RX23E-A Group

Channel-to-channel isolated analog measurement system

Introduction

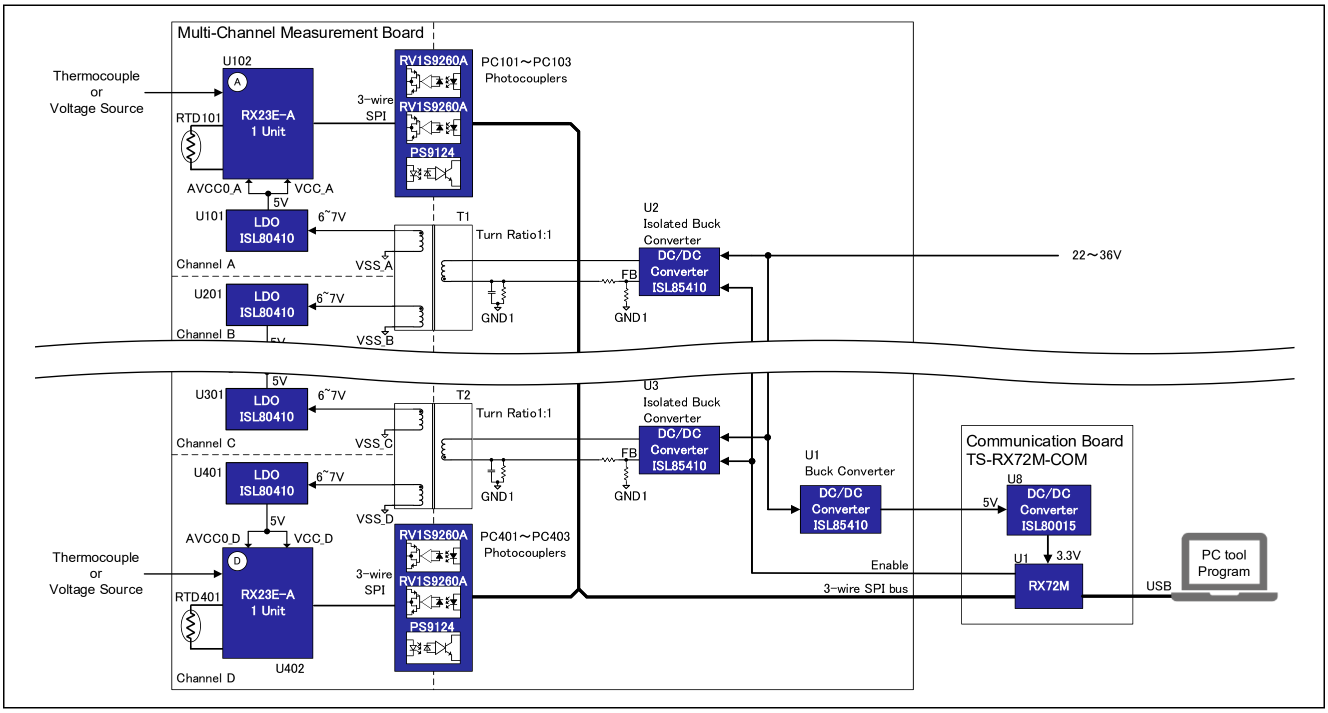
This document describes a system which has 4 pieces of Renesas microcontroller RX23E-A measuring temperature or voltage synchronously with channel-to-channel isolation. RX23E-A in each unit samples output voltage of thermocouple/RTD or pin input voltage with built-in 24-bit Δ-ΣA/D converter (DSAD) in cycle of approximate 1 msec, performs filter processing, and converts to temperature or voltage.

As an upper layer MCU, RX72M obtains temperature or voltage measured in each unit in cycles of 10 ms and transmits to PC via USB. As a result, 4-channel synchronous measurement can be realized within 1 ms.

Communication between 4 pieces of RX23E-A and RX72M is performed by a single channel 3-wire serial communication, and individual communications with the specified unit address and the broadcast communication are performed. This can reduce isolators comparing to 4-wire SPI communication which uses chip select.

Target Application:

- Analog input module
- Temperature controller
- Recorder



Appearance and Block Diagram of Channel-to-Channel Isolated Analog Measurement System

Target Device

RX23E-A (R5F523E6SDNF)

RX72M (R5F572MNDDBD)

Contents

1. Overview

Channel-to-Channel Isolated Analog Measurement System consists of Multi-channel measurement board which has 4 channel measurement unit, and Communication board which controls each measurement unit and acquires measurement results.

RX23E-A performs measurement processing in each measurement unit, and RX72M performs host processing on Communication board.

1.1 Function / Specification

Table 1-1 Specification of Channel-to-Channel Isolated Analog Measurement System

<table>
<tr><th colspan="3">Item</th><th>Specification</th><th>Remarks</th></tr>
<tr><td colspan="3">Operation voltage</td><td>22 to 36 [V]</td><td>typ. 24 [V]</td></tr>
<tr><td colspan="2">Isolated withstand voltage</td><td>Primary vs Secondary</td><td>1500 [VAC]</td><td>Design value</td></tr>
<tr><td colspan="2" rowspan="2">Measurement result acquisition</td><td>Cycle</td><td>10.0 [ms]</td><td></td></tr>
<tr><td>Maximum error between channels</td><td>1.0 [ms]</td><td></td></tr>
<tr><td rowspan="2">Measurement unit</td><td colspan="2">Number of isolated measurement channels</td><td>4</td><td></td></tr>
<tr><td colspan="2">Power consumption</td><td>150 [mW/ch]</td><td></td></tr>
<tr><td rowspan="7"></td><td rowspan="2">Voltage measurement</td><td>Absolute input voltage range</td><td>AVSS0 to AVCC0 [V]</td><td>AVSS0 = 0 [V]
AVCC0 = 5 [V]
VREF =2.5[V]</td></tr>
<tr><td>Differential input voltage range</td><td>±VREF</td><td>VREF = 2.5 [V]</td></tr>
<tr><td rowspan="3">Temperature measurement</td><td>Measurement range</td><td>-75 to 251 [°C]</td><td></td></tr>
<tr><td>Sensor</td><td>K-Type Thermocouple</td><td></td></tr>
<tr><td>Reference junction compensation measurement</td><td>RTD (pt100)</td><td></td></tr>
<tr><td colspan="2">Sampling cycle</td><td>1.024 [ms/ch]</td><td></td></tr>
<tr><td colspan="2">Step response time</td><td>70 [ms]</td><td>63.2% settling time</td></tr>
<tr><td colspan="3">Ambient operation temperature</td><td>-40 to 85 [°C]</td><td>Design value</td></tr>
</table>

1.2 Introduction of Renesas Electronics' Products

Table 1-2 lists the Renesas Electronics' products used in this system.

Table 1-2 List of Renesas Electronics' Products in This System

Part No.	Part Name	Board	Quantity
RX23E-A (R5F523E6SDNF)	MCU (single unit DSAD)	Multi-channel measurement board	4
ISL85410	DC/DC Converter	Multi-channel measurement board	3
ISL80410	LDO	Multi-channel measurement board	4
RV1S9260A	Photocoupler	Multi-channel measurement board	8
PS9124	Photocoupler	Multi-channel measurement board	4
RX72M (R5F572MNDDBD)	MCU	Communication board	1
ISL80015	DC/DC converter	Communication board	1
ISL32740E	RS-485 driver	Communication board	1

(1) RX23E-A

Table 1-3 shows an overview of the specifications of RX23E-A used in this system.

RX23E-A has a low-noise 24-bit Δ-ΣA/D converter (DSAD) that allows high-precision measurement. DSAD has a programmable gain instrumentation amplifier (PGA) whose gain is selectable from x1, x2, x4, x8, x16, x32, x64, and x128. It also has an analog front-end (AFE) circuit suitable for sensor measurement of thermocouples, resistance temperature detectors, and strain gauges. Up to 6 channels can be measured by switching the analog multiplexer (AMUX) built in the AFE. In addition, it has one channel of the successive approximation 12-bit A/D converter (S12AD).

In this system, RX23E-A operates as microcontroller and AFE in each measurement unit, and transmits the measurement result of voltage or temperature to RX72M by SPI communication.

For details about RX23E-A, refer to "RX23E-A Group User’s Manual: Hardware”.

Table 1-3 Overview of the specifications of RX23E-A

Item	Description
Product group	RX23E-A
Part No.	R5F523E6SDNF (single unit DSAD)
CPU max. operating frequency	32 MHz
Bit count	32 bits
Package/pin count	HWQFN / 40 pins
ROM	256 KB
RAM	32 KB
Operating temperature range	-40°C to +85°C
Storage temperature range	-55°C to +125°C

(2) ISL85410

ISL85410 is a 1A synchronous buck regulator with input voltage range from 3 V to 40 V. This is easy to handle with high-efficiency, enables to configure a power supply with fewer components, and is suitable for various applications.

In this system, each configuration of power consisting of ISL85410 and a transformer supplies isolated power to 2 pieces of RX23E-A in the Multi-channel measurement board. Also it is used to supply 5 V power to the communication board as a non-isolated power supply.

(3) ISL80410

ISL80410 is a low-noise LDO with a wide input voltage range from 6 V to 40 V, variable output voltage from 2.5 V to 12 V, and no-load current consumption of 18 μA.

In this system, it supplies 5 V power to RX23E-A.

(4) RV1S9260A

RV1S9260A is a high-speed photocoupler which consists of an AlGaAs LED on the input side and an integrated circuit with a photodiode on the output side. This product enables low current operation on 3.3/5 V power supply with high noise-tolerant CMR and high temperature operation up to Ta=125°C. This product is suitable for high-speed logic interface circuit.

In this system, it is used to isolate SPI communication signal (SCK, MOSI) between RX72M and RX223E-A.

(5) PS9124

The PS9124 is an optically coupled high-speed, active low type isolator containing an AlGaAs LED on the input side and a photodiode and a signal processing circuit on the output side on one chip.

In this system, this product is used to isolate SPI communication signal (MISO) between RX72M and RX23E-A. As PS9124 is open collector output, output of PS9124 becomes Hi-Z when output of RX23E-A with no-response is High or Hi-Z, so that this enables communication as a bus without occupying the MISO communication line.

(6) RX72M

The RX72M Group microcontrollers are high performance products operating at 240 MHz with RX's 3rd generation CPU core "RXv3 core". Double-precision floating-point processing instructions can significantly improve processing power. It incorporates an EtherCAT® slave controller and realizes a system configuration that requires a dedicated controller on a single chip, contributing to a reduction in the number of parts and space saving.

In this system, RX72M, as a host microcontroller, controls 4 pieces of RX23E-A on multi-channel measurement boards and transmits measurement results to PC by USB communication. Measurement results can be obtained with PC tool program of RSSKRX23E-A.

(7) ISL80015

ISL80015 is a highly efficient, monolithic, synchronous step-down DC/DC converters that can deliver up to 1.5 A of continuous output current from 2.7 V to 5.5 V input supply.

In this system, this product supplies 3.3 V for RX72M.

2. Related Documents

- R01UH0801 RX23E-A Group User’s Manual: Hardware
- R20UT4542 RSSKRX23E-A User’s Manual
- R20AN0540 Application Note RSSKRX23E-A PC Tool Program Operation Manual
- R01AN4747 Application Note RX23E-A Group Temperature Measurement Example Using a Thermocouple
- R01AN4799 Application Note RX23E-A Group Effective use of AFE and DSAD
- R01AN4661 Application Note RX72M Group Communications Board Hardware Manual included in “R01AN4882 Application Note RX72M Group Communications Board Sample Program Package”
- R01AN4359 Application Note RX Family RX DSP Library Version 5.0

3. Environment for Operation Confirmation

The environment for operation confirmation of each measurement unit and host processing are given in Table 3-1 and Table 3-2 respectively.

Table 3-1 Environment for Operation Confirmation of Measurement Unit

Item		**Description**
Board		Multi-channel measurement board (MULT-RX23E-A-1U-A)
	MCU	RX23E-A (R5F523E6SDNF) Power voltage (VCC, AVCC0): 5 V Operating frequency (ICLK): 32 MHz Peripheral operating frequency (PCLKB): 32 MHz (DSAD0、RSPI) DSAD operating frequency (f_{DR}): 4 MHz DSAD modulator clock frequency (f_{MOD}): 0.5 MHz
Thermocouple		K-Type
IDE		Renesas e² studio 2021-07
Tool Chain		Renesas CC-RX V3.03.00
	Endian	Little Endian
Emulator		E2 Emulator Lite

Table 3-2 Environment for Operation Confirmation of Host Processing

Item		**Description**
Board		RX72M communication board (TS-RX72M-COM) TESSERA TECHNOLOGY INC.
	MCU	RX72M (R5F572MNDDBD) Power voltage (VCC): 3.3 V Operating frequency (ICLK): 240 MHz Peripheral Operating frequency (PCLKB): 60 MHz (SCI6, SCI8)
IDE		Renesas e² studio 2021-07
Tool Chain		Renesas CC-RX V3.03.00
	Endian	Little Endian
Emulator		E2 Emulator Lite

4. System Configuration

Figure 4-1 shows the configuration of this system and Figure 4-2 shows the appearance of this system.

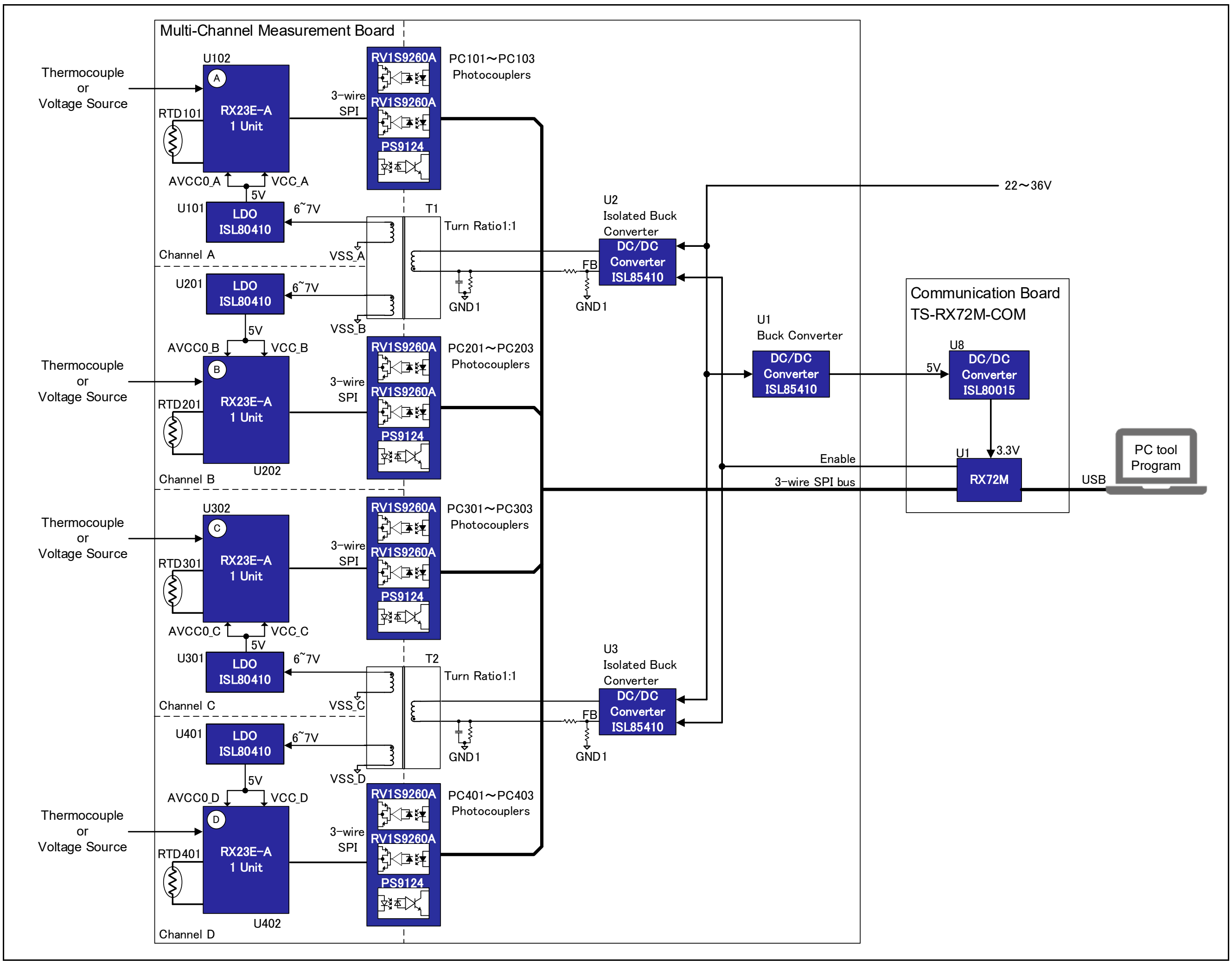


Figure 4-1 Configuration of This System

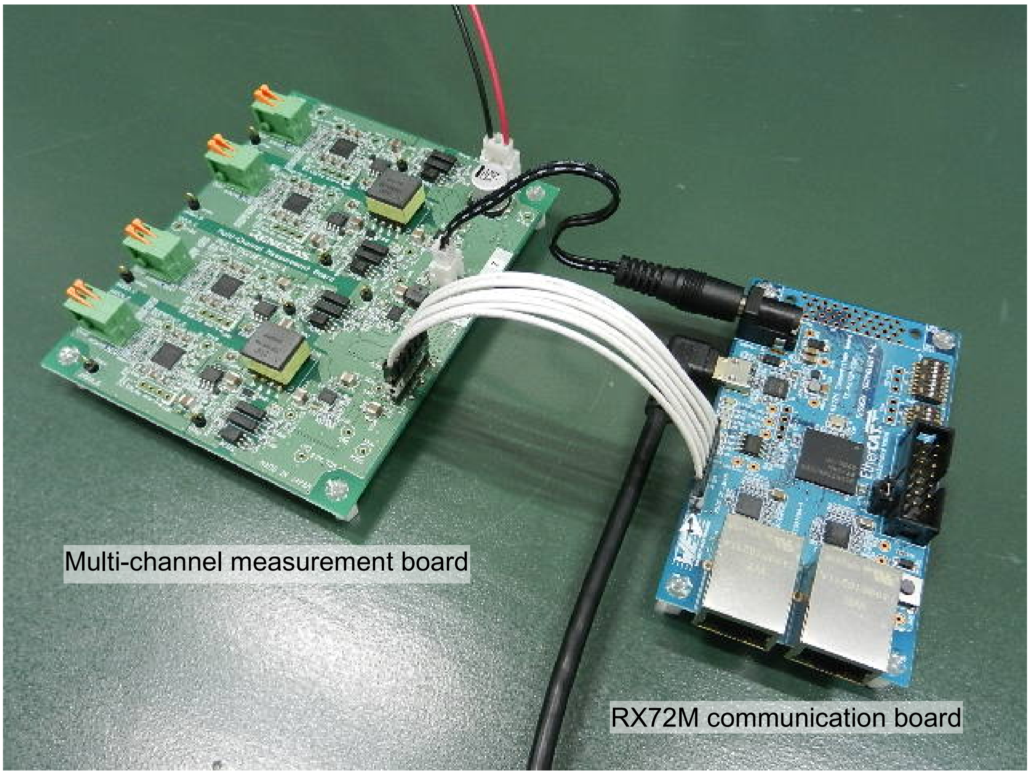


Figure 4-2 Appearance of This System

Measurement result can be monitored by using the Application tab of the PC tool program (hereafter called the "PC Tool") of RSSKRX23E-A which is shown in Figure 4-3.

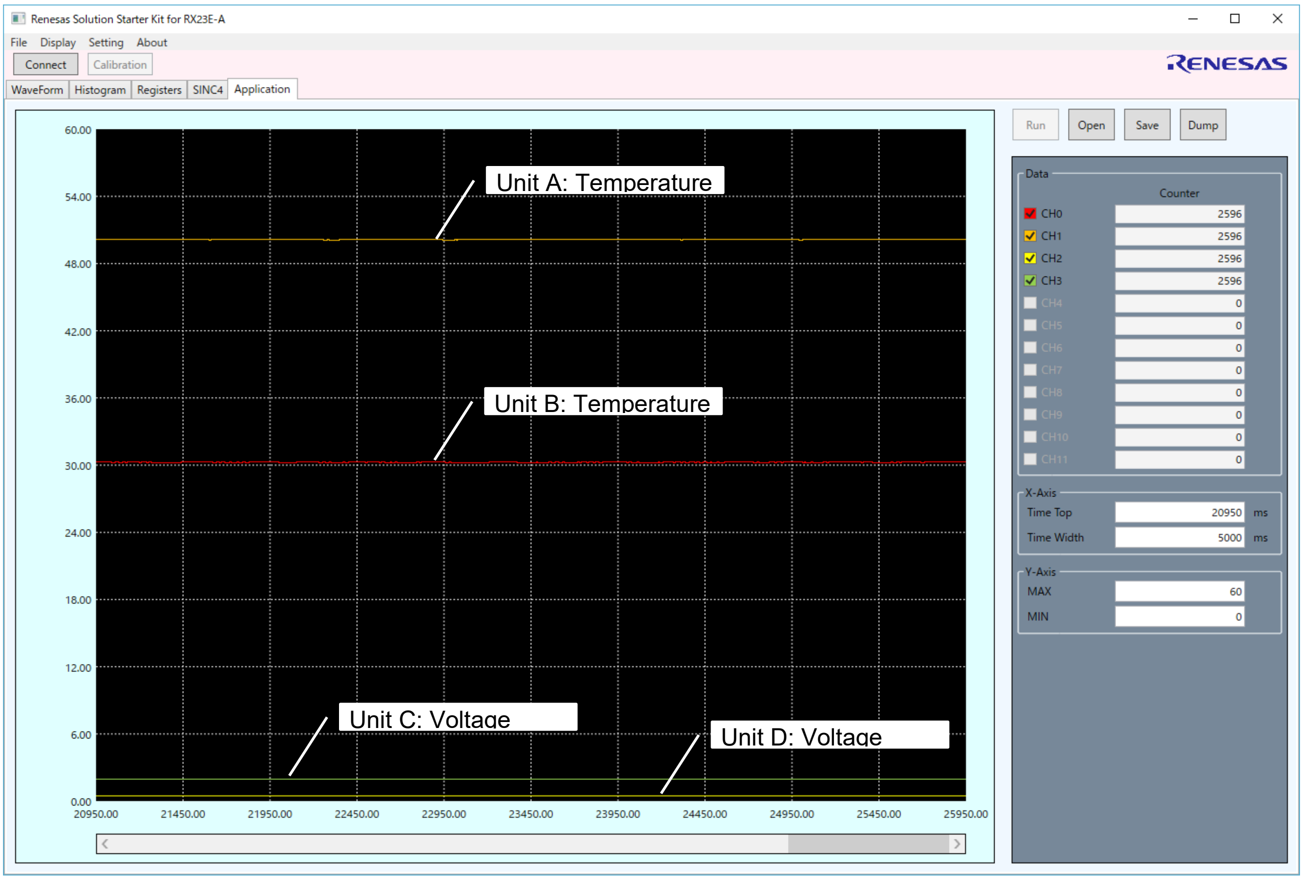


Figure 4-3 Display Example of the PC Tool Program

5. Hardware Configuration

5.1 Communication Board

The communication board is TESSERA TECHNOLOGY INC TS-RX72M-COM with RX72M. For more detail, refer to “RX72M Group Communications Board Hardware Manual”, or web page of TESSERA TECHNOLOGY INC. https://www.tessera.co.jp/eng/products/ts-rx72m-com.html.

5.2 Multi-Channel Measurement Board

5.2.1 Descriptions of Circuits

(1) Non-isolated Step-Down Power Supply Circuit

Figure 5-1 shows the non-isolated step-down power supply circuit using ISL85410. In this system, it is used with input voltage of 22 to 36 V and output voltage of 5 V. Output voltage of 5 V is supplied to the communication board TS-RX72M-COM via CN2.

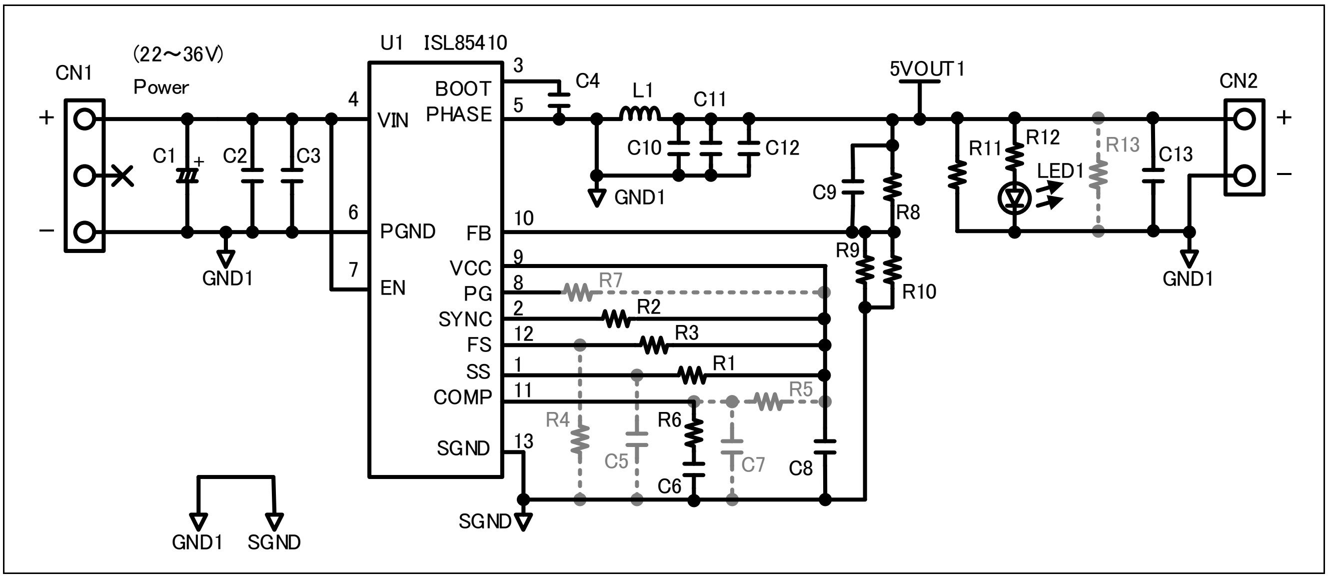


Figure 5-1 Non-isolated Step-Down Power Supply Circuit

(2) Isolated Step-Down Power Supply Circuit

Figure 5-2 shows the isolated step-down power supply circuit, and it consists of ISL85410 as well as a non-isolated step-down power supply circuit. In this isolated step-down power supply circuit, isolation transformer of 1 input 2 output is used instead of coils. Primary voltage is set approximate 7.3 V and the secondary side outputs equivalent voltage since the winding ratio of a transformer is 1:1. This is rectified and smoothed with diode and capacitor on the secondary side and stabilized with LDO. Approximate 7 V input voltage is supplied to LDO due to the winding ratio and forward voltage drop across a diode. The LDO on the secondary side uses ISL80410. ISL80410 supplies 5V power to RX23E-A in each channel on the secondary side. In this configuration, 2 channels of isolated power supply are provided with a single power supply IC and a transformer.

EN pin of ISL85410 is connected to the port of RX72M, and activating and stopping of power supply can be performed from RX72M. EN pin is pulled up with 3.3 V power supply of RX72M. It is set so that a power supply of RX72M activates then ISL85410 activates and power is supplied to RX23E-A.

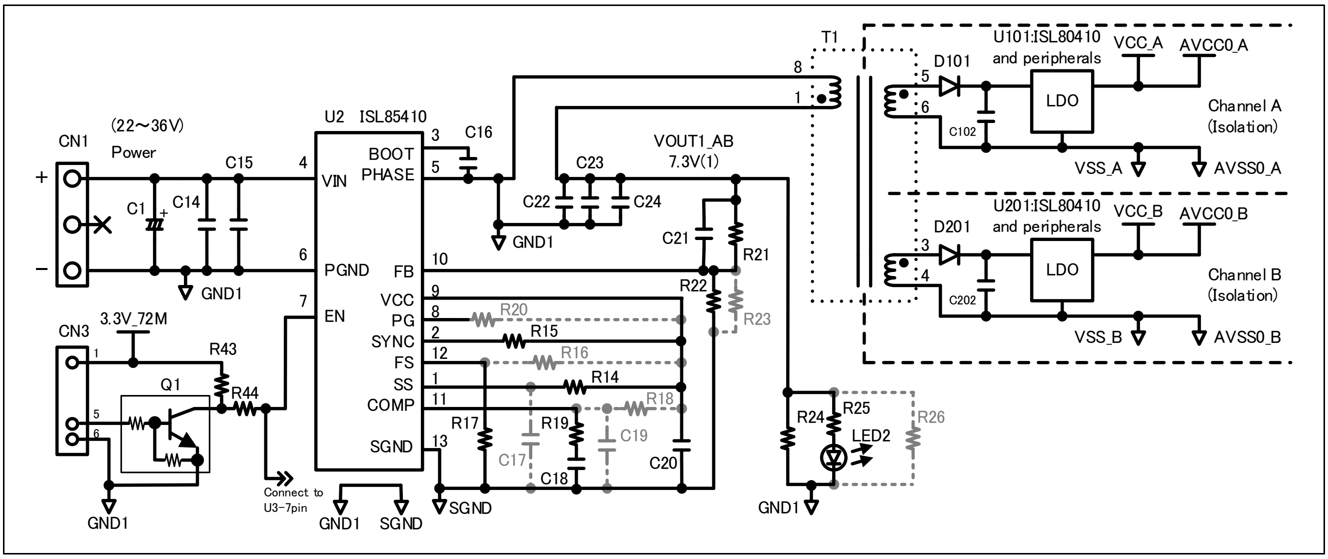


Figure 5-2 Isolated Step-Down Power Supply Circuit (around U2)

(3) Isolated Communication Circuit

Figure 5-3 shows the isolated communication circuit. In this system, SPI communication from RX72 on the communication board to 4 units of RX23E-A is performed. The CMOS output photocoupler RV1S9260A and the open collector output type photocoupler PS9124 are used to isolate communication channels. SCK and MOSI, which are output from RX72M, go through 4 pieces of RV1S9260A respectively (i.e., 8 pieces in total) and clock synchronization communication is performed. As there is not enough driving capacity to drive 4 photocouplers directly from RX72M, a buffer IC is inserted to U4 for communication.

The MISO signal transmits measurement results and operational status to RX72M via PS9124 from RX23E-A in each measurement unit. As PS9124 is open collector output, RX23E-A does not respond unless RX72M specifies and is Hi-Z in the idle state, so that communication lines are not occupied.

On activating, the unit address is read by pulling-up/down of I/O input of RX23E-A in each measurement unit and setting bit information. This enables to embed the same FW and reduce the workload for software management. The device to be communicated is specified by sending the unit address on communication. In this configuration, the target device of communication can be specified without providing chip select signal for device selection. As chip select signal is unnecessary, the number of photocouplers can be reduced and it contributes to the BOM cost reduction.

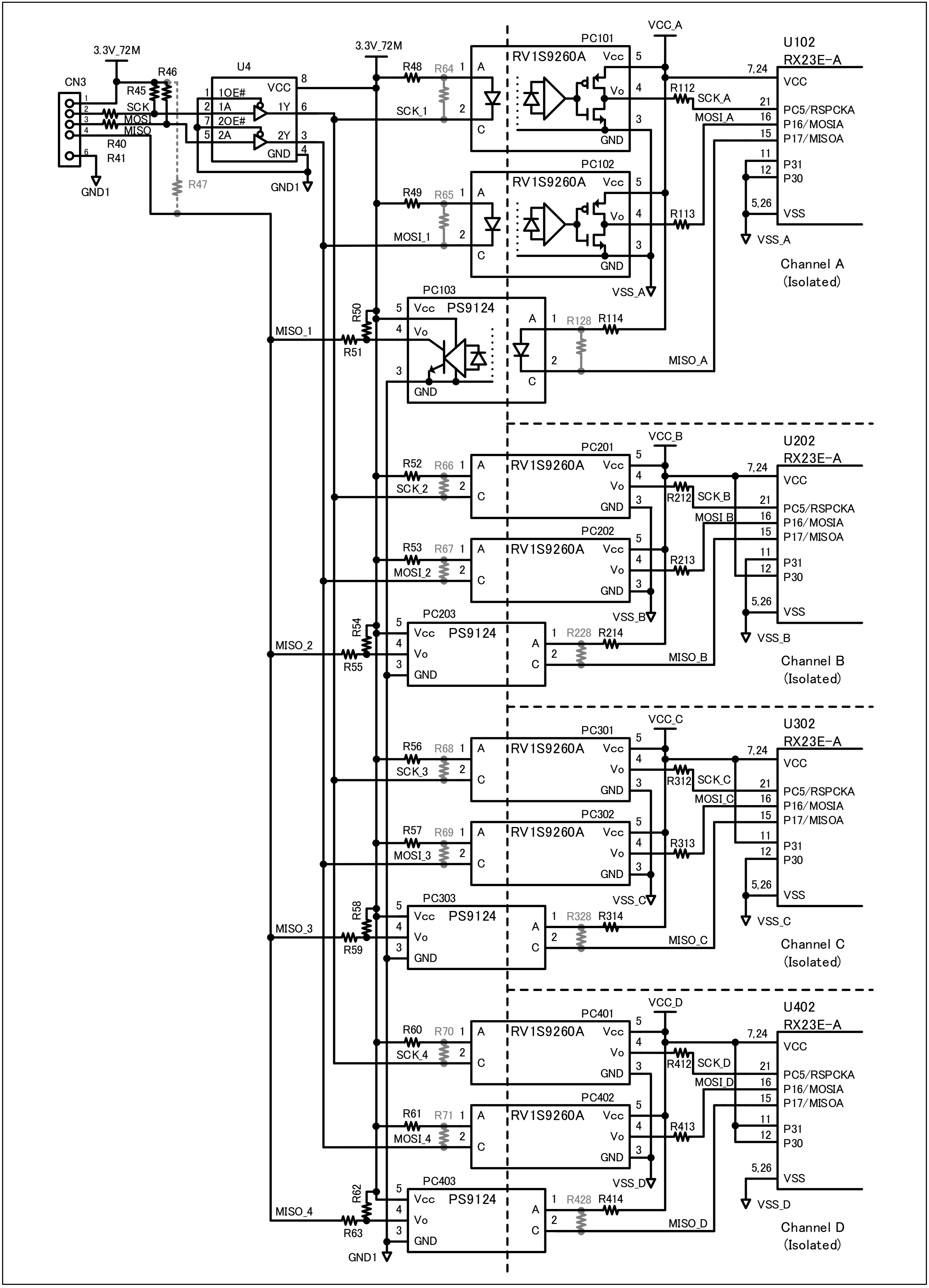


Figure 5-3 Isolated Communication Circuit

RENESAS

(4) Temperature Measurement Circuit

Figure 5-4 shows the temperature measurement circuit in this system.

Note that the hundreds place is referred to as “x” in part references hereafter of circuit descriptions: x = 1 for channel A, x=2 for channel B x=3 for channel C, and x=4 for channel D. (Ex. Rx27 indicates R227 for channel B.)

The thermocouple is connected to CNx01 for temperature measurement. For reference junction compensation, the resistance temperature detector RTDx01 is placed around the CNx01 and junction temperature is measured. The measurement of reference junction with RTD is performed by 4-wire ratiometric measurement.

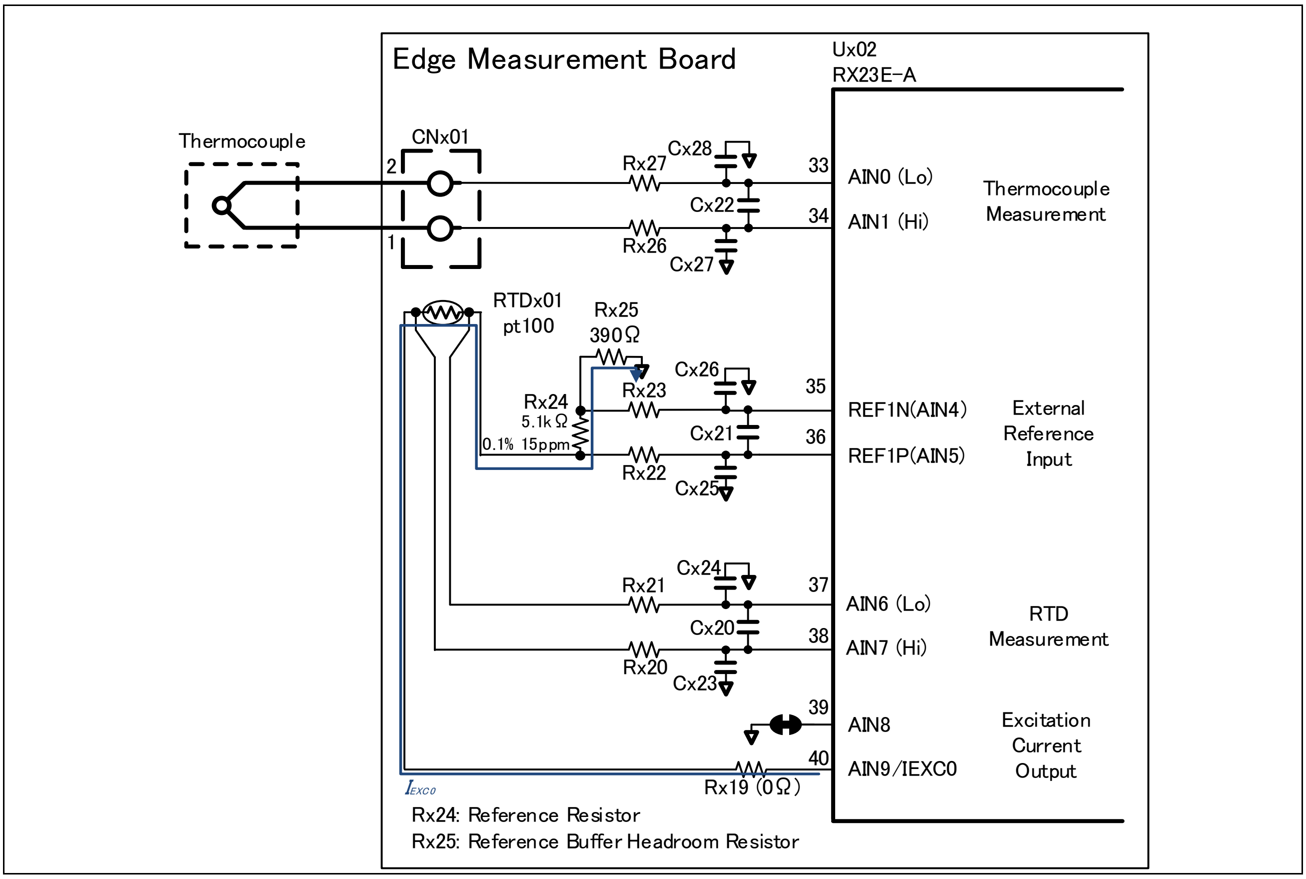


Figure 5-4 Temperature Measurement Circuit

(5) Voltage Measurement Circuit

Figure 5-5 shows the voltage measurement circuit in this system. For voltage measurement, the signal source is connected to CNx01.

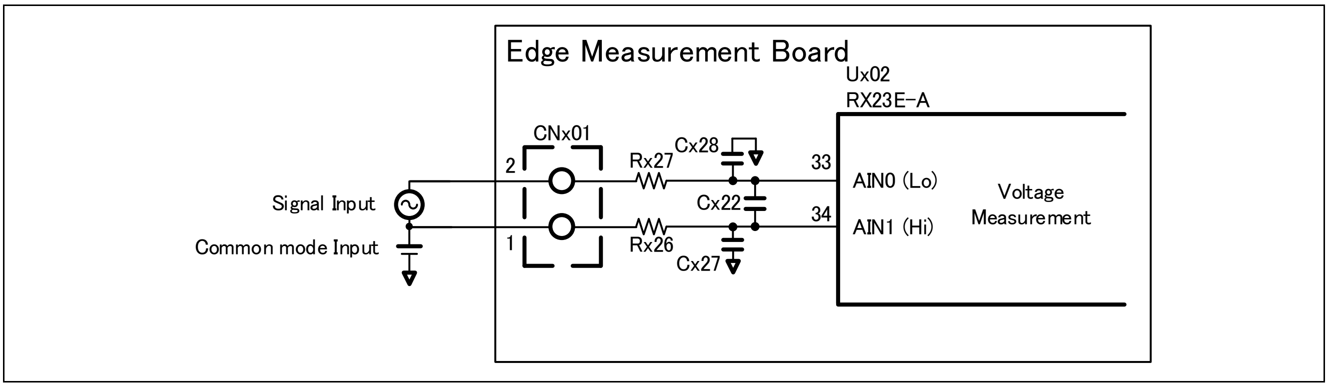


Figure 5-5 Voltage Measurement Circuit

6. Measurement Process

RX23E-A measures temperature or voltage by instruction from the host. The following describes each measurement process.

6.1 Temperature Measurement

Temperature measurement is conducted by using thermocouples with the reference junction temperature which is measured with RTD placed on the board. Figure 6-1 shows the procedure for calculating temperature of thermocouple from each A/D conversion value obtained by thermocouple and RTD.

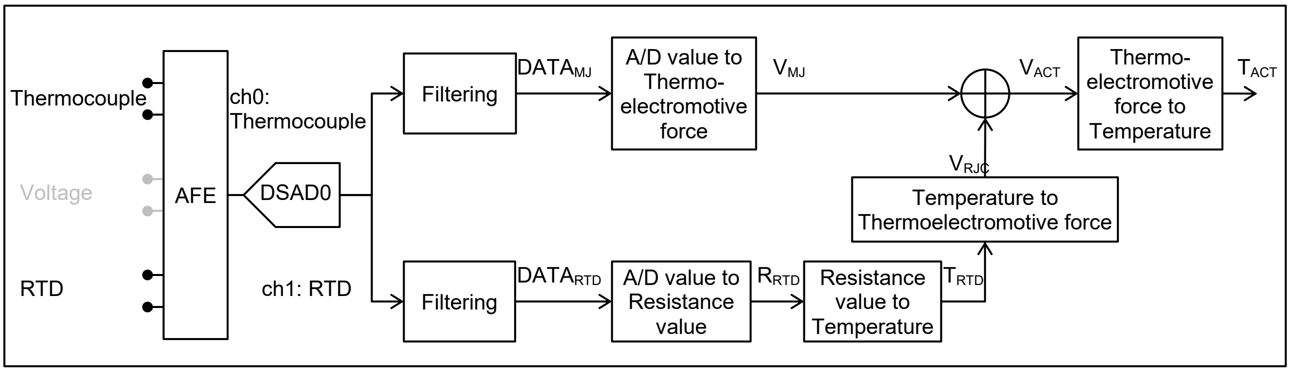


Figure 6-1 Temperature Calculation Procedure

6.1.1 A/D Conversion of Thermocouple and RTD

By using the channel function of DSAD0, A/D conversion of each voltage of thermocouple and RTD is performed in this order. The sequence of A/D conversion of thermocouple and RTD is shown in Figure 6-2, and A/D conversion conditions are shown in Table 6-1.

In this example, A/D conversion is performed for thermocouple on CH0 and for RTD on CH1 by channel scan. Each A/D conversion value is acquired when a A/D conversion end interrupt flag ADI0 occurs. Completion of A/D conversion of a pair of CH0 and CH1 is detected with the scan end interrupt flag SCAND0 then the temperature calculation is processed.

For details of A/D conversion using channel function, refer to Application Note “RX23E-A Group Effective use of AFE and DSAD”.

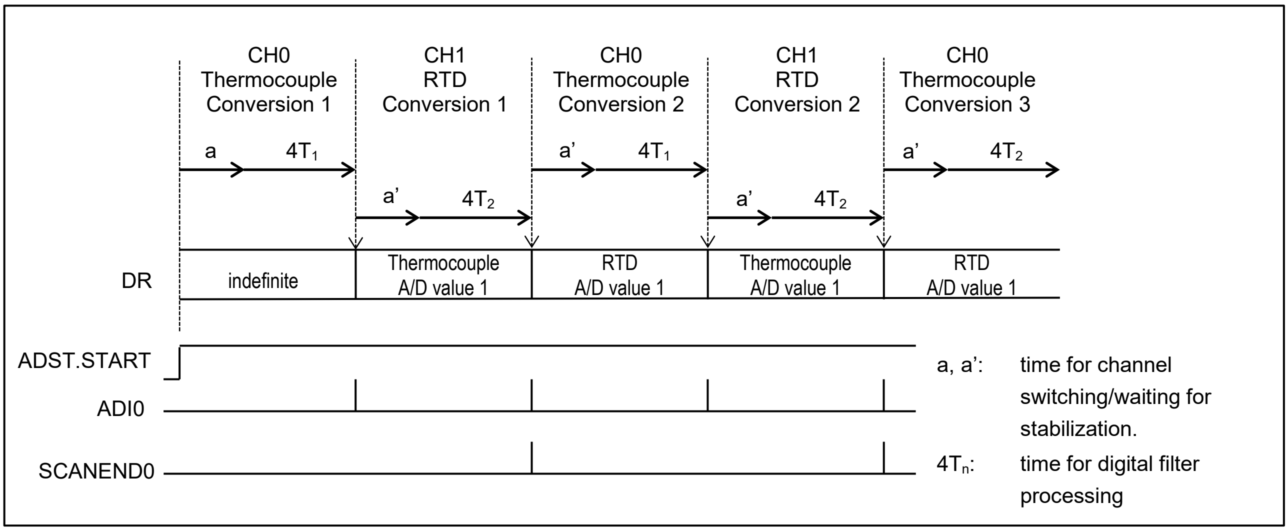


Figure 6-2 Sequence of A/D Conversion of Temperature Measurement

Table 6-1 DSAD0 Conversion Conditions of Temperature Measurement

Normal Mode: f_{MOD} = 0.5MHz

Channel		CH0: Thermocouple	CH1: RTD	Remarks
Setting	Input pin	+: AIN1 –: AIN0	+: AIN7 –: AIN6	
	PGA gain	x128	x32	
	Reference voltage	REFOUT – AVSS0	REF1P – AVSS0	
	OSR_n	32	32	Oversampling ratio setting
A/D conversion time		512 [μs]	512 [μs]	a' + $4T_n$
	A	259 [μs]		Time for switching channels and stabilization
	a'	256 [μs]		
	T_n	64 [μs]		Time for digital filter processing $T_n = OSR_n / f_{MOD}$
Data rate		976.5625 [sps/ch]		1 / total of A./D conversion time= 1 / ((a'+$4T_1$) + (a'+$4T_2$))
Digital filter gain		1		SINC4

6.1.2 Filter Processing

Filter processing is performed to remove the noise in A/D conversion value. In this example, moving average filter, band elimination filter, and lowpass filter are used to remove commercial power frequency noise and high frequency noise. Figure 6-3 shows the signal flow of filter processing and Figure 6-4 shows the frequency characteristics of filters. The expected attenuation of commercial power frequency noise by filter processing is 73dB at 50±0.3Hz and 64dB at 60±0.3Hz.

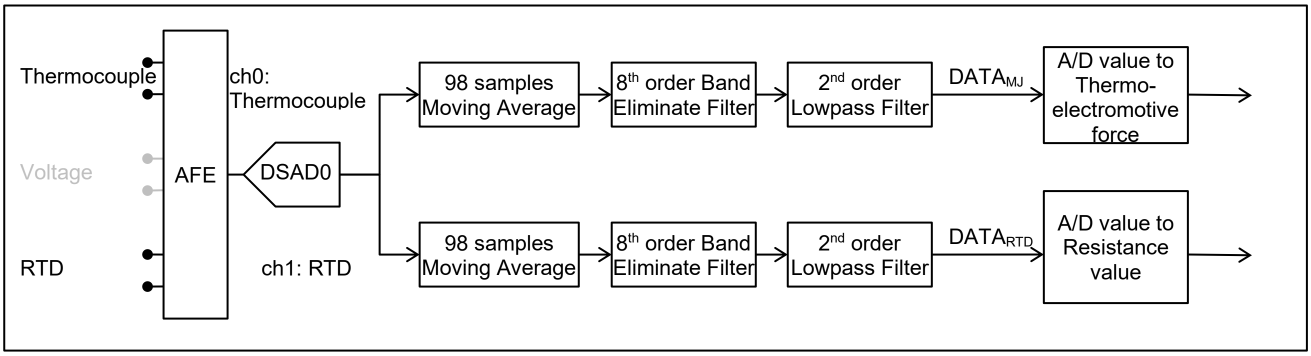


Figure 6-3 Filter Processing in Temperature Measurement

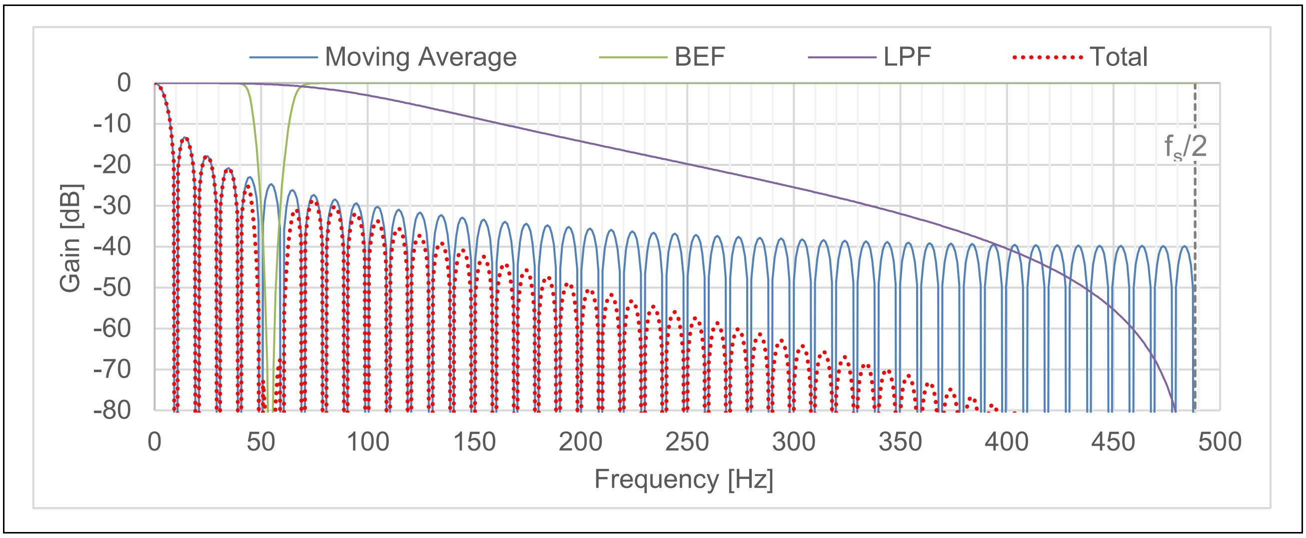


Figure 6-4 Frequency Characteristics of Filters

6.1.2.1 Moving Average Filter

Setting the suppression frequency in 10 Hz increment to reduce the commercial power frequency of 50 Hz and 60 Hz, average samples is calculated with the below formula assuming the output data rate of DSAD0 as output sampling frequency f_s.

$$Average\ Samples = {}^{f_s}/_{1stDip\ frequency} = {}^{976.5625}/_{10} = 97.65625 \cong 98$$

According to above formula, average samples is 98.

6.1.2.2 Band Elimination Filter and Lowpass Filter

Band elimination filter is used to reinforce the removal of commercial power frequency noise by the moving average filter's removal, and lowpass filter is used to remove high frequency power.

Both filleters are calculated with cascade connection of IIR Biquad filter shown in Figure 6-5. IIR Biquad Filter API of "RX Family RX DSP Library Version 5.0" is used for calculation of Biquad filter. The transfer function of Biquad filter is shown below, and IIR Biquad filter design condition and coefficients are shown in Table 6-2.

$$H(z) = \prod_{m=1}^{M} \frac{b_0^m + b_1^m * Z^{-1} + b_2^m * Z^{-2}}{1 + a_1^m * Z^{-1} + a_2^m * Z^{-2}}$$

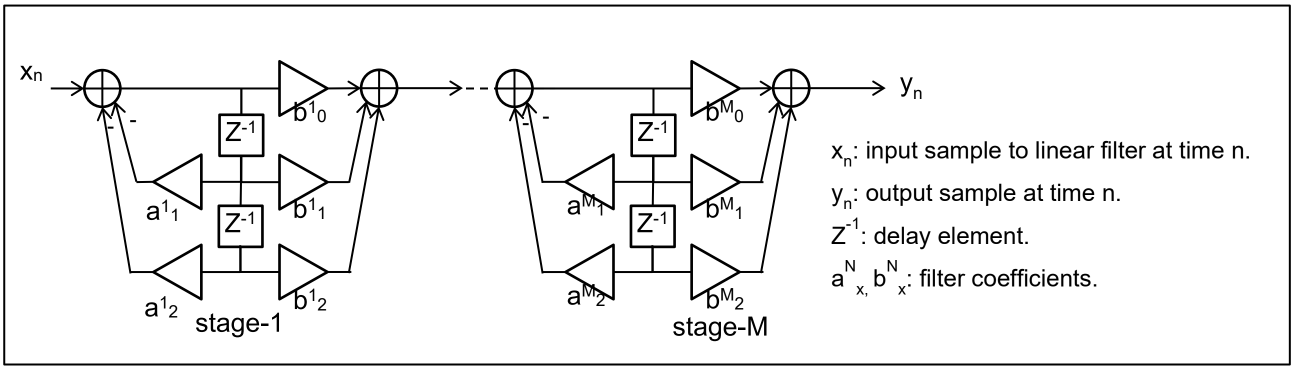


Figure 6-5 IIR Biquad Filter

Table 6-2 IIR Biquad Filter Design Condition and Coefficients

Sampling Frequency = 976.5625 [Hz]

Item		Band Eliminate Filter				Lowpass Filter
Design condition		Characteristic: Butterworth Lower passband edge frequency: 42 [Hz] Lower stopband edge frequency: 48 [Hz} Higher stopband edge frequency: 62 [Hz] Higher passband edge frequency: 70 [Hz] Passband Attenuation: 0.5 [dB] Stopband Attenuation: 12 [dB]				Characteristic: Butterworth Cut off frequency: 100 [Hz]
stage		1	2	3	4	5
Coefficients	b0	0.882516447	1	0.945210113	1	0.070192889
	b1	-1.658423596	-1.879198515	-1.776237442	-1.879198515	0.140385778
	b2	0.882516447	1	0.945210113	1	0.070192889
	a1	-1.790124941	-1.739501201	-1.875074887	-1.771797069	-1.123519837
	a2	0.887934131	0.87117146	0.95719745	0.939758826	0.404291392

6.1.3 Temperature Calculation

The measurement temperature is calculated with reference junction compensation from each A/D conversion value of thermocouple and RTD whose noise is reduced by moving average filter. For detail about temperature measurement using thermocouple, refer to Application Note “RX23E-A Group Temperature Measurement Example Using a Thermocouple”.

6.2 Voltage Measurement

The procedure for voltage calculation is shown in Figure 6-6.

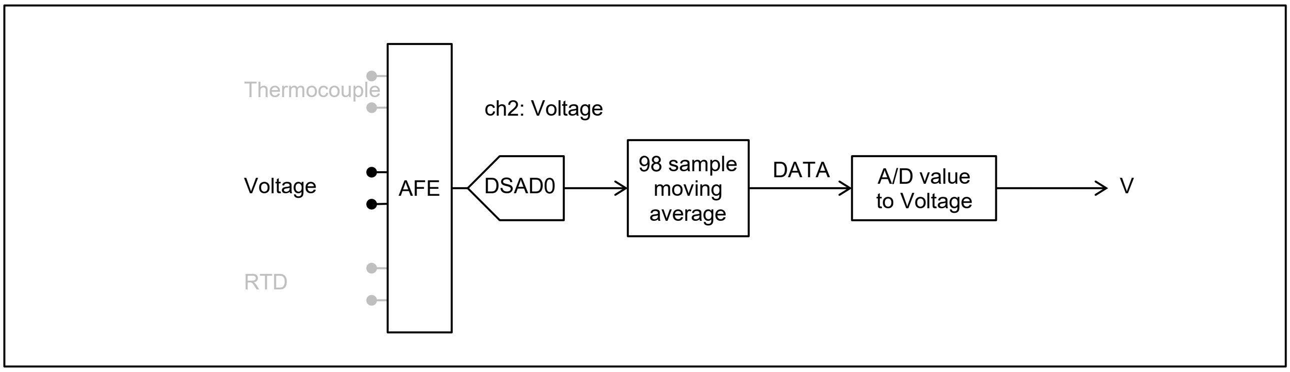


Figure 6-6 Voltage Calculation Procedure

6.2.1 A/D Conversion of Input Voltage

The A/D conversion of pin input voltage is performed with DSAD0. In this example, A/D conversion of input voltage is performed by setting CH2 of DSAD0. A/D conversion conditions are shown in Table 6-3.

Table 6-3 DSAD0 Conversion Conditions for Voltage Measurement

Normal Mode: f_{MOD} = 0.5MHz

Channel		CH2	Remarks
Setting	Input pin	+: AIN1 –: AIN0	
	PGA gain	x1	
	Reference voltage	REFOUT – AVSS0	
	OSR	512	Oversampling ratio
Data rate		976.5625 [sps]	
Digital filter gain		1	SINC4

6.2.2 Moving Average Filter

Same as temperature measurement, filter processing is performed to reduce the noise in A/D conversion value. In this example, the moving average filter is used to reduce the noise including commercial power frequency noise.

According to the conditions described in Table 6-3 DSAD0 Conversion Conditions for Voltage Measurement, the output data rate of DSAD0 is the same as that of temperature measurement, average samples is 98. Figure 6-7 shows the frequency characteristic of moving average filter.

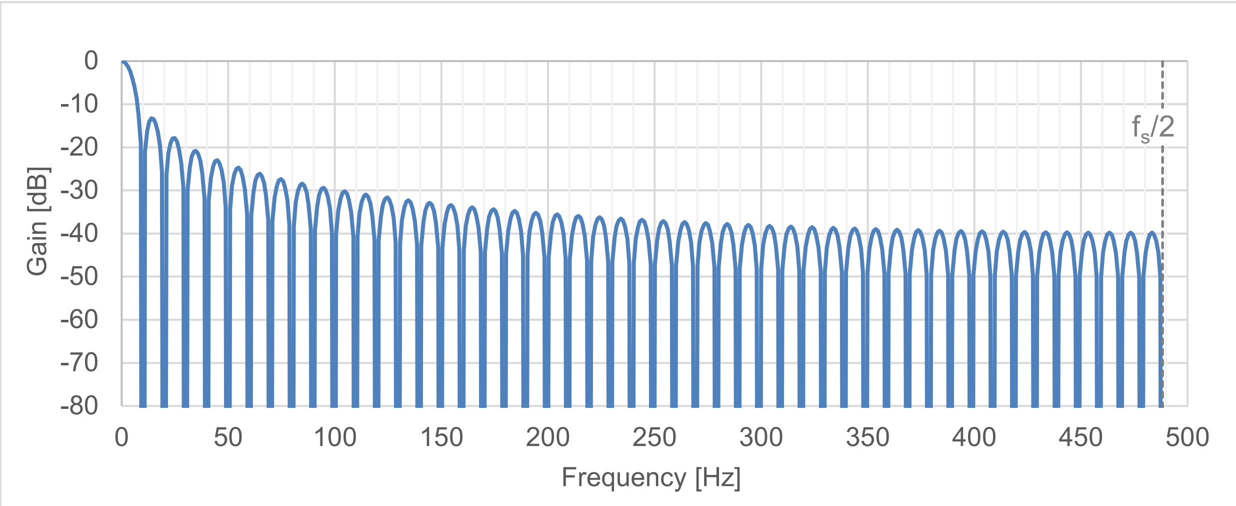


Figure 6-7 Frequency Characteristic of Moving Average Filter

6.2.3 Voltage Calculation

The pin input voltage is calculated from the result of A/D conversion.

Assuming that the set gain of the PGA is G_{PGA2}, the digital filter gain is G_{DF2}, the full scale of A/D conversion value is 2^{24} and DSAD reference voltage is V_{REF2}, the pin input voltage V for A/D conversion result DATA is calculated with the formula below.

$$V = \frac{2 \cdot V_{REF2}}{2^{24} \cdot G_{PGA2} \cdot G_{DF2}} \cdot DATA$$

Based on the conditions in Table 6-3, G_{DF2} is 1.

7. Sample Program

This section describes the sample program.

7.1 Communication Specification

7.1.1 Communication between Host and Measurement Unit

The communication between host (RX72M) and each measurement unit (RX23E-A) is performed by SPI with the host as a master and the each measurement unit as a slave.

7.1.1.1 SPI Communication Specification

Table 7-1 shows the conditions of SPI communication and Figure 7-1 shows the timing chart.

Table 7-1 SPI Communication Conditions

Item	Condition
Transfer speed	1 Mbps
Bit length	8 bits
Parity	None
Format	MSB first
SPCK phase	No clock delay
SPCK polarity	No polarity reverse

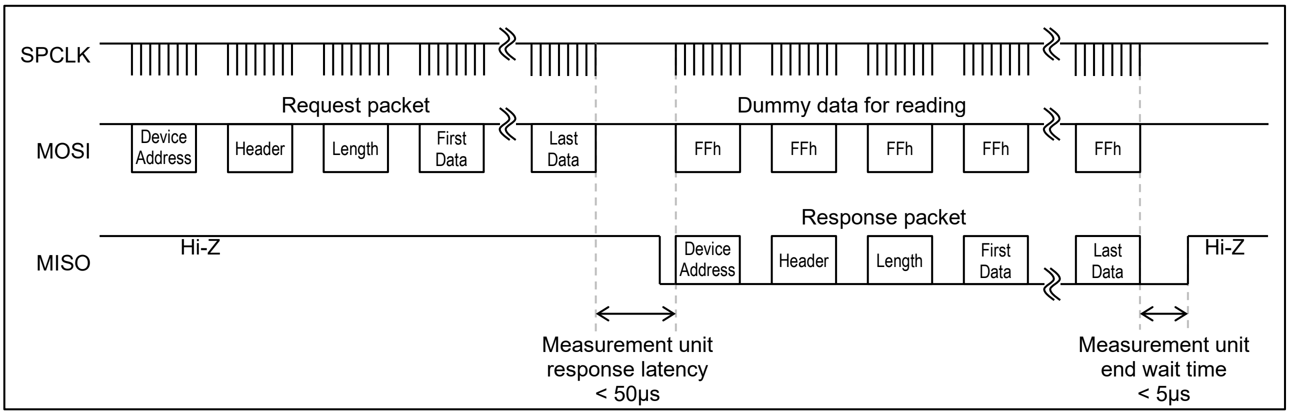


Figure 7-1 SPI Communication Timing Chart

7.1.1.2 Communication Sequence

For SPI communication the host sends a request packet, and the measurement unit returns a response packet. Figure 7-2 shows the communication sequence.

The host specifies a unit address which is assigned to each measurement unit and sends packets. The unit address has an individual address and a common address for broadcast transmission from the host to all measurement units.

In response to the request packet sent to its own individual address, the measurement unit returns a ACK for reception and a NACK for non-reception. It does not return a response packet for a common address.

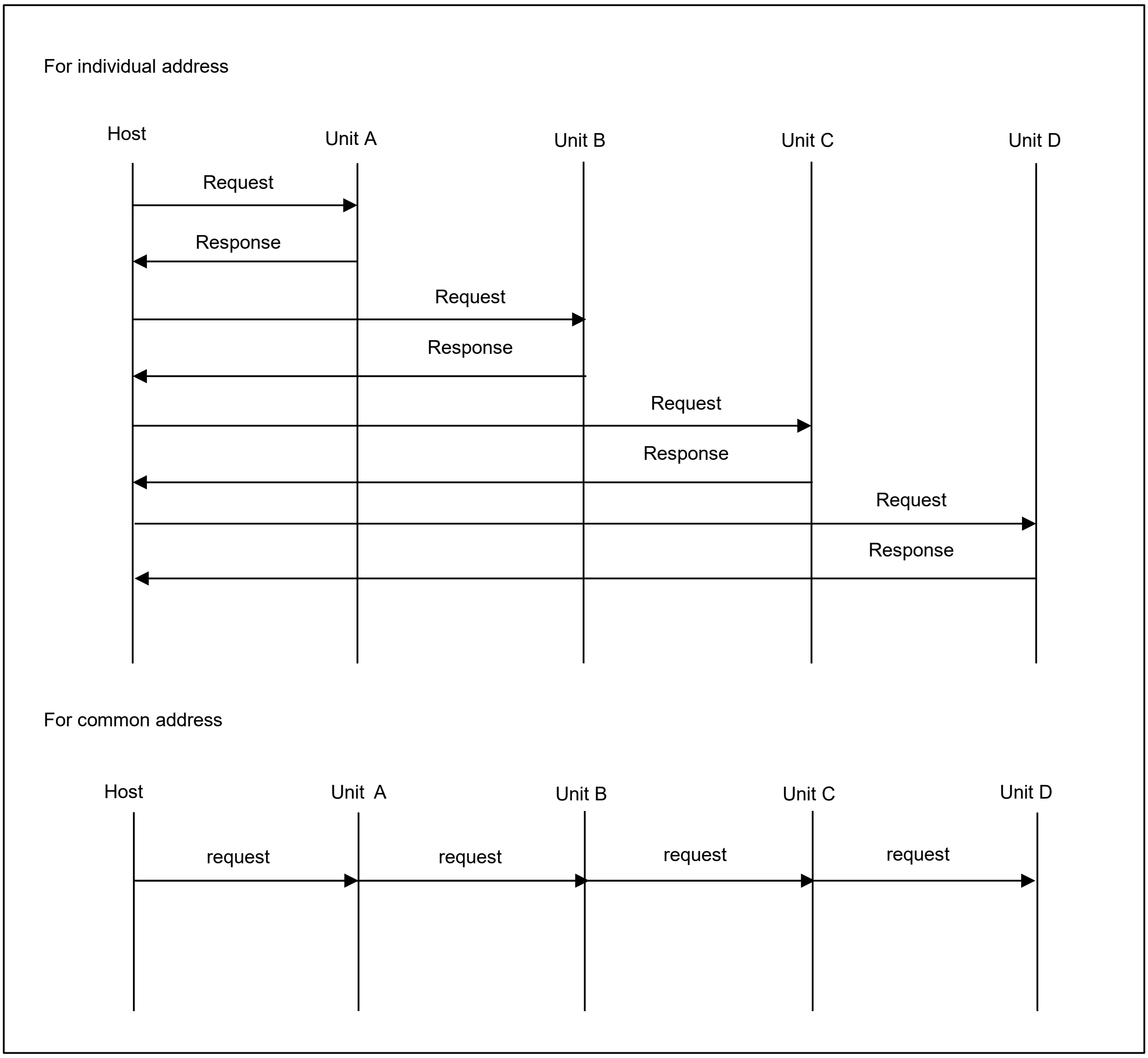


Figure 7-2 Communication Sequence

7.1.1.3 Packet Structure

Table 7-2 shows the packet structure and Table 7-3 shows the packet header structure.

Table 7-2 Packet Structure

offset [Byte]	Item	Description
0	Unit Address	Individual address：0Ah to 0Eh Common address：0Fh
+1	Header	Packet header (ref. Table 7-3)
+2	Data Length	Attached data length：0x00 to 0x7D
+3	Data	Attached data

Table 7-3 Packet Header Structure

Header	bit	Item	Description
	b7 - b6	Identifier	10b：Valid ID (Fixed value)
	b5	Type	0：Request 1：Response
	b4	ACK/NACK	0：ACK、1：NACK Host：ACK fixed
	b3 - b0	Command	Ref. Table 7-4 Command List

7.1.1.4 Command

Table 7-4 shows the command list, and the details of each command are described hereafter.

Table 7-4 Command List

Value	Command	Common address	Description
0x00	Negotiation	Disable	Acquisition of measurement unit function and Setting function
0x01 - 0x02	-	-	Reserved
0x03	Run	Enable	Start measurement
0x04	Stop	Enable	Stop measurement
0x05	GetData	Disable	Acquisition of measurement result
0x06 - 0x0F	-	-	Reserved

(1) Negotiation

Host acquires the measurement function which the measurement unit supports, or sets the measurement function which the measurement unit performs. The host specifies the Mode as Get or Set. The measurement unit returns the supporting measurement function for Get or returns the specified measurement function for Set.

The table of packet structure is shown in Table 7-5 and the data configuration is shown in Table 7-6.

Table 7-5 Negotiation Packet Structure

Type	Header	Data Length	Data	
Request	0x80	0x01	Mode: Get (1byte)	
		0x02	Mode: Set (1byte)	Function (1byte)
Response	0xA0	0x02	Mode (1byte)	Function (1byte)

Table 7-6 Data Structure

Name	Value	Description
Mode	00h: Get 01h: Set	Get: Acquisition of the measurement function which the measurement unit has Set: Setting the measurement function on the measurement unit
Function	00000001b: Temperature measurement 00000010b: Voltage measurement others: reserved	Functions which the measurement unit supports

(2) Run

The host requests the measurement unit to start measuring. The packet structure is shown in Table 7-7.

Table 7-7 Run Packet Structure

Type	Header	Data Length	Data
Request	0x83	0x00	None
Response	0xA3		

(3) Stop

The host requests the measurement unit to stop measuring. The packet structure is shown in Table 7-8.

Table 7-8 Stop Packet Structure

Type	Header	Data Length	Data
Request	0x84	0x00	None
Response	0xA4		

(4) GetData

The host requests the measurement unit to transmit the measurement results. The measurement unit returns the specified measurement result in float format.

The packet structure is shown in Table 7-9 and the data structure is shown in Table 7-10.

Table 7-9 GetData Packet Structure

Type	Header	Data Length	Data	
Request	0x85	0x01	Channel (1byte)	
Response	0xA5	0x05	Channel (1byte)	Measured Value (4byte)

Table 7-10 Data Structure

Name	Value	
Channel	Temperature measurement function	Voltage measurement function
	0x00: Measuring junction temp. 0x01: Reference junction temp. 0x02: Measuring junction thermoelectromotive force	0x00: Pin voltage
Measured Value	Measurement result (float format, MSB first)	

7.1.2 Communication between PC Tool and Host

The communication between the host (RX72M) and the PC tool is performed by PC tool program communication specification. For details, refer to the Application Note “RSSKRX23E-A PC Tool Program Operation Manual”.

7.2 Measurement Processing (RX23E-A)

7.2.1 Operation Overview

RX23E-A measures temperature or voltage according to the measurement instruction from the host based on “7.1.1 Communication between Host and Measurement Unit” then transmits the measurement result in response to the request from the host.

Figure 7-3 shows the process flow of this sample program.

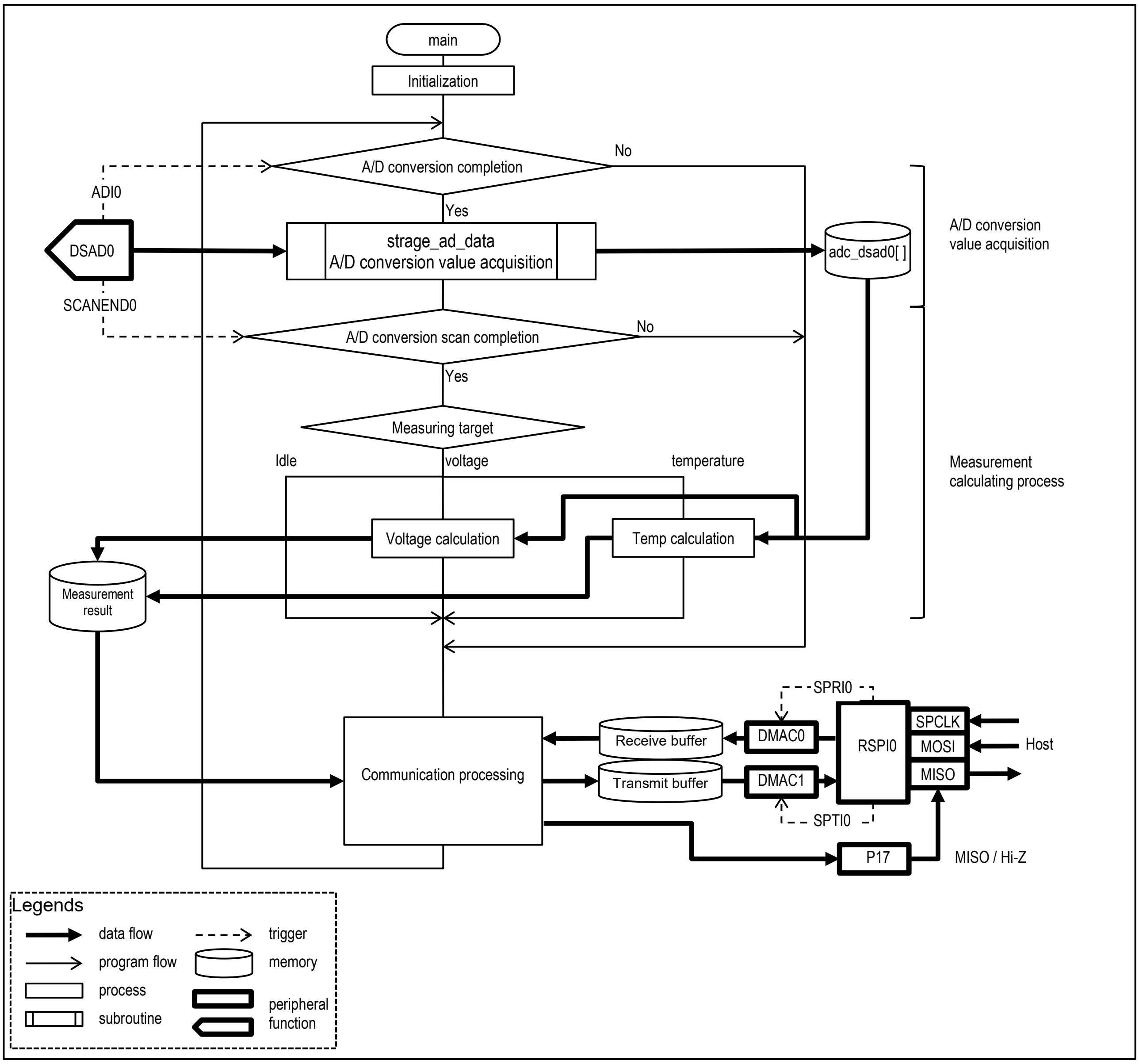


Figure 7-3 RX23E-A Program Flow

The following provides an overview of each process.

- Initialization

  The following are performed.

  — Acquires the individual address for host communication.

  — Sets MISO pin to input mode.

  — Initializes communication and activating RSPI0, DMAC0 and DMAC1
- Acquires A/D conversion value

  Acquires A/D conversion value with the A/D conversion completion as a trigger.
- Measurement calculation process

  Measurement calculation is performed with A/D conversion scan completion. In measurement calculation process, the temperature by thermocouples or the pin input voltage is measured according to the host instruction. For details, refer to “6.Measurement Process”.
- Communication process

Communication with the host is processed to set the measurement functions, start the measurement operations, and transmit the measurement results by commands. For details about communication process, refer to “7.2.3 Communication Process”.

7.2.2 Peripheral Functions and Pins Used

The peripheral functions used in this sample program are listed in Table 7-11, and the used pins are listed in Table 7-12, and the unused pins and their handlings are listed in Table 7-13. The conditions for setting each peripheral function are described together.

The settings for peripheral functions are generated by using the code generation function of Smart Configurator (referred to as SC in the remainder of this manual).

Table 7-11 Peripheral Functions Used

Peripheral function	Use
AFE, DSAD0	A/D conversion of sensor output
RSPI0	SPI communication with the host
DMAC0	Data transfer with a receive buffer full interrupt of RSPI0 as a trigger
DMAC1	Data transfer with a transmit buffer empty interrupt of RSPI0 as a trigger
P17	Switching IN/OUT of MISO pin
P30、P31	Setting unit individual address

Table 7-12 Pins Used

Pin No.	Pin name	I/O	Use
21	RSPCKA	I	Host communication
16	MOSIA	I	
15	MISOA / P17	I/O	
12	P30	I	Setting unit individual address
11	P31	I	
33	AIN0	I	Negative input of thermocouple or measured voltage, BIAS applying for thermocouple
34	AIN1	I	Positive input of thermocouple or measured voltage
35	REF1N	I	For RTD measurement
36	REF1P	I	
37	AIN6	I	
38	AIN7	I	
40	AIN9	O	Excitation current output for RTD measurement

Table 7-13 Unused Pins and Their Handlings

Pin No.	Pin name	I/O	Handling of unused pin
4	P37	O	open, Low output
22	PC4	O	pull-down, Low output
6	P36	O	open, Low output
10	P35	I	pull-up
13	P27	O	open, Low output
14	P26	O	open, Low output
17	P15	O	open, Low output
18	P14	O	open, Low output
19	PH1	O	open, Low output
20	PH0	O	open, Low output
23	PB1	O	open, Low output
25	PB0	O	open, Low output
39	AIN8	I	AVSS
32	REF0P	I	AVCC
31	REF0N	I	AVSS
30	LSW	-	AVSS

7.2.2.1 AFE・DSAD0

The conditions for measuring temperature and voltage of AFE and DSAD0 are shown in Table 7-14 and Table 7-15. For temperature measurement, A/D conversion is performed by scan with setting channel 0 for measurement of thermocouple and channel 1 for that of RTD.

For voltage measurement, A/D conversion is performed with setting channel 2.

Table 7-14 AFE Settings

Item		Setting	
		Temperature Measurement	Voltage Measurement
Bias output setting	Enable bias output setting	Enable	Disable
	Pin output	AIN0	-
Excitation current output setting	Enable excitation current output	Enable	Disable
	Operating mode	2-channel output mode	-
	Excitation current	500μA	
	IEXC0 output pin	AIN9	
	IEXC0 disconnect detection assist	Disable	
	IEXC1 output pin	Output disabled	
	IEXC1 disconnect detection assist	Not used	
Low level voltage detection setting		Not used	
Low-side switch control setting		Not used	

Note Temperature and voltage are measured by switching channel.

Table 7-15 DSAD0 Settings

<table>
<tr><th colspan="2">Item</th><th colspan="3">Setting</th></tr>
<tr><th colspan="2"></th><th colspan="2">Temperature Measurement</th><th>Voltage Measurement</th></tr>
<tr><td colspan="2">Analog input channel setting</td><td>Channel 0</td><td>Channel 1</td><td>Channel 2</td></tr>
<tr><td colspan="2">ΔΣ A/D Converter operation voltage setting</td><td colspan="3">3.6 V - 5.5 V (High precision)</td></tr>
<tr><td colspan="2">ΔΣ A/D Converter operation mode setting</td><td colspan="3">Normal mode</td></tr>
<tr><td colspan="2">Operation clock setting</td><td colspan="3">PCLKB/8 (4 MHz)</td></tr>
<tr><td colspan="2">Conversion start trigger setting</td><td colspan="3">Software trigger</td></tr>
<tr><td rowspan="4">Interrupt setting</td><td>Enable ΔΣ A/D conversion completion interrupt (ADI0)</td><td colspan="3">Enable</td></tr>
<tr><td>Priority</td><td colspan="3">Level 0 (disabled)</td></tr>
<tr><td>Enable ΔΣ A/D conversion scan completion interrupt (SCANENDI0)</td><td colspan="3">Enable</td></tr>
<tr><td>Priority</td><td colspan="3">Level 0 (interrupt disabled)</td></tr>
<tr><td colspan="2">Voltage fault and disconnection detection setting</td><td colspan="3">Not used</td></tr>
<tr><td rowspan="5">Analog input setting</td><td>Positive input signal</td><td>AIN1</td><td>AIN7</td><td>AIN1</td></tr>
<tr><td>Negative input signal</td><td>AIN0</td><td>AIN6</td><td>AIN0</td></tr>
<tr><td>Reference input</td><td>REFOUT/AVSS0</td><td>REF1P/REF1N</td><td>REFOUT/AVSS0</td></tr>
<tr><td>Positive reference voltage buffer</td><td>-</td><td>Enable</td><td>-</td></tr>
<tr><td>Negative reference voltage buffer</td><td>-</td><td>Enable</td><td>-</td></tr>
<tr><td rowspan="2">Amplifier setting</td><td>Amplifier selection</td><td colspan="3">PGA</td></tr>
<tr><td>PGA gain setting</td><td>x128</td><td>x32</td><td>x1</td></tr>
<tr><td rowspan="7">ΔΣ A/D conversion setting</td><td>A/D conversion mode</td><td colspan="3">Normal operation</td></tr>
<tr><td>Data format</td><td colspan="3">Two’s complement</td></tr>
<tr><td>A/D conversion number</td><td colspan="3">Immediate value mode, 1</td></tr>
<tr><td>Oversampling ratio
(Output data rate)</td><td colspan="2">32
(976.5625 SPS/ch)</td><td>512
(976.5625 SPS)</td></tr>
<tr><td>Set offset calibration value</td><td colspan="3">Not used (device default)</td></tr>
<tr><td>Set gain calibration value</td><td colspan="3">Not used (device default)</td></tr>
<tr><td>Enable averaging data</td><td colspan="3">Not used</td></tr>
<tr><td colspan="2">Disconnect detection assist setting</td><td colspan="3">Not used</td></tr>
</table>

Note: Temperature and voltage are measured by switching channel.

7.2.2.2 RSPI0・DMAC0・DMAC1・P17

For communication with the host, RSPI0 is used in SPI clock synchronous mode (3-wire)/Slave transmission mode. To obtain receive data, DMAC0 is used, and to set transmit data, DMAC1 is used. If data is not transmitted, MISO pin is switched to P17 input in the high-impedance state.

The conditions for setting each peripheral function are listed below.

Table 7-16 RSPI Settings

Item		Setting
Buffer access width		32 bits
Parity bit		Does not add the parity bit to transmit data and does not check the parity bit of receive data
Pin control setting	Output pin mode selection	CMOS output
Transfer data processing		Data handled by DMAC
Interrupt setting	SPT0, SPRI0, SPEI0 priority	Level 15 (highest)
	Enable error interrupt (SPEI0)	Enable
Callback function setting	Transmission end	Enable
	Reception end	Disable
	Error detection	Disable
Command setting	Number of commands, number of frames	Number of command:1、Number of transfer frame: 1
	Data length	8 bits
	Format	MSB-first
	RSPCK phase	Data variation on odd edge, data sampling on even edge
	RSPCK polarity	High when idle

Table 7-17 DMAC Settings

<table>
<tr><th colspan="2" rowspan="3">Item</th><th colspan="3">Setting</th></tr>
<tr><th rowspan="2">DMAC0</th><th colspan="2">DMAC1</th></tr>
<tr><th>On SPI transmitting</th><th>Others</th></tr>
<tr><td colspan="2">Activation source</td><td>RSPI0 (SPRI0)</td><td colspan="2">RSPI0 (SPTI0)</td></tr>
<tr><td colspan="2">Activation source flag control</td><td colspan="3">Clear interrupt flag of the activation source</td></tr>
<tr><td colspan="2">Transfer mode</td><td>Free running mode</td><td>Normal mode</td><td>Free running mode</td></tr>
<tr><td colspan="2">Transfer data size</td><td colspan="3">32 bits</td></tr>
<tr><td colspan="2">Block / Repeat area setting</td><td>-</td><td>(Set on execution)</td><td>-</td></tr>
<tr><td rowspan="3">Source address setting</td><td>Source address</td><td>0008 8384h (RSPI0.SPDR)
Fixed</td><td>(Set on execution)
Incremented</td><td>(Set on execution)
Incremented</td></tr>
<tr><td>Specify the transfer source as extended repeat area</td><td rowspan="2">-</td><td colspan="2" rowspan="2">-</td></tr>
<tr><td>Extended repeat area</td></tr>
<tr><td rowspan="3">Destination address setting</td><td>Destination address</td><td>(Set on execution)
Incremented</td><td colspan="2">0008 8384h (RSPI0.SPDR)
Fixed</td></tr>
<tr><td>Specify the transfer destination as extended repeat area</td><td>Enable</td><td colspan="2" rowspan="2">-</td></tr>
<tr><td>Extended repeat area</td><td>Lower 9 bits of the address (512 bytes)</td></tr>
<tr><td colspan="2">Interrupt setting</td><td colspan="3">Not used</td></tr>
</table>

Note: DMAC1 is programmed to change its setting depending on conditions.

Table 7-18 P17 Settings

<table>
<tr><th colspan="2" rowspan="2">Item</th><th colspan="2">Setting</th></tr>
<tr><th>On SPI transmitting</th><th>Others</th></tr>
<tr><td>PORT1</td><td>P17</td><td>Out
CMOS Out
High-drive output</td><td>In</td></tr>
</table>

Note: Programmed to change its setting depending on conditions.

7.2.2.3 P30・P31

To set unit addresses, P30 and P31 are used. The conditions of setting P30 and P31 are listed in Table 7-19 and setting unit addresses is shown in Table 7-20.

Table 7-19 P30 and P31 Settings

Item		Setting
PORT3	P30	In
	P31	In

Table 7-20 Unit Address Settings

Unit	Address	Input	
		P31	P30
A	0Ah (0Ah + 00b)	Low	Low
B	0Bh (0Bh + 01b)	Low	High
C	0Ch (0Ch + 10b)	High	Low
D	0Dh (0Dh + 11b)	High	High

7.2.3 Communication Process

Based on “7.1.1 Communication between Host and Measurement Unit”, host communication process is performed to start measurement operations and transmit the measurement results. A flow of communication processes is shown in Figure 7-4.

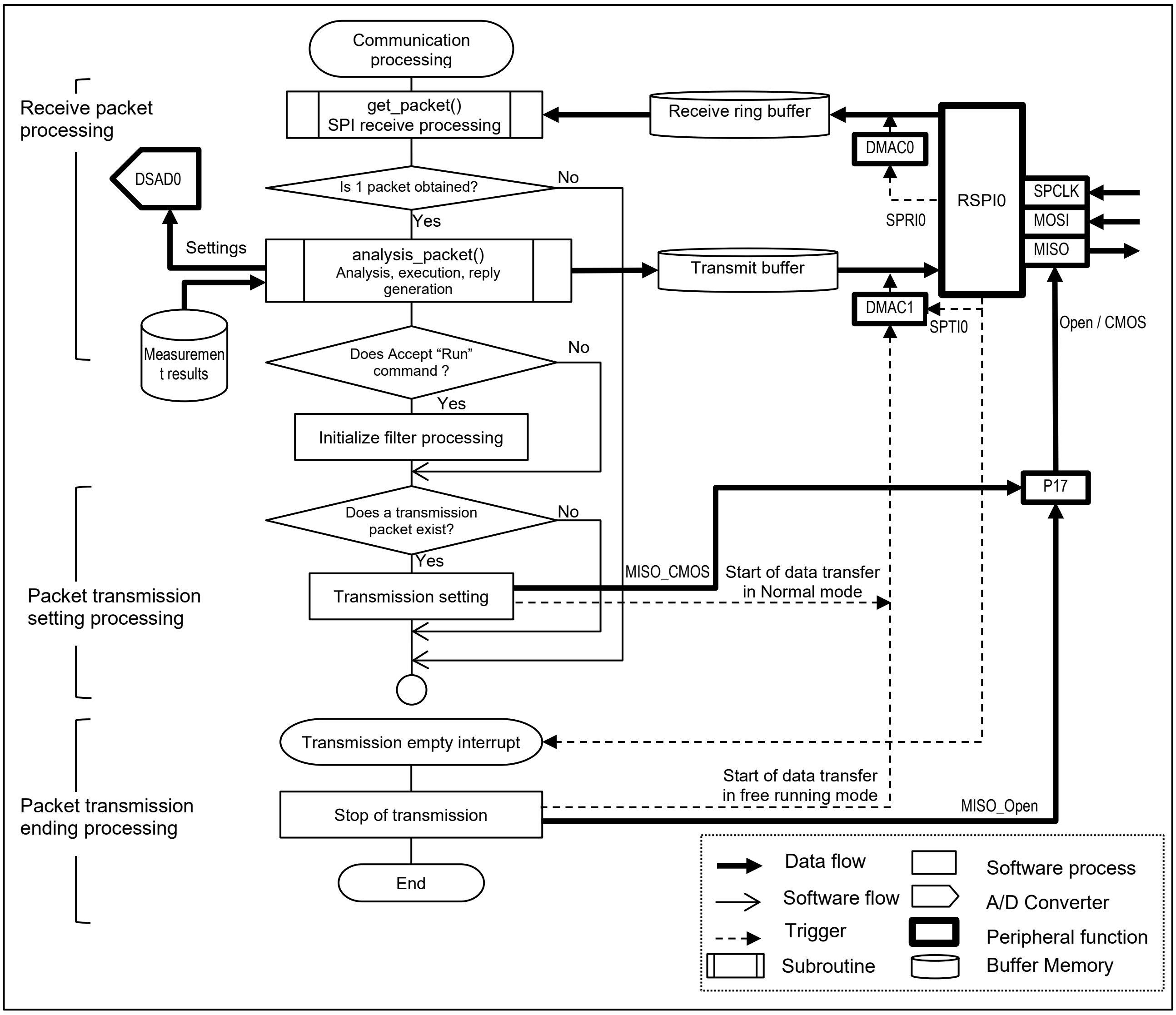


Figure 7-4 Communication Process Flow

The following provides an overview of each process.

- ·Receive packet processing

Obtains a packet from the receive ring buffer, analyzes a command, performs processing corresponding to the command in the packet, and stores a response packet in the transmit buffer. Table 7-21 lists the commands supported by this program and the processes corresponding to the commands. For an unsupported command, a NACK is returned.

Table 7-21 Packets and Actions

Receive command	Processing	Response
Negotiation	Setting AFE/DSAD by specified function	Return the measurement function of the measurement unit
Run	Start A/D conversion	-
Stop	Stop A/D conversion	-
GetData	-	Return the specified measurement results

The data stored in the transmit buffer is constituted by a response packet +FFh in the following description.

- Packet transmission setting processing

If a transmission packet exists, the transmission setting is performed as below procedures. Figure 7-5 shows its operation.

1. Stops RSPI0
2. Sets DMAC1 in normal transfer mode, sets the number of transfers to "transmission packet length+ 1 byte", and enable transferring.
3. Switches MISO pin to output
4. Starts RSPI0

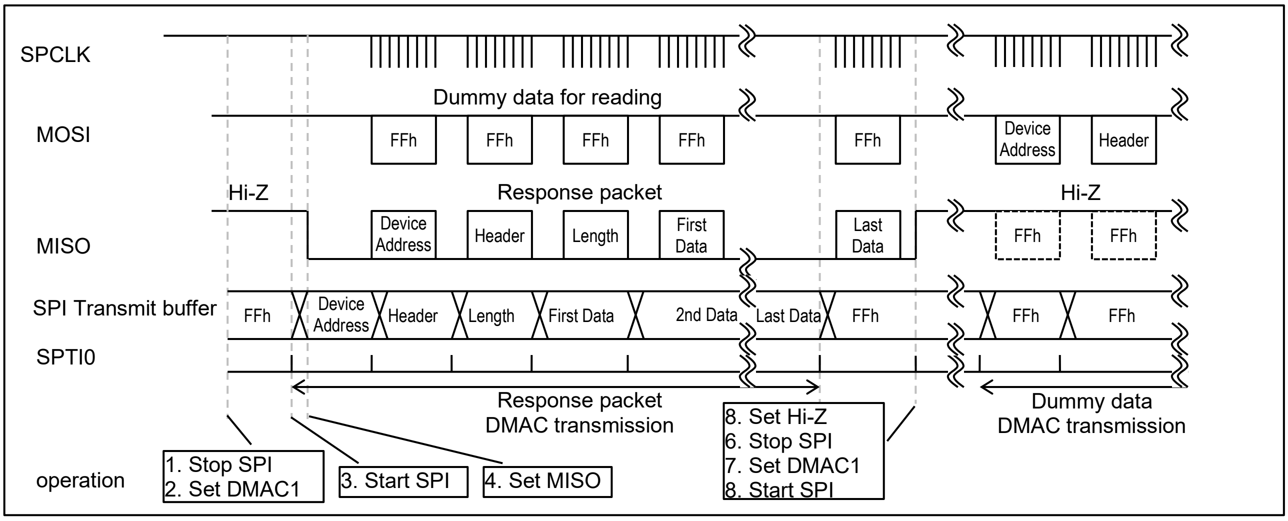


Figure 7-5 Packet Transmission Process Operation

- Packet transmission ending processing

With RSPI0 transmit buffer empty interrupt (SPTI0) which occurs after completing the transfer of DMAC1, the following processes are performed. Figure 7-5 shows its operation.

5. Switches MISO pin to input
6. Stops RSPI0
7. Sets DMAC1 in free running transfer mode and sets to transfer the fixed value FFh and enables transferring.
8. Starts RSPI0

The ring buffer used for reception is for DMAC transmission to an extended repeat area, therefore, its address is arranged in the alignment adjusted for each buffer size. In this program, section name is declared "B_DMAC_REPEAT_AREA" and arrangement is set.

7.2.4 Program Configuration

7.2.4.1 File Configuration

Table 7-22 File Configuration

Folder name, file name	Description
src	
├ smc_gen	Smart Configurator generation
│ ├ general	
│ ├ r_bsp	
│ ├──Config_DMAC0	
│ ├──Config_DMAC1	
│ ├──Config_DSAD0	
│ ├──Config_PORT	
│ ├──Config_RSPI0	
│ └ r_config	
│ └ r_pincfg	
├rx23ea_edge.c	Main processing
├r_ring_buffer_control_api.c	Ring buffer control program
├r_ring_buffer_control_api.h	Ring buffer control API definition
├r_sensor_common_api.c	Table search, linear interpolation process program
├r_sensor_common_api.h	Table search, linear interpolation process API definition
├r_thermocouple_api.c	Thermocouple measurement calculation program, temperature vs. thermoelectromotive force table
├r_thermocouple_api.h	Thermocouple measurement calculation API definition
├r_thermocouple_cfg.h	Definition of Thermocouple measurement condition
├r_rtd_api.c	Resistance temperature detector measurement calculation program, temperature vs. resistance value table
├r_rtd_api.h	Resistance temperature detector measurement calculation API definition
├r_rtd_cfg.h	Definition of Resistance temperature detector measurement condition
├r_voltage_api.c	Voltage measurement calculation program
└r_voltage_api.h	Voltage measurement calculation API definition

7.2.4.2 Macro Definitions

Table 7-23 rx23ea_dege.c Definition

Definition name	Type	Value	Description
D_CAL_AVERAGE_NUM	int32_t	98	Number of moving average processing

Table 7-24 r_thermocouple_cfg.h Definitions

Definition name	Type	Value	Description
D_TC_CFG_REFOUT	float	2.5F	REFOUT voltageV_{REF0} [V]
D_TC_CFG_PGA_GAIN	float	128.0F	Gain of PGA for thermocouple measurement G_{PGA0} [X]
D_TC_CFG_CODE_FS	int32_t	8388608	2^{23}
D_TC_CFG_DF_GAIN	float	1.0F	Digital filter gain

Table 7-25 r_thermocouple_api.h Definitions

Definition name	Type	Value	Description
D_TC_GAIN	float	D_TC_CFG_REFOUT / (D_TC_CFG_CODE_FS * D_TC_CFG_PGA_GAIN * D_TC_CFG_DF_GAIN) * 1000000	Coefficient for conversion from A/D value to thermoelectromotive force [μV] $\frac{V_{REF0}}{2^{23} \cdot G_{PGA0} \cdot G_{DF0}} \cdot 10^6$
D_TC_OFFSET	float	0.0F	Thermoelectromotive force offset [μV]
D_TC_TABLE_TEMP_MIN	float	-75.0F	Minimum temperature in the table [°C]
D_TC_TABLE_TEMP_MAX	float	251.0F	Maximum temperature in the table [°C]

Table 7-26 r_rtd_cfg.h Definitions

Definition name	Type	Value	Description
D_RTD_CFG_TYPE	-	1	Resistance temperature detector 1: 4-wire 2: 3-wire
D_RTD_CFG_RREF	float	5100.0F	RREF resistance value R_{REF} [Ω]
D_RTD_CFG_PGA_GAIN	float	32.0F	Gain of PGA for RTD measurement G_{PGA1} [X]
D_RTD_CFG_CODE_FS	int32_t	8388608	2^{23}
D_RTD_CFG_DF_GAIN	float	1.0F	Digital filter gain G_{DF1}
D_RTD_CFG_OFFSET	float	0.0F	RTD resistance value offset. [Ω]

Table 7-27 r_rtd_api.h Definitions

Definition name	Type	Value	Description
D_RTD_GAIN	float	D_RTD_CFG_RREF / (D_RTD_CFG_CODE_FS * D_RTD_CFG_PGA_GAIN * D_RTD_CFG_DF_GAIN)	Coefficient for conversion from A/D value to RTD resistance value [Ω] $\frac{R_{REF}}{2^{23} \cdot G_{PGA1} \cdot G_{DF1}}$
D_RTD_TABLE_TEMP_MIN	float	-40.0F	Minimum temperature in the table [°C]
D_RTD_TABLE_TEMP_MAX	float	86.0F	Maximum temperature in the table [°C]

Table 7-28 r_voltage_api.h Definitions

Definition name	Type	Value	Description
D_VOLTAGE_VREF	float	2.5F	VREF voltage V_{REF} [V]
D_VOLTAGE_PGA_GAIN	float	1.0F	Gain of PGA for pin voltage measurement G_{PGA} [X]
D_VOLTAGE_CODE_FS	float	8388608.0F	2^{23}

7.2.4.3 Structures and Unions

Table 7-29 rx23ea_edge.c: Main Processing File Structures and Unions

Structure type name	st_unit_info_t		
Member variable	Type	Name	Description
	uint32_t	addr	Unit address
	uint32_t	func	Measurement function
Union type name	u_measure_data_t		
Member variable	Type	Name	Description
	float	dataf	float type measurement result data
	uint8_t	buf[4]	8-bit type measurement result data storage array

Table 7-30 r_ring_buffer_control_api.h: Ring Buffer Control Header File Structure

Structure type name	st_ring_buf_t		
Member variable	Type	Name	Description
	uint8_t *	p_buf	Pointer to the ring buffer
	size_t	length	Ring buffer length
	uint32_t	r_index	Read index
	uint32_t	w_index	Write index

Table 7-31 r_sensor_common_api.h: Common calculation API Header File Structure

Structure type name	st_cal_moveavg_t		
Member variable	Type	Name	Description
	int32_t	count	Number of counts
	int32_t	sumdata	Input data addition value
	int32_t *	p_deldata	Pointer to the input data storage array
	int32_t	avgnum	Number of moving average samples

7.2.4.4 Functions

Table 7-32 rx23ea_edge.c Functions

Function name/Overview	Return value Type	Return value Value	Argument I/O	Argument Type	Argument Name	Argument Description
main main function	void	-	-	void	-	-
analysis_pakect According to a receive packet, executes the command and stores a response packet	uint32_t	Response packet length	I	const uint32_t	rcv_pkt[]	Receive packet storage array
			O	uint32_t	snd_pkt[]	Response packet storage array
			I/O	st_unit_info_t *	p_info	Pointer to the measurement result transmission enable flag
			I	float	meas_buf[]	Measurement result storage array
get_packet Reads a single packet from the receive ring buffer	size_t	Receive packet length	I/O	st_ring_buf_t *	r_buf	Pointer to the receive ring buffer
			O	uint32_t	rcv_pkt[]	Receive packet storage array
			I	const uint32_t	my_addr	Own unit address
strage_ad_data Obtains A/D conversion value	void	-	O	int32_t	dsad[]	A/D conversion value storage array

Table 7-33 r_ring_buffer_control_api.c Functions

Function name/Overview	Return value Type	Return value Value	Argument I/O	Argument Type	Argument Name	Argument Description
R_RINGBUF_GetData Reads a specified number of bytes from the ring buffer	size_t	Number of bytes to read	I	st_ring_buf_t *	ary	Pointer to the ring buffer
			O	uint8_t	data[]	Data storage array
			I	size_t	len	Number of bytes to read
			I	bool	index_update	Index update flag true: Update false: Not update
R_RINGBUF_SetData Writes a specified number of bytes to the ring buffer	size_t	Number of bytes to write	O	st_ring_buf_t *	ary	Pointer to the ring buffer
			I	uint8_t	data[]	Data storage array
			I	size_t	len	Number of bytes to write
R_RINGBUF_GetDataLength Reads the number of bytes stored in the ring buffer	size_t	Number of bytes stored	I	st_ring_buf_t *	ary	Pointer to the ring buffer
R_RINGBUF_SetDataIndex Updates the index of the ring buffer	uint32_t	Index value	O	st_ring_buf_t *	ary	Pointer to the ring buffer
			I	uint16_t	value	Index value
			I	uint8_t	select	Target index 0:Read、1:Write

Table 7-34 r_sensor_common_api.c Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_CALC_BinarySearch Does a binary search from the search table, and returns the index of a recent value that does not exceed the data to search for	uint16_t	Index value	I	const float *	p_data_table	Pointer to the search table (ascending order)
			I	uint16_t	table_size	Number of elements in the search table
			I	float	data	Data to search for
R_CALC_Lerp From two points (x0, y0) and (x1, y1), determines y for input x with liner interpolation	float	Linear interpolation results	I	float	x0	x0 value
			I	float	y0	y0 value
			I	float	x1	x1 value
			I	float	y1	y1 value
			I	float	x	X value
R_CALC_MovingAverage Returns the moving average processing result for input data	float	Moving average result	I	const int32_t	data	Input data
			I	st_cal_moveavg_t *	p_cal_moveavg	Pointer to the moving average processing variable

Table 7-35 r_thermocouple_api.c Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_TC_TempToEmf Calculates the thermoelectromotive force of the thermocouple from the temperature	float	Thermoelectromotive force [μV]	I	float	temp	Temperature [°C]
R_TC_DsadToEmf Calculates the thermoelectromotive force of the thermocouple from the A/D conversion value	float	Thermoelectromotive force [μV]	I	float	dsad	A/D conversion value
R_TC_EmfToTemp Calculates the temperature from the thermoelectromotive force of the thermocouple	float	Temperature [°C]	I	float	emf	Thermoelectromotive force [μV]

Table 7-36 r_rtd_api.c Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_RTD_DsadToTemp Calculates the temperature from the A/D conversion value	float	Temperature [°C]	I	float	dsad	A/D conversion value

Table 7-37 r_voltage_api.c Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_VOLTAGE_DsadToVoltage Calculates the pin voltage from the A/D conversion value	float	Voltage [V]	I	float	dsad	A/D conversion value

Table 7-38 Config_DSAD0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_DSAD0_IsConversionEnd Returns information as to whether A/D conversion is in progress with the conversion completion flag of DSAD0	bool	false：Conversion true：Conversion end	-	void	-	-
R_DSAD0_ClearConversionFlag Clears the conversion completion flag of DSAD0	void	-	-	void	-	-
R_DSAD0_IsScanEnd Returns information as to whether scan is in progress with the scan completion flag of DSAD0	bool	false：Scan true：Scan end	-	void	-	-
R_DSAD0_ClearScanFlag Clears the scan completion flag of DSAD0	void	-	-	void	-	-
R_DSAD0_CHnEN Enables the channel of DSAD0 and Sets AFE Enable/Disable	void	-	I	uint32_t	ch	enable channel

Table 7-39 Config_DMAC0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_DMAC0_SetDestAddr Sets DMDAR of DMAC0	void	-	I	void *	p_addr	destination address
R_DMAC0_GetDestAddr Returns DMDAR of DMAC0 (macro function)	void	-	-	void	-	-

Table 7-40 Config_DMAC1 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_DMAC1_SetSrcAddr Sets DMSAR of DMAC1	void	-	I	void *	p_addr	source address
R_DMAC1_SetTxCount Sets DMCRA of DMAC1	void	-	I	uint32_t	cnt	transfer count
R_DMAC1_SetFreerunMode Sets DMAC1 to free running mode	void	-	-	void	-	-
R_DMAC1_SetNormalMode Set DMAC1 to normal mode	void	-	I	uint32_t	cnt	transfer count

Table 7-41 Config_PORT User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_PORT_SetOpenMiso Sets P17/MISO pin to input (macro function)	void	-	-	void	-	-
R_PORT_SetCmosMiso Sets P17/MISO pin to output (macro function))	void	-	-	void	-	-
R_PORT_GetUnitAddr Returns the unit address additional value	uint32_t	Unit address additional value	-	void	-	-

Table 7-42 Config_RSPI0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_RSPI0_SendStart Starts RSPI0 transmission	void	-	-	void	-	-
R_RSPI0_SendStop Stops RSPI0 transmission	void	-	-	void	-	-
R_RSPI0_ReceiveStart Starts RSPI0 reception	void	-	-	void	-	-

7.3 Host Processing (RX72M)

7.3.1 Operation Overview

RX72M performs the communication with PC tool. Based on “7.1.1 Communication between Host and Measurement Unit”, according to Run command from the PC tool, it obtains the temperature or voltage, which 4 measurement units (RX23E-A) measured, in 10 msec cycle, and transfers to the PC tool.

Figure 7-6 shows the process flow of this sample program.

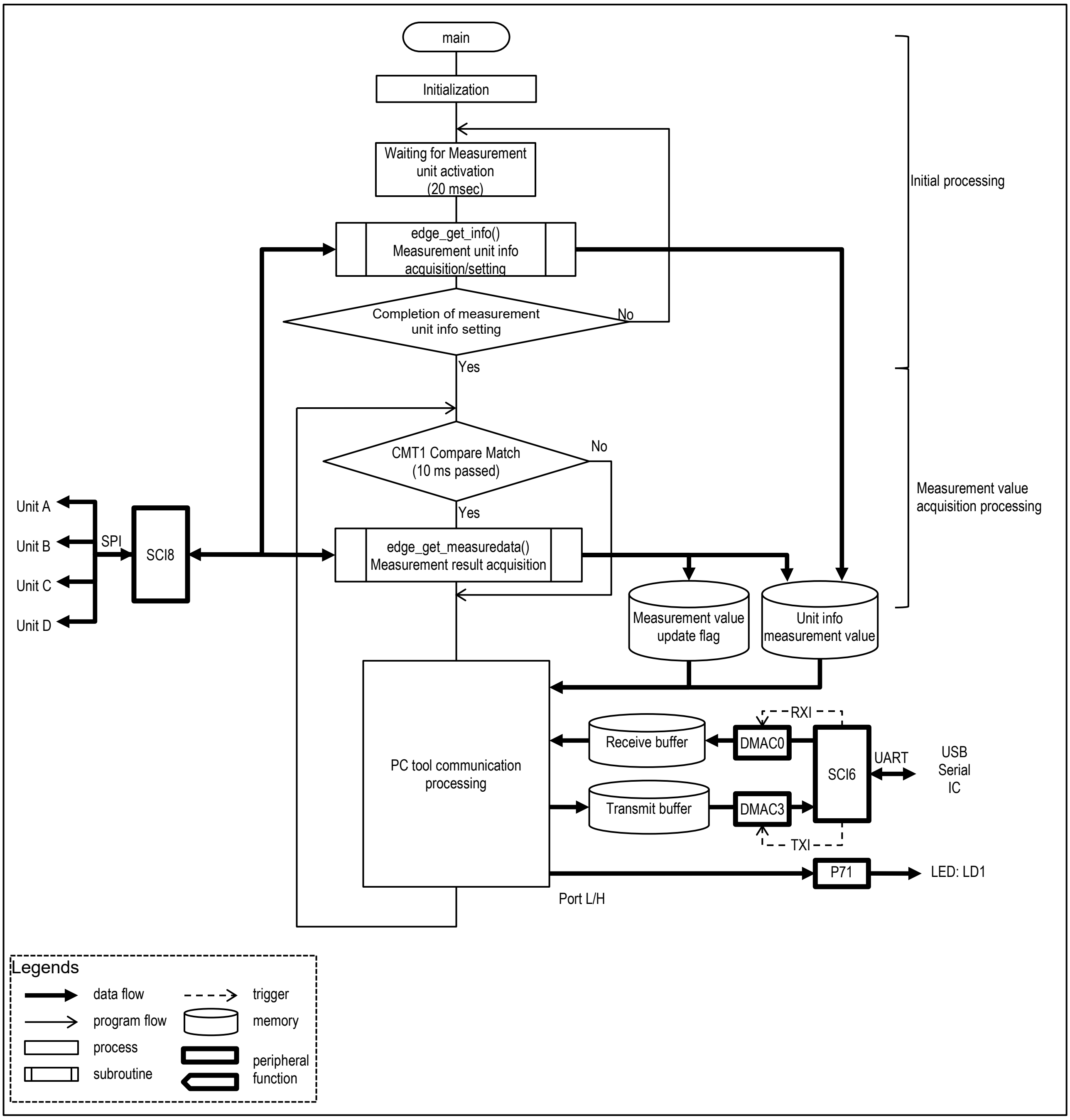


Figure 7-6 RX72M Program Flow

The following provides an overview of each process.

- Initialization
  The following are performed.
  — Initializes the communication buffer and the starts SCI6, DMAC0, and SCI8 operation
  — After waiting time for the measurement unit activates, acquires information and sets the measurement function by communication with the edge.
- Measurement value acquisition processing
  With CMT1 compare match (10 msec) as a trigger, acquires the measurement result from the edge and sets a measurement result update flag. In this process, communication with the measurement unit is performed to acquire the measurement result.
- PC tool communication processing
  Analyzes a receive packet from the PC tool program, starts/stops measurement, and transmits a response packet. Measurement values are transmitted when a measurement result update flag is set.
  For details, refer to “7.3.4 PC tool Communication Processing”.

For details about process of communication with measurement unit, refer to “7.3.3 Measurement Unit Communication Processing”.

7.3.2 Peripheral Functions and Pins Used

The peripheral functions used in this sample program are listed in Table 7-43, and the pins used are listed in Table 7-43. The conditions for setting each peripheral function are described together.

The settings for peripheral functions are generated by using the code generation function of SC.

Table 7-43 Peripheral Functions Used

Peripheral function	Use
SCI6	Communication with the PC tool program
SCI8	Simple SPI communication with the measurement unit
DMAC0	Data transfer with a receive complete interrupt of SCI6 as a trigger
DMAC3	Data transfer with a transmission data empty interrupt of SCI6 as a trigger
CMT0	Detection of a communication timeout of SCI6
CMT1	Timing of the measurement result acquisition
P71	LED:LD1 ON/OFF control

Table 7-44 Pins Used

Pin No.	Pin name	I/O	Use
M5	PJ0/SCK8	O	SCI8 clock output pin
L6	PJ2/SMOSI8	O	SCI7 transmit pin
R9	PC6/SMISO8	I	SCI8 receive pin
J9	PK3	O	Isolated power supply control signal
J13	P71	O	LED:LD1 ON/OFF control
E3	P00/TXD6	O	SCI6 transmit pin
D5	P01/RXD6	I	SCI6 receive pin
H7	PJ3/CTS6#	I	CTS6 signal input pin

7.3.2.1 SCI8

For communication with the measurement unit, SCI8 is used in SPI clock synchronous mode/master transmission. The conditions for setting SCI8 are described in Table 7-45.

Table 7-45 SCI8 Settings

Item		**Setting**
Transfer direction setting		MSB-first
Data inversion setting		Normal
Transfer speed setting	Transfer clock	Internal clock
	Bit rate	1000 kbps
	Enable modulation duty correction	Disable
Clock setting	Enable clock delay	Disable
	Enable clock polarity inversion	Disable
Data handling setting	Transmit data handling	Data handling in interrupt service routine
	Receive data handling	Data handling in interrupt service routine
Interrupt setting	TXI8 priority	Level 15 (highest)
	RXI8 priority	Level 15 (highest)
	Enable reception error interrupt	Enable
	TEI8, ERI8 priority	Level 15 (highest)
Callback function setting	Transmission end	Enable
	Reception end	Enable
	Reception error	Enable

7.3.2.2 SCI6・DMAC0・DMAC3・CMT0

For communication with the PC tool program, SCI6 is used in asynchronous mode. DMAC0 is used to obtain receive data and DMAC3 is used to set transmit data. To detect a communication timeout, CMT0 is used.

The conditions for setting each peripheral function are listed below.

Table 7-46 SCI6 Settings

Item		Setting
Start bit edge detection setting		Low level on RXD6 pin
Data length setting		8 bits
Parity setting		None
Stop bit setting		1 bit
Transfer direction setting		LSB-first
Transfer rate setting	Transfer clock	Internal clock
	Bit rate	3,000,000 bps
	Enable modulation duty correction	Enable
	SCK6 pin function	SCK6 is not used
Noise filter setting	Enable noise filter	Not used
Hardware flow control setting		CTS6#
Data match detection setting		Not used
Data handling setting	Transmit data handling	Data handled by DMAC
	Receive data handling	Data handled by DMAC
Interrupt setting	TXI6 priority	Level 15 (highest)
	RXI6 priority	Level 15 (highest)
	Enable reception error interrupt (ERI6)	Disable
	TEI6, ERI6 priority (Group BL0)	Level 15 (highest)
Callback function setting		Not used

Table 7-47 DMAC Settings

Item		Setting	
		DMAC0	DMAC3
Activation Source		SCI6 (RXI6)	SCI6 (TXI6)
Activation source flag control		Clear interrupt flag on the activation source	
Transfer mode		free running mode	Normal mode
Transfer data size		8 bits	
Block / Repeat area setting		-	(Set on execution)
Source address setting	Source address	0008 A0C5h (SCI6.RDR) Fixed	(Set on execution) Incremented
	Specify the transfer source as extended repeat area	-	Enable
	Extended repeat area		Lower 12 bits of the address (4 Kbytes)
Destination address setting	Destination address	(Set on execution) Incremented	0008 A0C3h (SCI6.TDR) Fixed
	Specify the transfer destination as extended repeat area	Enable	-
	Extended repeat area	Lower 9 bits of the address (512 bytes)	
Interrupt setting		Not used	

Table 7-48 CMT0 Settings

Item		Setting
Count clock setting		PCLKB/512
Compare match setting	Interval time	1000 ms
	Enable compare match interrupt (CMI0)	Not used

7.3.2.3 CMT1

CMT1 is used for timing of obtaining measurement results. The conditions for setting CMT1 are described in Table 7-49.

Table 7-49 CMT1 Settings

Item		Setting
Count clock setting		PCLKB/8
Compare match setting	Interval time	10 ms
	Compare match interrupt (CMI1)	Enable
	Priority	Level 0 (disabled)

7.3.2.4 P71

By using P71, LED:LD1 is turned ON and OFF. While the measurement unit is measuring, LD1 is ON. The condition for setting P71 is listed in Table 7-50.

Table 7-50 P71 Settings

Item		Setting
PORT7	P71	Out CMOS Out Output 1

7.3.3 Measurement Unit Communication Processing

To acquire information of measurement units, set measurement functions, and acquire measurement results, the communication with measurement units is processed based on '7.1.1 Communication between Host and Measurement Unit". The flow of measurement units communication processing is shown in Figure 7-7. For functions to be used, refer to "Table 7-57 rx72m_host.c functions".

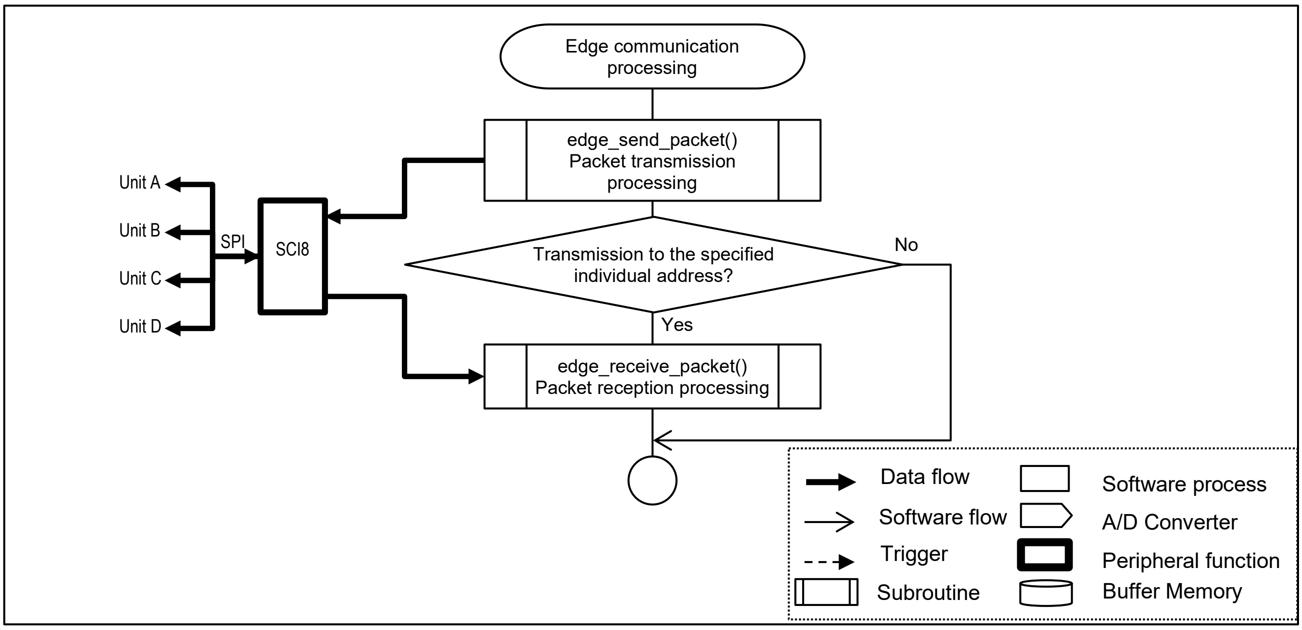


Figure 7-7 Measurement Unit Communication Processing Flow

The following provides an overview of each process.

- Packet transmission processing
  Transmits a request packet created in the upper processing which performs information acquisition, measurement function setting, and measurement result acquisition of measurement units.
- Packet reception processing
  Obtains a response packet from the measurement unit when a packet is transmitted to the specified individual address.

Communication with measurement unit is performed in 1 byte unit for both transmission and reception.

Table 7-51 lists the commands supported by this program and the processes and the occurrences corresponding to the commands.

Table 7-51 Packets and Actions

Command	Process	Occurrence
Negotiation (Get)	Select a measurement function from the measurement functions acquired from the measurement units	Measurement unit information acquisition
Negotiation (Set)	Set a measurement function to the measurement units	Measurement unit information setting
Run	Start the measurement of the measurement units	On receiving Run command from the PC tool
Stop	Stop the measurement of the measurement units	On receiving Stop command from the PC tool
GetData	Store the acquired measurement result in measurement result data of the measurement units information	Measurement result acquisition

7.3.4 PC tool Communication Processing

Based on the RSSKRX23R-A communication specification Rev.2.0, processes with PC tool program are performed. The flow of PC tool communication process is shown in Figure 7-8.

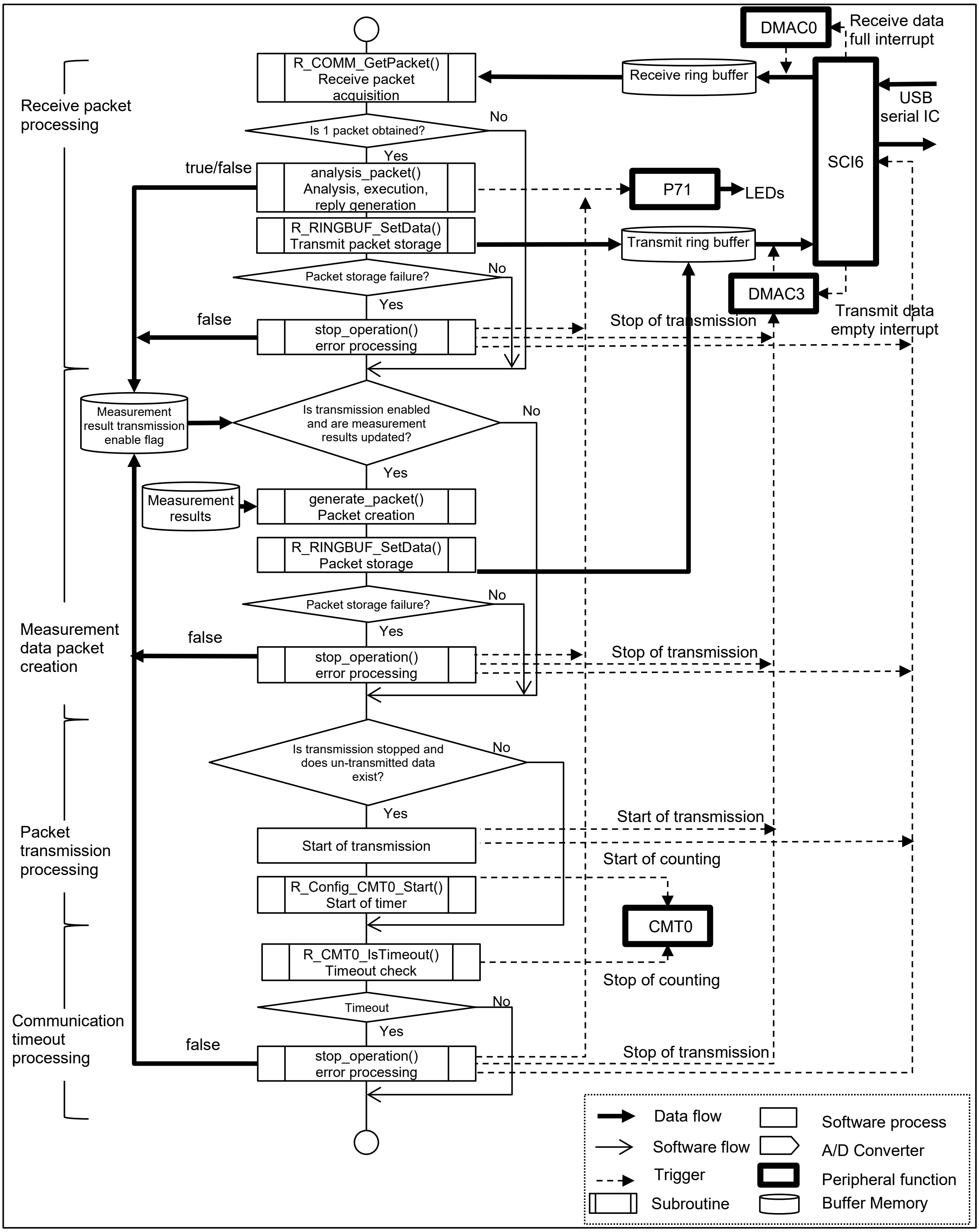


Figure 7-8 PC Tool Communication Process Flow

The following provides an overview of each process.

- Receive packet processing

Obtains a receive packet from the receive ring buffer, analyzes a command, and performs processing corresponding to the command in the packet, then stores a response packet in the transmit ring buffer. Table 7-52 lists the commands supported by this program and the processes corresponding to the commands. For an unsupported command, a NACK is returned.

If the response packet cannot be stored in the transmit ring buffer, communication error processing is performed.

Table 7-52 Packets and Actions

Command	Process
Negotiation	Return the system condition status with a response packet
Run	Start measuring of the measurement units, set the measurement result transmission enable flag, and turn LD1 ON.
Stop	Stop measuring of the measurement units, clear the measurement result transmission enable flag, and turn LD1 OFF
ExtraInformation	Return output data rate with a response packet

- Measurement data packet creation

If the measurement result transmission enable flag is set and the measurement results are updated, a transmission packet of the measurement results is created and is stored in the transmit ring buffer.

If the response packet cannot be stored in the transmit ring buffer, communication error processing is performed.

- Packet transmission processing

If data is not being transmitted and the transmit ring buffer contains un-transmitted data, transmission starts with DMAC3 and 1-second counting starts with CMT0 for timeout detection.

- Communication timeout processing

If transmission is completed, CMT0 for timeout detection is stopped.

If transmission is in progress, the timer is checked for a compare match, and if a compare match has occurred, this is judged as a timeout. If it is judged as a timeout, communication error processing is performed.

- Communication error processing

If the transmit packet cannot be stored in the transmit ring buffer or a communication timeout occurs, communication is stopped and the following processes are performed to make a reconnection possible.

  — Stop SCI6 and DMAC3, which are used for transmission
  — Clear the transmit buffer and the measurement result transmission enable flag
  — Turn LD1 OFF

Each ring buffer used for transmission and reception is for DMAC transmission, therefore, their address is arranged in the alignment adjusted for each buffer size. In this program, section name is declared “B_DMAC_REPEAT_AREA” and arrangement is set based on the largest buffer size.

7.3.5 Program Configuration

7.3.5.1 File Configuration

Table 7-53 File Configuration

Folder name, file name	Description
src	
├ smc_gen	Smart Configurator generation
│ ├ general	
│ ├ r_bsp	
│ ├──Config_CMT0	
│ ├──Config_CMT1	
│ ├──Config_DMAC0	
│ ├──Config_DMAC3	
│ ├──Config_PORT	
│ ├──Config_SCI6	
│ ├──Config_SCI8	
│ └ r_config	
│ └ r_pincfg	
├rx72m_host.c	Main processing
├r_ring_buffer_control_api.c	Ring buffer control program
├r_ring_buffer_control_api.h	Ring buffer control API definition
├r_communication_control_api.c	PC tool communication control program
└r_communication_control_api.h	PC tool communication control API definition

7.3.5.2 Macro Definitions

Table 7-54 rx72m_host.c Definitions

Definition name	Type	Value	Description
D_EDGE_NUMS	uint32_t	4	Number of measurement units

7.3.5.3 Structures and Unions

Table 7-55 rx72m_host.c: Main Processing File Structures and Unions

Structure type name	st_edge_info_t		
Member variable	**Type**	**Name**	**Description**
	uint32_t	addr	Unit address
	uint32_t	func	Measurement function
	uint32_t	type	Type of measurement result data
	float	data	Measurement result data
Structure type name	u_edge_data_t		
Member variable	float	dataf	float type measurement result data
	uint8_t	buf[4]	8-bit type measurement result data storage array

Table 7-56 r_ring_buffer_control_api.h: Ring Buffer Control Header File Structure

Structure type name	st_ring_buf_t		
Member variable	**Type**	**Name**	**Description**
	uint8_t *	buf	Pointer to the ring buffer
	size_t	length	Ring buffer length
	uint32_t	r_index	Read index
	uint32_t	w_index	Write index

7.3.5.4 Functions

Table 7-57 rx72m_host.c functions

Function name / Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
main main function	void	-	-	void	-	-
stop_operation Stops DMAC/SCI6, initializes the ring buffer, and turns LD1 OFF	void	-	I	st_ring_buf_t *	ary	Pointer to the ring buffer
analysis_pakect According to the receive packet, executes the command and stores a response packet. For the Run/Stop commands, updates the measurement result transmission enable flag.	size_t	Response data length	I	uint8_t const	recv_pkt[]	Receive packet storage array
			O	uint8_t	send_pkt[]	Response packet storage array
			O	bool *	p_tx_flag	Pointer to the measurement result transmission enable flag
			I	st_edge_info_t	info_buf[]	Pointer to the measurement unit information buffer
edge_cmd_negotiation Executes Negotiation command to the measurement unit, obtains functions, and performs setting	void	-	I	const uint32_t	addr	Unit address
			I/O	uint32_t *	p_func	Pointer to the edge measurement unit function setting buffer
			I	const uint32_t	mode	Negotiation command operation setting
edge_cmd_run Executes Run command to the measurement unit	void	-	I	const uint32_t	addr	Unit address
edge_cmd_stop Executes Stop command to the measurement unit	void	-	I	const uint32_t	addr	Unit address
edge_get_info Acquires measurement unitinformation and sets function	bool	false：Failure to acquire true： Completion of acquisition	I/O	st_edge_info_t	info_buf[]	Pointer to the measurement unit information buffer
			I	const uint32_t	func_buf[]	Pointer to the measurement unit function setting buffer
			I	const uint32_t	num	Number of units
edge_send_packet Transmits data to the measurement unit	void	-	I	uint32_t *	p_data	Pointer to the transmit data buffer
			I	const uint32_t	len	Number of transmit data
edge_receive_packet Receives data from the measurement unit	bool	false: NACK response true: ACK response	O	uint32_t *	p_data	Pointer to the receive data buffer
edge_get_measuredata Acquires the measurement result from the measurement unit	bool	false: Failure to acquire true: Completion of acquisition	I	st_edge_info_t	info_buf[]	Pointer to the measurement unit information buffer
			I	const uint32_t	num	Number of units
delay_usec Executes software delay in microseconds.	void	-	I	uint32_t	delay	Delay time

Table 7-58 r_communication_control_api Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_COMM_GetPacket Reads a single packet from the receive ring buffer.	size_t	Packet length [Byte]	I	st_ring_buf_t *	r_buf	Pointer to the receive ring buffer
				uint8_t	r_packet[]	Receive packet storage array

Table 7-59 r_ring_buffer_control_api.c Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_RINGBUF_GetData Reads a specified number of bytes from the ring buffer	size_t	Number of bytes to read	I	st_ring_buf_t *	ary	Pointer to the ring buffer
			O	uint8_t	data[]	Data storage array
			I	size_t	len	Number of bytes to read
			I	bool	index_update	Index update flag true: Update false: Not update
R_RINGBUF_SetData Writes a specified number of bytes to the ring buffer	size_t	Number of bytes to write	O	st_ring_buf_t *	ary	Pointer to the ring buffer
			I	uint8_t	data[]	Data storage array
			I	size_t	len	Number of bytes to write
R_RINGBUF_GetDataLength Reads the number of bytes stored in the ring buffer	size_t	Number of bytes stored	I	st_ring_buf_t *	ary	Pointer to the ring buffer
R_RINGBUF_SetDataIndex Updates the index of the ring buffer	uint32_t	Index value	O	st_ring_buf_t *	ary	Pointer to the ring buffer
			I	uint16_t	value	Index value
			I	uint8_t	select	Target index 0:Read、1:Write

Table 7-60 Config_CMT0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_CMT0_IsTimeout Returns information as to whether a timeout has occurred	bool	false: Counting true: Timeout	I	bool	flag	Stop of counting false: Continuation true: Stop
R_CMT0_CntClear Clears the compare match timer/counter of CMT0	void	-	-	void	-	-

Table 7-61 Config_CMT1 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_CMT1_CheckTimer Returns information as to whether 10 msec passed	bool	false: Counting true: 10 msec passed	-	void	-	-
R_CMT1_IrClear Clears the IR flag of CMT1	void	-	-	void	-	-

Table 7-62 Config_DMAC0 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_DMAC0_SetDestAddr Sets DMDAR of DMAC0	void	-	I	void *	p_addr	destination address
R_DMAC0_GetDestAddr Returns DMDAR of DMAC0 (macro function)	void	-	-	void	-	-

Table 7-63 Config_DMAC3 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_DMAC3_SetSrcAddr Sets DMSAR of DMA3	void	-	I	void *	p_addr	source address
R_DMAC3_SetTxCount Sets DMCRA of DMAC3	void	-	I	uint32_t	cnt	transfer count

Table 7-64 Config_PORT User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_LED1_On Turns LD1 ON (macro function)	void	-	-	void	-	-
R_LED1_Off Turns LD1 OFF (macro function)	void	-	-	void	-	-

Table 7-65 Config_SCI6 User Defined Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_SCI6_SendStart Starts transmission of SCI6	MD_STATUS	MD_OK	-	void	-	-
R_SCI6_SendStop Stops transmission of SCI6	MD_STATUS	MD_OK	-	void	-	-
R_ SCI6_ReceiveStart Starts receiving of SCI6	MD_STATUS	MD_OK	-	void	-	-
R_SCI6_IsTransferEnd Returns the transfer status of SCI6	bool	false: Transferring true: Transfer end	-	void	-	-

Table 7-66 Config_SCI8 User Additional Functions

Function name/Overview	Return value		Argument			
	Type	Value	I/O	Type	Name	Description
R_ SCI8_ClearStatus Clears the transfer status of SCI8	void	-	-	void	-	-
R_SCI68_CheckStatus Returns the transfer status of SCI8	bool	false: Transferring true: Transfer end	-	void	-	-

8. Importing a Project

After importing the sample project, make sure to confirm build and debugger setting.

8.1 Importing a Project into e2 studio

Follow the steps below to import your project into e^2 studio. Pictures may be different depending on the version of e^2 studio to be used.

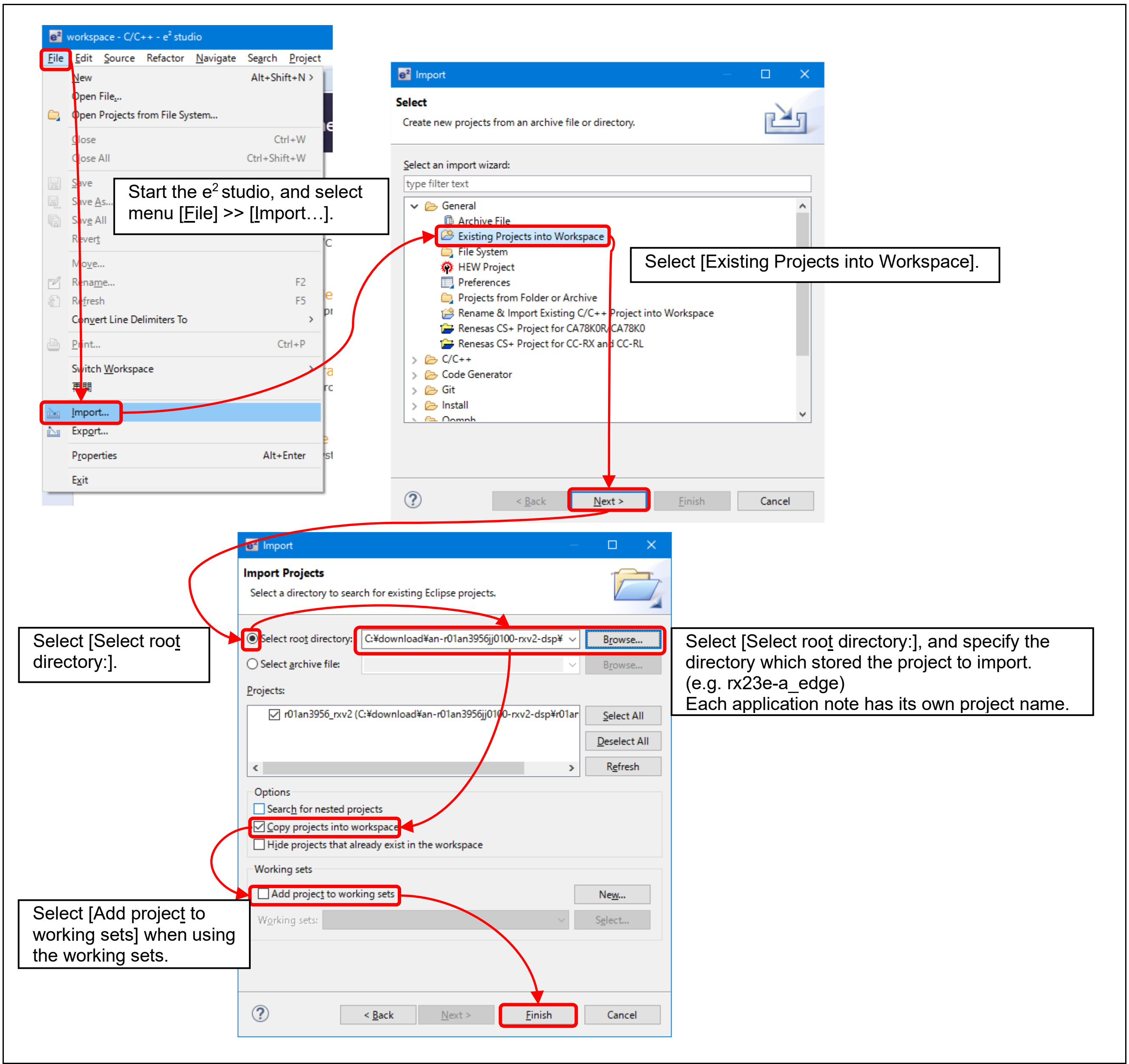


Figure 8-1 Importing a Project into e2 studio

8.2 Importing a Project into CS+

Follow the steps below to import your project into CS+. Pictures may be different depending on the version of CS+ to be used.

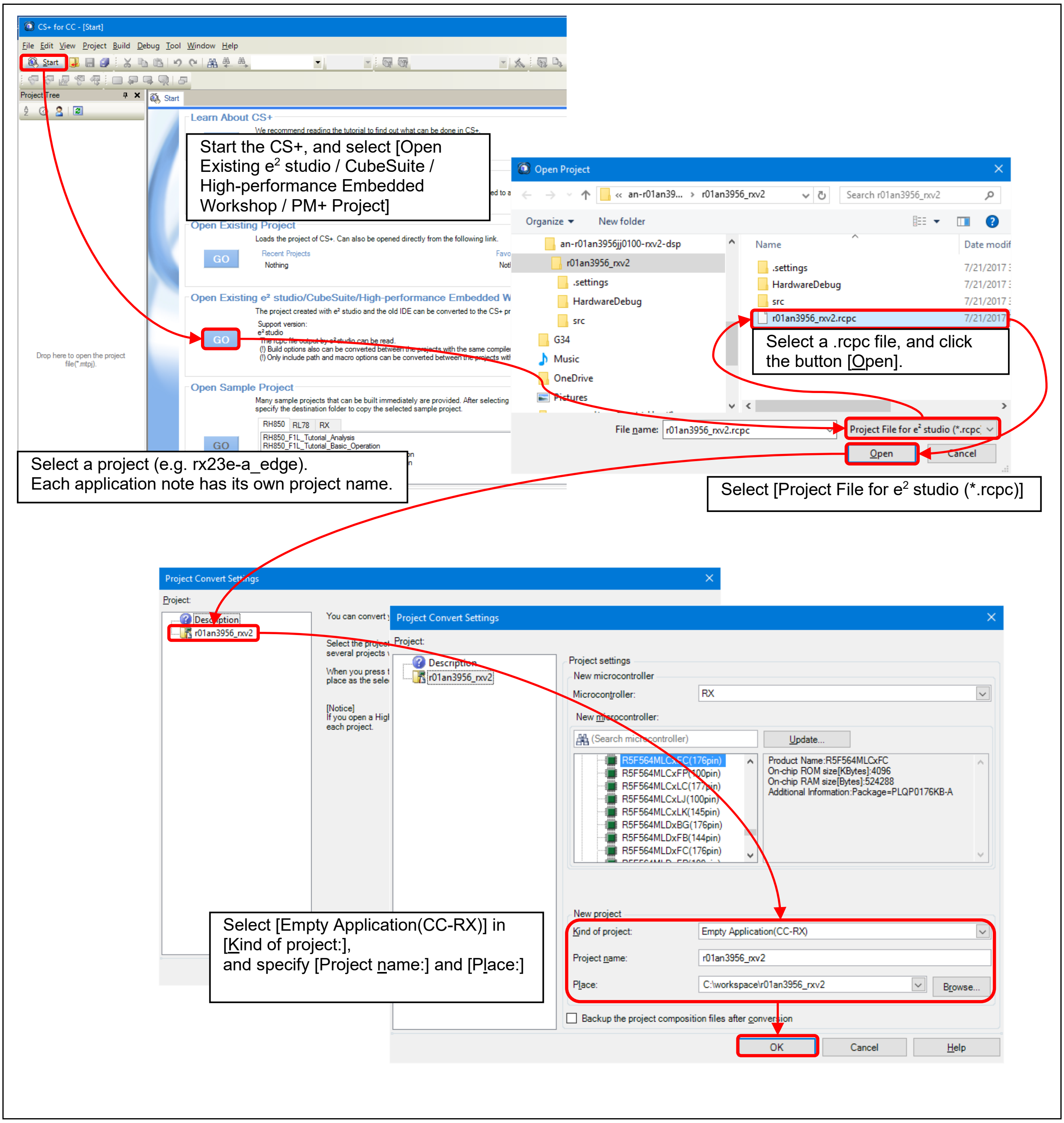


Figure 8-2 Importing a Project into CS+

9. Operation Results with the Sample Program

9.1 Memory Usage and Number of Execution Cycles

9.1.1 Measurement Processing (RX23E-A)

9.1.1.1 Build Conditions

In “Table 3-1 Environment for Operation Confirmation of Measurement Unit”, the build conditions for sample program are shown in Table 9-1. This setting is default setting when project is generated except for memory allocation to support the PC tool.

Table 9-1 Build Conditions

Item	Setting
Compiler	-isa=rxv2 -utf8 -nomessage -output=obj -debug -outcode=utf8 -nologo
Linker	-noprelink -output="rx23ea_edge" -form=absolute -nomessage -vect=_undefined_interrupt_source_isr -list=rx23ea_edge.map -nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -nologo

9.1.1.2 Memory Usage

The amount of memory usage of sample program is shown in Table 9-2.

Table 9-2 Amount of Memory Usage

Item		Size [byte]	Remarks
ROM		11362	
	Code	7068	
	Data	4294	
RAM		9394 (4326)	Note
	Data	4274	
	Stack	5120 (52)	Note

Note: RAM usage for stack is shown in “()”.

9.1.1.3 Number of Execution Cycles

The number of execution cycles and processing load for each block in “Figure 7-3 RX23E-A Program Flow” is shown in Table 9-3.

Table 9-3 Number of Execution Cycles

ICLK=32MHz

Block	Number of Execution Cycles (Execution time)	Process load [%]	Condition
Acquisition of A/D conversion value	20cycle (0.625usec)	0.063	
Temperature calculation	689cycle (21.53usec)	2.153	Filter processing of A/D conversion value to temperature calculation
Voltage calculation	50cycle (1.56usec)	0.156	Filter processing of A/D conversion value to voltage calculation
Communication processing	634cycle (19.81usec)	1.981	Maximum number of processing cycles under normal operation

9.1.2 Host Processing (RX72M)

9.1.2.1 Build Conditions

In “Table 3-2 Environment for Operation Confirmation of Host Processing”, the build conditions for sample program are shown in Table 9-4. This setting is default setting when project is generated except for memory allocation to support the PC tool.

Table 9-4 Build Conditions

Item	Setting
Compiler	-isa=rxv3 -fpu -dpfpu -asmopt=-bank -utf8 -nomessage -output=obj -debug -outcode=utf8 -tfu=intrinsic -nologo
Linker	form=absolute -nomessage -vect=_undefined_interrupt_source_isr -list=rx72m_host.map -nooptimize -rom=D=R,D_1=R_1,D_2=R_2 -nologo

9.1.2.2 Memory Usage

The amount of memory usage of sample program is shown in Table 9-5.

Table 9-5 Amount of Memory Usage

Item		Size [byte]	Remarks
ROM		13647	
	Code	11726	
	Data	1921	
RAM		13164 (8192)	Note
	Data	8044	
	Stack	5120 (148)	Note

Note: RAM usage for stack is shown in “()”.

9.1.2.3 Number of Execution Cycles

The number of execution cycles and processing load for each block in “Figure 7-6 RX72M Program Flow” is shown in Table 9-6.

Table 9-6 Number of Execution Cycles

ICLK=240MHz

Block	Number of Execution Cycles (Execution time)	Process load [%]	Conditions
Measurement processing	149221cycle (621.8usec)	6.218	Occurrence of compare match of CMT1 to completion of acquisition of the measurement results
PC tool communication processing	16458cycle (68.6usec)	0.686	Maximum number of processing cycles under normal operation

9.2 Example of Operation

9.2.1 Multi-channel Measurement

Two temperature calibrators and two voltage sources are connected to this system for measuring temperature and voltage. Figure 9-1 shows the configuration of measurement, and Table 9-7 shows equipment used in measurement, and Figure 9-2 shows the measurement result. As shown in Figure 9-2, it is confirmed that multiple signal sources can be simultaneously measured.

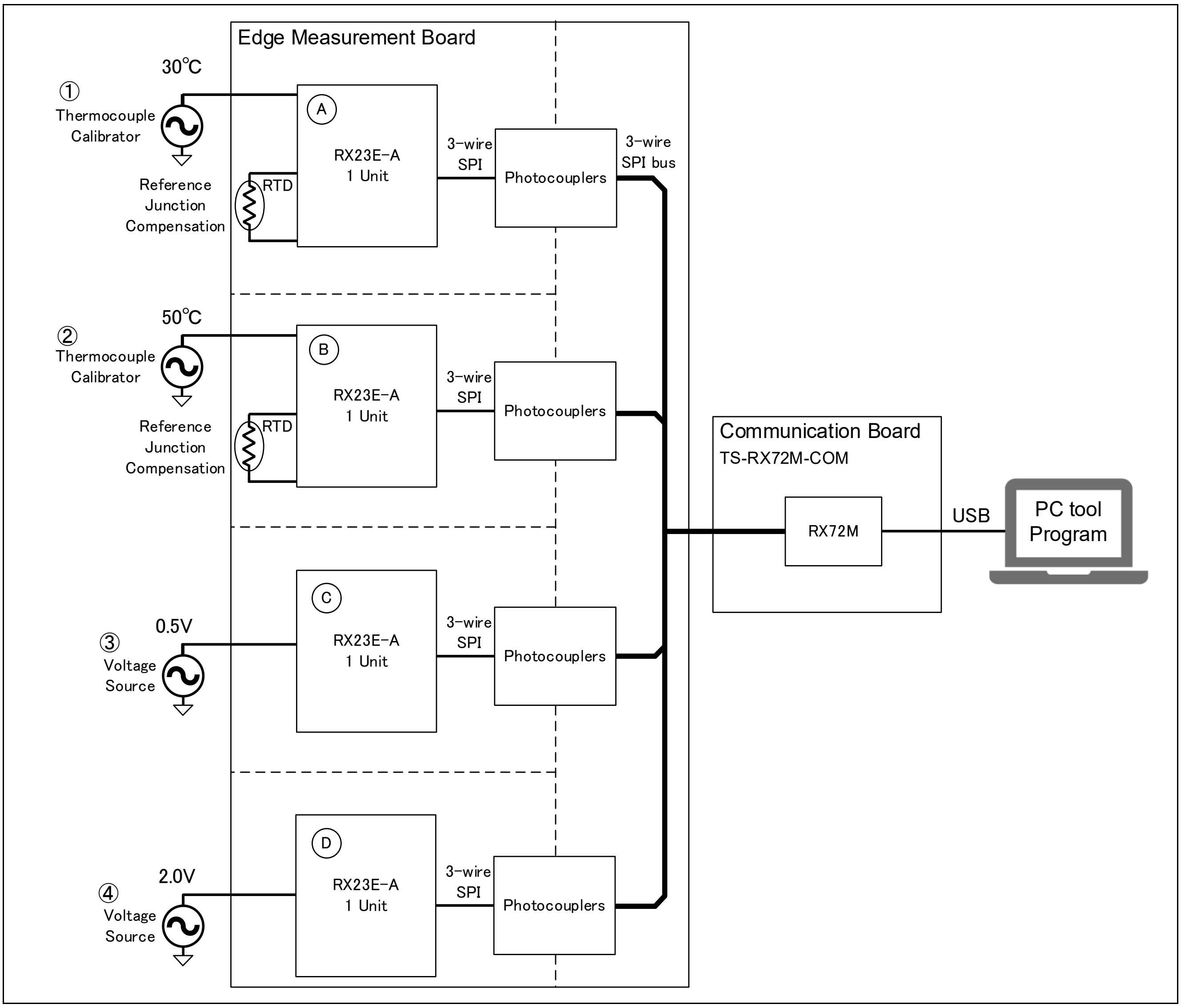


Figure 9-1 Configuration of Multi-Channel Measurement

Table 9-7 Equipment Used in Measurement

No.	Name	Model	Manufacturer
1, 2	Thermocouple calibrator	CA320	Yokogawa Test & Measurement Corporation
3, 4	Voltage source	PA14A1	ShibaSoku Co., LTD

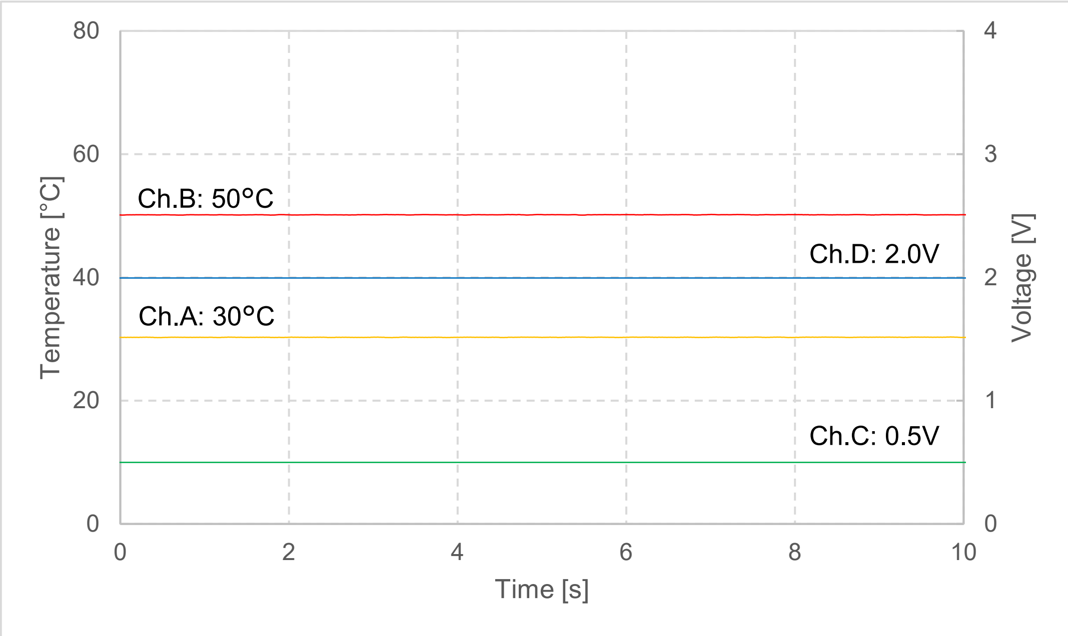


Figure 9-2 Result of Multi-Channel Measurement

9.2.2 Response Characteristics

Step input of temperature from 30°C to 40°C is applied to channel A by using thermocouple calibrator, and step input of voltage from 0.5V to 1.5V to channel C to confirm the response characteristics. Figure 9-3 shows the configuration of measurement equipment, and Figure 9-4 shows the measurement result.

The time constant of step response, i.e., the time to reach 63.2% of the final value is 70ms and 95% settling time is 100ms. The delay of 98 sample moving average processing is 100.352ms for the output rate of DSAD of 976.5625sps, and this is mostly in line with the measurement result.

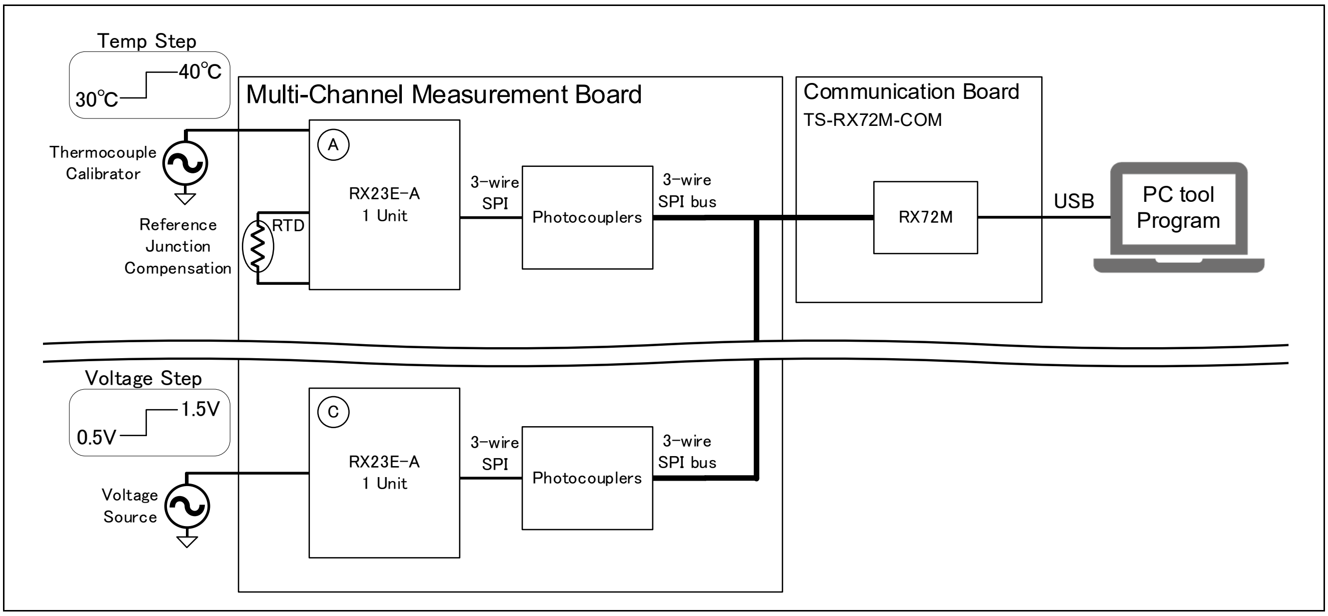


Figure 9-3 Configuration of Measurement of Response Characteristics

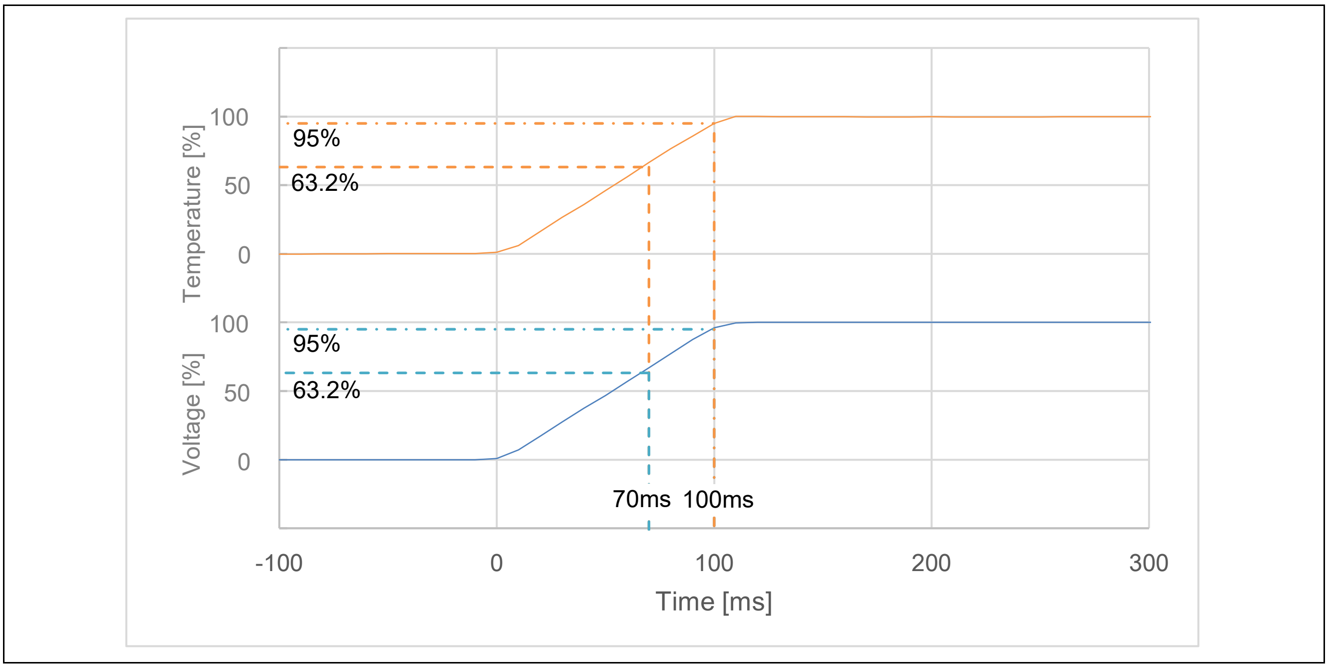


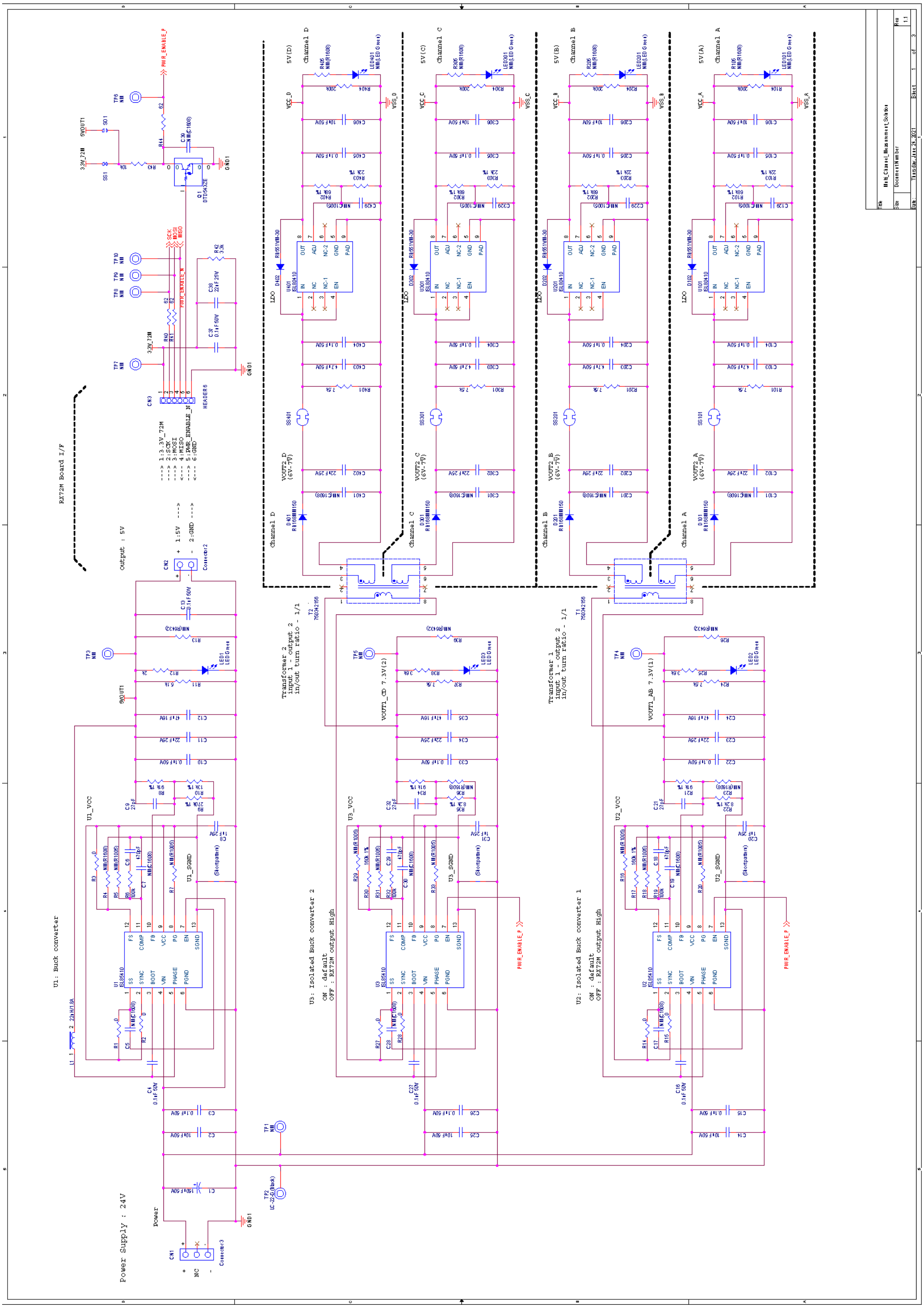
Figure 9-4 Step Response

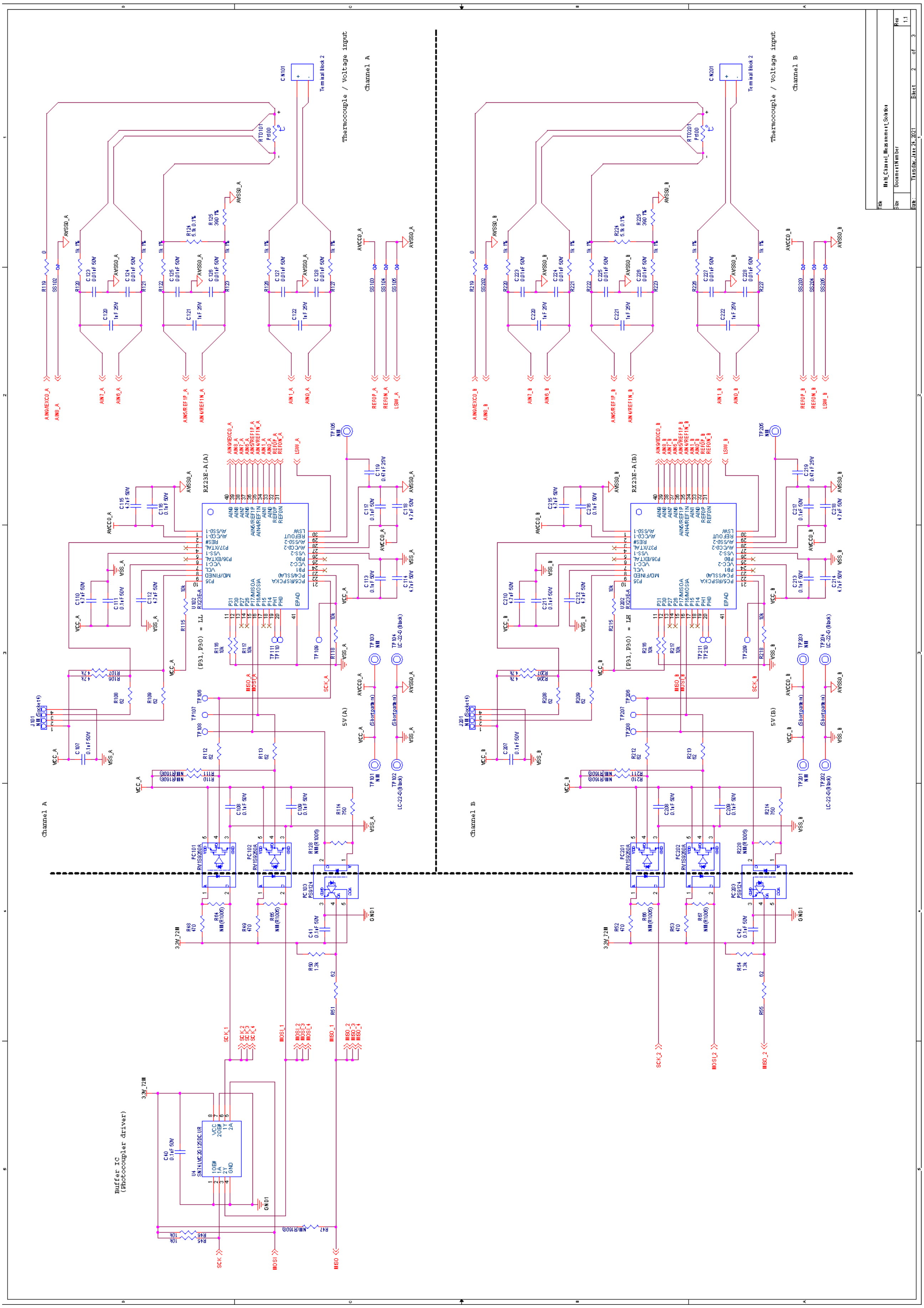
Appendix 1 Parts List of the Multi-channel Board

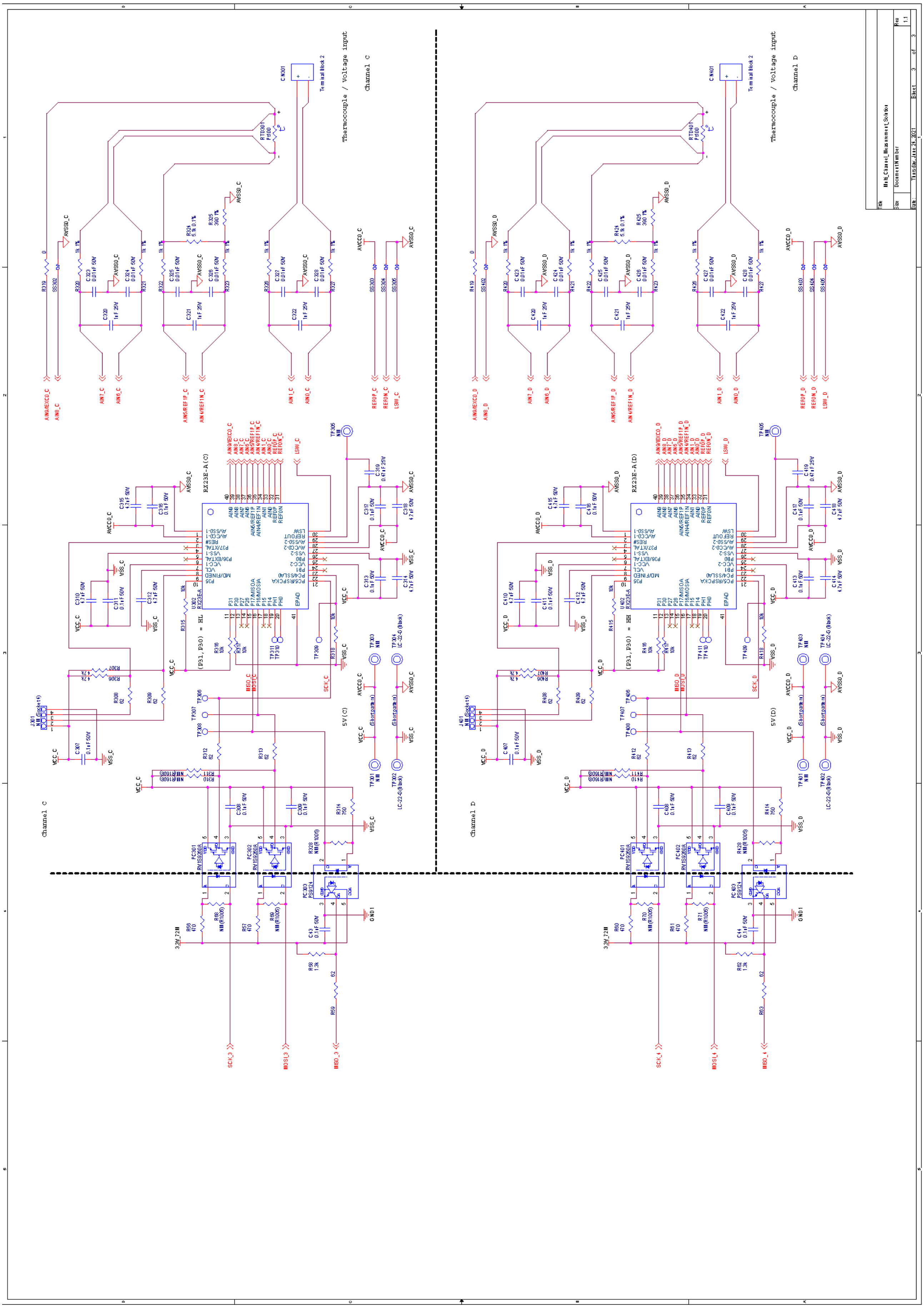
No.	Quantity (Mounted)	Reference Designator (Mounted)	Reference Designator (Not Mounted)	Description	Part Name	Manufacturer Part Name	Manufacturer
1	3	U1,U2,U3		DCDC converter 1A	IC	ISL85410FRZ	Renesas
2	1	U4		Dual Bus Buffer Gate	IC	SN74LVC2G125DCUR	TI
3	4	U101,U201,U301,U401		LDO,Output 2.5 to 12V, 150mA	IC	ISL80410IBEZ	Renesas
4	4	U102,U202,U302,U402		RX23E-A	IC	R5F523E6SDNF#20	Renesas
5	8	PC101,PC102,PC201,PC202, PC301,PC302,PC401,PC402		CMOS output	Photocoupler	RV1S9260ACCSP-10YV	Renesas
6	4	PC103,PC203,PC303,PC403		Open collector output	Photocoupler	PS9124-V-AX	Renesas
7	1	CN1		Connector 3	Connector	DF1BZ-3P-2.5DSA	HRS
8	1	CN2		Connector 2	Connector	DF1BZ-2P-2.5DSA	HRS
9	1	CN3		HEADER 6	Pin header	M20-8770642	HARWIN
10	0		J101,J201,J301,J401	NM (Socket 4)	Socket	M20-7820446	HARWIN
11	11	R1,R2,R3,R14,R15,R27,R28, R119,R219,R319,R419	R5,R16,R18,R29,R31	0	Resistor	RK73Z1ETTP	KOA
12	0		R4,R23,R36,R47, R110,R111,R210,R211, R310,R311,R410,R411	NM(R1608)	Resistor		
13	0		R7,R20,R33,R64,R65,R66, R67,R68,R69,R70,R71, R128,R228,R328,R428	NM(R1005)	Resistor		
14	3	R6,R19,R32		100k	Resistor	RK73B1JTTD104J	KOA
15	3	R8,R21,R34		91k 1%	Resistor	RK73H1JTTD9102F	KOA
16	1	R9		270k 1%	Resistor	RK73H1JTTD2703F	KOA
17	1	R10		13k 1%	Resistor	RK73H1JTTD1302F	KOA
18	1	R11		5.1k	Resistor	RK73B1JTTD512J	KOA
19	1	R12	R105,R205,R305,R405	2k	Resistor	RK73B1JTTD202J	KOA
20	0		R13,R26,R39	NM(R6432)	Resistor		
21	2	R17,R30		160k 1%	Resistor	RK73H1JTTD1603F	KOA
22	2	R22,R35		8.2k 1%	Resistor	RK73H1JTTD8201F	KOA
23	6	R24,R37,R101,R201,R301,R401		7.5k	Resistor	RK73B1JTTD752J	KOA
24	2	R25,R38		3.6k	Resistor	RK73B1JTTD362J	KOA
25	23	R40,R41,R44,R51,R55,R59,R63, R108,R109,R112,R113, R208,R209,R212,R213, R308,R309,R312,R313, R408,R409,R412,R413		62	Resistor	RK73B1ETTP620J	KOA
26	1	R42		3.3k	Resistor	RK73B1JTTD332J	KOA
27	19	R43,R45,R46,R115,R116, R117,R118,R215,R216,R217, R218,R315,R316,R317,R318, R415,R416,R417,R418		10k	Resistor	RK73B1ETTP103J	KOA
28	8	R48,R49,R52,R53,R56,R57, R60,R61		470	Resistor	RK73B1JTTD471J	KOA
29	4	R50,R54,R58,R62		1.3k	Resistor	RK73B1JTTD132J	KOA
30	4	R102,R202,R302,R402		68k 1%	Resistor	RK73H1ETTP6802F	KOA
31	4	R103,R203,R303,R403		22k 1%	Resistor	RK73H1ETTP2202F	KOA
32	4	R104,R204,R304,R404		200k	Resistor	RK73B1JTTD204J	KOA
33	8	R106,R107,R206,R207,R306, R307,R406,R407		4.7k	Resistor	RK73B1ETTP472J	KOA
34	4	R114,R214,R314,R414		750	Resistor	RK73B1JTTD751J	KOA
35	24	R120,R121,R122,R123,R126, R127,R220,R221,R222,R223, R226,R227,R320,R321,R322, R323,R326,R327,R420,R421, R422,R423,R426,R427		1k 1%	Resistor	RK73H1ETTP1001F	KOA
36	4	R124,R224,R324,R424		5.1k 0.1%	Resistor	ERA3-APB512V	Panasonic
37	4	R125,R225,R325,R425		390 1%	Resistor	RK73H1JTTD3900F	KOA
38	4	CN101,CN201,CN301,CN401		Terminal Block 2	Connector	FFKDSA1/H-2.54-2-1792511	PHOENIX CONTACT
39	1	C1		150uF 50V	Electrolytic capacitor	EEEFK1H151P	Panasonic
40	7	C2,C14,C25,C106,C206, C306,C406		10uF 50V	Ceramic capacitor	GCM32EC71H106KA03L	Murata
41	52	C3,C4,C10,C13,C15,C16,C22, C26,C27,C33,C37,C40,C41, C42,C43,C44,C104,C105,C107, C108,C109,C111,C113,C116, C117,C204,C205,C207,C208, C209,C211,C213,C216,C217, C304,C305,C307,C308,C309, C311,C313,C316,C317,C404, C405,C407,C408,C409,C411, C413,C416,C417		0.1uF 50V	Ceramic capacitor	CGA2B3X7R1H104K050BB	TDK
42	0		C5,C7,C17,C19, C28,C30,C39, C101,C201,C301,C401	NM(C1608)	Ceramic capacitor		
43	3	C6,C18,C29		470pF 100V	Ceramic capacitor	GCM1885C2A471JA16	Murata
44	3	C8,C20,C31		1uF 25V	Ceramic capacitor	GCM188R71E105KA64	Murata
45	3	C9,C21,C32		27pF 100V	Ceramic capacitor	GCM1885C2A270JA16	Murata
46	8	C11,C23,C34,C38, C102,C202,C302,C402		22uF 25V	Ceramic capacitor	GCM32EC71E226KE36	Murata
47	3	C12,C24,C35		47uF 16V	Ceramic capacitor	GRM32EC81C476KE15	Murata
48	24	C103,C110,C112,C114,C115, C118,C203,C210,C212,C214, C215,C218,C303,C310,C312, C314,C315,C318,C403,C410, C412,C414,C415,C418		4.7uF 50V	Ceramic capacitor	GRM21BC71H475KE11	Murata
49	4	C119,C219,C319,C419		0.47uF 25V	Ceramic capacitor	TMK107B7474KA	Taiyo Yuden
50	12	C120,C121,C122,C220,C221, C222,C320,C321,C322,C420, C421,C422		1uF 25V	Ceramic capacitor	C1005X5R1E105K050BC	TDK
51	24	C123,C124,C125,C126,C127, C128,C223,C224,C225,C226, C227,C228,C323,C324,C325, C326,C327,C328,C423,C424, C425,C426,C427,C428		0.01uF 50V	Ceramic capacitor	GCM155R71H103KA55	Murata
52	0		C129,C229,C329,C429	NM(C1005)	Ceramic capacitor		
53	1	L1		22uH/1.8A	Coil	VLS5045EX-220M	TDK
54	2	T1,T2		66uH, in1/out2, turn ratio 1:1	Transformer	750342156	Wurth Elektronik
55	4	D101,D201,D301,D401		Schottky barrier	Diode	RB168MM150	Rohm
56	4	D102,D202,D302,D402		Schottky barrier	Diode	RB551VM-30	Rohm
57	3	LED1,LED2,LED3	LED101,LED201,LED301, LED401	LED Green	LED	SML-E12M8W	Rohm
58	1	Q1		12V,500mA	Digital transistor	DTD543ZE	Rohm
59	4	RTD101,RTD201,RTD301, RTD401		Pt100	RTD	PTS060301B100RP100	Vishay
60	9	TP2,TP102,TP104,TP202, TP204,TP302,TP304,TP402, TP404	TP1,TP3,TP4,TP5,TP6,TP7, TP8,TP9,TP10,TP101,TP103, TP105,TP201,TP203,TP205, TP301,TP303,TP305,TP401, TP403,TP405	hole 1mm	Test pin	LC-22-G(Black)	MAC8
M1	4			Polyacetal, both-sides female spacer	Spacer	AS-310	Hirosugi
M2	4			Polycarbonate, M3 6mm	Screw	PC-0306	Hirosugi

Note: This parts list is for reference purposes only. It is subject to change without notice.

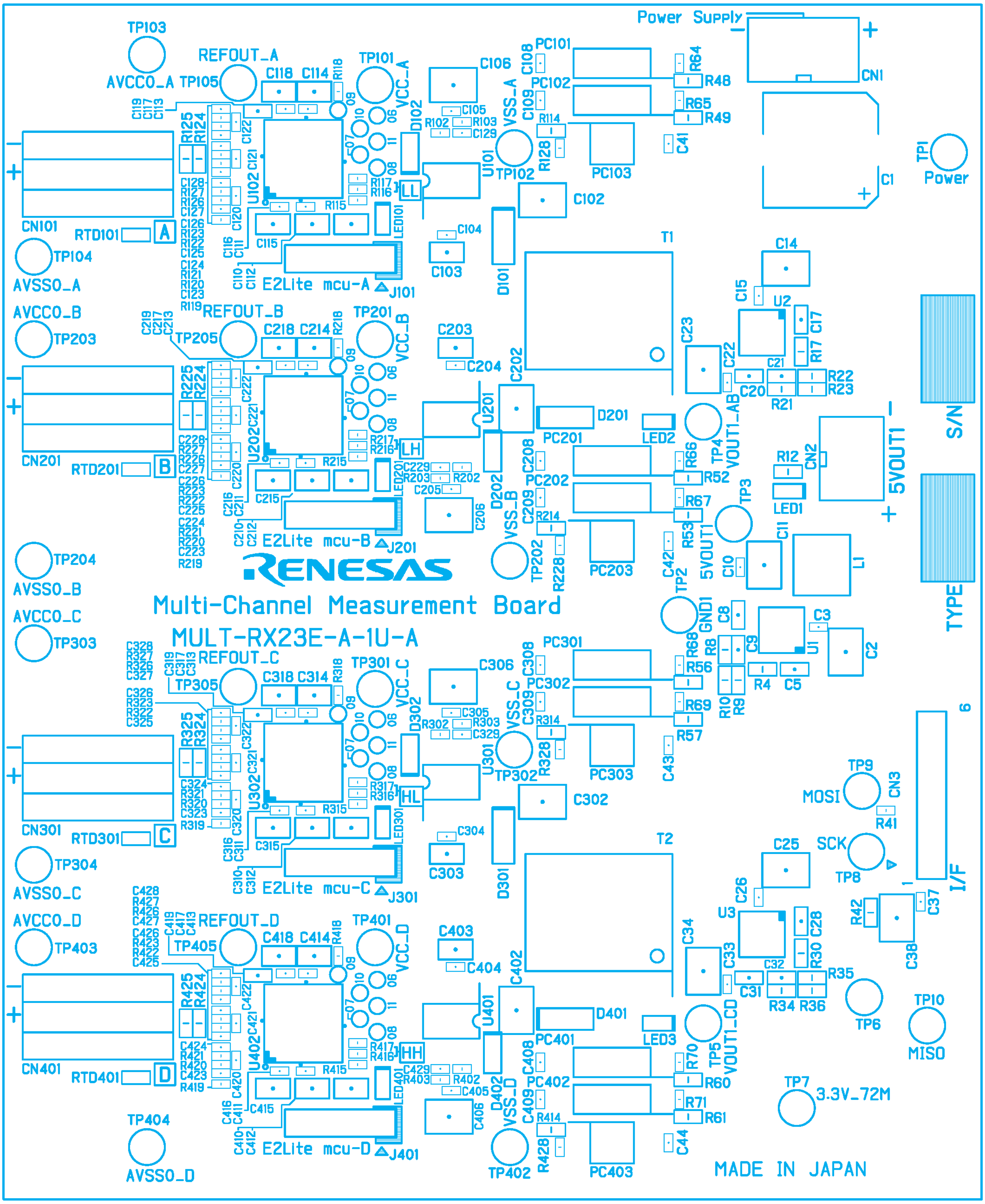
Appendix 2 Circuit Diagrams of the Multi-channel Board



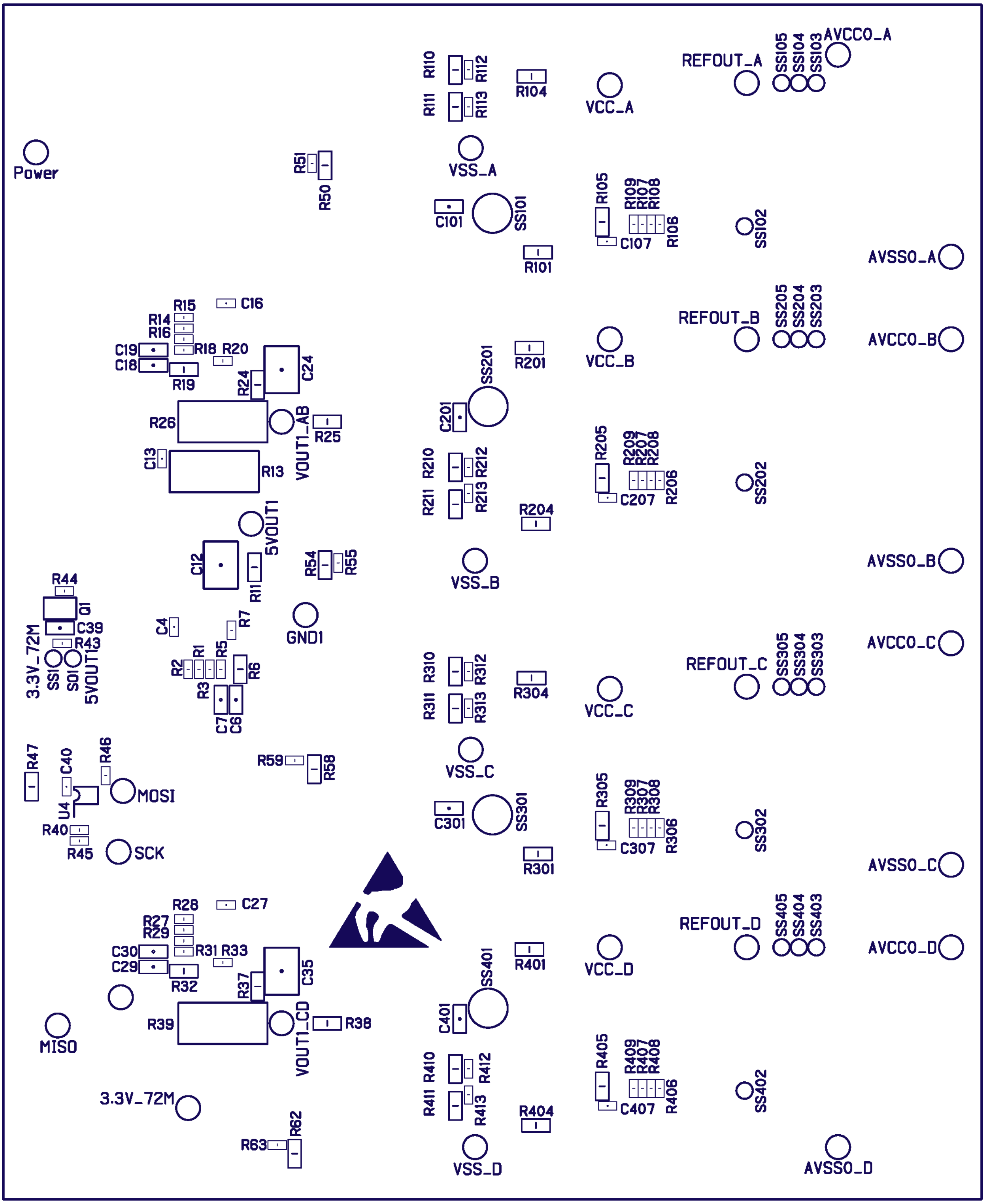



Thermocouple / Voltage input
Channel C
Thermocouple / Voltage input
Channel D
RX23E-A(C)
RX23E-A(D)
Channel C
Channel D

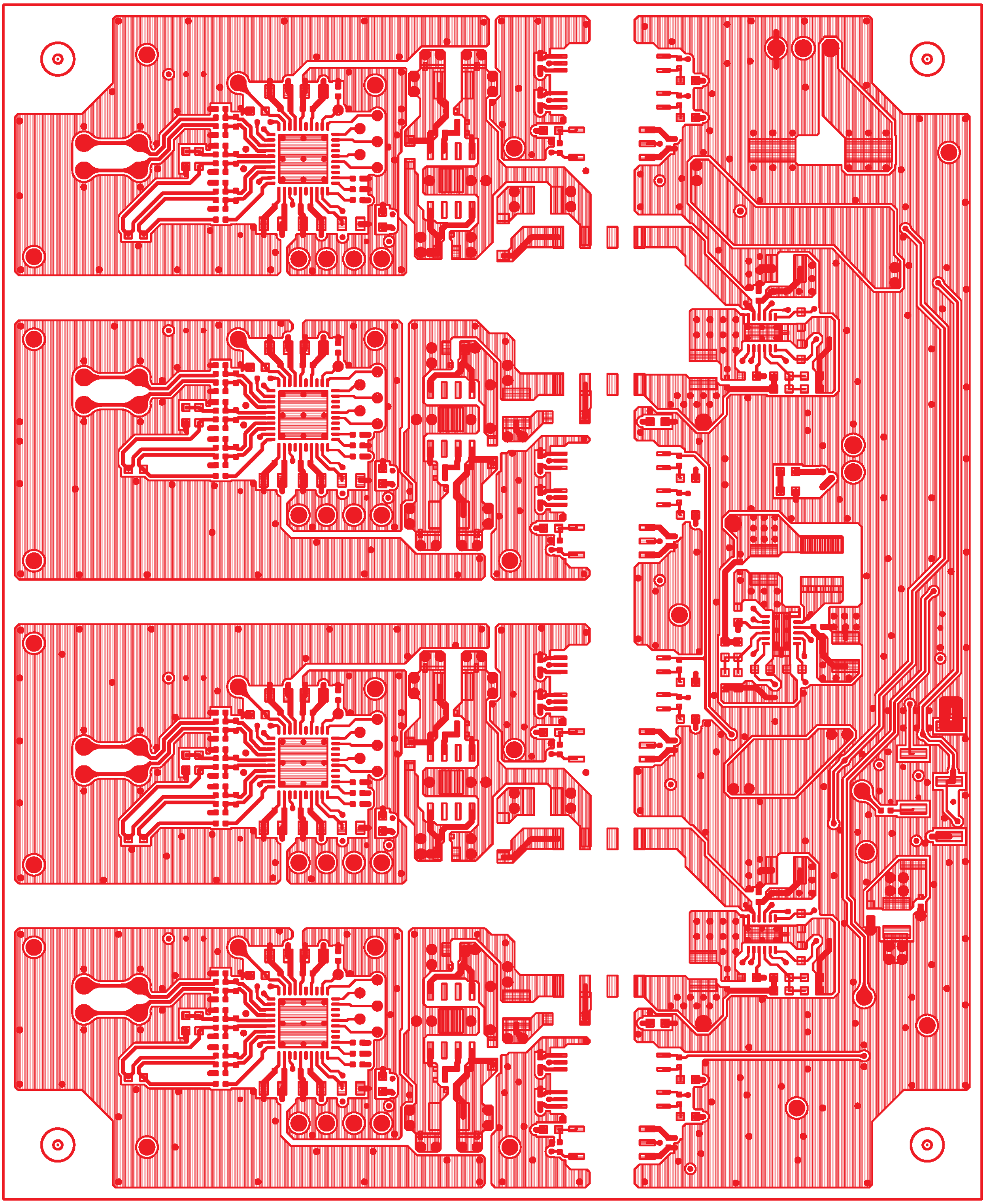
Appendix 3 Board Diagram of Multi-channel Board



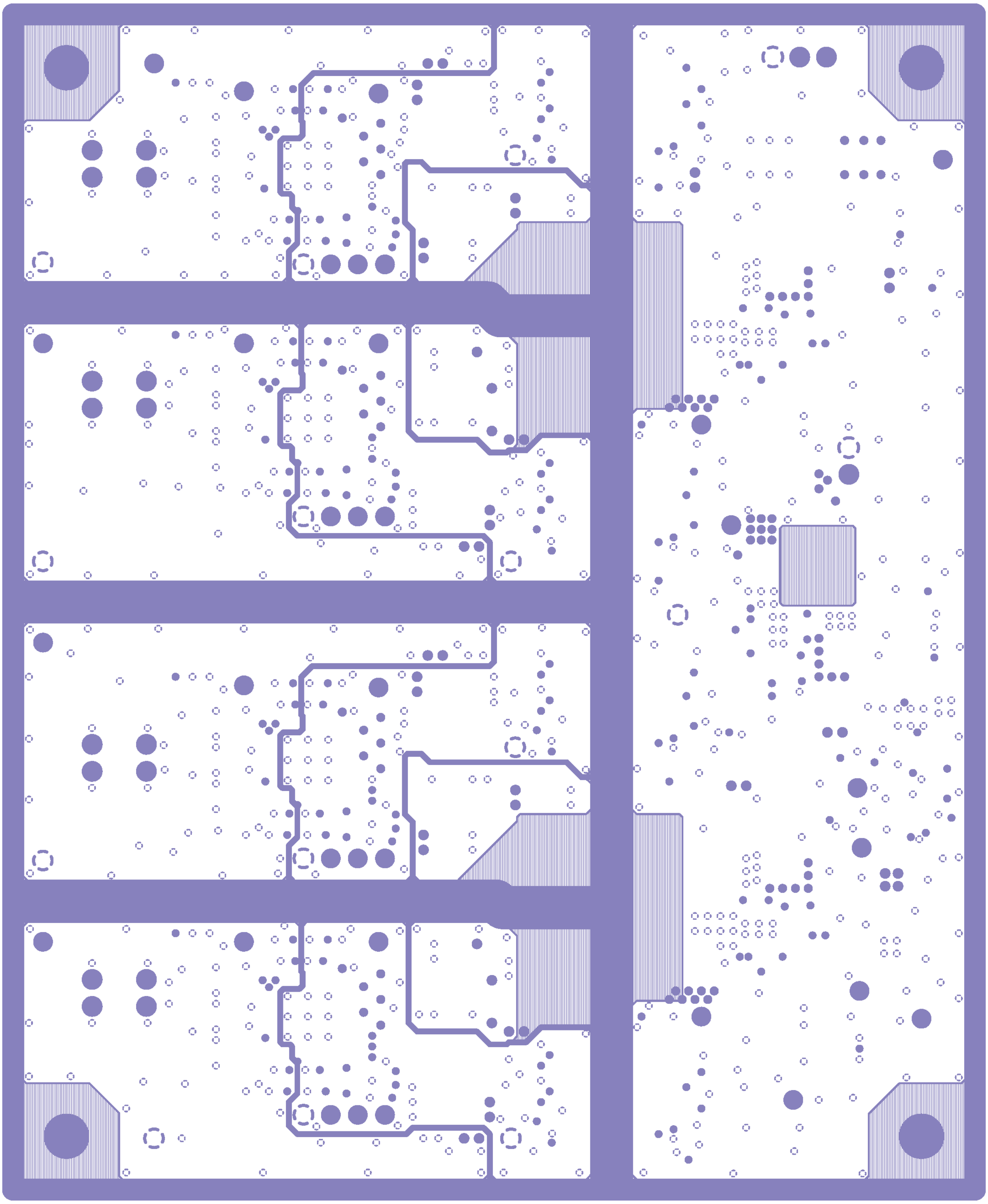
Silk of Component Side



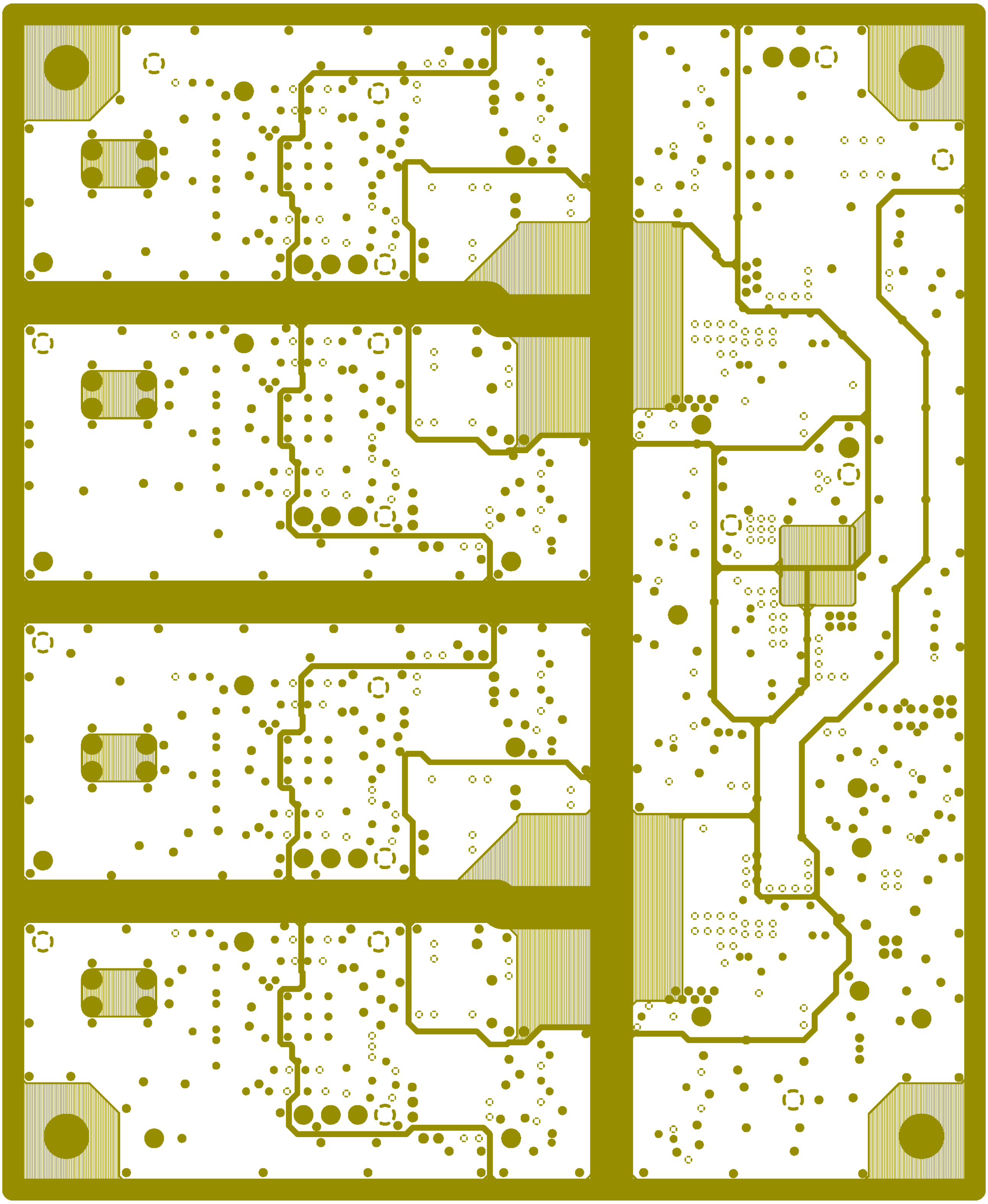
Silk of Solder Side (Solder Surface View)



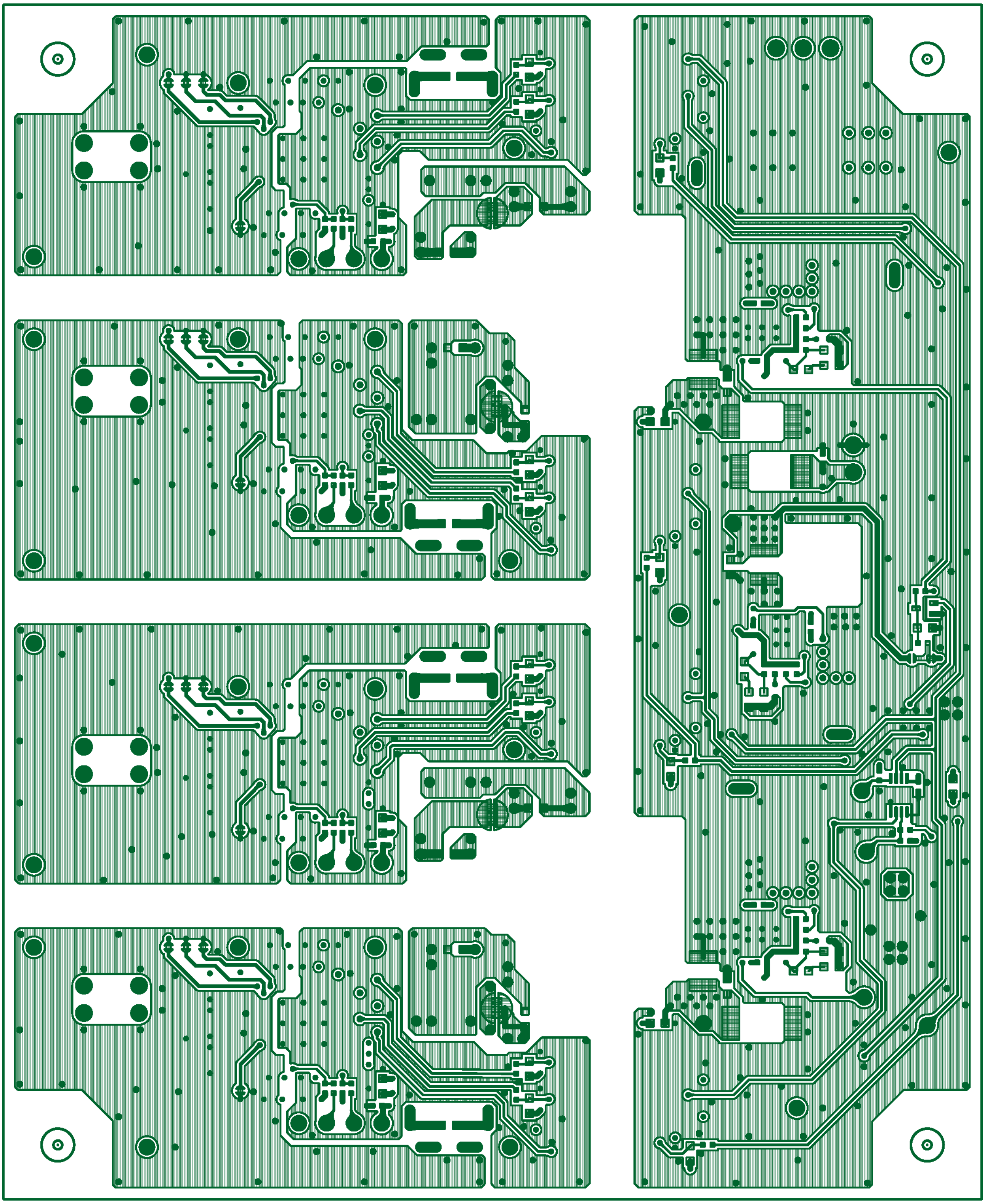
Layer 1: Parts Side Pattern



Layer 2: GND Layer



Layer 3: Power Supply Layer



Layer 4: Solder Side Pattern (Parts Surface View)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	May.25.21	−	-
1.10	July.16.21	p.4	Table 1-1: Correction of specification of this system
		p.7	Table 3-1 Table 3-2: Updated IDE and Tool Chain, added Endian
		p.9	Figure 4-2: Added the appearance
		p.15	6.1.2 Filter Processing: Changed the description due to change of filter processing in temperature measurement
		p.19	Figure 7-1: Changed response time of measurement unit due to change of the filter processing
		p.32	Figure 7-4: Correction due to change of the filter processing
		p.34	Table 7-22: Changed the file structure
		p.35	7.2.4.2 Macro Definitions: Correction due to change of the file structure
		p.36	7.2.4.3 Structures and Unions: Correction due to change of the file structure
		p.38	Table 7-34: Changed the name of moving average function and moved to this table
		p.59	Table 9-2, Table 9-3: Correction due to change of the program
		p.61-p.63	9.2 Example of Operation: Added example of operation
		p.64	Appendix 1 Parts List of the Multi-channel Board: Changed some constants
		p.65-p.67	Appendix 2 Circuit Diagrams of the Multi-channel Board: Changed some constants
		p.68-p.73	Appendix 3 Board Diagram of Multi-channel Board: Added

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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Contact information

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