	21F	22A	22F	÷	M	Y5				COM1
COM2	15B	15G	16B	16G	17B	17G	18B	18G	%	19B	19G	20B	20G	21B	21G	22B	22G	×	K	Y6			COM2	
COM3	15C	15E	16C	16E	17C	17E	18C	18E	°F2	19C	19E	20C	20E	21C	21E	22C	22E	−	E	Y7		COM3		
COM4	15H	15D	16H	16D	17H	17D	18H	18D	°C2	19H	19D	20H	20D	21H	21D	22H	22D	+		Y8	COM4			

Specifications of Operation

Clock for bias generation circuit voltage multiplication:	1/16 LSCLK (2 kHz)
Bias of the bias generation circuit:	1/4
Duty:	1/4 duty
Frame frequency:	73 Hz

2.4. Software Configuration

Figure 2-4 shows the software configuration.

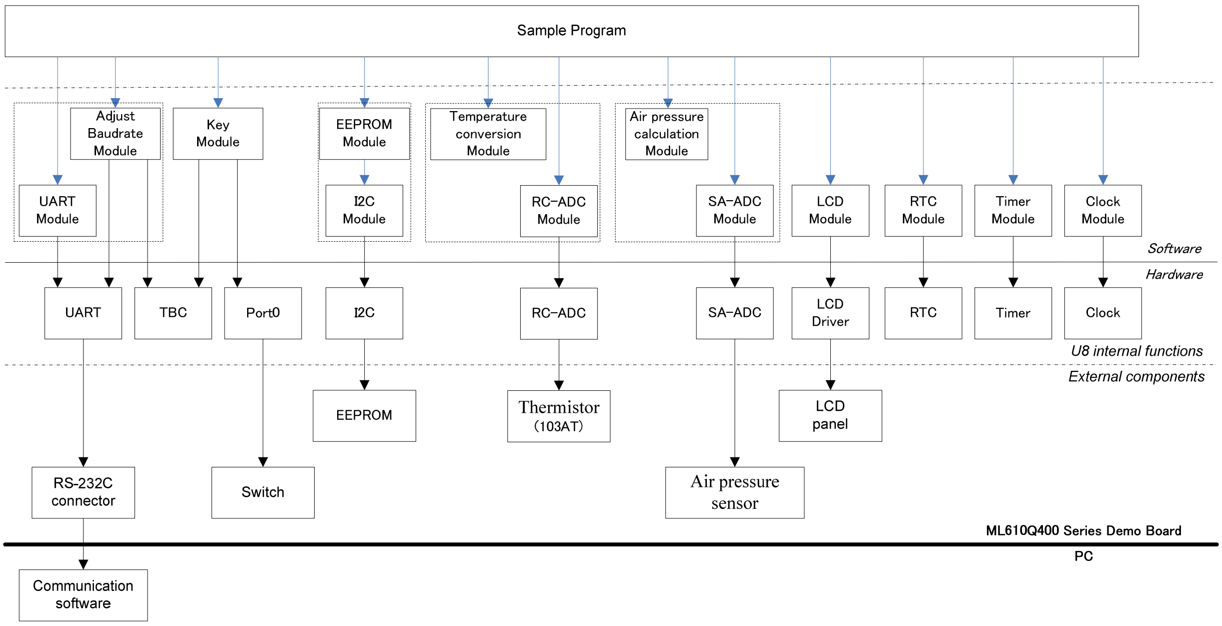


Figure 2-4 Software Configuration

2.5. List of Folders and Files

The folders and the files are as listed below.

```
[baro]
├ [_output]                    … Build result output folder
│ ├ [_hex]
│ ├ [_lst]
│ ├ [_obj]
│ └ [_prn]
├ [adjustBaudrate]             … UART baud rate correction module folder
│ ├ adjustBaudrate.c
│ └ adjustBaudrate.h
├ [barometer]                  … Pressure calculation module folder
│ ├ baro.c
│ └ baro.h
├ [bld]                        … BLD control module folder
│ ├ bld.h
│ └ bld_chk.c
├ [clock]                      … Clock control module folder
│ ├ clock.c
│ ├ clock.h
│ ├ clock_sysFunc.c
│ └ clock_sysFunc.h
├ [common]                     … General-purpose function module folder
│ ├ common.c
│ └ common.h
├ [eeprom]                     … EEPROM control module folder
│ ├ eeprom.c
│ └ eeprom.h
├ [i2c]                        … I2C communication control module folder
│ ├ i2c.c
│ └ i2c.h
├ [irq]                        … Interrupt control module folder
│ ├ irq.c
│ └ irq.h
├ [key]                        … Key input control module folder
│ ├ key.c
│ └ key.h
├ [lcd]                        … LCD display control module folder
│ ├ LCD.c
│ ├ LCD.h
│ ├ U8_Sample.tac
│ └ U8_Sample.tbc
├ [main]                       … Sample program main folder
│ ├ mcu_large
│ │ └ mcu.h
│ ├ mcu_small
│ │ └ mcu.h
│ ├ eepromMap.h
│ ├ main.BAK
│ ├ main.c
│ ├ main.h
│ ├ S610431SW.asm
│ └ S610435LW.asm
│
```

[continued from the previous page]

```
├ [rcAdc]                    … RC-ADC control module folder
│ ├ rcAdc.c
│ └ rcAdc.h
├ [rtc]                      … Real-time clock control module folder
│ ├ rtc.c
│ └ rtc.h
├ [saAdc]                    … SA-ADC control module folder
│ ├ saAdc.c
│ └ saAdc.h
├ [tbc]                      … Time base counter control module folder
│ ├ tbc.c
│ └ tbc.h
├ [temp]                     … Temperature calculation module folder
│ ├ temp.c
│ └ temp.h
├ [timer]                    … Timer control module folder
│ ├ timer.c
│ └ timer.h
├ [uart]                     … UART communication control module folder
│ ├ uart.c
│ └ uart.h
├ readme.txt                 … Description of compile options
├ S16_div10_and_mod.asm      … Sample program assembler code (Div10)
├ U8_Baro_Sample_Large.PID  … Project file for large model MCU
└ U8_Baro_Sample_Small.PID  … Project file for samll model MCU
```

2.6. Build Procedure

① Start IDEU8, select the menu “Open” and open the project file (PID file). In the case that MCU memory model is small model, the project file is “U8_Baro_Sample_Small.PID”. In the case of large model, the project file is “U8_Baro_Sample_Large.PID”. Correspondence of MCU and PID file is shown below.

Table 2-2 Correspondence of MCU and PID file

	U8_Baro_Sample_Small.PID	U8_Baro_Sample_Large.PID
Supported MCU	ML610Q431/432	ML610Q435/436

② In the default setting, ML610Q431 is set as the target MCU.
If your target MCU is different, follow the procedure below to change the setting.

(1) Select the menu “Project” -> “Options” -> “Compiler/assembler”.

(2) In the displayed window, select the target MCU from the “Target microcontroller” list in the “General” tab. Also, modify the following option in the “Additional options” field in the “Assembler control” group.
    /DEFTARGET=TYPE(M6104XX)
    About the “XX” part, replace with the type number of MCU
    For example, if ML610Q432 is used, input the following option.
    /DEFTARGET=TYPE(M610432)

(3) Remove the startup file “S610431SW.asm“ registered in the file tree of IDEU8. Instead of that, register your target MCU’s startup file. (In the case of ML610Q432, it is S610432SW.asm.)

(4) Define the macro that represents the target MCU.
    Select the menu “Project” -> “Options” -> “Compiler/assembler” -> ”Macro”tab. In the displayed window, define the macro like following name.
    _ML610Q4XX
    About the “XX” part, replace with the type number of MCU
    For example, if ML610Q432 is used, define the following macro.
    _ML610Q432
    In the case that the macro other than the type number in the above Table 2-2 is defined, the case that macro such as above is not defined, or the case that the memory model that is supported by PID file is different from the memory model of MCU that is defined by the above macro, the compiler issues the following error at the beginning of the output messages.
    Error : E2000 : #error : “Unknown target MCU”

(5) If necessary, modify other macro definitions.
    About the available macro definitions, see the “readme.txt” in the sample program folder.
    - For ML610Q43X series MCU
    LCD_TYPE = 1
    FREQ_TIMER_MODE = 0
    _RTC_TYPE
    _SAADC_REG

③ Select the menu “Project” -> “Rebuild”. Then the build procssing for the sample program starts.

④ When the build processing is completed, .abs file is generated in the project folder and .hex file is generated in _output¥_hex folder.

2.7. Restrictions

2.7.1. About Available Functional Modules

In the functional modules that compose this sample program, the available functional modules are different by target MCU, due to the difference of MCU peripherals. In the case that these functional modules are applied to user application, available functional modules on each MCU are shown below.

Table 2-3 List of available functional modules

			Supported MCU			
			ML610Q43X	ML610Q42X	ML610Q41X	ML610Q48X
Functional modules	SA-ADC Control Module *4		○	○ *2	○ *2	×
	Pressure Calculation Module		○	○	○	○
	RC-ADC Control Module *4		○	○	○	○
	Temperature Calculation Module *4		○	○	○	○
	UART Communication Control Module *4		○	○	○	○
	UART Baud Rate Correction Module *4		○	○	○	○
	Frequency measurement mode *4		×	○	○ *1	○
	I2C Communication Control Module *4		○	○	○	○
	EEPROM Control Module *4		○	○	○	○
	LCD Display Control Module *4		○	○ *3	○ *3	×
	Key Input Control Module *4		○	○	○	○
	RTC Control Module *5	Hardware RTC	○	×	×	×
		Software RTC	○	○	○	○
	Timer Control Module *4		○	○	○	○
	Clock Control Module *4		○	○	○	○
	Time Base Counter Control Module *4		○	○	○	○
	BLD Control Module *4		○	○	○	○

○ : Available
× : Not available

*1: Frequency measurement mode by hardware is not available on ML610Q415 because it does not have low-speed crystal oscillation clock.
*2: Function that uses the differential amplification input or the selection of amplifier gain and offset is not available.
*3: All display area of LCD panel can not be available, because the number of SEG pin that is connected to LCD panel is not enough.
*4: For the details of these modules, please see the “ML610Q400 Series Sample Program AP Notes For Sensor/Mesurement Application”.
*5: For the details of these modules, please see the “ML610Q400 Series Sample Program AP Notes For RTC Application”.

2.7.2. About Functions of Sample Program

This sample program is available on only ML610Q43X series MCU.

Note: This sample program is not available on ML610Q42X and ML610Q41X series MCU, because SA-ADC does not support the differential amplification input and the selection of amplifier gain and offset, which are required for operating the application. Also this sample program is not available on ML610Q48X series MCU, because it does not have SA-ADC.

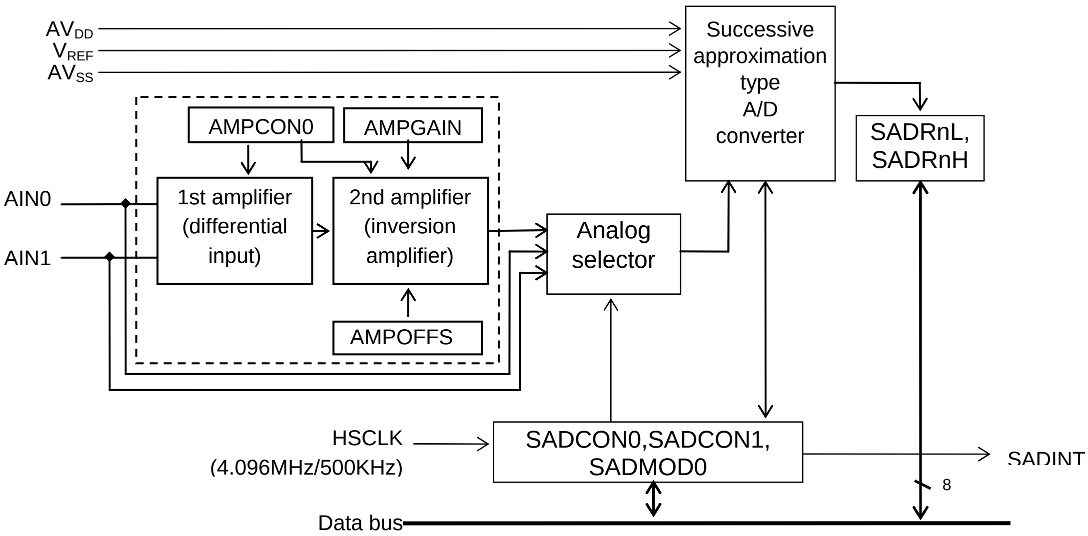
3. Description of Functional Modules

3.1. Air Pressure Calculation Module

3.1.1. Built-in A/D Converter

3.1.1.1. Configuration of SA-ADC

This MCU has a 2-channel successive approximation type A/D converter (SA-ADC) with a built-in sample & hold. This SA-ADC consists of two stages, the first one being the first amplifier that supports differential amplification input and the second one being the second amplifier that allows gain and offset adjustment. By combining these two amplifiers, various analog input values can be measured. In addition, by short-circuiting between input pins at the time of differential amplification input, the offset value of the amplifiers can be measured.



SADR0L:	SA-ADC result register 0L
SADR0H:	SA-ADC result register 0H
SADR1L:	SA-ADC result register 1L
SADR1H:	SA-ADC result register 1H
SADCON0:	SA-ADC control register 0
SADCON1:	SA-ADC control register 1
SADMOD0:	SA-ADC mode register 0
AMPOFFS:	Amplifier offset register
AMPGAIN:	Amplifier gain register
AMPCON0:	Amplifier control register 0

Figure 3-1 Configuration of SA-ADC

Table 3-1 List of Pins

Pin name	I/O	Description
AV_{DD}	—	Positive power supply pin for successive approximation type A/D converter
V_{REF}	—	Reference power supply pin for successive approximation type A/D converter
AV_{SS}	—	Negative power supply pin for successive approximation type A/D converter
AIN0	I	Successive approximation type A/D converter input pin 0
AIN1	I	Successive approximation type A/D converter input pin 1

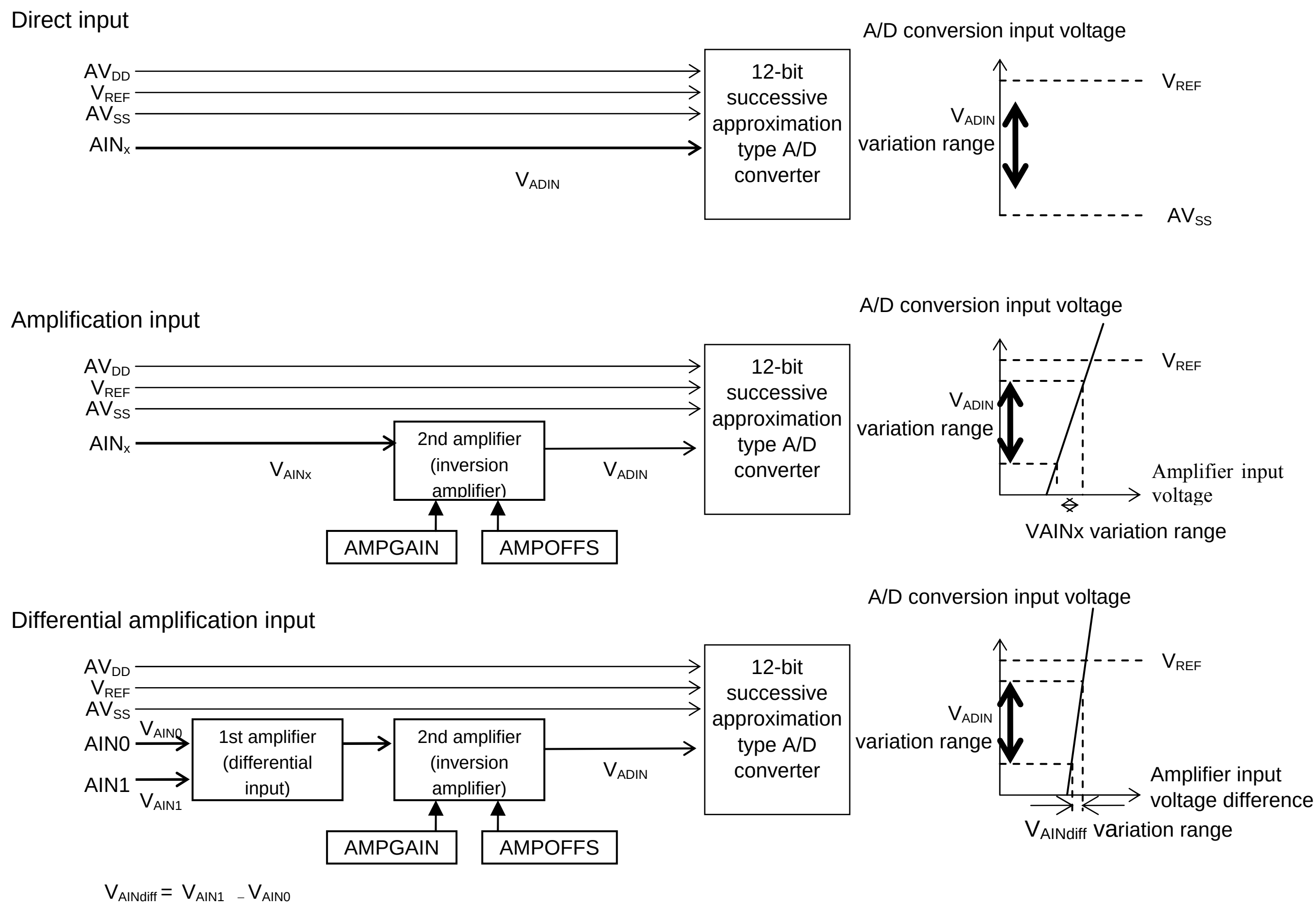


Figure 3-2 Amplifier Configurations

* For details, refer to the chapter "Successive Approximation Type A/D Converter (SA-ADC)" of the User's Manual for your target MCU.

3.1.1.2. Input voltage for A/D converter in differential amplification input setting

The following equation 3.1.1.2-1 shows the theoretical equation for the output voltage from the second amplifier of SA-ADC in differential amplification inupt setting.

$$V_{ADIN} = ((AIN1–AIN0) \times AmpGain\_1st – Ratio\_AmpOffset \times AV_{DD}) \times AmpGain\_2nd \times (–1) + (1/2 + Ratio\_AmpOffset) \times AV_{DD} \qquad \text{... (3.1.1.2-1)}$$

V_{ADIN}	: Input voltage to A/D converter. That is, the output voltage from the second amplifier.
AIN1–AIN0	: Voltage difference between two input pins (AIN1 and AIN0).
AmpGain_1st	: Gain of the first amplifier. It is fixed to 3 times.
AmpGain_2nd×(-1)	: Gain of the second amplifier. It is selected by AMPGAIN register. The multiplication of (-1) is due to the inversion amplifier.
Ratio_AmpOffset	: Amount of the input offset of the second amplifier [%]. It is selected by AMPOFFS register.

Example for calculating the input voltage to A/D converter (V_{ADIN}) is shown below.

Conditions:

- ■ AV_{DD} is 3V.
- ■ Gain of the second amplifier is 1.
- ■ Amount of the input offset of the second amplifier is 6 %.
- ■ Voltage difference between two input pins is -0.3V.

$$\begin{aligned} V_{ADIN} &= ((-0.3) \times 3 – 0.06 \times 3) \times 1 \times (–1) + (1/2 + 0.06) \times 3 \\ &= -(-0.9-0.18) + 1.68 \\ &= 0.6[V] \end{aligned}$$

3.1.2. Measurement by Air Pressure Sensor

To measure air pressure, the sample program introduces the air pressure sensor using effect of piezo resistive bridge circuit. The value of air pressure is calculated from the voltage difference between two output pin of the sensor. To perform A/D conversion of the voltage difference as the analog input signal, use SA-ADC in differential amplification input setting.
This AP note describes how to mesure air pressure from the actual output of the sensor which is obtained by the differential amplification input setting.

3.1.2.1. Operating Conditions

This section describes the operating condition, valid range and restrictions for the air pressure measurement.

3.1.2.1.1. Hardware

The following shows the operating conditions of hardware (MCU and air pressure sensor).

- ■ Power supply : 3V
- ■ Vref : 2.3V (describe later.)
- ■ AVss : 0V (=GND)

Characteristics of the air pressure sensor is shown in Table

- ■ Manufacturer : 3V
- ■ Product number : HSPPAR003C
- ■ Classify of Pressure : Absolute

Table 3-2 Characteristics of air pressure sensor

Item	Unit	Driving current 0.55mA	Driving current 0.4mA
Range of measurement pressure	kPa	50.0 ~ 110.0	
Operating temperature	ºC	-20 ~ 85	
Bridge Resistance (Max.)	Ω	7000	
Bridge Resistance (Min.)	Ω	5000	
Driving Voltage (Max.)	V	3.85	2.8
Driving Voltage (Min.)	V	2.75	2.0
Full Span Output	mV	44	32
Output Voltage(110kPa)	mV	79	57.454545
Output Voltage(50kPa)	mV	35	25.45331
Output Voltage(101.3kPa)*	mV	(72.6)	(52.8)

* The data at 101.3kPa is a reference value.

- ■ Driving current : 0.4mA

The official driving voltage of the sensor is from 3.85V to 2.75V. Because the sample program assumes that the sensor is drived by dry cell battery, it is designed so that the sensor is drived within 3V by reducing the driving current to 0.4mA. In this case, the output voltage becomes 1/1.375. (0.55/0.4 = 1.375)

3.1.2.1.2.Software

The following shows the operating conditions of software (application).

- Range of measurement pressure : 500hPa ~ 1100hPa (It is the same as the air pressure sensor.)
- Unit of the pressure displayed on LCD : 1hPa
- Operating temperature : -10 ºC ~ 40ºC
- Aaccuracy : ±(pressure difference × 1% + 3)hPa (-10 ºC ~ 40ºC, 500hPa ~ 1100hPa)
  ±(pressure difference × 1% + 6.138)hPa (-10 ºC ~ 5ºC, lower than 784hPa)

3.1.2.1.3.Peripheral Circuit Composition of Sensor

Figure 3-3 shows the circuit diagram for air pressure measurement. Because the manufacturer recommends using a constant current for the sensor driving current, the constant current circuit is connected to the sensor.

* The driving voltage of the sensor must be lower than the maximum output voltage of the operational amplifier which is used for the constant current circuit. In the case that the power supply for the operational amplifier is the same as the power supply for MCU (=3V), please be careful that the value of "(R3 + 7000Ω) × driving current" in Figure 3-3 must be lower than 3V.

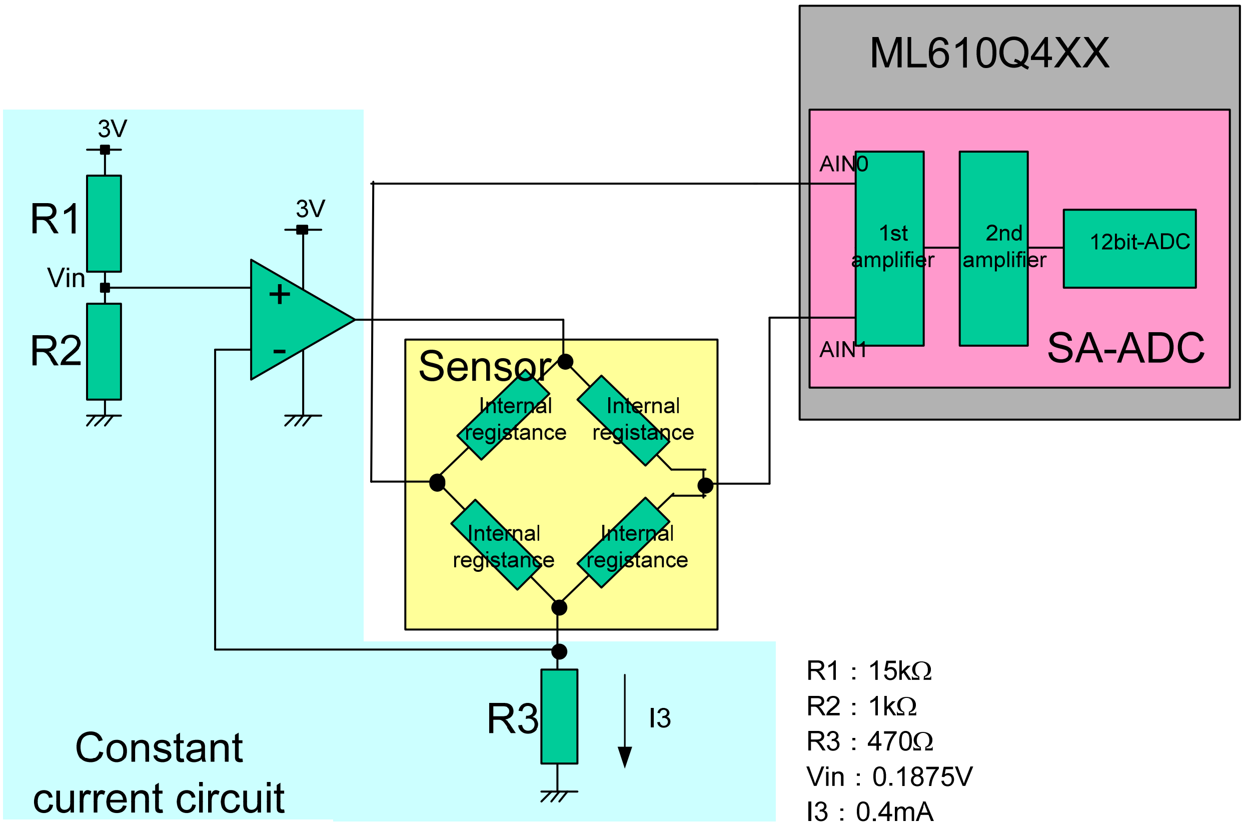
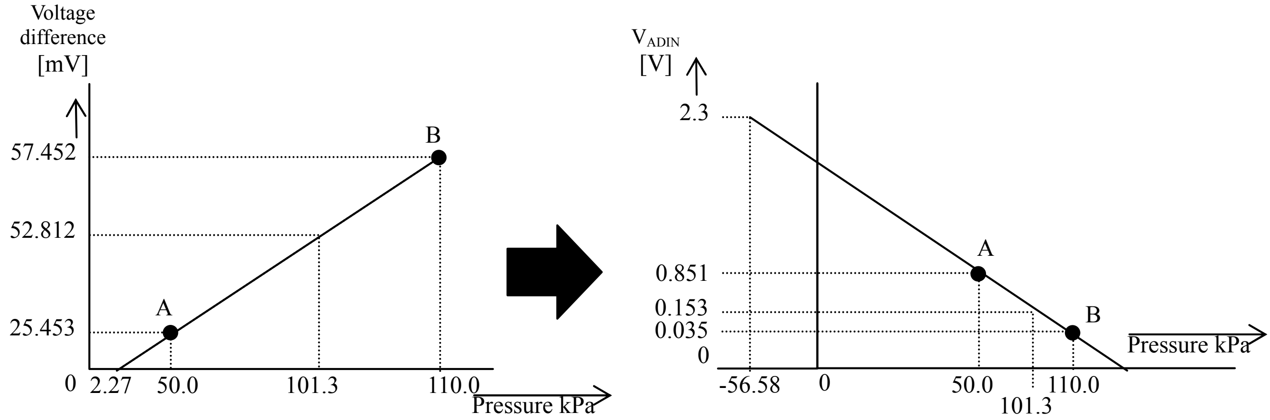


Figure 3-3 Circuit diagram for air pressure measurement

3.1.2.2. Range of A/D Conversion

According to Table 3-2, the output voltage difference of the air pressure sensor in 50kPa and 100kPa can be obtained. By using the equation (3.1.1.2-1) in the section 3.1.1.2, the input voltage to A/D converter can be calculated and the result is shown in Table 3-3.



[Pressure - Voltage difference] characteristics

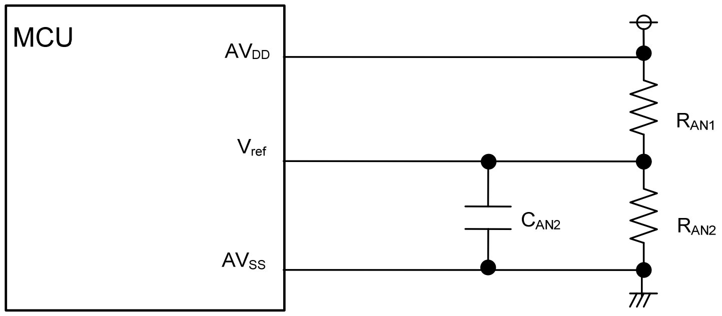
[Pressure - A/D input voltage] characteristics

Table 3-3 Characteristics of air pressure sensor

Pressure (kPa)	Sensor output voltage difference (mV)	Input voltage to A/D converter (V)
50	25.45331	0.850941
101.3	52.81207	0.153292
110	57.45185	0.034978
(2.27)*	0	--

* The pressure when the sensor output voltage difference is 0mV is a reference value.

Because the range of the input voltage is from 0.851 to 0.03V, which corresponds to the air pressure measurement range from 50kPa to 110kPa, it is desirable that the voltage of Vref is set to the same voltage as one at 110kPa (=0.851V). But, Vref must be higher than 2.2V, due to the electrical characteristic of SA-ADC in MCU. Therefore, in the sample program, Vref is set to approximately 2.3V by dividing AV_{DD} with the resistor of 10kΩ and 33kΩ. Also, the capacitor of 100µF is connected in order to prevent Vref from dropping, caused by current draining into Vref pin when SA-ADC measurement starts.



AV_{DD}	:3.0V
V_{ref}	:2.3V
R_{AN1}	: 10kΩ
R_{AN2}	: 33kΩ
C_{AN2}	: 100uF

* About the electrical characteristics of SA-ADC, refer to the chapter “Electrical Characteristics” of the User’s Manual for your target MCU.

3.1.2.3. Air Pressure Calculation

To calculate the air pressure, in advance define Pressure - AD value characteristic, which is based on Pressure - Voltage difference characteristic which is shown in the section 3.1.2.2. The air pressure is calculated by this characteristic and A/D conversion result.

If we define the values of voltage difference when AD values are 0 and 4095 as Vdiff_0 and Vdiff_4095 respectively, they are calculated as follows, assuming that the offset of the amplifier is 0.

Vdiff_0 $= (0\text{mV} - 1/2AV_{DD}) / (-25.5) = 58.823529$ mV

Vdiff_4095 $= (2300\text{mV} - 1/2AV_{DD}) / (-25.5) = -31.372549$ mV

From this result, A/D resolution is

(58.823529 - (-31.372549))/4095 = 90.196/4095 = 0.022mV/LSB

When the input voltage of A/D converter is $1/2AV_{DD}$ (=1.5V), AD value is calculated as follows.

$1.5 \times (2.3 / 4095) = 2670.652$

$2670 \times (2.3 / 4095) = 1.499634$, 1.499634 - 1.5= -0.000366

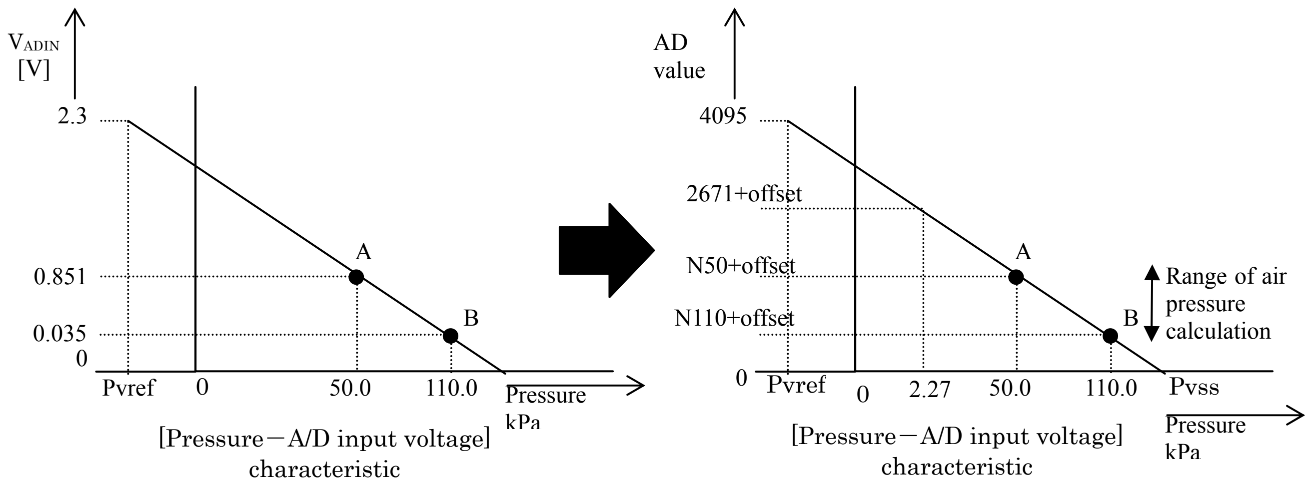
$2671 \times (2.3 / 4095) = 1.500195$, 1.500195 - 1.5= 0.000195

Because 2671 is the nearest AD value to 1.5V, $1/2AV_{DD}$ is defined as 1.500195 in the sample program. At this time the offset of AD value is set so that the voltage difference becomes 0 in Pressure - Voltage difference characteristic.

The offset of AD value is calculated as follows.

(Offset of AD value) = 2671 - 4095 = -1424

In the sample program, in order to enable a fine adjustment of the range of A/D conversion, the start position of the air pressure calculation can be adjusted in units of 0.022mV by adjusting the offset of AD value.



[Pressure－A/D input voltage] characteristic

[Pressure－A/D input voltage] characteristic

N50: AD value at 50.0kPa
N110: AD value at 110.0kPa
Pvss: Pressure at $V_{ADIN}=0$
Pvref: Pressure at V_{ADIN}=Vref

Note: Because the second amplifier of SA-ADC in MCU is the inversion amplifier, AD value decreases when the input voltage increases.

When the value of AD value is n, the equation which directly calculates air pressure from Pressure - AD value characteristic is as follows.

$$\text{Press\_n} = \text{Press\_Min} + \text{Slope} \times \text{V\_n} \quad \ldots (3.1.2.3\text{-}1)$$

Press_n : Calculated air pressure

Press_Min : Minimum pressure of Pressure - Voltage difference characteristic = 2.272876 kPa

Slope : Slope (sensitivity) of Pressure - Voltage difference characteristic = (110kPa - 50kPa) / (57.452mV - 25.453mV)

V_n : Voltage difference which is converted from A/D to = $(90.196\text{mV} / 4095) \times n$

In the sample program, in order to reduce the error in calculation of air pressure, the range of air pressure measurement (50kPa ~ 110kPa) is divided and the calculation parameters for each divided range is saved in ROM table. If the air pressure sensor is changed, please change also this calculation table to match with the sensor's characteristics.

In the air pressure calculation, in order to calculate real number as integer, a significant figure of each operand in the above equation is adjusted, that is, shifted N bit to left.

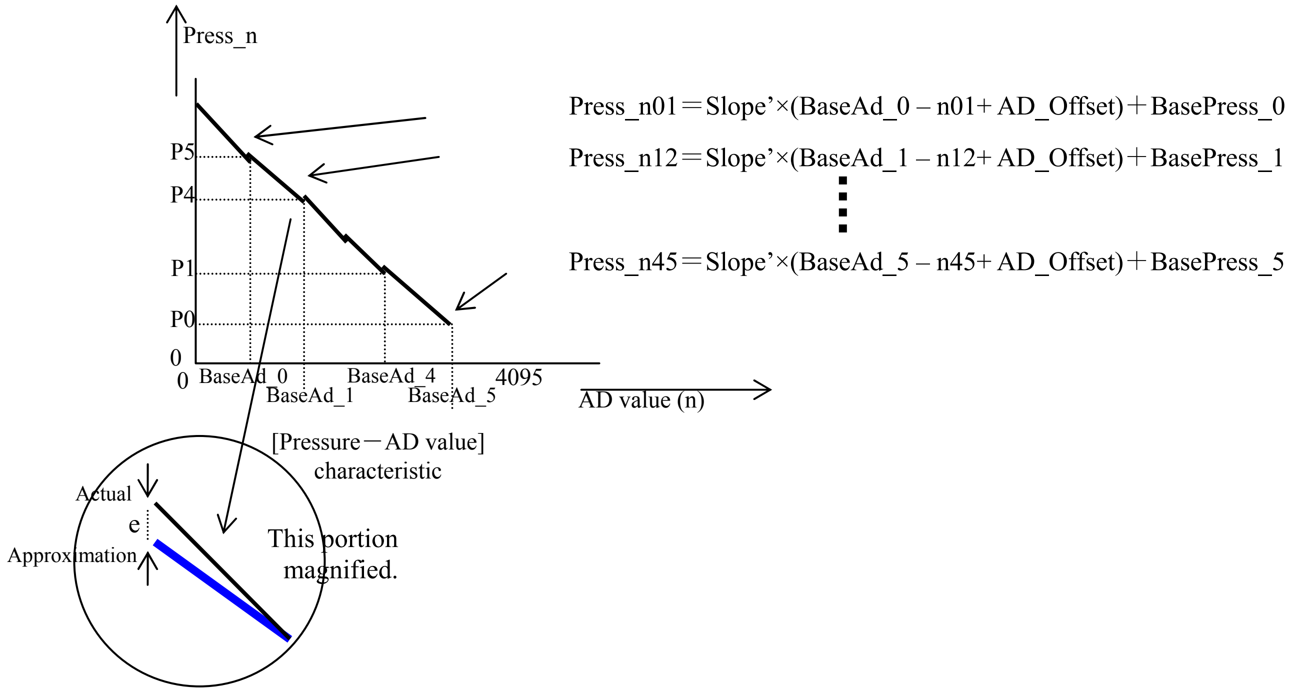
Press_n = (BasePress' << N + (Slope' << N) × (Inverted n - Inverted BaseAd)) >> N
= (BasePress + Slope'' × (BaseAd - n + AD_Offset)) >> N
*Assume that N = 8

AD_Offset	: Offset of AD value (= -1424)
Inverted n	: 4095 - AD value + AD_Offset After this, "Inverted" means that 4095 - AD value + AD_Offset.
Slope'	: Slope × (90.196mV / 4095) × 100 = 0.0413 × 100 This is a part of the equation 3.1.2.3-1. It is multipled by 100 in order to perform the calculation in the unit of hPa.
Slope''	: The integer value, made by shifting Slope' N bit to left. (= 1058) * In the case that N is 8, Slope' multiplied by 256 is 1057.291469. But, considering that the calculated result (Press_n) is rounded down by shifting to right later, Slope'' is rounded up so that the end result of calculation becomes higher value.
BaseAd	: The value of the base AD value (AD value which corresponds to the minimum air pressure in the divided range)
BasePress'	: The value of the minimum air pressure in the divided range
BasePress	: The integer value, made by shifting BasePress' N bit to left (The base air pressure set in air pressure calculation table)

The air pressure calculation table is shown in Table 3-4. The value of BasePress is registered in this table after shifting N bit to left, in order to reduce the number of calculation operations.

Table 3-4 Air pressure calculation table

Table address	Parameter		Range of air pressure(hPa)
	BaseAd	BasePress	
0	1806	968 hPa $\times 2^N$	x >= 968
1	2198	806.1 hPa $\times 2^N$	968 > x >= 806.1
2	2567	653.7 hPa $\times 2^N$	806.1 > x >= 653.7
3	2940	499.7 hPa $\times 2^N$	653.7 > x >= 499.7



Here, the maximum error between the linear approximation and actual characteristics is “e”.
If “e” is larger than the maximum error for measuring air pressure, it is necessary to make a finer portion and redo the approximation procedure.

Example of calculation:

In the case that AD value is 623 and offset of AD value is -1424,

① Look up the air pressure calculation table.

(AD value - offset of AD value) is lower than 2198.
Therefore, the table address is determined to 1.

Table address = 1
BaseAd = 2198
BasePress = 2063868

② Calculate air pressure by using the table parameter.

Press_623= (2063868 + 1058 * (2198-623-1424)) >> 8
= (2063868 + 1058 * 151) >> 8
= (2063868 + 159758) >> 8
= 2223626 >> 8
= 8686
→868.6(hPa)

3.1.2.4. Temperature Dependence of Voltage Difference

The voltage difference of the air pressure sensor changes, depending on temperature. Therefore, the temperature correction is necessary for accurate measurement. The temperature characteristic of the sensor is described below.

The air pressure at the temperature T°C is calculated from Pressure - Voltage difference characteristic at 25°C by using the following equation.

$V_{25}(T, Vt) = Vt / (1 + Kt(T))$ ... (3.1.2.4-1)

$V_{25}(T, Vt)$	: Voltage difference at 25°C, converted from voltage difference at T°C
Vt	: Voltage difference at T°C
Kt(T)	: Temperature correction value $Kt(T) = A\times (T - 25)^2 + B \times (T - 25)^2$ $A = 6.88 \times 10^{-6}$ $B = -7.41 \times 10^{-5}$

$Press\_t(T) = (V_{25}(T,Vt) + Intercept25) / Slope25$ ... (3.1.2.4-2)

Press_t(T)	: Air pressure at T°C
Slope25	: Slope of Pressure - Voltage difference characteristic at 25°C
Intercept25	: Intercept of Pressure - Voltage difference characteristic at 25°C

The sample program correct the air pressure calculation result simply so that the error due to temperature dependence at 101.3kPa (1013hPa) is minimized, by using the following method.

1) According to the equation 3.1.2.4-1, 3.1.2.4-2 and 3.1.2.3-1, calculate air pressure, using AD value at temperature T°C.

$$Press\_t\_n = Press\_Min + Slope25 \times V_{25}(T, n) \qquad \text{... (3.1.2.4-3)}$$

Press_t_n	: Air pressure at T°C when AD value is n
n	: AD value at T°C
V_{25}(T, n)	: Voltage difference at 25°C, converted from voltage difference at T°C by using the equation 3.1.2.4-2
Slope25	: Slope of Pressure - Voltage difference characteristic at 25°C (It is the same as Slope in the equation 3.1.2.3-1)
Press_Min	: Minimum pressure of the range of A/D conversion (It is the same as Press_Min in the equation 3.1.2.3-1)

2) Calculate air pressure in the equation 3.1.2.3-1, by using AD value which the calculation result of 1) is 101.3kPa.

3) Define the difference between 1) and 2) as the correction value for air pressure. The following shows the correction values which corresponds to each temperatures. The sample program uses the correction value as the integer value in the unit of 0.1hPa.

Temperature (°C)	**Correction value(kPa)**	**Correction value (0.1hPa)**
40	-0.04323	-4
39	-0.03081	-3
38	-0.01975	-2
37	-0.01006	-1
36	-0.00172	0
35	0.005249	1
34	0.010858	1
33	0.015104	2
32	0.017979	2
31	0.019506	2
30	0.019663	2
29	0.018456	2
28	0.015886	2
27	0.011953	1
26	0.006658	1
25	0	0
24	-0.00802	-1
23	-0.01741	-2
22	-0.02815	-3
21	-0.04026	-4
20	-0.05374	-5
19	-0.06857	-7
18	-0.08476	-8
17	-0.10234	-10
16	-0.12124	-12
15	-0.14156	-14
14	-0.16318	-16
13	-0.18622	-19
12	-0.21055	-21
11	-0.23632	-24

[continued from the previous page]

10	-0.26346	-26
9	-0.29185	-29
8	-0.32171	-32
7	-0.35293	-35
6	-0.38552	-39
5	-0.4193	-42
4	-0.4546	-45
3	-0.49126	-49
2	-0.52928	-53
1	-0.56866	-57
0	-0.6094	-61
-1	-0.65148	-65
-2	-0.69493	-69
-3	-0.73972	-74
-4	-0.78586	-79
-5	-0.83369	-83
-6	-0.88254	-88
-7	-0.93274	-93
-8	-0.98428	-98
-9	-1.03715	-104
-10	-1.09181	-109

The sample program uses the correction value which corresponds to the temperature rounded off to integer value.
Example:

The correction value at -9.5°C is regarded as the correction value at -10°C (= -109)
The correction value at -30.4°C is regarded as the correction value at 30°C (= -2)

In this method, the maximum error is -0.5728kPa (-5.728hPa), which is observed as the maximum error in the full scale range at -9.9°C. Including the error due to A/D resolution (= 0.41hPa/LSB) also, the total error is 6.138hPa.

3.1.3. Calibration

When performing highly precise air pressure measurement, a required calibration is shown.
The measured air pressure value shifts for every product. A cause has the following.

1) Offset voltage of the air pressure sensor
Offset (=Typical voltage difference - actual measurement) of the output voltage from the sensor may differ minutely for every product of an air pressure sensor. Thereby, the input voltage to SA-ADC may shift.
2) Offset of the amplifier of SA-ADC built-in MCU
Offset of the amplifier built by SA-ADC may differ minutely for every product of MCU. Thereby, an A/D conversion result may shift.

This sample has an air pressure calibrating function in order to solve this gap.
Compare reference air pressure value Pref with the air pressure measurement value Ps (the result of Procedure 6) in the section "3.1.7.2 Air pressure calculation procedure") calculated by this software, and please correct Ps to become the same as Pref by key operation. Henceforth, air pressure calibration value (Pref - Ps) is added to the measured air pressure value. This value is determined as final air pressure value.
For key operation method, refer to "4.4 Functions of Sample Program".

Moreover, when air pressure calibration value is known beforehand, AD value which is counted backward from air pressure calibration value can be added to the measured A/D conversion result. In this case, please calculate AD value equivalent to an air pressure calibration value, and set the value to the following variable.

File	Variable name	Type	meaning
main.c	_adcOffset	short	AD value equivalent to air pressure calibration value

For example, when air pressure calibration value is 5hPa, AD value equivalent to this can be calculated as follows.

(AD value equivalent to air pressure calibration value)
= (Air pressure calibration value) / (Air pressure resolution per 1 AD value)
= (Air pressure calibration value) / ((Slope of Pressure - Voltage difference characteristic × (AD resolution))
= 5hPa / (((1100hPa – 500hPa) / (57.452mV – 25.453mV)) × (90.196mV / 4095) × (-1))

* AD resolution is multiplied by -1, because the input from the air pressure sensor is inverted when A/D conversion is carried out.

= 5hPa / (-0.41hPa)
= -12

3.1.4. API Function

The API function which this module provides is explained below.

3.1.4.1. barometer_calc Function

This function calculates the air pressure on 25℃Typical condition from AD value of SA-ADC.
Air pressure is returned as the result of calculation, in units of 0.1hPa.
(Example : In the case of 1013.3hPa, it is 10133.)
In case that it converts into a hectopascal, calculate it to 1/10.

Function name:	int barometer_calc(unsigned short adc_value signed short adc_offset_value unsigned short * baro tBaroTableList * pTbl)
Arguments:	unsigned short adc_value … AD value signed short adc_offset_value … A/D offset value When not adjusting the start A/D value of the air pressure calculation, specify 0. unsigned short *baro …Pointer to the area which stores air pressure.(0.1hPa unit) (Example : In the case of 1010.5hPa, it is 10105.) tBaroTableList *pTbl … Pointer to an air pressure calculation table.
Return values:	int Air pressure calculation succeeded: BARO_R_OK(=0) (AD value – AD offset val) is larger than maximum value(=BARO_MAX_AD_VALUE) : BARO=R=ERR=H(=-1) AD offset value is larger than BARO_MAX_AD_OFFSET_VALUE : BARO_R_ERR_H(=-1) AD offset value is smaller than BARO_MIN_AD_OFFSET_VALUE : BARO_R_ERR_L(=-2)

3.1.5. List of Constants

Table 3-1 Constants for Return Values

Constant name	Defined value	Description
BARO_R_OK	0	Processing succeeded.
BARO_R_ERR_H	-1	➢ AD value is larger than 4095 ➢ AD offset value is larger than maximum value (=RARO_MAX_AD_OFFSET_VALUE) ➢ (AD value - AD offset value) is larger than maximum value (=RARO_MAX_AD_VALUE)
BARO_R_ERR_L	-2	➢ AD offset value is smaller than minimum value (=RARO_MIN_AD_OFFSET_VALUE)

Table 3-6 Constant for Calculation parameter

Constant name	Defined value	Description
BARO_FLOATING_LEN	8	Number of integer compensation bits of air pressure calculation.
BARO_MAX_AD_OFFSET_VALUE	1155	Maximum AD offset value
BARO_MIN_AD_OFFSET_VALUE	-1456	Minimum AD offset value
BARO_MAX_AD_VALUE	2940	AD value at the minimum air pressure, when AD offset is 0. (AD value at 49.97kPa)
BARO_MAX_TBL_NO	4	Air pressure calculation table size. (Number of division of the air pressure measurement range.)
BARO_SLOPE	1058	Slope of air pressure calculation. (For details, see the chapter 3.1.2.3)

3.1.6. Structures

This section describes the structures referred in the air pressure calculation table.

Air pressure calculation table

```
Typedef struct {
        unsigned long       basePress;      // Base air pressure
        unsigned short      baseAd;         // Base AD value
} tBaroTableList;
```

Table 3-7 Air pressure calculation table setting value

Table address	Defined value		Air pressure range (hPa)
	baseAd	basePress	
0	1806	2478326	x >= 968
1	2198	2063868	968 > x >= 806.1
2	2567	1673727	806.1 > x >= 653.7
3	2940	1279357	653.7 > x >= 499.7

3.1.7. Sample of Use

The subsection below shows the sample which uses the functional module offered with sample software.

3.1.7.1. A/D Conversion Procedure

The procedure, which uses SA-ADC module from the initialization to the acquirement of A/D conversion result by the differential amplification input setting, is shown below.

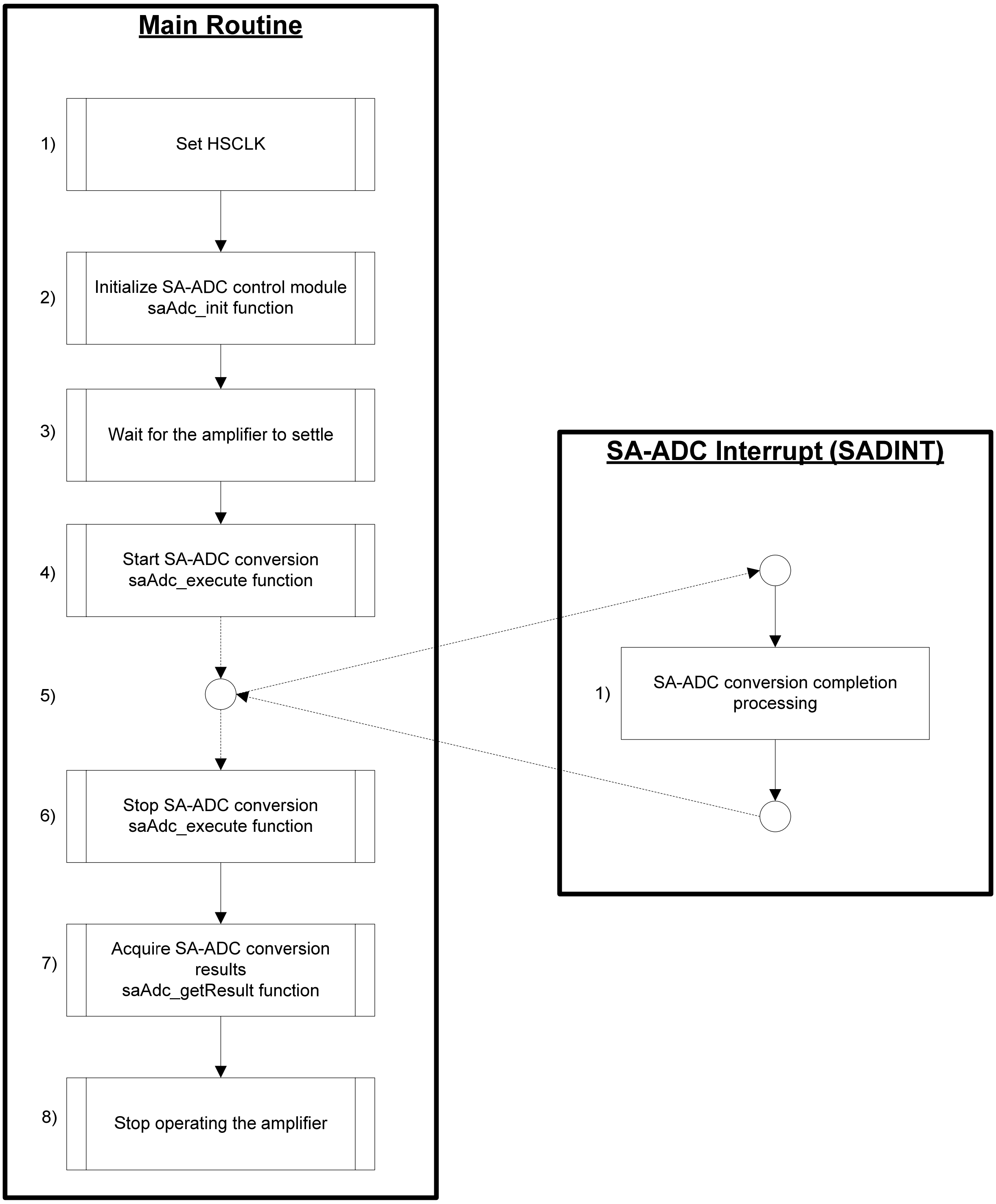


Figure 3-4 Conversion Procedure

[Main Routine]

1) Set HSCLK.
   - The SA-ADC counts HSCLK to set conversion time; therefore, it is necessary to set the settings for HSCLK before conversion.
2) Initialize the SA-ADC control module.
   - Set the following conversion conditions to the **saAdc_init function** and initialize the SA-ADC control module.
     ① Specify the number of times conversion is performed.
     The number of times of conversion specifies "Single AD conversion only" in the case that AD conversion is performed by the differential amplification input. Because the amplifier settling time is required before AD conversion starts.
     ② Specify the range of clock frequency of HSCLK.
     ③ Specify the operating mode.
     The AD conversion by the differential amplification input is specified.
     ④ Set the input offset of the 2nd amplifier.
     ⑤ Set the gain (multiplication factor) of the 2nd amplifier.
3) Wait for the amplifier to settle.
   - Wait the required time for the amplifier settling (more than 94us).
4) Start SA-ADC conversion.
   - Specify the channel 0 to the saAdc_execute function and start SA-ADC operation.
5) Wait for SA-ADC conversion completion.
   - Wait until SA-ADC interrupt occurs (conversion complete).
6) Stop SA-ADC conversion
   - Specify stopping of conversion in the designated parameter of the **saAdc_execute function** and stop SA-ADC operation.
7) Acquire SA-ADC conversion results.
   - Specify the channel 0 number to the saAdc_getResult function and acquire the SA-ADC conversion results. In a differential amplification input, the conversion result of a channel 0 is surely acquired.
8) Stop operating the amplifier.
   - In order to reduce power consumption, shut off the power supply for the amplifier by setting the analog input as the direct input. In the sample program, it sets the following conditions to the **saAdc_init function** and initializes the SA-ADC control module to the initial setting after power-on.
     ① Specify the number of times conversion as "Single AD conversion only".
     ② Specify the range of clock frequency of HSCLK as 1.5MHz~4.2MHz.
     ③ Specify the operating mode as the direct input.
     ④ Set the input offset of the 2nd amplifier as 0 %.
     ⑤ Set the gain (multiplication factor) of the 2nd amplifier as 1 time.

[SA-ADC interrupt (SADINT)]

1) SA-ADC conversion completion processing
   - The SA-ADC interrupt processing sets the flag that indicates conversion completion.

3.1.7.2. Air pressure calculation procedure

The procedure, from the temperature measurement to the air pressure calculation by using the air pressure calculation module, is shown.

[Main Routine]

1) RC-ADC conversion.
- This sample performs RC-ADC conversion required for temperature calculation, in order to carry out temperature correction to the calculation result of air pressure.

  NOTE:

  For RC-ADC module details, refer to "3.2 RC-ADC Control Module" of "ML610Q400 series sample program AP note sensor measurement application".

2) Temperature calculation
- Temperature value is calculated from the conversion result of RC-ADC based on the frequency ratio - temperature conversion table for thermistor 103AT.

  NOTE:

  For SA-ADC module accuracy, refer to "3.3 Temperature Calculation Module" of "ML610Q400 series sample program AP note sensor measurement application".

3) SA-ADC conversion
- The AD conversion of the voltage difference between AIN1 and AIN0 pin is carried out.

  (For details, refer to the section 3.1.7.1)

4) AD value correction
- The AD value equivalent to air pressure calibration value is added to the acquired AD result.

  (_adcOffset:default is 0)

5) Air pressure calculation
- The air pressure value is calculated with barometer_calc function using the acquired AD result and air pressure calculation table for air pressure sensor HSPPAR003C.
- When temperature is outside of the measurement range (40.1°C or more, less than -10°C), the calculation itself is skipped, and "----hPa" is displayed.

6) Temperature correction
- The air pressure correction value corresponding to the acquired temperature is acquired from an air pressure compensation table. (For details, refer to the chapter 3.1.2.4)
- The air pressure is calculated by adding the air pressure correction value to the calculation result of barometer_calc function.

7) Air pressure caribration
- The air pressure calibration value acquired by the calibration is added to the present air pressure.
- The final air pressure value is rounded within the limits.

  It is fixed to 500hPa when air pressure value is less than 500 hPa.

  It is fixed to 1100hPa when air pressure value is larger than 1100hPa.

NOTE:

When not performing temperature correction, the procedure of 1) and 2) is not needed.

4. Description of the Sample Program

The following shows the functional specification of the sample program.

4.1. Common Specifications

1) System clock
   - SYSCLK=HSCLK (RC oscillation mode 500 kHz)
2) UART
   - 9600 bps, 8-bit, no parity, 1 Stop bit, positive logic, LSB first
     * To use RS232C interface mounted on ML610Q400 Series Demo Kit, it is necessary to set P42 and P43 as a secondary function by selection of a port function jumper switch (short-circuit between 2-1 pins) on ML610Q400 Series Demo Kit.
3) Timer
   - Channels 0/1, 16-bit mode, operating clock LSCLK, overflow interval 10 ms
4) LCD driver
   - Bias voltage multiplying clock: 2 kHz
   - Bias : 1/4 bias for the ML610Q431/Q432
     : 1/3 bias for the ML610Q411/Q412/Q415 (fixed by hardware)
   - Duty : 1/4 duty
   - Frame frequency : 73 Hz
5) RTC
   - Initial value of a date : 00/01/01
   - Initial value of time : 23/59/57
   - Initial value of the day of the week : 1(Sunday)
6) SA-ADC
   - Conversion count : 1
   - HSCLK : 375 kHz to 1.1 MHz
   - Operating mode : Differential amplification input
   - Input gain and offset : gain: 25.5, offset: 0%
7) RC-ADC
   - Channel : 0
   - Reference clock : LSCLK
   - Oscillation mode : RS0-CS0 oscillation / RT0-CS0 oscillation
8) Temperature measurement range and accuracy
   - –30 to +65°C (±1°C)
     –50 to -31°C and +66 to +105°C (±2°C)

4.2. Configuration of the LCD Panel

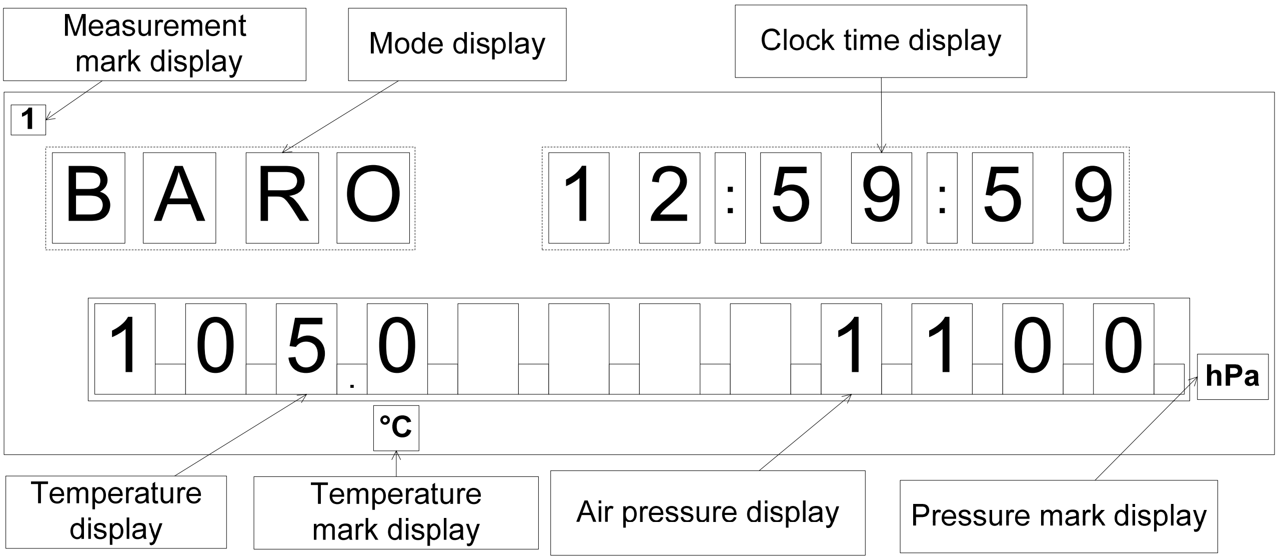
The following subsections describe the LCD panel configuration and types of display.

The LCD panel has two types of display patterns depending on the type of the LCD driver built into the MCU: one with the display allocation function and the other without it. The section from here onward assumes that the LCD panel is equipped with the display allocation function.

4.2.1. LCD Display Image with Display Allocation Function

The display allocation function is available if DSPMOD1's DASN (bit 2) can be set to "1".

The display image in this case is shown below.



4.3. Key Event

The key events that the sample program handles are shown below.

Short-press push:	Polling is performed at 128-Hz intervals from the time a key was pressed, and a short-press push is confirmed if a match occurs four times. A short-press melody is output if it is a valid event.
Short-press release:	Polling is performed at 128-Hz intervals from the time a key was pressed, and a short-press release is confirmed if a match occurs four times but the key is released in less than 2 seconds.
Long press:	A long press is confirmed if a key is held down for 2 seconds or more. Once a long press is confirmed, no further long press event occurs even if the key is held down continuously.
Priority:	Key S1 > Key S2 > Key S3 > Key S4

4.4. Functions of Sample Program

Measurement of RC-ADC and SA-ADC is performed at intervals of 1 second (*1), and the temperature calculated from the measurement result of RC-ADC and the air pressure calculated from AD value of SA-ADC are displayed on LCD. And, measurement time, temperature, the count value of RC-ADC, AD value of SA-ADC, air pressure, air pressure calibration value, and the adjusted baud rate count value are saved at EEPROM (*2).

(*1) "1-sec intervals" here means that the time from the end of the first measurement of the temperature and air pressure to the start of the next measurement is 1 second. In this sample program, a measurement of the temperature and air pressure takes about 0.7 second. Therefore, time from the start of the first measurement to the start of the next measurement is about “0.7 + 1 = 1.7” second.

(*2) The data saved at EEPROM can be transmitted to PC via UART. And, adjustment of the count value for UART baud rates is possible.

4.4.1. State Transition

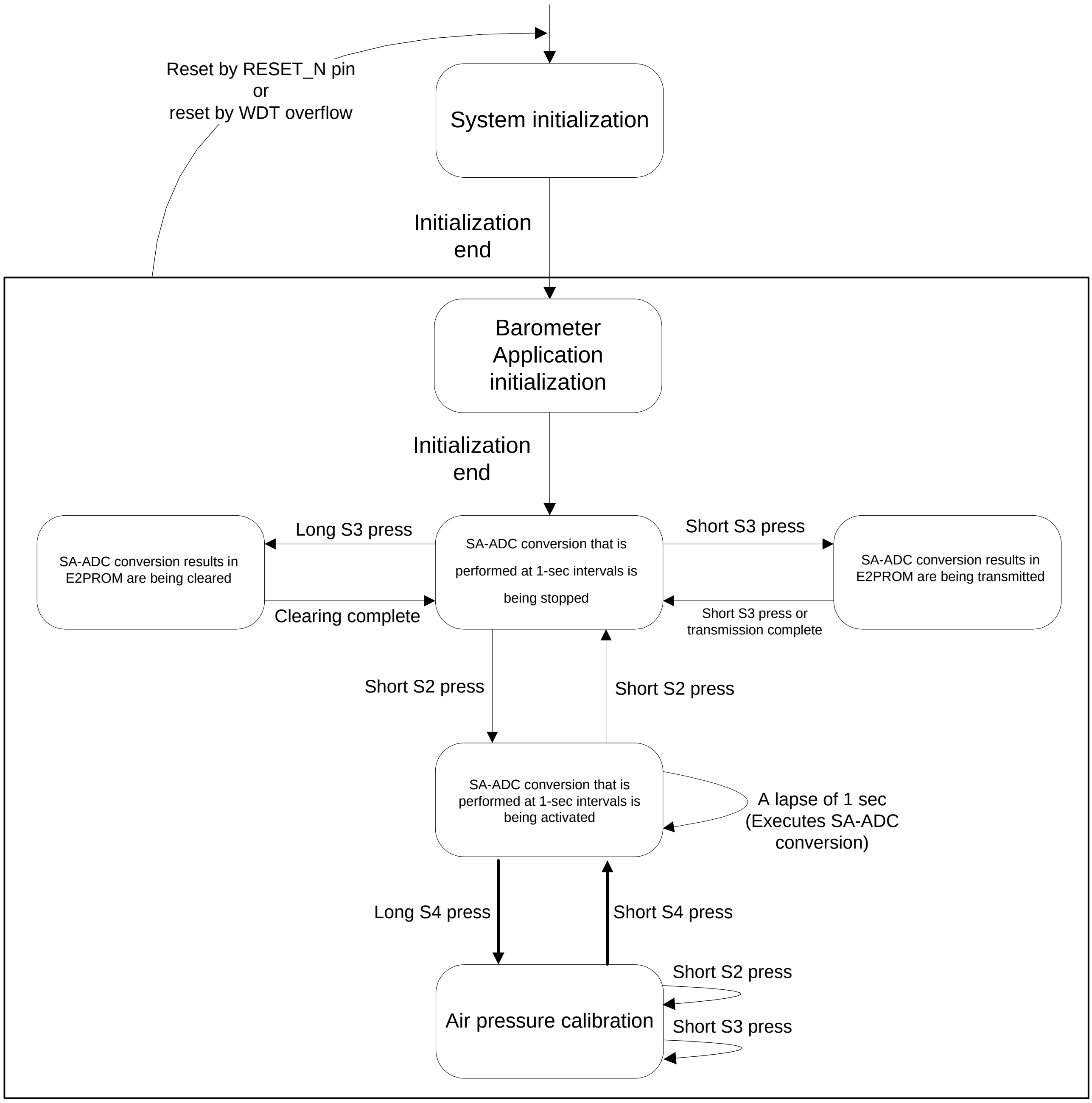


Figure 4-2 State Transition Diagram (SA-ADC Measurement)

State	Description
System initialization	• After power-on, the barometer application will be in this state. • The signature of EEPROM preservation area is checked and the writing of the signature of this sample and clear of reserve area.
Barometer Application initialization	• The number of the saved SA-ADC conversion result is read from EEPROM, and barometer application is initialized.
SA-ADC conversion that is performed at 1-sec intervals is being stopped	• A short S2 key press starts SA-ADC conversion. • A short S3 key press transmits the SA-ADC conversion results stored in EEPROM. • A long S3 key press clears the SA-ADC conversion results stored in EEPROM. (*)
SA-ADC conversion that is performed at 1-sec intervals is being activated	• Performs temperature measurement and SA-ADC conversion at 1-sec intervals and corrects baud rate. • The calculation result of air pressure is displayed in the "Air pressuer display" area of the LCD as a decimal number. • Stores the elapsed time, conversion results, and corrected baud rate in EEPROM. • A short S2 key press stops SA-ADC conversion. • A long S4 key press SA-ADC conversion is stopped and it shifts to air pressure calibration. But, when it is the following conditions, it does not shift to air pressure calibration. ➢ Measured temperature is outside renge of -10 to 40 .
SA-ADC conversion results in E2PROM are being transmitted	• When transmission of all data has been completed, a transition is made to the "SA-ADC conversion that is performed at 1-sec intervals is being stopped" state. • A short S3 key press stops transmission and makes a transition to the “SA-ADC conversion that is performed at 1-sec intervals is being stopped” state.
SA-ADC conversion results in E2PROM are being cleared	• After clearing the number of the saved SA-ADC conversion result is read from EEPROM, a transition is made to the "SA-ADC conversion that is performed at 1-sec intervals is being stopped" state.
Air pressure calibration	• A short S2/S3 key adjusts the air pressure value currently displayed. S2 key : The air pressure value to display is increased by 1. (A maximum is 1100hPa, or the measured air pressure, which could not be calibrated, plus 600hPa.) S3 key : The air pressure value to display is decreased by 1. (A minimum is 500hPa, or the measured air pressure, which could not be calibrated, minus 600hPa.) • A short S4 key press makes a transition to the "SA-ADC conversion that is performed at 1-sec intervals is starting" state.

* When you operate a sample program for the first time, in order to avoid incorrect operation, please clear the data of EEPROM by a long S3 key press.

4.4.2. Description of LCD Display

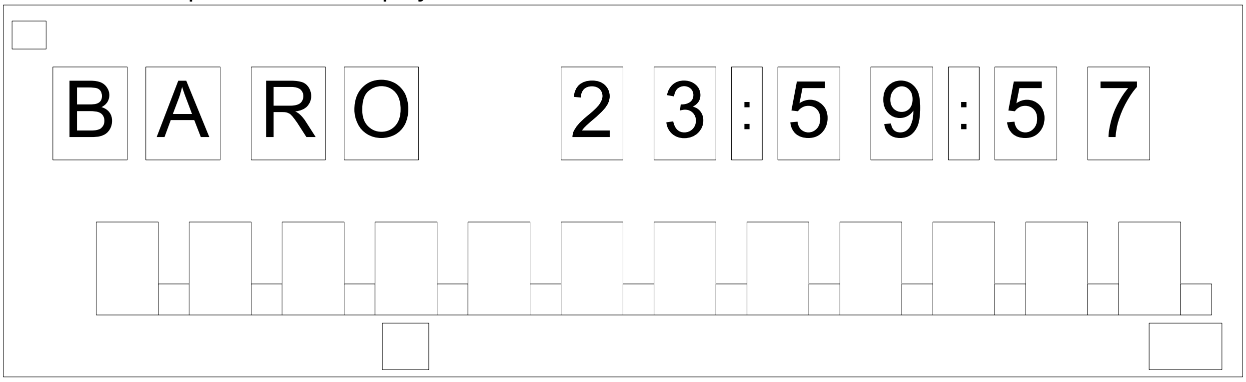


Figure 4-3 The time display after power-on

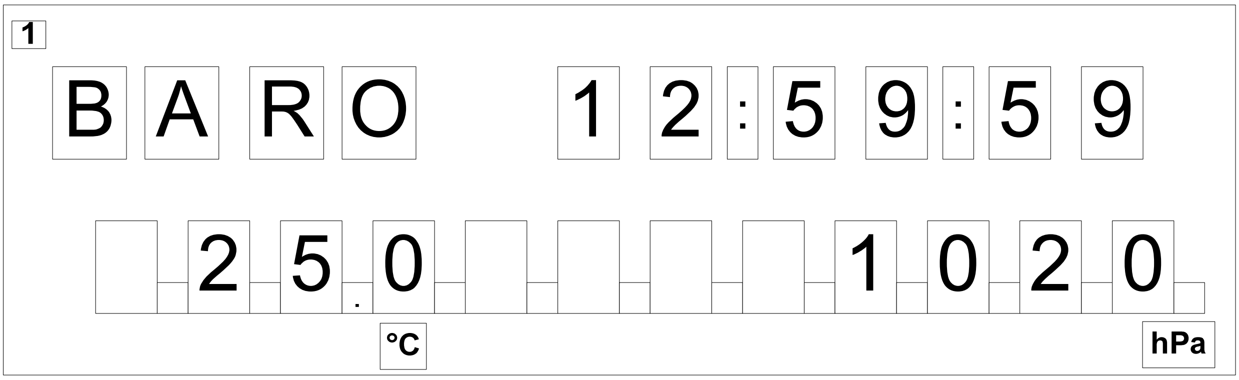


Figure 4-4 A display during air pressure measurement (25°C)

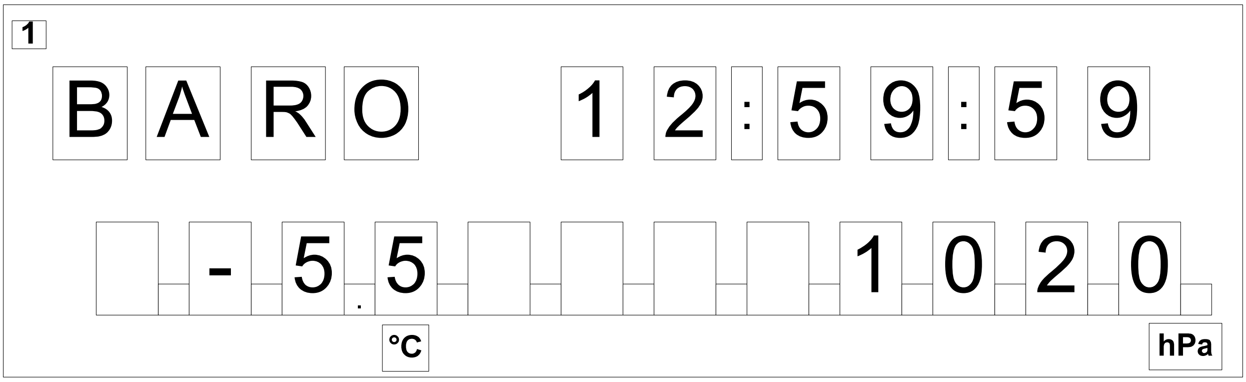


Figure 4-5 A display during air pressure measurement (-5.5°C)

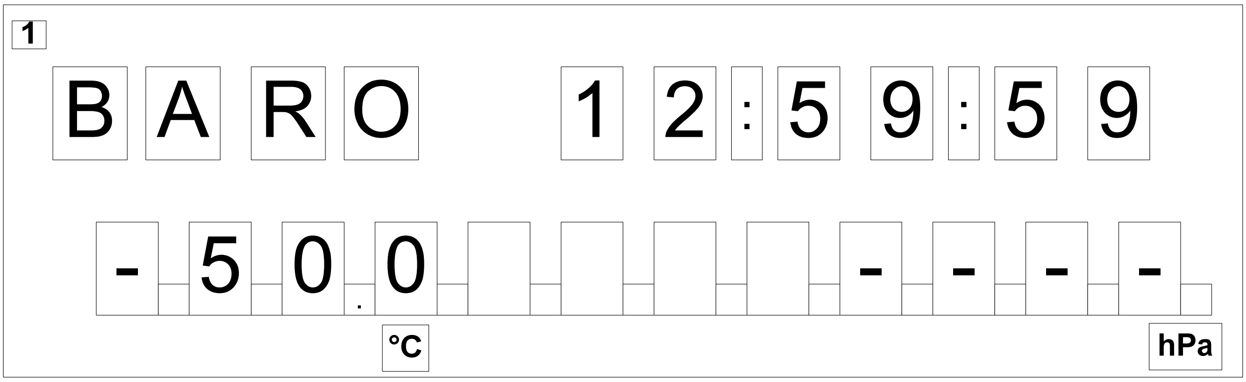


Figure 4-6　A display during air pressure measurement

(Temperature is outside of the air pressure measurement range)

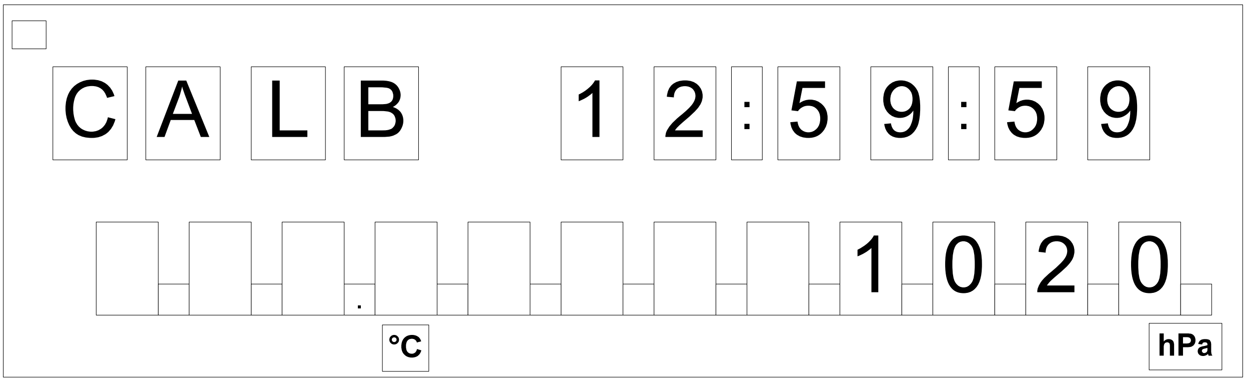


Figure 4-7　A display during air pressure calibration

Name	Content to be displayed
Mode display	Displays the "BARO". (Abbreviation of Barometer) Displays the "CALB" during air pressure calibration. (Abbreviation of Calibration)
Clock time display	Displays the time elapsed after activation in the range of “ 0:00:00” to “23:59:59”. Only the digits of hours are zero-suppressed.
Temperature display	Displays the temperature calculated from the RC-ADC conversion results. If the temperature is a negative value, “–” is displayed at one digit before the significant digit. Displayable temperature values are in the range of “–50.0” to “105.0” and zero suppression is performed to the displayed value. (It does not display immediately after Power-ON and during air pressure calibration.)
Air pressure display	Displays the air pressure calculated from the SA-ADC conversion results as a decimal number. The range is "1100" to "500", and zero suppression is performed to the displayed value. When temperature is out of range in air pressure measurement, it is displayed as "----."The air pressure will be set up as the present air pressure is displayed during air pressure calibration. (It does not display immediately after Power-ON.)
Pressure mark display	Displays the "hPa" mark. (It does not display immediately after Power-ON.)
Temperature mark display	Displays the "°C" mark. (It does not display immediately after Power-ON.)
Measurement mark display	During air pressure measurement, "1" is displayed on the upper left.

4.4.3. Description of UART Display

```
SA1 00:00:01 SADR=123 BARO=1020[hPa] CALB=0000 RC1 CNT= 616A4 020.0[C] UABRT= 33
SA1 00:00:02 SADR=122 BARO=0999[hPa] CALB=0000 RC1 CNT= 616A3 019.9[C] UABRT= 32
SA1 00:00:11 SADR=011 BARO=0990[hPa] CALB=-020 RC1 CNT= 5883C –10.0[C] UABRT= 33
SA1 00:00:12 SADR=012 BARO=0980[hPa] CALB=-020 RC1 CNT= 5883B –10.4[C] UABRT= 34
SA1 00:00:13 SADR=012 BARO=----[hPa] CALB=-020 RC1 CNT= 5B096 –50.0[C] UABRT= 34
...
```

Content to be displayed	Display data
Type of ADC	Displays the "SA1"
Measured clock time	Displays in the range of 00:00:00 to 23:59:59
Measurement results (A/D value)	Displays in the range of 000 to FFF (in the hexadecimal format), after "SADR=".
Measurement results (air pressure value)	Displays in the range of 0000 to 9999 (in the decimal format), after "BARO =". Displays the "----" when the air pressure stored in EEPROM is negative value.
Air pressure calibration value	Displays in the range of -600 to 600 (in the decimal format), after "CALB =".
Displays the type of ADC	Displays the "RC1"
Measurement results (Count value)	Displays in the range of 000000 to FFFFFF (in the hexadecimal format), after "CNT =".
Measurement results (Temperature value)	Displays in the range of -50.0[C] to 105.0[C] (in the decimal format).
Baud rate count value	Displays in the range of 000 to FFF (in the hexadecimal format), after "UABRT=".

4.4.4. Explanation of Key Operation

4.4.4.1. SA-ADC measurement

Key		Operation
S1	Short press	No effect.
	Long press	No effect.
S2	Short press	Starts/stops SA-ADC measurement.
	Long press	No effect.
S3	Short press	Starts/stops transmission of the SA-ADC measurement result data stored in EEPROM. - Other than during data transmission -> Starts data transmission. - During data transmission -> Stops data transmission.
	Long press	Clears all the SA-ADC measurement result data stored in EEPROM.
S4	Short press	No effect.
	Long press	It shifts to air pressure calibration. It does not shift, when measurement temperature is the outside range of -10℃ to 40℃.

4.4.4.2. Air pressure calibration

Key		Operation
S1	Short press	No effect.
	Long press	No effect.
S2	Short press	The air pressure value to display is increased by 1. (A maximum is 1100hPa, or the measured air pressure, which could not be calibrated, plus 600hPa.)
	Long press	No effect.
S3	Short press	The air pressure value to display is decreased by 1. (A minimum is 500hPa, or the measured air pressure, which could not be calibrated, minus 600hPa.)
	Long press	No effect.
S4	Short press	It shifts to the SA-ADC measurement.
	Long press	No effect.

4.4.5. UART Data Formats

Table 4-1 shows the data format for UART transmission in SA-ADC measurement mode

Table 4-1 SA-ADC measurement result transmission data format

Offset	Size (byte)	Content of data	Value of data	Remarks
0	2	Type of ADC	“SA”	
2	1	Channel No.	“1”	Fixed to “1”, due to the differencial amplification input.
3	1	Space	“ ”	Insert a space as a data delimiter.
4	2	Hour data	“00” to ”23”	BCD format
6	1	:	“:”	Insert a colon “:” as a clock-time delimiter.
7	2	Minute data	“00” to ”59”	BCD format
9	1	:	“:”	Insert a colon “:” as a clock-time delimiter.
10	2	Second data	“00” to ”59”	BCD format
12	1	Space	“ ”	Insert a space as a data delimiter.
13	5	SADR=	“SADR=”	
18	3	A/D value	“000” to ”FFF”	
21	1	Space	“ ”	Insert a space as a data delimiter.
22	5	BARO=	“BARO=”	
27	4	Air pressure	500 to 1100 or “----”	BCD format * Displays the "----" when the air pressure stored in EEPROM is negative value.
31	5	hPa	“[hPa]”	Insert "[hPa]" as air pressure unit.
36	1	Space	“ ”	Insert a space as a data delimiter.
37	5	CALB=	“CALB=”	
42	4	Air pressure calibration value	-600 to 600	BCD format
46	1	Space	“ ”	Insert a space as a data delimiter.
47	2	Type of ADC	“RC”	
49	1	Channel No.	“1”	Fixed to channel 1.
50	1	Space	“ ”	Insert a space as a data delimiter.
51	4	CNT=	“CNT=”	
55	6	Count value	“000000” to ”FFFFFF”	
61	1	Space	“ ”	Insert a space as a data delimiter.
62	5	Temperature	-50.0 to 105.0	
67	3	℃	“[C]”	Insert "[C]" as temperature unit.
70	1	Space	“ ”	Insert a space as a data delimiter.
71	6	UABRT=	“UABRT=”	
77	3	BRT value	“000” to ”FFF”	
80	1	Line feed	“¥r”	Insert a linefeed code to indicate the termination of data.
Total	81			

*Data value is text data.

4.5. EEPROM Memory Map

The memory map of EEPROM in the sample program is shown below.

Address	Area name	Size
0x0000 to 0x000E	Management information storage area	15bytes
0x000F to 0x0716	SA-ADC measurement result storage area	1800 bytes (for 100 data items)
0x0717 to 0x7FFF	Reserve area	30953bytes

4.5.1.1. Management Information Storage Area

Management information is stored in the following data format.

Table 4-5 Management Information Storage Area Storage Data Format

Offset	Size (bytes)	Content of data	Value of data	Remarks
0	11	Signature	"U8AmpSample"	ASCII data
11	2	The number of SA-ADC measurement result data items that have been stored	0 to 65535	Binary data
13	2	Reserve	0x0000	-
Total	15			

4.5.1.2. SA-ADC Measurement Result Storage Area

SA-ADC measurement results are stored successively in the following data format. In the sample program, the maximum number of data items that can be stored in the SA-ADC measurement storage area is 100.

Table 4-6 SA-ADC Measurement Result Storage Data Format

Offset	Size (bytes)	Content of data	Value of data	Remarks
0	1	Type of ADC	0	
1	1	Channel No.	1	Fixed to "1", due to the differencial amplification input.
2	1	Hour data	0 to 23	BCD format
3	1	Minute data	0 to 59	BCD format
4	1	Second data	0 to 59	BCD format
5	2	SA-ADC value	"000"～"FFF"	
7	2	Air pressure value	0 to 0x9999,0xFFFF	BCD format When an air pressure calculation result is an error, data 0xFFFF is saved. (An error is the case where the barometer_calc function returns value other than BARO_R_OK)
9	2	Air pressure calibration value	0xF600 to 0x0600	BCD format * When air pressure calibration value is negative, it saves so that 1 may be set to higher 4 bits and it can distinguish that it is negative.
11	3	RC-ADC count value	0 to 0xFFFFFF	
14	2	Temperature value	0xF500 to 0x1050	BCD format * The value which is multiplied by 10 is saved. When Temperature value is negative, it saves so that 1 may be set to higher 4 bits and it can distinguish that it is negative.
16	2	BRT value	0 to 0xFFF	
Total	18			

*Data value is binary data.

Revision History

Revision History

Edition	Date	Page		Description
		Previous Edition	Current Edition	
2	April 16, 2010	–	–	Initial Edition