WS129-SAS-REFZ

Steering Angle Sensor Board

Introduction

The Steering Angle Sensor is a vital component in modern vehicle control systems, responsible for accurately measuring the rotational position and movement of the steering mechanism. By detecting the precise angle and rate at which the steering wheel or handlebars are turned, this sensor provides essential data to safety and stability systems such as Electronic Stability Control (ESC), Anti-lock Braking Systems (ABS), and advanced driver-assistance systems (ADAS).

It is based on an RAA2P4520 inductive proximity sensor paired with the Renesas RL78 MCU, offering high-precision measurements and robust performance. The sensor system uses both CAN and UART protocols for flexible communication with various vehicle modules.

Features

- Measures the precise angle and speed of steering wheel rotation for vehicle safety and control systems.
- Uses the Renesas RL78/F1X family MCU for reliable, low-power signal processing and communication.
- Solution is suitable for harsh environments and extreme temperatures
- Immune to Magnetic Stray fields, hence no need for Magnetic shielding
- The RAA2P4520 has been developed according to ISO26262 for implementation in safety-relevant systems up to ASIL C

Key Applications

- Throttle Orientation Sensor, Throttle Angle Sensor
- Steering Value, Pedal Sensor, Rotor Position Sensor

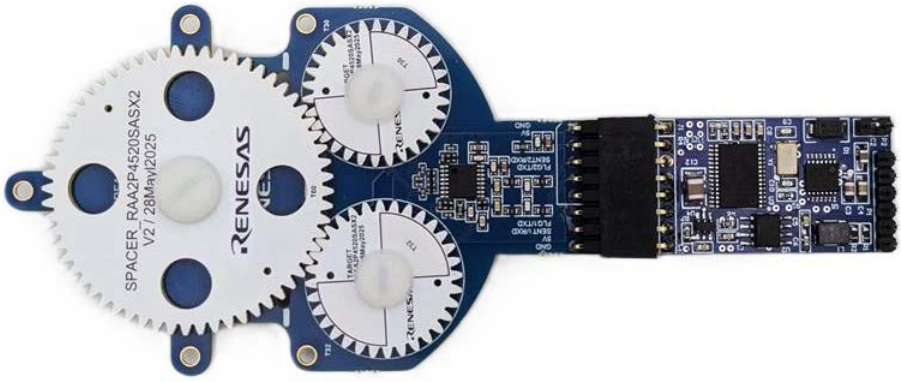


Figure 1. Steering Angle Sensor Board

Contents

1. Sensor Overview

The Steering Angle Sensor (SAS) Evaluation Kit is a comprehensive design and testing platform based on the RL78/F13 microcontroller and the RAA2P4520 inductive position sensor.

This kit enables evaluation of the performance and integration of the RAA2P4520, an advanced magnet-free inductive position sensor that delivers high accuracy steering angle measurements for automotive applications. The RL78/F13 MCU manages signal processing and CAN bus communication and provides seamless data transfer to the electronic control units of the vehicle.

The system is ready for integration into evaluation setups or target platforms, with BoM, schematics, and firmware available in the kit package.

The GUI enables real-time visualization of steering data for ESC, EPS, and ADAS applications, while onboard controls allow standalone system operation without external software.

The power supply of the board allows an input voltage of 12V.

The block diagram highlights the main parts of the system (see Figure 2).

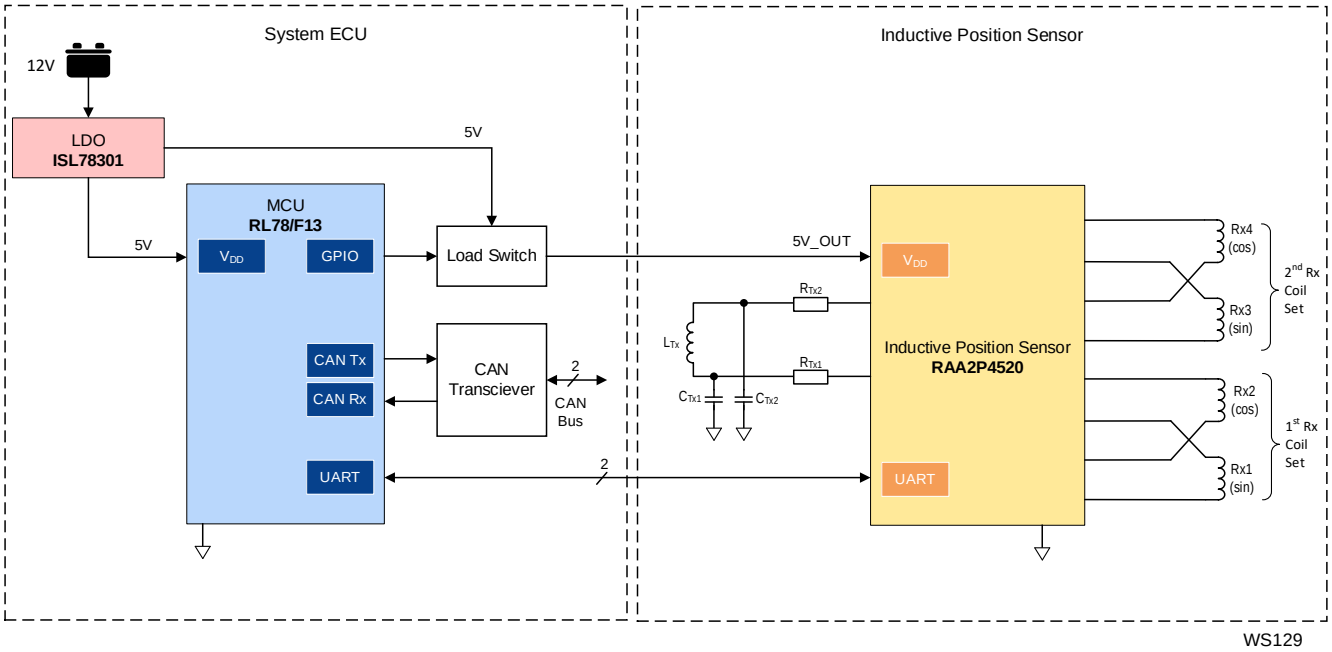


Figure 2. WS129-Steering Angle Sensor Block Diagram

2. Scope of the Document

The scope of the document is to explain the Steering Angle Sensor hardware and software and guide the user to get started with step-by-step procedures about operating the board.

3. Sensor Kit Content

The WS129 steering angle sensor kit is delivered pre-assembled and includes the RL78/F1X control board, RAA2P4520 inductive position sensor board, and software files (source code and GUI).

Items included in the steering angle sensor kit:

- RL78/F1X control board
- RAA2P4520 inductive position sensor board
- Software files (source code and GUI software)

Required items not included in the kit:

- 12V power supply
- CAN Analyzer device

Optional items not included in the kit:

- E1/E2 or compatible debugger

4. Hardware Overview

4.1 IPS Sensor Board

The sensor unit RAA2P452X is a dual-track Inductive Position Sensor (IPS) designed to measure the steering angle. The measured steering angle is then output to the MCU using UART for further processing.

The RAA2P4520 detects the position of a metallic target by using eddy currents generated in coils printed on a PCB. A transmitter coil induces voltages in two receiver coils, and these voltages vary depending on the position of the metal above the coils. By processing these signals, the device accurately determines the target's location, and it works with various types of metals.

4.1.1 Features

- Immune to magnetic stray fields; no shielding required
- Dual Track coil input enabling increased reliability, angle difference or high-resolution measurement
- The RAA2P4520 provides Analog, PWM, UART and SENT Interfaces.

Figure 1: IPS Sensor board

4.2 MCU/Control Board

4.2.1 Power Supply Section

The entire system is powered by a 12V vehicle battery. This voltage is regulated by the ISL78301FVEAZ Low Dropout Regulator (LDO) which converts the 12V input to a stable 5V output.

For detailed specifications and features of the ISL78301 LDO, visit www.renesas.com/ISL78301.

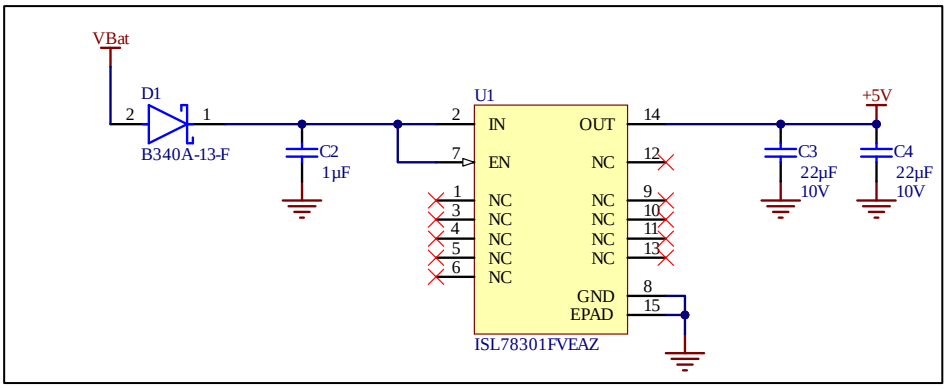


Figure 3: Power Section

4.2.2 Microcontroller Unit

The RL78/F13 microcontroller interfaces with an IPS sensor to acquire sensor data through the UART communication protocol. When receiving data through UART, the MCU processes the sensor information internally. After processing, the MCU transmits the data to a connected system through the CAN bus protocol. This data is then displayed on a graphical user interface (GUI) for monitoring and user interaction. Additionally, the MCU controls a load switch using its GPIO because to enter the programming mode, a programming entry command must be sent during power-up over the programming interface (1-Wire UART) from MCU to RAA2P4520 between a specific timeframe.

4.2.2.1 Specifications

- CPU Core: RL78 core, max. 32MHz
- Voltage Range: Operates from 2.7V to 5.5V
- Memory: Up to 128KB Flash and 8KB SRAM
- Analog: 10-bit ADC with up to 8 channels
- Interfaces: CAN and LIN
- Timers/PWM: Multiple PWM outputs and motor-control timer for body and motor functions.
- Safety: ECC for RAM, PLL lock, watchdog oscillator, and stack overflow detection ensures system reliability.

For more information visit www.renesas.com/RL78/F13.

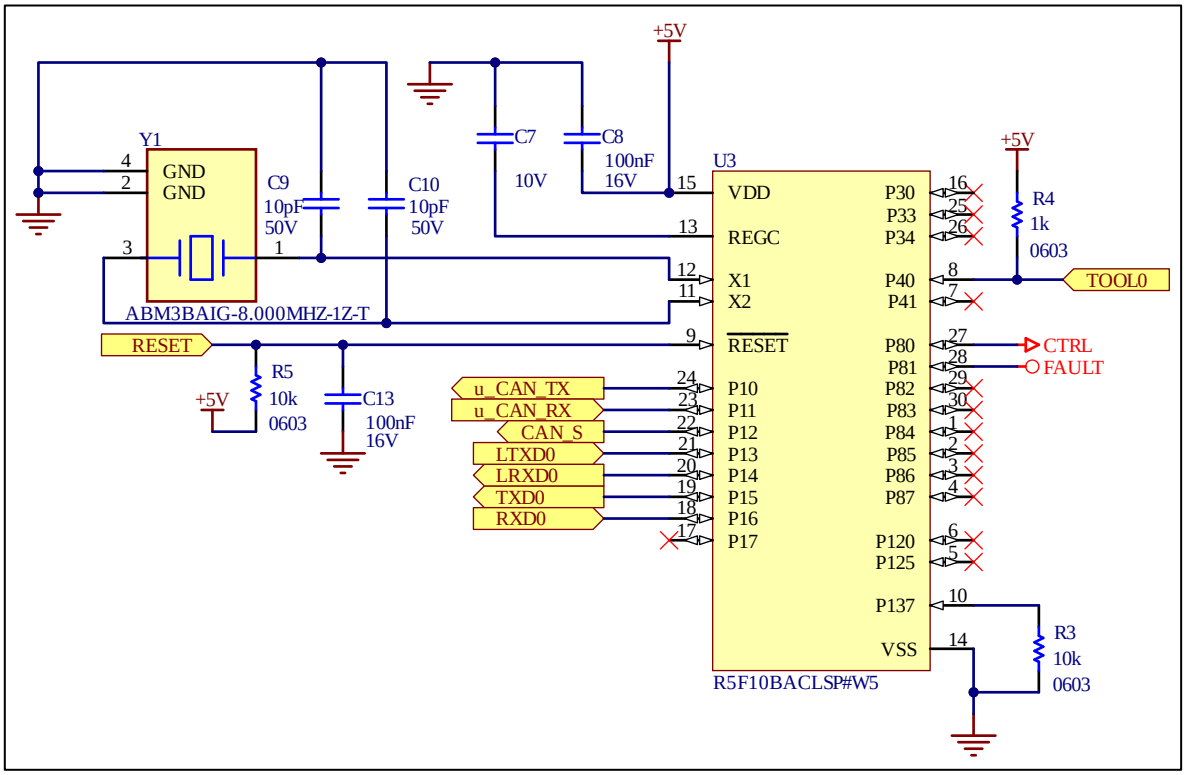


Figure 4. MCU Section

4.2.3 Load Switch

The NPS4053GV-Q100 load switch supplies +5V_OUT to the IPS sensor from a regulated +5V LDO input with its ON pin controlled by the MCU using CTRL to enable power.

For Programming the current limit threshold through a resistor, review the datasheet.

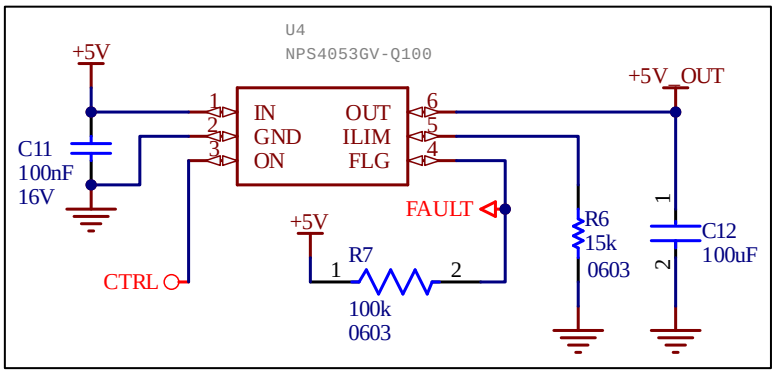


Figure 5. Load Switch Section

4.2.4 Connectivity

- The system uses the CAN bus for communication.
- The MCU processes data received from the sensor and transfers it to the CAN transceiver.
- The processed data is then sent over the CAN network, where it is displayed on the GUI for monitoring and user interaction.

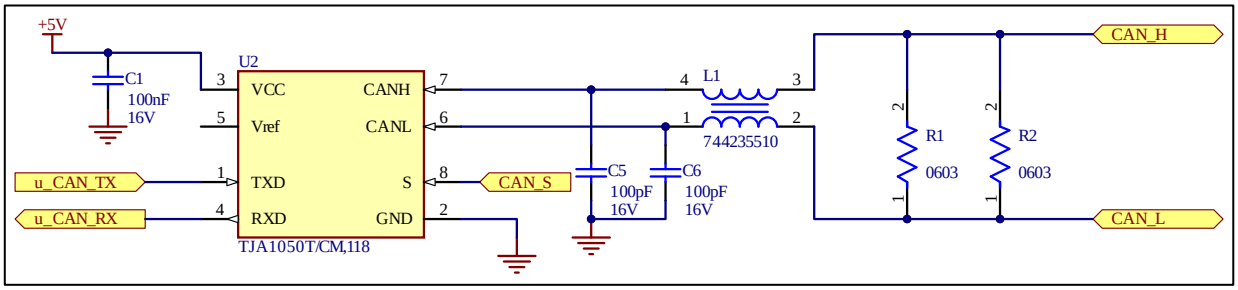


Figure 6: CAN Interface

4.2.5 Connectors

4.2.5.1 Battery Connector (P2)

This connector provides the 12V vehicle battery input to the system power section.

4.2.5.2 CAN and Programming Connector (P1)

The connector provides CAN_H, CAN_L for external CAN devices, debug signals including reset, clock, and data pins for MCU programming, along with ground and power reference in a single line.

4.2.5.3 UART Connector J1

J1 provides a stable +5V output to power the IPS sensor or modules, and includes UART lines for serial communication between the MCU and sensor or external UART devices.

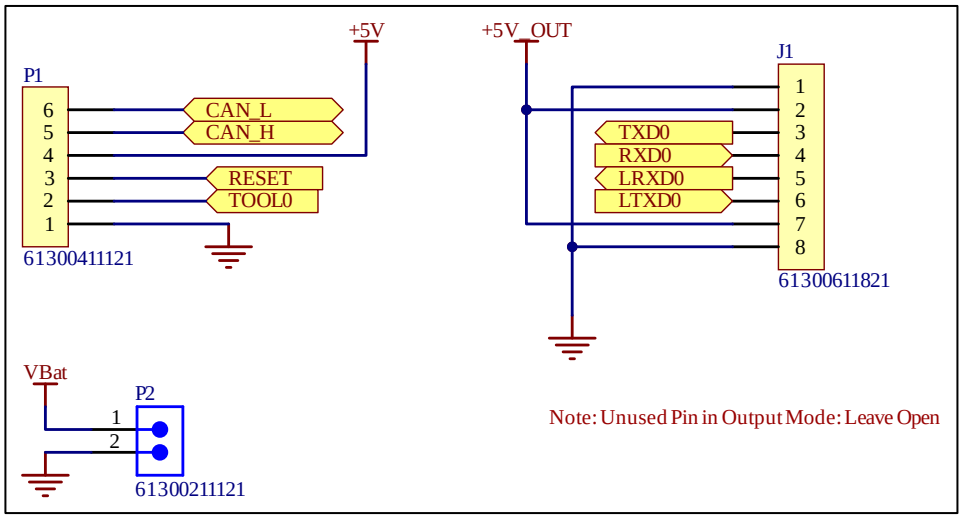


Figure 7: Connectors

5. Software Overview

5.1 RL78/F13 Pin Configurations

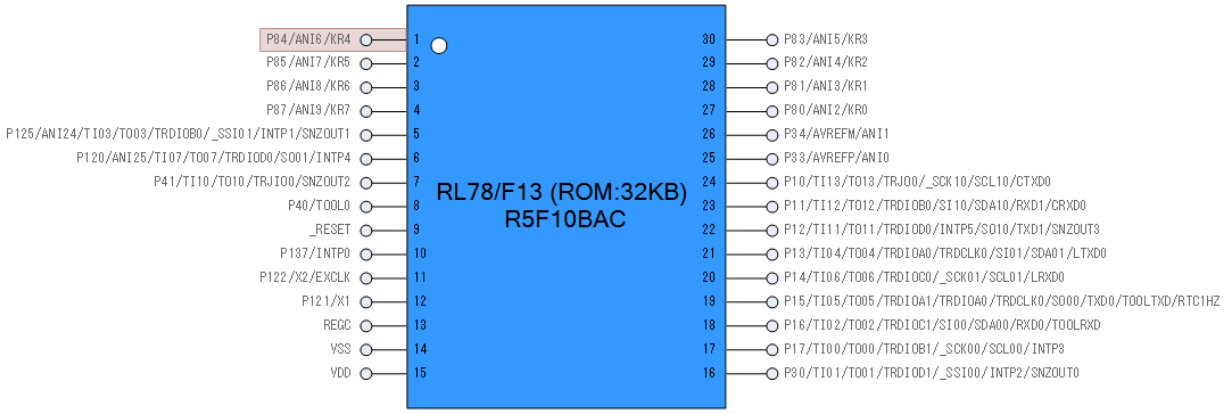


Figure 8. RL78/F13 Pin Configurations

Table 1: Pin Configuration

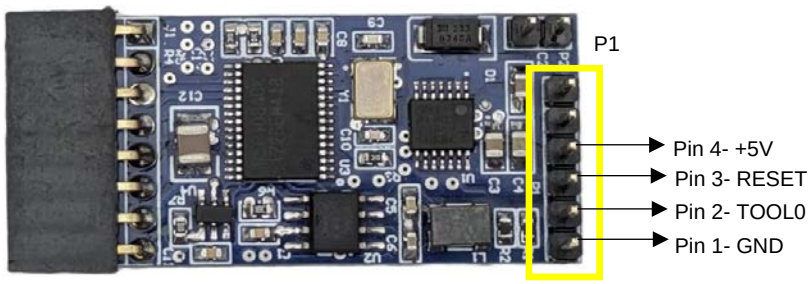
Pin Number	Pin Name / Port	Direction	Default Peripheral / Function	User Functionality / Assignment
1	P84 / ANI6 / (KR4)	I/O	Analog Input	-
2	P85 / ANI7 / (KR5)	I/O	Analog Input	-
3	P86 / ANI8 / (KR6)	I/O	Analog Input	-
4	P87 / ANI9 / (KR7)	I/O	Analog Input	-
5	P125 / ANI24 / TI03 / TO03 / TRDIOB0 / SSI01 / INTP1 / SNZOUT1	I/O	ADC Input, Timer I/O, Serial, Interrupt	-
6	P120 / ANI25 / TI07 / TO07 / TRDIO0D / SO01 / INTP4	I/O	ADC Input, Timer I/O, Serial, Interrupt	-
7	P41 / TI10 / TO10 / TRJIO0 / SNZOUT2	I/O	Timer I/O, Snooze Output	-
8	P40 / TOOL0	I/O	Debug / Tool	TOOL0
9	RESET	Input	Reset	RESET
10	P137 / INTP0	I/O	External Interrupt	
11	P122 / X2 / EXCLK	Input	Crystal Oscillator / External Clock	Xout
12	P121 / X1	Input	Crystal Oscillator Input	Xin
13	REGC	—	Internal Regulator Cap Connection	
14	VSS	Power	Ground	
15	VDD	Power	Supply Voltage	5V
16	P30 / TI01 / TO01 / TRDIO1D / SSI00 / INTP2 / SNZOUT0	I/O	Timer I/O, Serial, Interrupt, Snooze	-
17	P17 / TI00 / TO00 / TRDIOB1 / SCK00 / SCL00 / INTP3	I/O	Timer I/O, Serial Clock, Interrupt	-
18	P16 / TI02 / TO02 / TRDIOC1 / SI00 / SDA00 / RXD0 / TOOLRXD	I/O	Timer I/O, Serial Data, UART RX	RXD0
19	P15 / TI05 / TO05 / TRDIOA1 / (TRDIOA0) / (TRDCLK0) / SO00 / TXD0 / TOOLTXD / RTC1HZ	I/O	Timer I/O, Serial Data Out, UART TX, RTC	TXD0
20	P14 / TI06 / TO06 / TRDIOC0 / SCK01 / SCL01 / LRXD0	I/O	Timer I/O, Serial Clock, LIN RX	LRXD0

21	P13 / TI04 / TO04 / TRDIOA0 / TRDCLK0 / SI01 / SDA01 / LTXD0	I/O	Timer I/O, Serial Data In, LIN TX	LTXD0
22	P12 / TI11 / TO11 / (TRDIO0) / INTP5 / SO10 / TXD1 / SNZOUT3	I/O	Timer I/O, Serial Data Out, UART TX, Snooze	CAN_S
23	P11 / TI12 / TO12 / (TRDIOB0) / SI10 / SDA10 / RXD1 / CRX0	I/O	Timer I/O, Serial Data In, UART RX, CAN RX	U_CAN_RX
24	P10 / TI13 / TO13 / TRJIO0 / SCK10 / SCL10 / CTXD0	I/O	Timer I/O, Serial Clock, CAN TX	U_CAN_RX
25	P33 / AVREFP / ANI0	Input	ADC Reference Positive / Analog Input	-
26	P34 / AVREFM / ANI1	Input	ADC Reference Negative / Analog Input	-
27	P80 / ANI2 / (KR0)	I/O	Analog Input / Key Return	CTRL
28	P81 / ANI3 / (KR1)	I/O	Analog Input / Key Return	Fault
29	P82 / ANI4 / (KR2)	I/O	Analog Input / Key Return	-
30	P83 / ANI5 / (KR3)	I/O	Analog Input / Key Return	-

5.2 Debugging Using CS+

Users receive the board with pre-flashed code allowing immediate use. However, for customization, updates, or debugging, a dedicated hardware debugger like E2 is required. The board provides a dedicated connector P1 for this purpose. Connect E1/E2 (see e² Emulator Lite) with your board through P1.

P1	Connection
1	GND
2	TOOL0
3	RESET
4	+5V



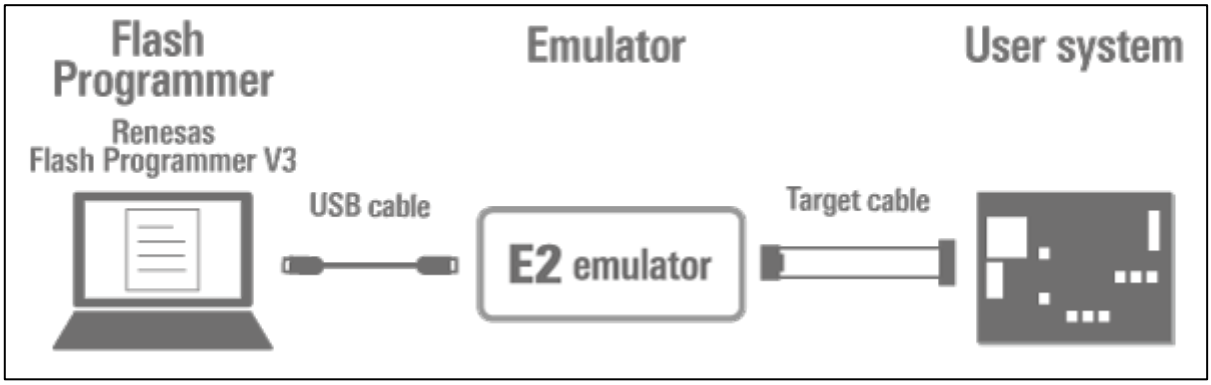
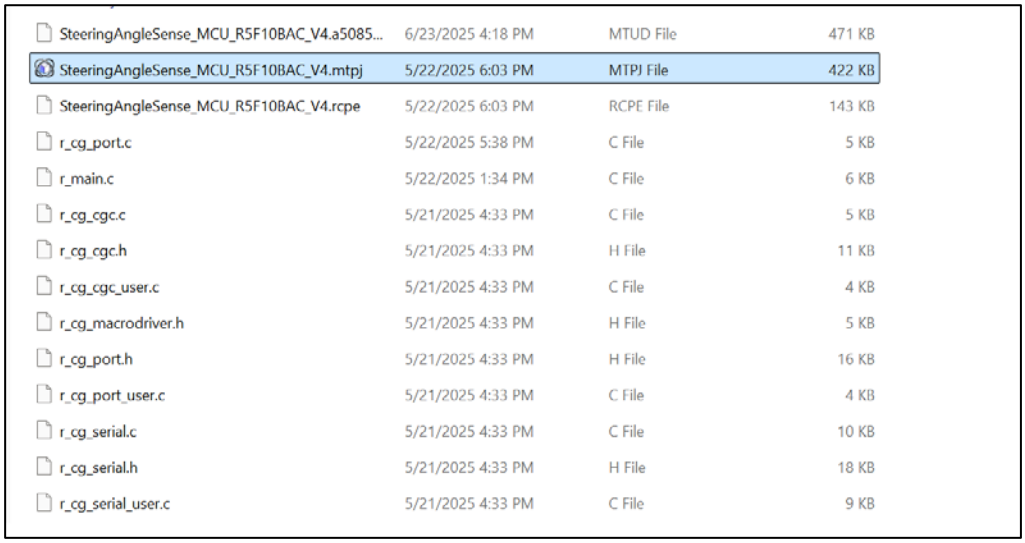


Figure 9. System Configuration

After the connection, debugging is primarily managed through the CS+ integrated development environment (IDE), which facilitates code uploading, testing, and troubleshooting. The following section outlines the step-by-step debugging process to assist users in effectively managing and modifying the software.

1. Open the RL78/F13 project in CS+ by double clicking **xxx.mtpj**.



SteeringAngleSense_MCU_R5F10BAC_V4.a5085...	6/23/2025 4:18 PM	MTUD File	471 KB
SteeringAngleSense_MCU_R5F10BAC_V4.mtpj	5/22/2025 6:03 PM	MTPJ File	422 KB
SteeringAngleSense_MCU_R5F10BAC_V4.rcpe	5/22/2025 6:03 PM	RCPE File	143 KB
r_cg_port.c	5/22/2025 5:38 PM	C File	5 KB
r_main.c	5/22/2025 1:34 PM	C File	6 KB
r_cg_cgc.c	5/21/2025 4:33 PM	C File	5 KB
r_cg_cgc.h	5/21/2025 4:33 PM	H File	11 KB
r_cg_cgc_user.c	5/21/2025 4:33 PM	C File	4 KB
r_cg_macrodriver.h	5/21/2025 4:33 PM	H File	5 KB
r_cg_port.h	5/21/2025 4:33 PM	H File	16 KB
r_cg_port_user.c	5/21/2025 4:33 PM	C File	4 KB
r_cg_serial.c	5/21/2025 4:33 PM	C File	10 KB
r_cg_serial.h	5/21/2025 4:33 PM	H File	18 KB
r_cg_serial_user.c	5/21/2025 4:33 PM	C File	9 KB

Figure 10. .mtpj File in the Project

2. After the project opens (see Figure 11), click on the Build icon (marked as 1), or press F7 to build the project. After the build is successful, click on the Download icon (marked as 2), or press F6 to download the project.

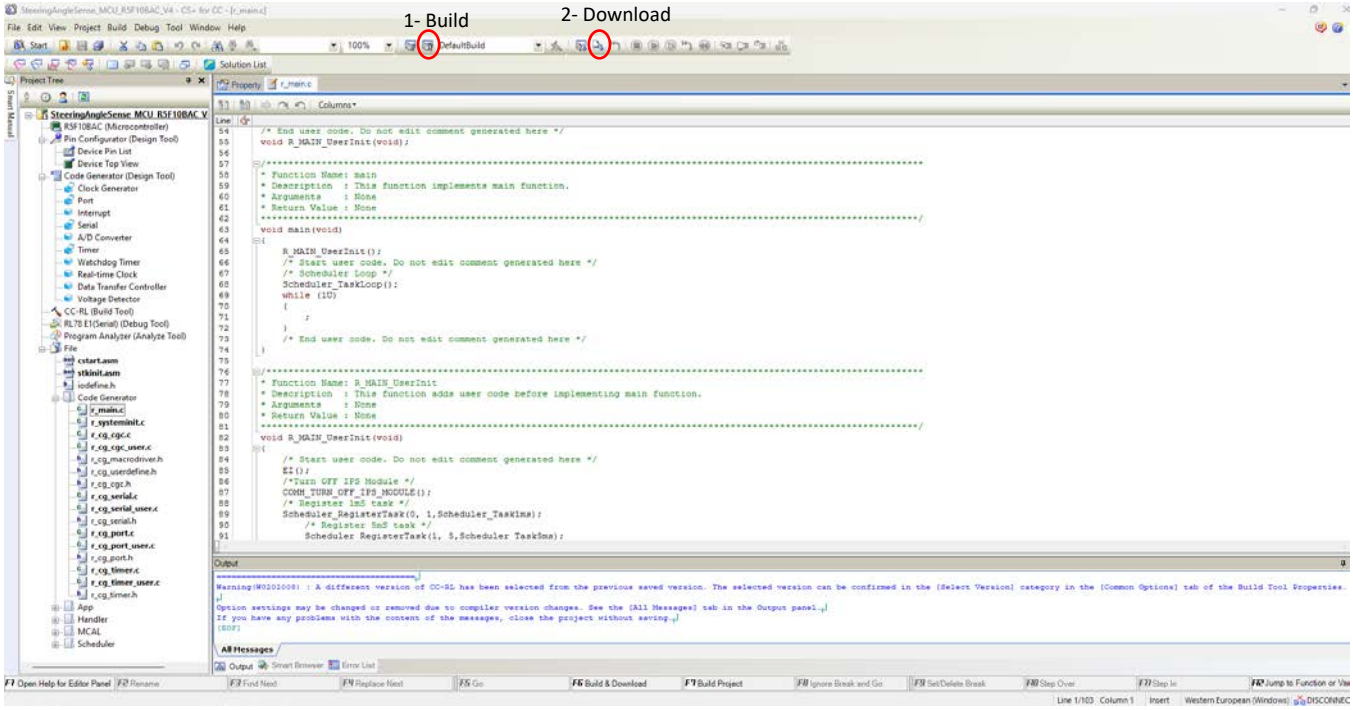


Figure 11: Build and Download the Project

3. After the download is successful, CS+ opens the debug window (see Figure 12).

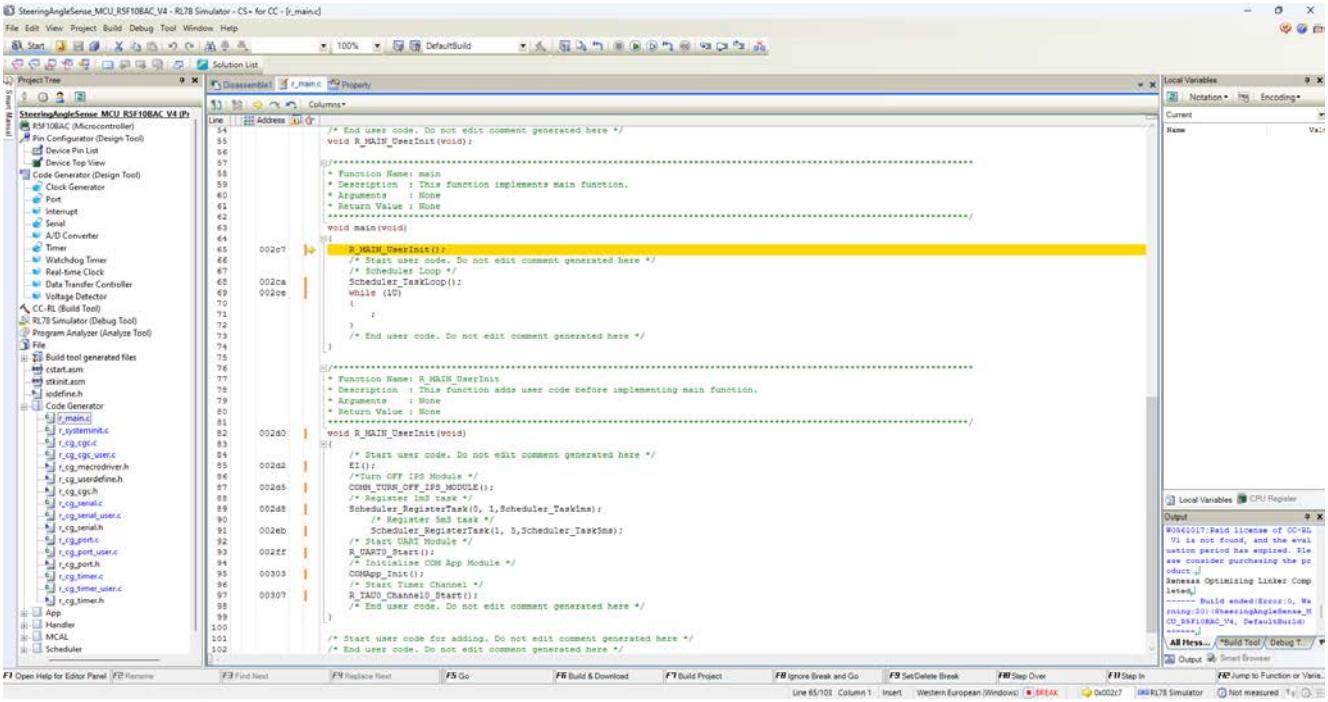


Figure 12: Debug Window

4. After the download is completed, click on the Execute icon as highlighted in Figure 13.

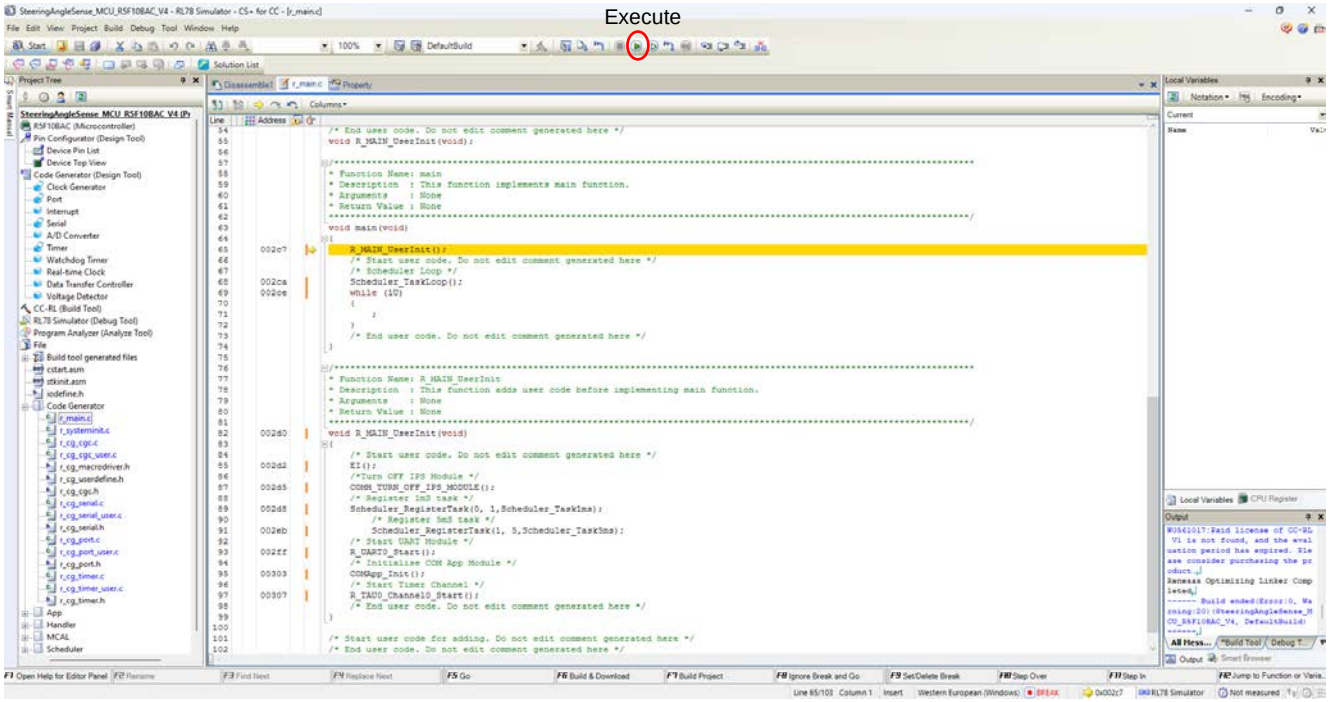


Figure 13: Execute the Program

5.2.1 GUI Setup

For the GUI setup, download the provided executable file and install it on a PC. The GUI displays a dashboard (see Figure 14), featuring a steering angle dial, current angle readout, and plausibility status for easy monitoring and user interaction.

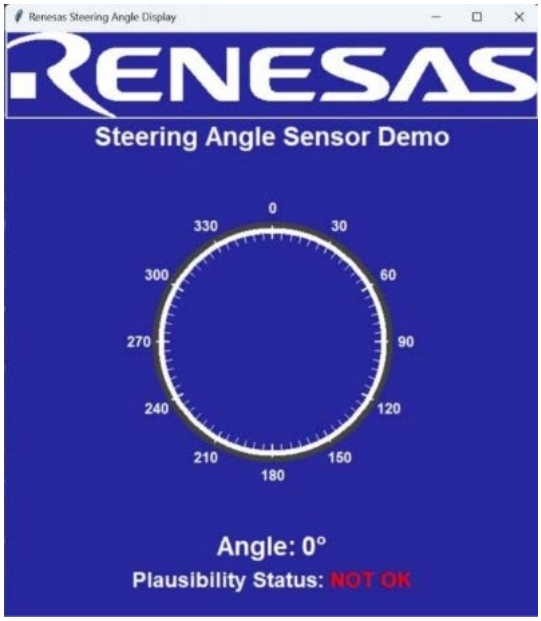


Figure 15: GUI Interface when Sensor Board is Not Connected to GUI

Figure 14. GUI Interface after Rotating the Gears on Sensor Board

5.2.2 Software Algorithm Flowchart

The software primarily operates two tasks.

- Communication Task – The MCU reads sensor data through UART, processes it to compute a high-resolution angle, and transmits this data over CAN.
- Plausibility Check Task – This task verifies the data for logical consistency and reasonableness, updates status accordingly, and reflects the validated state on the GUI.

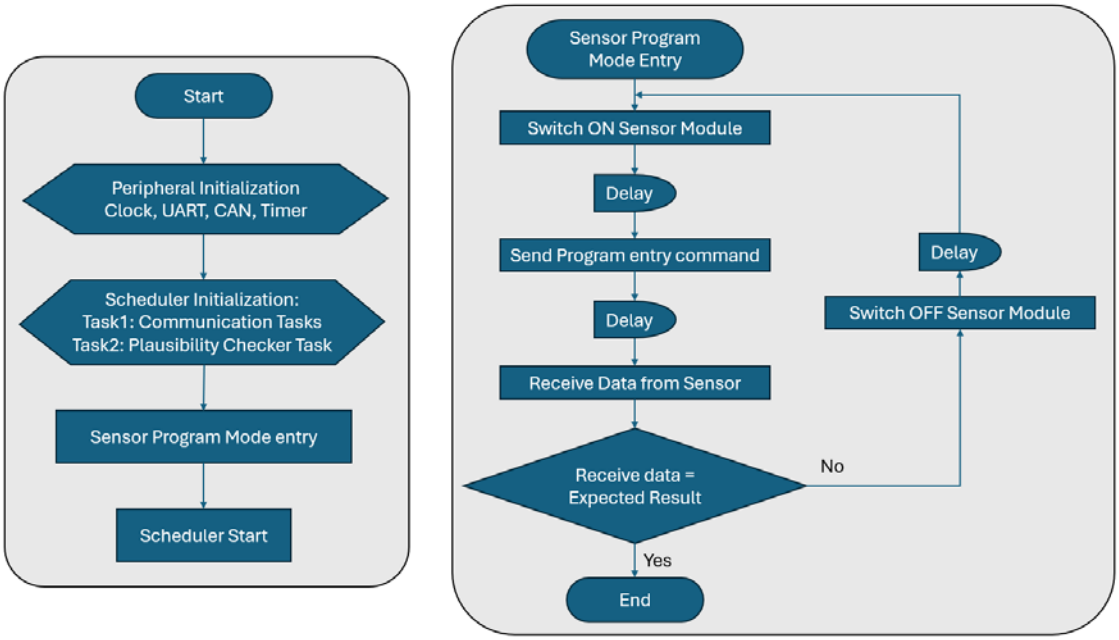


Figure 16. Algorithm Flowchart (a)

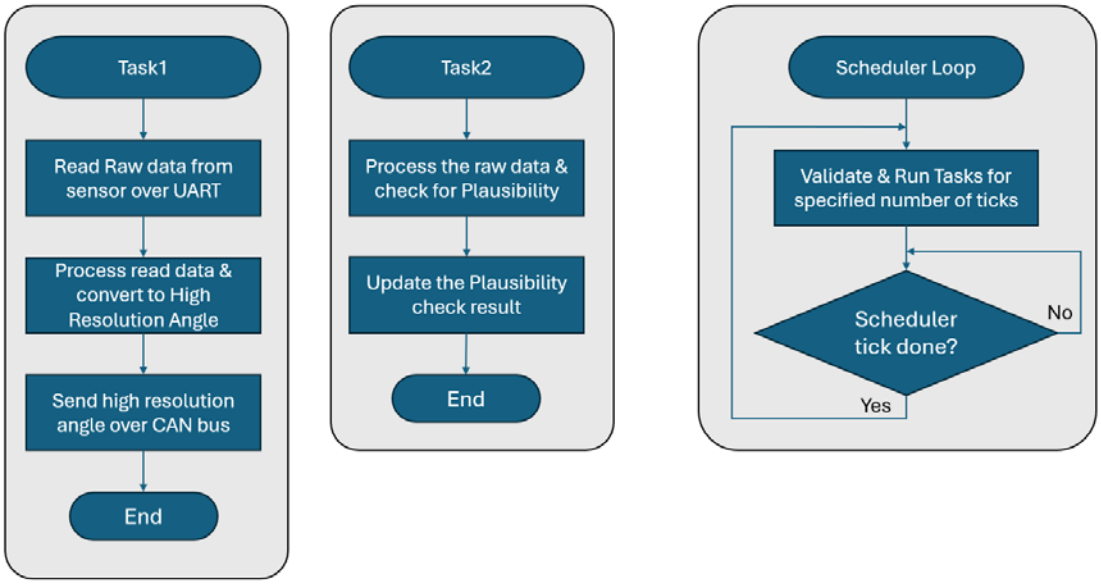


Figure 17. Algorithm Flowchart (b)

This structure ensures data accuracy and reliable communication in the system.

6. Board Overview

6.1 Schematics

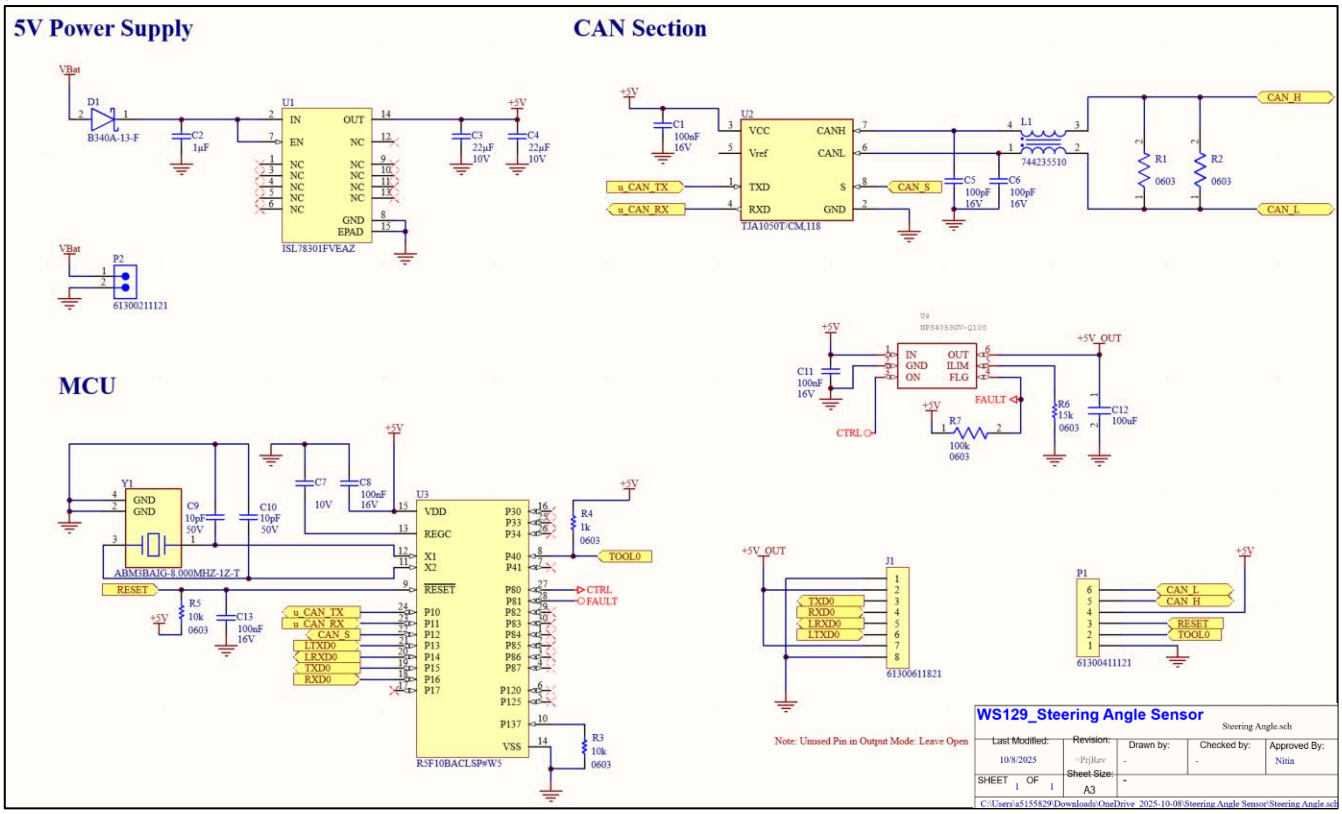


Figure 18: Steering Angle Sensor Schematic

6.2 MCU and Sensor Board

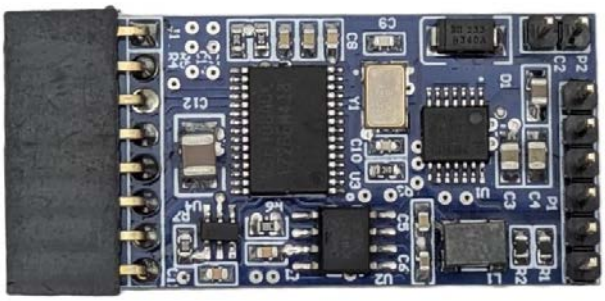


Figure 18: MCU Board Top View

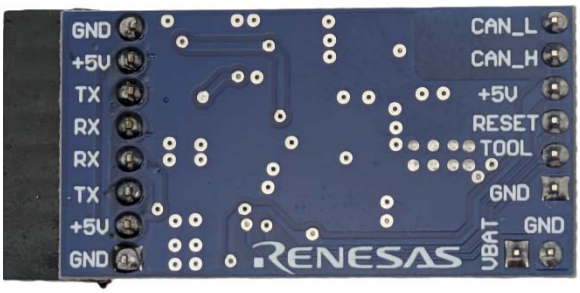


Figure 19: MCU Board Top View

Figure 20: IPS Board Top View

Figure 21: IPS Board Bottom View

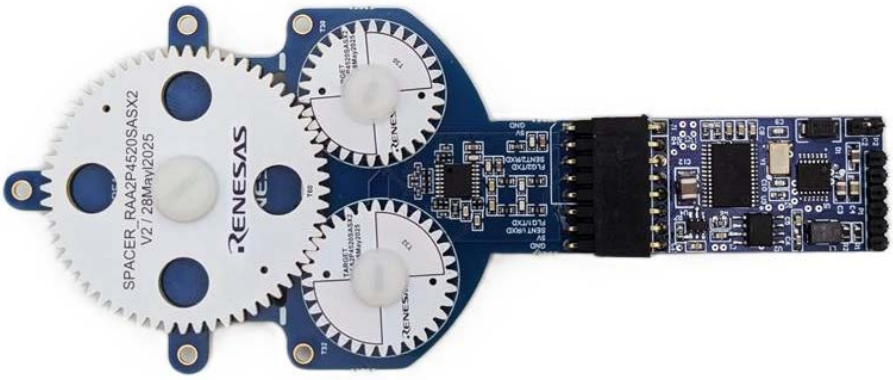


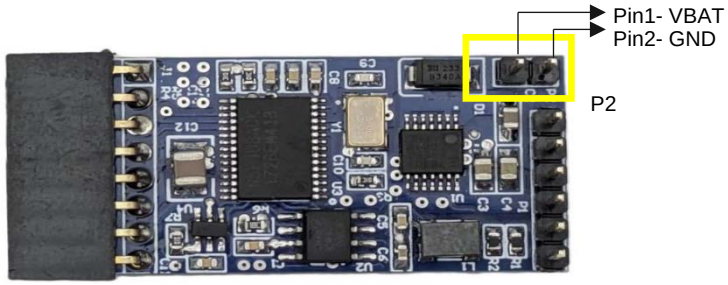
Figure 22: Assembled Board MCU and IPS Sensor

7. Device Setup

The following is the step-by-step device setup.

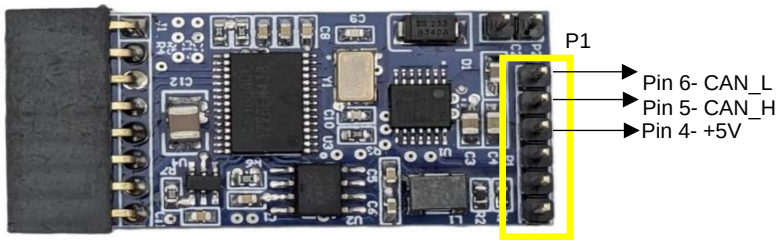
1. Power on the board by connecting a 12V battery to the P2 connector.

P2	Connection
1	12V
2	GND



2. Connect your CAN Analyzer device to the board using the P1 connector, linking the CANH, CANL, and 5V lines.

P1	Connection
4	+5V
5	CAN_H
6	CAN_L



3. Connect the CAN Analyzer device to your PC using a USB cable.
4. Rotate the gears on the sensor board; the results are displayed on the GUI.
5. The GUI shows **Plausibility- NOT OK** when you rotate the steering very fast, confirming the system detects rapid motion correctly.

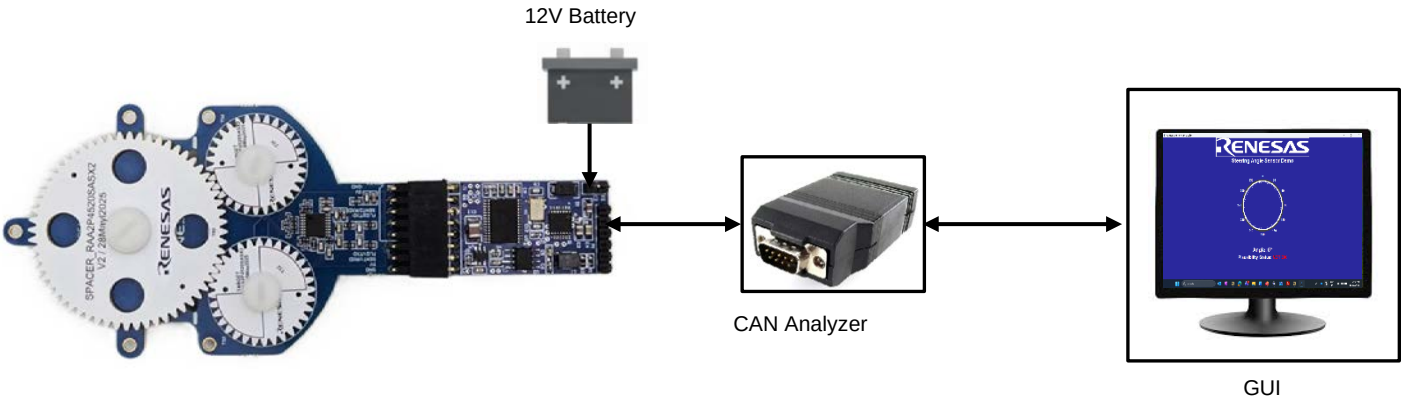


Figure 23. System Configuration

8. Bill of Materials (BOM)

Table 2: Steering Angle Sensor BOM

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
4	C1, C8, C11, C13	0.1µF ±10% 16V Ceramic Capacitor X7R 0603	Würth Elektronik	885012206046
1	C2	1µF ±10% 25V Ceramic Capacitor X7R 0805	Würth Elektronik	885012207078
2	C3, C4	22µF ±20% 10V Ceramic Capacitor X5R 0805	Würth Elektronik	885012107011
2	C5, C6	100pF ±10% 16V Ceramic Capacitor X7R 0603	Würth Elektronik	885012206028
1	C7	1µF ±10% 10V Ceramic Capacitor X7R 0603	Würth Elektronik	885012206026
2	C9, C10	10pF ±5% 50V Ceramic Capacitor C0G, NP0 0603	Würth Elektronik	885012006051
1	C12	100µF ±20% 16V Ceramic Capacitor X5R 1210	Taiyo Yuden	EMK325ABJ107MM-T
1	D1	Diode 40V 3A Surface Mount SMA	Diodes Incorporated	B340A-13-F
1	J1	6 Position Receptacle Connector 0.100" (2.54mm) Through Hole Gold	Würth Elektronik	61300611821
1	L1	51µH 2 Line Common Mode Choke Surface Mount 3 kΩ 200mA DCR 1Ohm	Würth Elektronik	744235510
1	P1	Connector Header Through Hole 4 position 0.100" (2.54mm)	Würth Elektronik	61300411121
1	P2	Connector Header Through Hole 2 position 0.100" (2.54mm)	Würth Elektronik	61300211121
2	R1, R2	240Ω ±1% 0.1W, 1/10W Chip Resistor 0603	Vishay Dale	CRCW0603240RFKEA
3	R3, R4, R5	Chip Resistor, 10KΩ, +/- 1%, 0.125 W, 0805, Tape and Reel, 1 kΩ ±1% 0.1W, 1/10W Chip Resistor 0603	Yageo	RC0603FR-0710KL, RC0603FR-071KL
1	R6	15 kΩ ±1% 0.1W, 1/10W Chip Resistor 0603	YAGEO	RC0603FR-0715KL
1	R7	100 kΩ ±1% 0.1W, 1/10W Chip Resistor 0603	YAGEO	RC0603FR-07100KL
1	U1	40V, Low Quiescent Current, 150mA Linear Regulator for Automotive Applications	Renesas	ISL78301FVEAZ
1	U2	IC TRANSCEIVER HALF 1/1 8SO		TJA1050T/CM,118
1	U3	MCU 16-Bit RL78/F13 RL78 CISC 32KB Flash 3.3V/5V 30-Pin LSSOP Embossed Tape	Renesas	R5F10BACLSP#W5
1	U4	5.5 V, 55 mΩ load switch with precision adjustable current limit	Nexperia	NPS4053GV-Q100H
1	Y1	8 MHz ±10ppm Crystal 18pF 150Ω 4-SMD, No Lead	Abracon LLC	ABM3BAIG-8.000MHZ-1Z-T

9. Board Layout

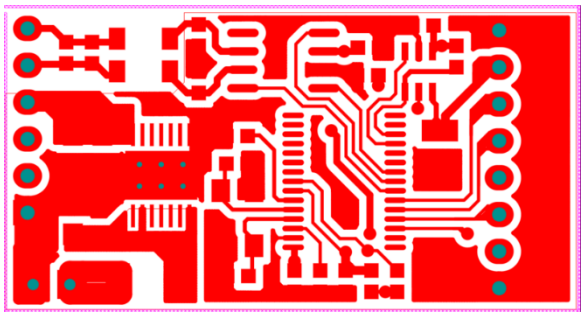


Figure 24: Top Mask

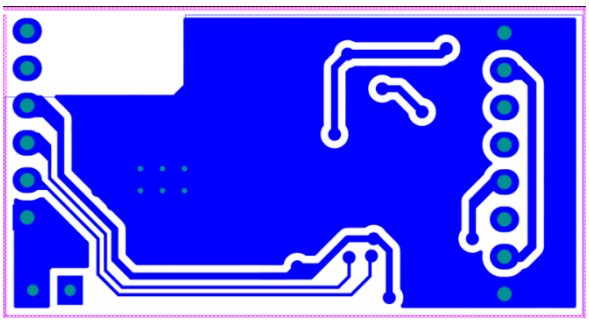


Figure 25. Bottom Layer

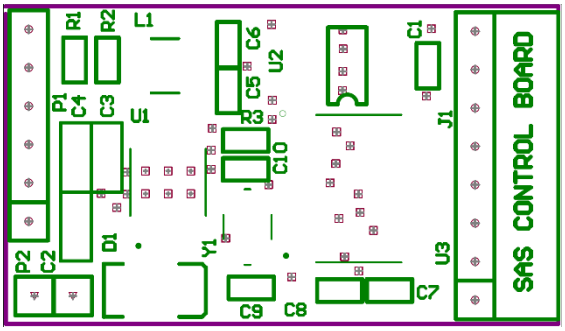


Figure 26. Top Silkscreen Overlay

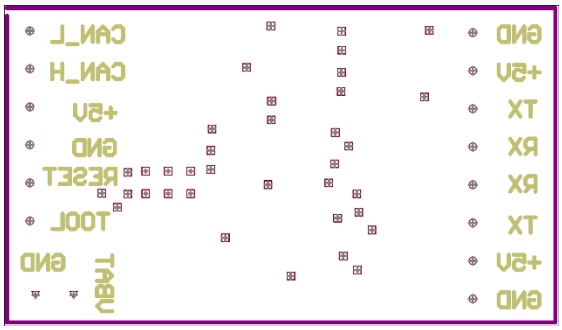


Figure 27. Bottom Silkscreen Overlay

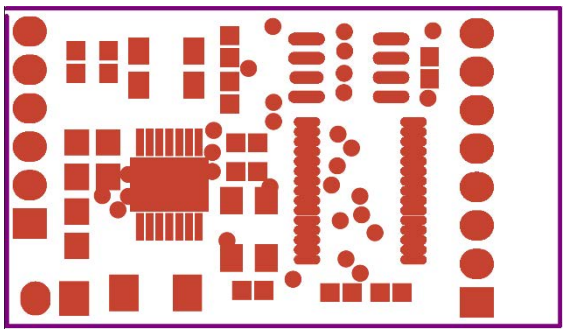


Figure 28. Top Solder Mask

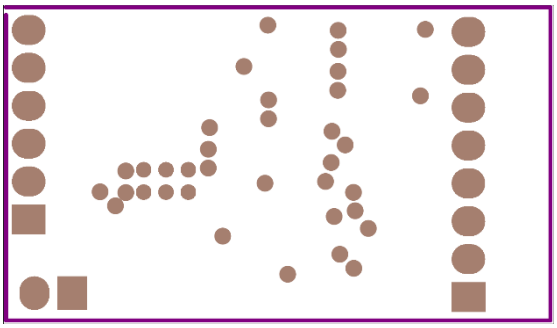


Figure 29. Bottom Solder Mask

10. Ordering Information

Part Number	Description
WS129-SAS-REFZ	WS129 Steering Angle Sensor Board

11. Revision History

Revision	Date	Description
1.00	Dec 1, 2025	Initial release.

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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