Renesas RA Family

Modulated IR Using SCI Mask on RA4C1

Introduction

This application note describes how to generate a signal from the RA4C1 MCU to drive an external infrared (IR) diode. This method enables carrier-modulated IR communication using only the AGT and SCI peripherals by leveraging the featured SCI mask functionality.

To illustrate, there is an accompanying application project demonstrating IR communication between 2 RA4C1 MCUs . The application note details the application's IR transmission and IR reception by covering the SCIMask operation, the IR circuit design, and encoding and decoding of IR messages.

Target Device

RA4C1

Requirements

To run and evaluate the accompanying application example, the following hardware and software are required.

Evaluation Hardware

- 2x EK-RA4C1 & debug cables
- IR LED (TSAL6200)
- IR Sensor (TSOP38238)
- 300-400 Ohm resistor
- Jumper cables
- Breadboard

Evaluation Software

- Renesas e^2 studio v2025-12
- FSP v6.4.0
- LLVM for ARM v18.1.3
- Tera Term or other serial terminal software

The e^2 studio platform installer and FSP are available in a single download from the Renesas GitHub, visit https://github.com/renesas/fsp.

Contents

1. IR Communication

Infrared (IR) communication has been used in embedded system applications for over four decades, long before radio frequency (RF) technologies like Bluetooth and Wi-Fi became ubiquitous for short-range communication.

IR communication remains relevant for use in consumer electronics, metering, industrial configuration ports, and secure point-to-point links due to a combination of its simplicity, low cost, deterministic behavior, and regulatory freedom. The direction and distance between IR devices in active communication matters greatly since communication is either line-of-sight or short-range reflective. It is immune to RF spectrum congestion and is easy to implement using LEDs, photodiodes, and timers.

Over the years, multiple IR communication paradigms have evolved that were optimized for different industry goals. They have been broadly categorized into four groups: metering/service ports, early optical OOK links, consumer IR remotes, and IrDA standardization.

1.1 Industrial Optical Ports

Industrial optical ports originated in the late 1970s-1980s as simple, baseband optical UART links for service, configuration, and metering interfaces. To date, they have been present in PLCs. energy meters, medical and instrumentation equipment, and field service ports (IEC 1107/ IEC 62056-21 style).

They use IR or near-IR light LEDs to transmit a signal and a photodiode/phototransistor to receive. The signals use UART-style asynchronous framing and transmit a DC optical level or a very long pulse. The receiver uses comparators to decode the signal. They are sensitive to ambient light, but are acceptable for operating indoors.

They were designed for their electrical isolation, low cost, and low-speed communication to a known peer device for simple service or configuration access. Since there is no standard, the communication is based on the known connection and is not necessarily interoperable across vendors.

1.2 OOK Optical Links (no carrier)

The other earliest IR systems of the 1970s-1980s used direct on/off keying (OOK), also referred to as intensity modulation/direct detection (IM/DD). They were used in early free-space IR data links, the first generation of fiber-optic systems, and in labs or industrial point-to-point optical links. The IR LEDs and photodiodes acting as the transceivers naturally support OOK.

These systems worked but were extremely susceptible to ambient light interference from sunlight, incandescent bulbs, or fluorescent lamps. As a result, the earliest IR communication systems had to be placed in close proximity, protected with shielded enclosures, and required tight optical alignment.

The issue of light interference led directly to the discovery and use of carrier-modulated IR, which was quickly adopted as the dominant approach for consumer remote devices. In a sense, IrDA SIR (standard 1.0) is still OOK but uses strict pulse shaping and timing rules to overcome the noise challenges.

1.3 Carrier-Modulated IR

Carrier-modulated IR communication introduces a known frequency to modulate the signal driving the IR LED. The IR transmitter and receiver in the system architecture must agree on the carrier frequency used.

Common values range from 36-40 kHz because it is ideal for rejecting any DC light sources, 100 or 120 Hz lighting flickers, and broadband optical noise. There are no legal restrictions for IR transmission in the band 30-56 kHz since the IR signals are confined within a room with only a short period of data transmission (https://www.vishay.com/docs/80071/dataform.pdf). Modern IR receivers commonly include a signal processing system with a band-pass filter centered at a specific frequency in the common range 36-40 kHz.

While "carrier-modulated IR" refers to how the infrared light is transmitted, the encoding scheme defines how bits are represented in time. There are 3 common encoding schemes found in commercial products: pulse distance encoding, pulse width encoding, and biphase/Manchester encoding.

In addition to different encoding schemes and carrier frequencies, there are further variations in the data formats. Data can be sent with and without pre-burst, with different numbers of bits in a command, with different bit lengths, and with different address or data bits. The details are outside of the scope of this application note and should be specified by the external IR device.

1.3.1 Pulse Distance Encoding (PDE)

In pulse distance encoding (PDE), all **carrier bursts have a fixed width,** and the **space between the bursts** encodes the bit value. As seen from the PDE waveform below, the shorter space represents a logical 0, and the longer space represents a logical 1. The specific PDE protocol used will define the lengths of the spaces.

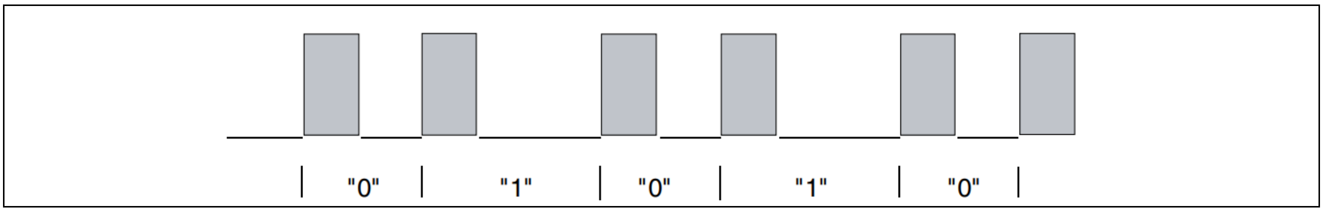


Figure 1. PDE uses the spaces between carrier bursts to encode a 0 or 1.

This encoding method works well because it is simple to decode by measuring the edge timing, it is very tolerant to clock drift, and it is efficient for low data rates. PDE is used in the NEC protocol (now Renesas) and can be found in Renesas, Samsung, LG, and JVC devices like TVs, air conditioners, and set-top boxes.

1.3.2 Pulse Width Encoding (PWE)

In pulse width (or pulse length) encoding (PWE), all **spaces are fixed width,** and the **duration of the carrier burst** encodes the bit value. As seen from the PWE waveform below, the shorter burst represents a logical 0, and the longer burst represents a logical 1. The specific PWE protocol used will define the lengths of the carrier bursts.

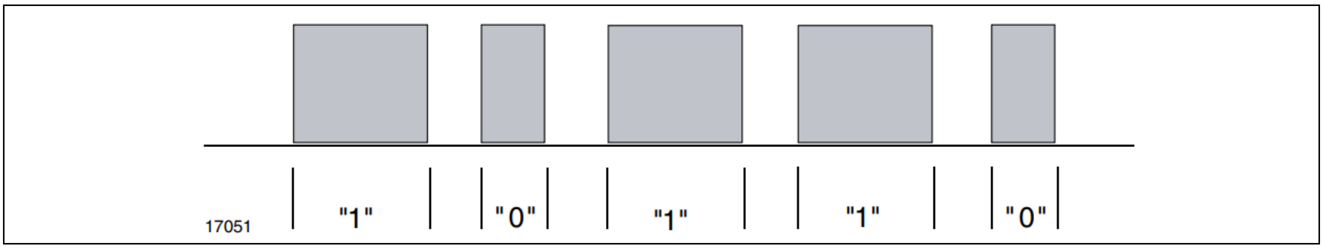


Figure 2. PWE uses the carrier burst width (length) to encode a 0 or 1

This encoding method works well with fixed-frequency timers and can be implemented with a simpler transmitter than PDE, when comparing the minimum logic and timing machinery to create a compliant waveform. However, this method is more sensitive to automatic gain control (AGC) behavior and is less robust in noisy optical environments.

PWE is used in the Sony SIRC protocol, so it is often found in their TVs and audio equipment. It can also be found in low-cost handheld remotes.

1.3.3 Bi-Phase/Manchester Encoding

In bi-phase, aka Manchester encoding, each bit has a guaranteed edge transition in the middle of the bit period, and the **edge direction** encodes the bit value. As seen in the bi-phase example diagram below, a falling edge indicates a logical 0 and a rising edge is a logical 1.

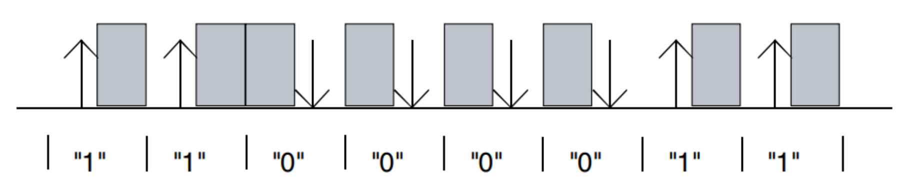


Figure 3. Bi-Phase/Manchester Encoding

This method is advantageous for being self-clocking, DC-balanced, and robust to timing drift. However, it has a lower effective data rate and requires slightly more complex decoding logic.

Within consumer electronics, the bi-phase or Manchester encoding has high reliability. It is often used in systems where repeated keypress detection matters.

1.4 Infrared Data Association (IrDA) Standard

The Infrared Data Association (IrDA) was established in 1993, and a year later, in 1994, it released the IrDA Standard Protocol v1.0. It was invented to find a cable replacement for UART-like data, have interoperability of IR across manufacturers, and achieve higher data rates than remote controls.

The IrDA Standard encompasses and defines different protocol layers. The following 3 are mandatory: the Physical Layer Specification (IrPHY) sets a standard for the IR transceiver, the modulation or encoding/decoding method, and other physical parameters; the Link Access Protocol (IrLAP) establishes the IR media access rules and various procedures for discovery, negotiation, information exchange, etc; and the Link Management Protocol (IrLMP) consists of two components that together manage IR devices linked in a network.

The IrDA 1.0 Physical Layer specifies a light wavelength of 850-900 nm, a distance range of 0-1 meters, a data rate from 9.6 kbps to 115.2 kpbs, and encoding that is UART-like with start/stop bits. Information is transmitted in pulses rather than using carrier frequency modulation.

The following diagram shows how the IrPHY layer is implemented inside RA devices based on UART frames. But unlike UART, which indicates a bit value by the DC level, IrDA specifies a short IR pulse of 3/16 of a period to indicate a logical 0 and no pulse to indicate a logical 1. The ambient light noise immunity is achieved by optical power and protocol design.

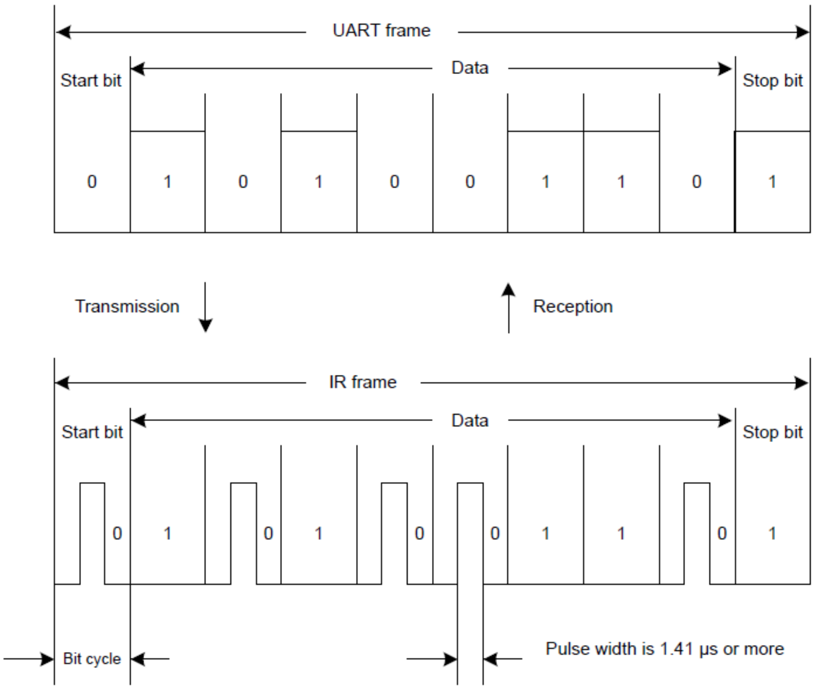


Figure 4. The IrDA 1.0 compliant messages are based on UART frames

IrDA is a widespread standard found within products like laptops, PDAs, printers, medical devices, and industrial handheld terminals.

1.5 Comparison of IR Communication Methods

So, overall, infrared communication has evolved and optimized for the specific use case at hand, balancing the tradeoff between

- Noise immunity,
- Power consumption,
- Implementation complexity,
- Interoperability.

Understanding your IR application is essential before designing a solution with Renesas RA MCUs.

Table 1. IR Communication Methods and their key features

System	Carrier	Encoding	Receiver style	Typical environment
Industrial optical port	No	Raw OOK / DC	Comparator	Controlled, short-range
OOK (no carrier)	No	OOK	Photodiode + amp	Lab / early fiber
Carrier IR (PDE)	Yes	Width of burst	Demodulator module	Consumer, noisy
Carrier IR (PWE)	Yes	Distance between bursts	Demodulator module	Consumer, noisy
Carrier IR (Manchester)	Yes	Bi-phase	Demodulator + timing	Consumer, robust
IrDA PHY 1.0	No	Pulsed OOK	Pulse detector	Consumer + industrial

There exists a possible fourth option for carrier-modulated IR: to design a custom encoding and decoding scheme. The proprietary communication would provide increased flexibility or security for short-distance communication. The example application explained in this document demonstrates carrier-modulated IR communication between 2 EK-RA4C1 MCUs, with a carrier frequency of 38kHz and "custom" encoding/decoding natively supported by UART modules.

2. Infrared Communication Options on RA4C1

The RA4C1 includes two different hardware mechanisms that can enable communication over an external infrared (IR) interface. Each hardware mechanism is explained further, and a comparison of their strengths and weaknesses is evaluated within different use cases.

2.1 IrDA Interface

The RA4C1 MCU features a dedicated IrDA hardware peripheral that adheres to the Infrared Data Association (IrDA) wireless standard.

The IrDA peripheral encodes and decodes the waveforms compliant with the IrDA Standard 1.0, and is integrated with SCI5 for generating and receiving the signals. A block diagram of the IrDA peripheral shows this relationship between the IrDA and SCI5 below.

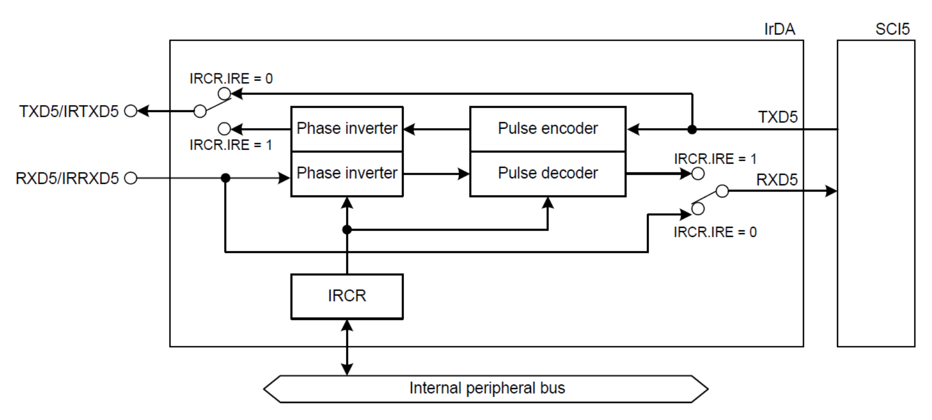


Figure 5. The block diagram shows the association between IrDA and SCI5 on the RA4C1

By setting the IRE bit of the IRCR register, the IrDA function is enabled. The SCI5 signals TXD5 and RXD5 are encoded and decoded into waveforms that conform to the standard because the IrDA shapes the waveform's pulse width appropriately.

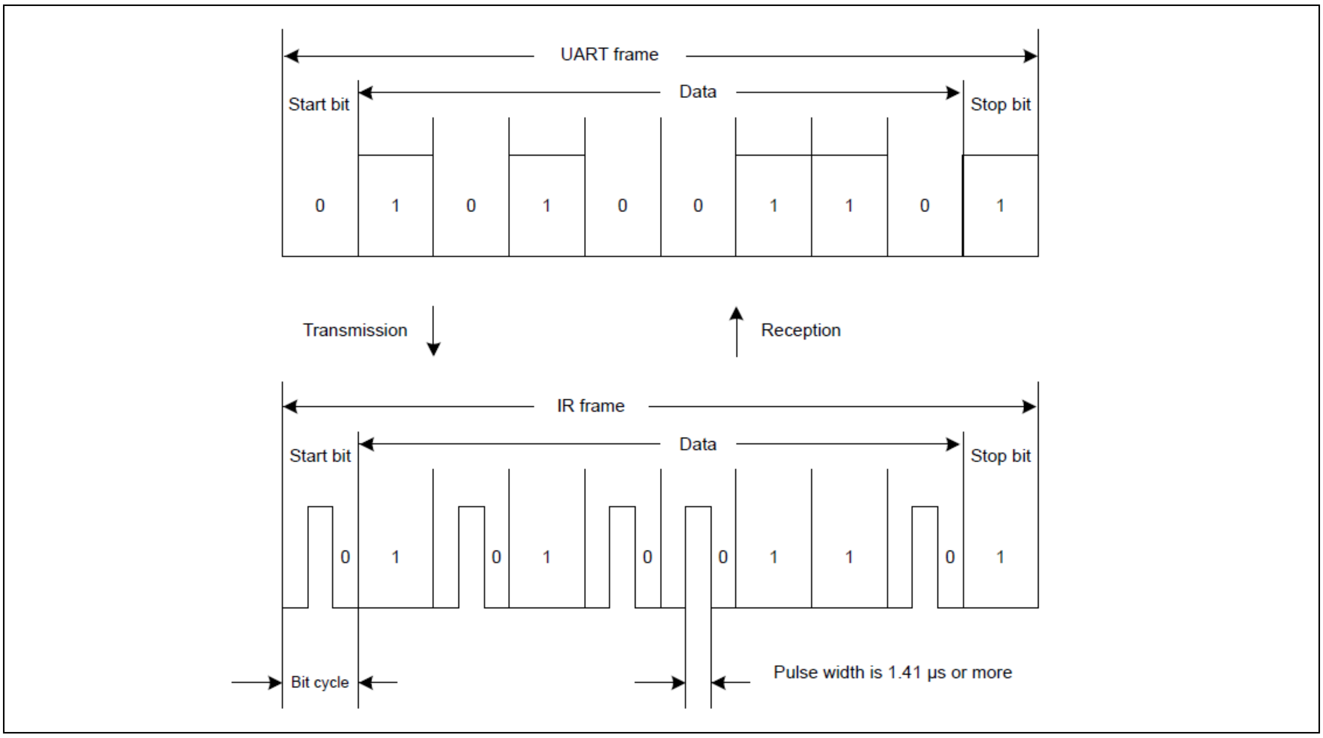


Figure 6. The IrDA messages are encoded from SCI UART messages

The IrDA module allows the MCU to communicate with any external device that adheres to the IrDA Standard 1.0. To do so, make sure the module is a part of the MCU hardware system and connect the IO to an external IR transceiver that conforms to the 1.0 Standard. The contents of the encoded messages are based on the receiving device's command specifications.

2.2 Carrier-Modulated IR: SCI, AGT & SCIMask

The SCI module on the RA4C1 MCU has a unique SCI mask function. When enabled, the output of the AGT (specifically the AGTOA0 signal) is gated by the output TXD of SCI5.

The block diagram below illustrates the relationship between the SCI and AGT with this mechanism. Setting the MSKEN bit of the SCIMSKEN register enables the SCI Mask function.

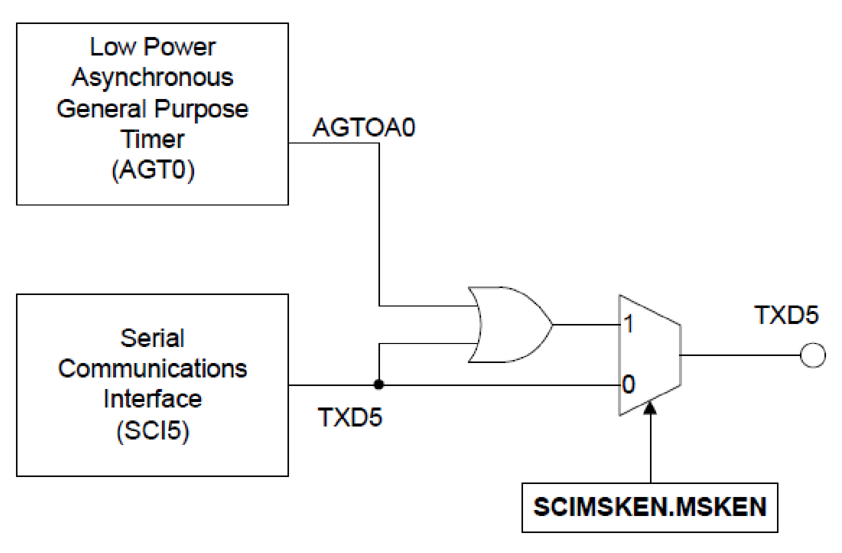


Figure 7. Carrier modulated IR

2.3 Quick Comparison

The following summary highlights the key differences between the two infrared communication approaches available on the RA4C1 MCU, helping designers select the method best suited to their application:

IrDA (SCI + IrDA Module)

MCU:

- Uses the SCI peripheral together with the dedicated IrDA peripheral.

Waveform:

- Implements IrDA Standard 1.0 compliant waveform by encoding and decoding hardware.

External hardware:

- Requires an external IrDA-compliant IR transceiver

Use Case:

- Provides interoperability with off-the-shelf IrDA devices and peripherals.

Carrier-Modulation with SCI Mask:

MCU:

- Uses the SCI peripheral gated by the AGT enabled by the SCIMask function.

Waveform:

- Generates a carrier-modulated IR signal (For example, 38kHz) suitable for consumer-style IR receivers.
- Encoding and decoding are managed by the SCI configuration and/or a software layer.

External Hardware:

- Requires an IR LED and a demodulating IR receiver but is not tied to any standard.

Use case:

- Carrier-modulated IR communication to external peripheral
- Custom or proprietary IR communication, including MCU to MCU links

3. The Application Project: IR Communication between 2 RA4C1 MCUs

The accompanying example demonstrates carrier-modulated IR transmission and reception between 2 EK-RA4C1 MCUs.

The block diagram for the project is illustrated below:

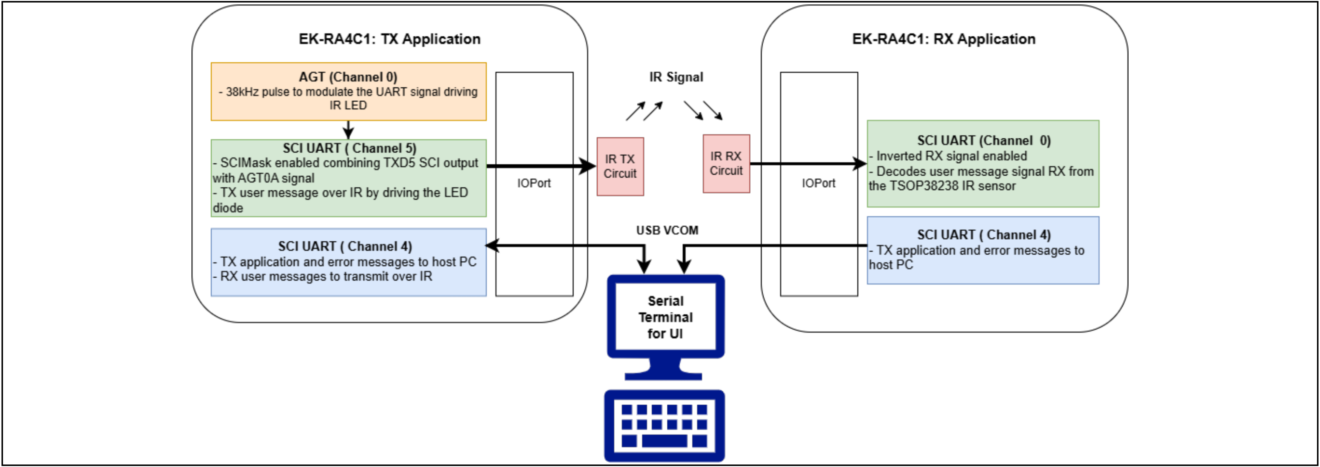


Figure 8. Modulated IR communication high-level block diagram

The transmission application runs on one EK-RA4C1 and drives an external IR LED with a carrier-modulated UART signal. The AGT peripheral generates the carrier frequency, which must match the frequency of the demodulation in the external IR receiver. The SCI peripheral uses the SCI Mask function to gate the AGT carrier with a UART message encoding. The combined signal is sent out of the MCU to drive the LED.

The reception application runs on the second EK-RA4C1 and decodes the transmitted IR signal. The external IR receiver's demodulating circuit removes the AGT signal, and then inputs the message as an inverted UART. The reception application uses the SCI UART peripheral to decode the inverted UART signal.

The USB VCOM communication enabled by SCI UART is used in both the TX and RX projects to control the application through a serial terminal software running on a host PC. Users can specify the messages to transmit over IR and view the decoded IR messages received. Any application system messages or errors will be displayed in the serial terminal.

3.1 External IR Interface Hardware

The design configurations for both projects are dependent on the external IR hardware selected. The implication details are explained in the Modulated IR Transmission and Reception sections.

The transmission project sends IR messages with the High Power IR LED Vishay TSAL6200.

- TSAL6200 Product Information on Vishay.com
- TSAL6200 Datasheet

The reception project detects IR messages with the IR Receiver Module Vishay TSOP38238.

- TSOP38238 Product Information on Vishay.com
- TSOP38238 Datasheet

Both the LED and photodiode are tuned to the same electromagnetic wavelength, 950nm:

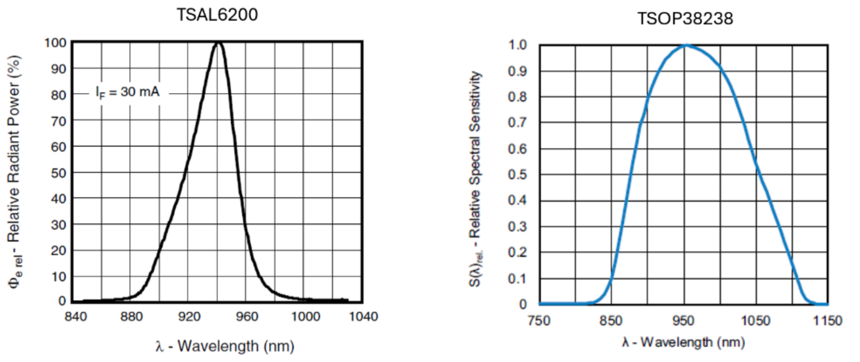


Figure 9. LED and photodiode tuned to 950nm

3.2 Modulated IR Transmission

The hardware and software configurations for the transmission are explained in the context of the application.

3.2.1 TX Circuit

Select output pins on the EK-RA4C1 can be configured as an open drain and drive an LED without an external transistor.

The circuit diagram below depicts the connection between TSAL6200 and the SCI Channel 5 TXD output on the EK-RA4C1. The value of resistor R_L required to drive a current I_{PORT} through the LED can be calculated using the following formula (V_{PORT} is trivial):

$R_L = (3v3 - V_{LED}) / I_{PORT}\ \Omega$

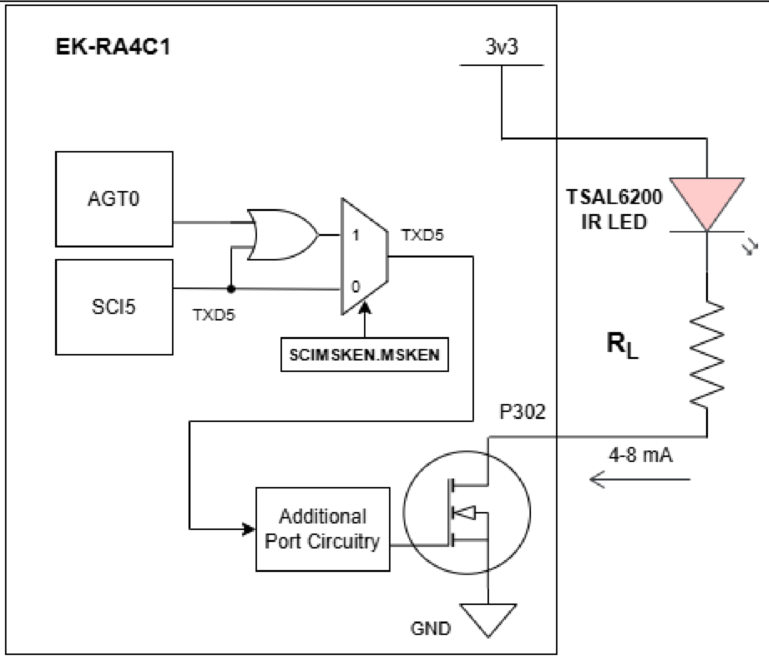


Figure 10. EK-RA4C1 and TSAL6200 IR transmission circuit diagram

The SCI Mask output TXD5 routes to pin 302 on the EK-RA4C1. Based on the Electrical Characteristics chapter of the Hardware User's Manual, this pin averages 4-8mA of current, the range for I_{PORT}.

The IR LED is an active component, where both the radiant intensity and the voltage vary based on the current, in this case exponentially. The TSAL6200 is high power, so at 4-8 mA of current, the radiant intensity is at a strong enough level for the receiver, ranging from around 3-6 mW/sr.

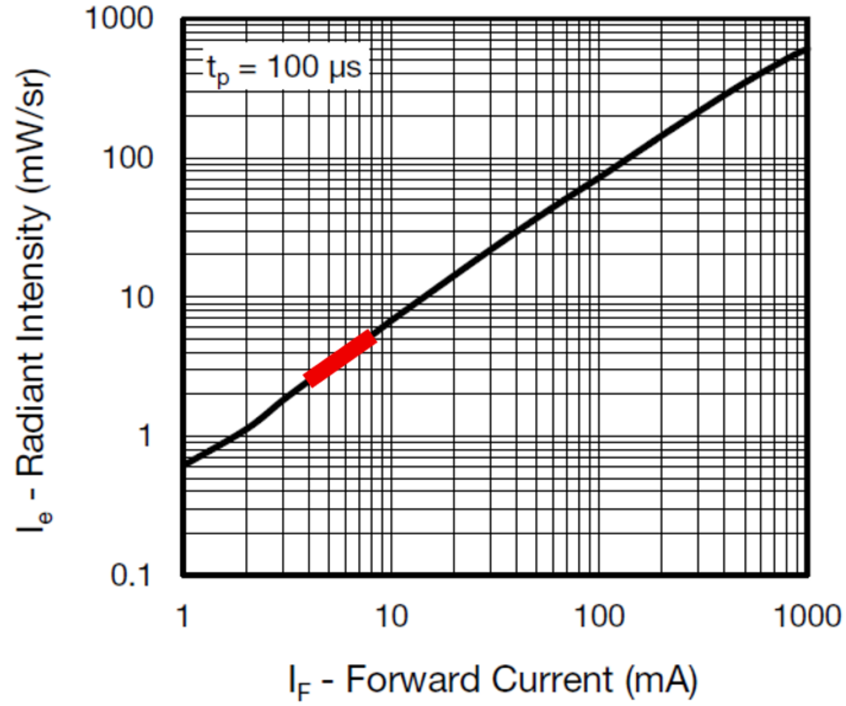


Figure 11. The LED has sufficient radiant intensity for the TXD5 output current

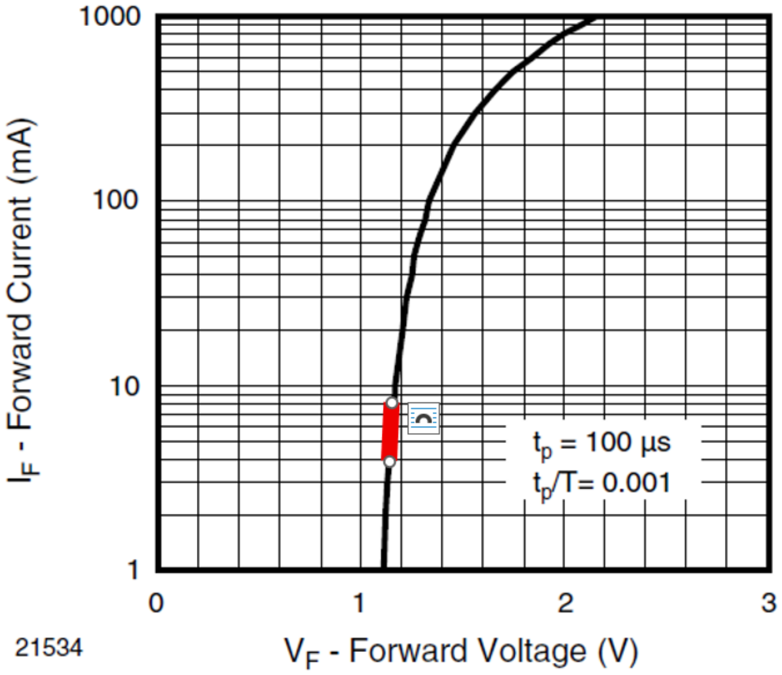


Figure 12. The forward voltage VLED can be averaged to 1.1V for 4-8mA of current.

R_L = (3.3-1.1 V)/(0.005 A) = 440 ohms

R_L = (3.3-1.1 V)/(0.008 A) = 275 ohms

A resistor R_L of 300-400 ohms for ideal circuit conditions.

3.2.2 TX Signal Waveform

The TSOP38238 receiver is tuned to remove a 38kHz carrier frequency, so the AGT is configured to run at the same frequency.

The image below from the TSOP datasheet shows that the minimum number of carrier pulses needed in a row to detect a logical 1 from the IR LED is 10 cycles. This provides guidance for acceptable SCI UART baud rates, which can be calculated using:

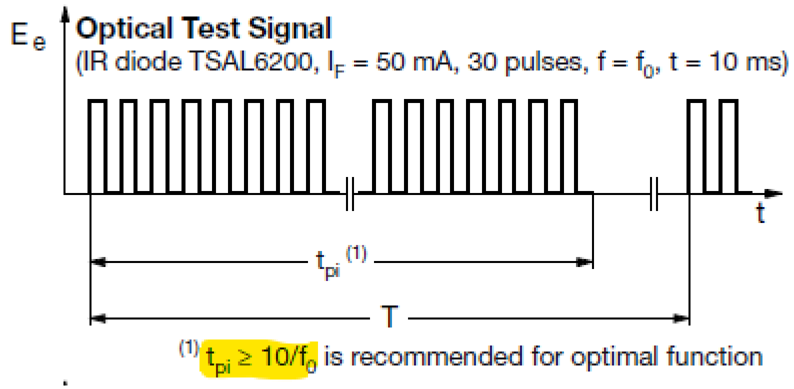


Figure 13. 38kHz / SCI UART baud rate > 10 pulses

Typical UART baud rates are best: 2400 gives about 15 pulses for the duration of a bit, and 1200 gives about 31.

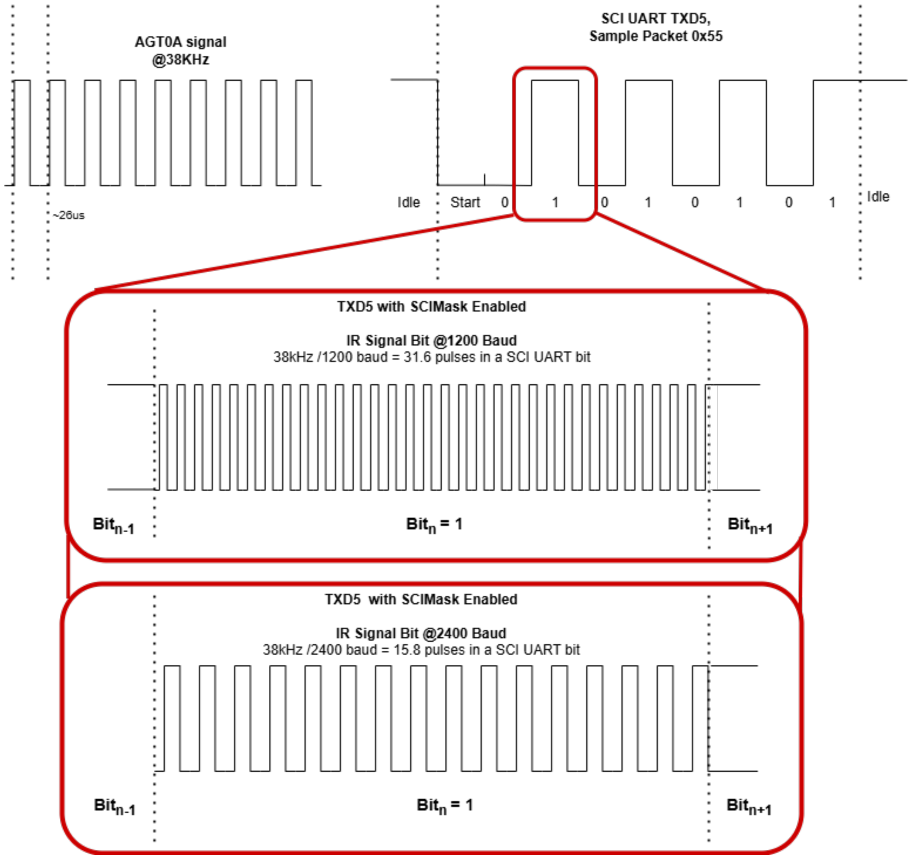


Figure 14. TXD5 output 38kHz AGT signal gated by the output of SCI UART for both baud rates

3.2.3 Stack Configurations

There are three modules needed for the **IR_TX_RA4C1:** the AGT channel 0 to generate a carrier signal, the SCI UART to encode the IR messages, and another SCI UART to connect with a serial terminal UI.

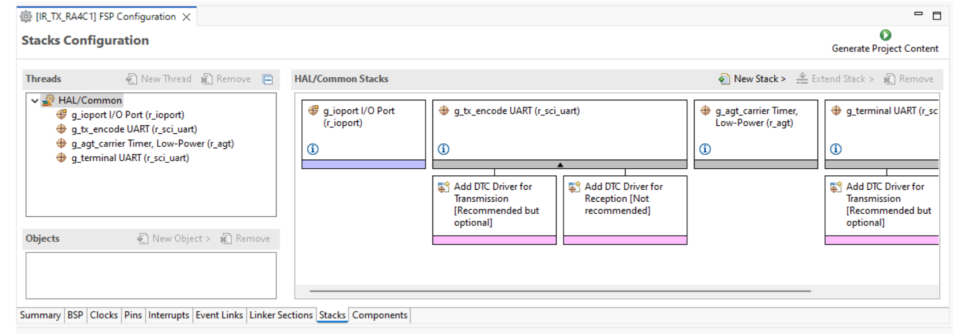


Figure 15 Stack configurations

The following tables show the configurations required for the application.

3.2.3.1 Carrier AGT Configuration

The carrier frequency is generated by the **r_agt** FSP module instance named **g_agt_carrier.**

Table 2. TX Project configurations for the g_agt_carrier that differ from the default.

Configuration	Default Value	Project Value	Reason
Common → Pin Output Support	Disabled	Enabled	Enable all pin output support for the AGT.
Module → General → Name	g_timer0	g_agt_carrier	Name the AGT module.
Module → General → Period	0x1000	38	Set the frequency to 38 kHz.
Module → General → Period Unit	Raw Counts	Kilohertz	Set the frequency to 38 kHz.
Module → Output → AGTOA Output	Disabled	Start Level Low	Enable the output for the AGTOA, since AGTOA0 is connected to SCI TXD5 by the SCI mask.

3.2.3.2 TX Encoder SCI UART Configuration

The IR messages are encoded using the **r_sci_uart** module instance named **g_tx_encode**.

Table 3. TX Project configurations for the g_agt_carrier that differ from the default.

Configuration	Default Value	Project Value	Reason
Module → General → Name	g_uart0	g_tx_encode	Name the SCI UART module.
Module → General → Channel	0	5	The SCI mask is only available for the TXD5 signal.
Module → Baud → Baud Rate	115200	2400	Either 2400 or 1200 is acceptable for TSOP38238. Value must match the RX project's UART's baud rate.
Module → Interrupts → Callback	NULL	encode_callback	Callback sends events when the message transmitted to the IR

			LED is complete or if a runtime module error occurs.

3.2.3.3 Serial Terminal SCI UART Configuration

The serial terminal interface is managed by a second **r_sci_uart** module instance named **g_terminal.**

Table 4. TX Project configurations for the g_agt_carrier that differ from the default.

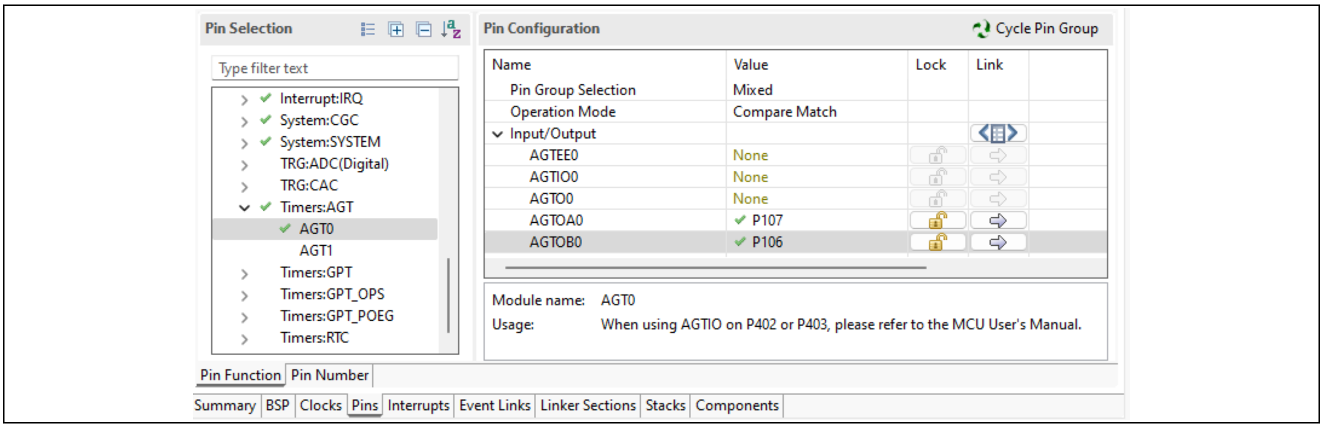
Configuration	Default Value	Project Value	Reason
Module → General → Name	g_uart0	g_terminal	Name the SCI UART module.
Module → General → Channel	0	4	The USB over VCOM routes to channel 4 of the SCI peripheral.
Module → Interrupts → Callback	NULL	terminal_callback	Callback sends events when serial messages are transmitted and received or if a runtime module error occurs.

3.2.4 Pin Settings

Navigate to the FSP Configuration Pin Tab to view the IO configuration for the TX project.

3.2.4.1 Carrier AGT Pins

Under **Peripherals** → **Timers:AGT**, the **AGT0** is used to access the AGT channel 0 pin configurations. The **Operation Mode** is set to **Compare Match,** which routes the **AGTOA0** to **P107.** This also enables the internal connection between the AGT and the SCI mask hardware.



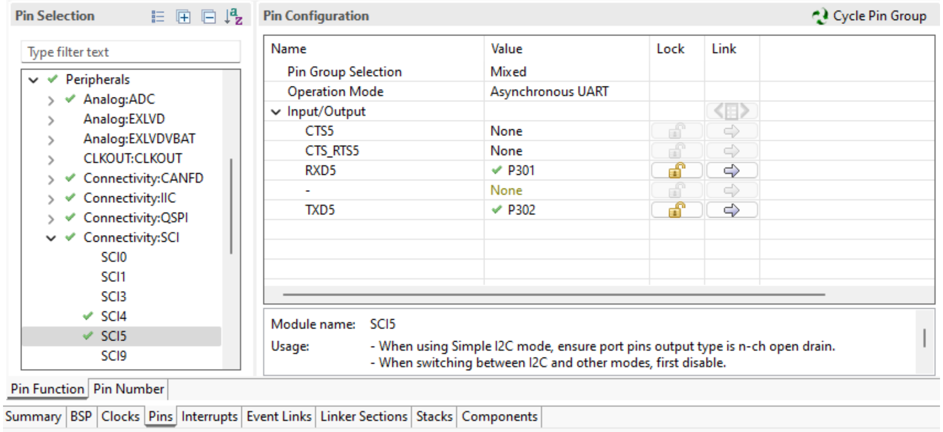
Name	Value	Lock	Link
Pin Group Selection	Mixed		
Operation Mode	Compare Match		
Input/Output			
AGTEE0	None		
AGTIO0	None		
AGTO0	None		
AGTOA0	✓ P107		
AGTOB0	✓ P106		

Module name: AGT0
Usage: When using AGTIO on P402 or P403, please refer to the MCU User's Manual.

Figure 16. AGT channel 0 pin configurations

3.2.4.2 TX Encoder SCI UART Pins

Under **Peripherals** → **Connectivity: SCI,** the **SCI5** is used to access the SCI channel 5 pin configurations. The **Operation Mode** is set to **Asynchronous UART** with IO signals routing **RXD5** to **P301** and **TXD5** to **P302**. RXD must be routed to an MCU pin, but it is not connected to an external device.



Name	Value	Lock	Link
Pin Group Selection	Mixed		
Operation Mode	Asynchronous UART		
Input/Output			
CTS5	None		
CTS_RTS5	None		
RXD5	✓ P301		
-	None		
TXD5	✓ P302		

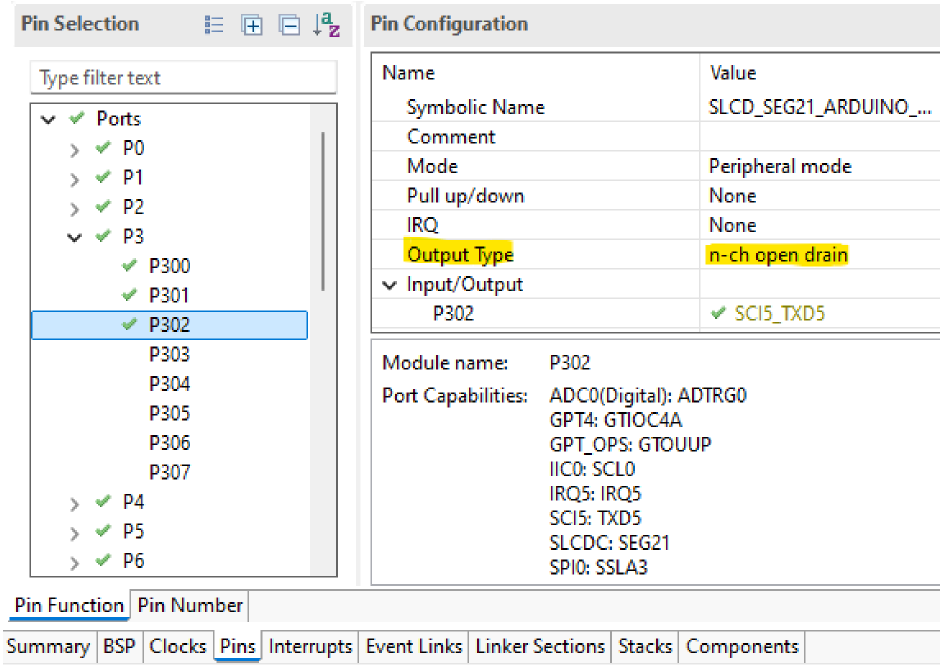
Module name: SCI5

Usage: - When using Simple I2C mode, ensure port pins output type is n-ch open drain.
- When switching between I2C and other modes, first disable.

Figure 17. SCI channel 5 pin configurations

The peripheral operation mode for **HMI: SLCDC** had to be **Disabled** to avoid pin conflicts.

The TXD5 signal output pin must be set as an open drain to drive the IR LED. The pin configurations for the specific P302 are accessed through **Ports** → **P3** → **P302,** and the **output type** is set to **n-ch type open drain.**



Name	Value
Symbolic Name	SLCD_SEG21_ARDUINO_...
Comment	
Mode	Peripheral mode
Pull up/down	None
IRQ	None
Output Type	n-ch open drain
Input/Output	
P302	✓ SCI5_TXD5

Module name: P302

Port Capabilities: ADC0(Digital): ADTRG0
GPT4: GTIOC4A
GPT_OPS: GTOUUP
IIC0: SCL0
IRQ5: IRQ5
SCI5: TXD5
SLCDC: SEG21
SPI0: SSLA3

Figure 18. The TXD5 output pin is configured as an open-drain to drive the IR LED

3.2.5 Enable SCI Mask Function

To enable the SCI mask function at runtime in code, the MSKEN bit of the SCIMSKEN register needs to be set to 1 when the module is open. The FSP does not yet provide an API to set and clear the bitfield.

The BSP provides convenient definitions in the file <MCU_part#>.h, including register structures for all special function registers, peripheral base addresses, bitfield positions, and bitfield masks. The **R_SCI5** struct defines all special function register addresses for SCI5, and the SCIMSKEN register can be accessed with **R_SCI5→SCIMSKEN,** and the bitfield MSKEN accessed with the **R_SCI0_SCIMSKEN_MSKEN_Pos** macro.

```
void sci_mask_en(void)
{
    R_SCI5->SCIMSKEN = SCIMSK_ENABLE << R_SCI0_SCIMSKEN_MSKEN_Pos;
}
```

3.3 Modulated IR Reception

The hardware and software configurations for the reception are explained in the context of the application.

3.3.1 RX Circuit

The following diagram depicts the connection between the TSOP38238 receiver and the EK-RA4C1 running the reception application. The TSOP sensor has a bandpass and demodulator circuit tuned to remove the 38kHz carrier frequency from the transmitted IR signal.

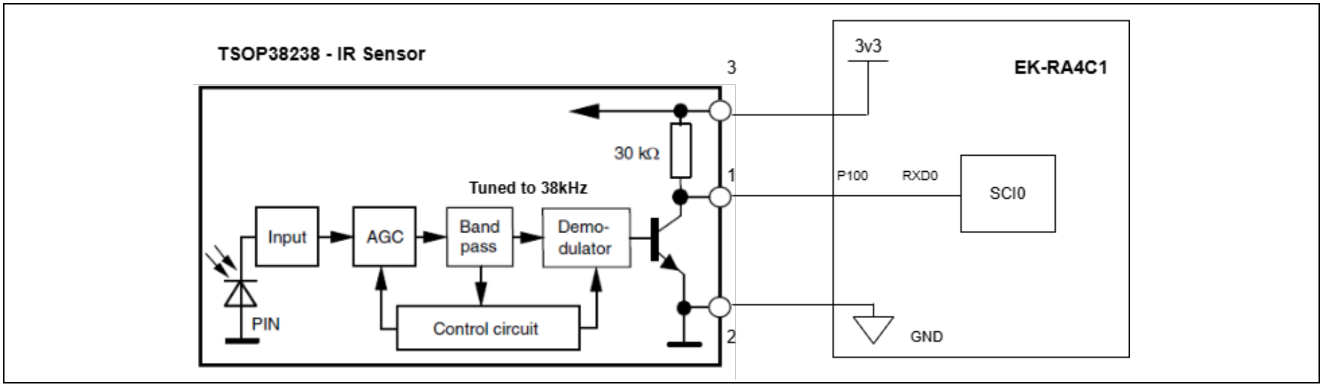


Figure 19. EK-RA4C1 and TSOP38238 IR transmission circuit diagram

3.3.2 RX Signal Waveform

After demodulation, the output signal from the TSOP38238 is in the form of inverted UART:

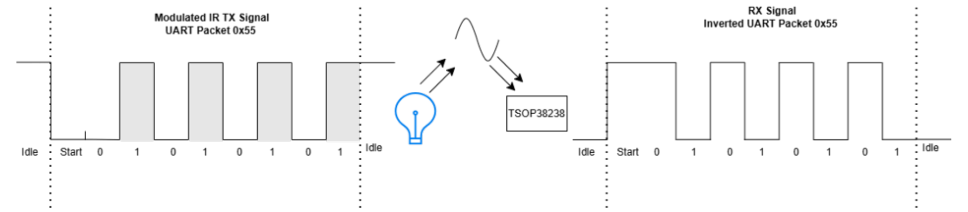


Figure 20. The RX signal waveform from TSOP38238 is an inverted UART

By design, the output of TSOP38238 can conveniently be routed to an available SCI UART channel for hardware decoding. SCI channel 0 is selected because it has a configuration option to invert the RXD signal.

In software, IR messages received can be read easily using the FSP APIs for the **r_sci_uart** module.

3.3.3 Stack Configurations

There are two modules required for the project **IR_RX_RA4C1:** a SCI UART to encode the IR messages and another SCI UART to connect with a serial terminal UI.

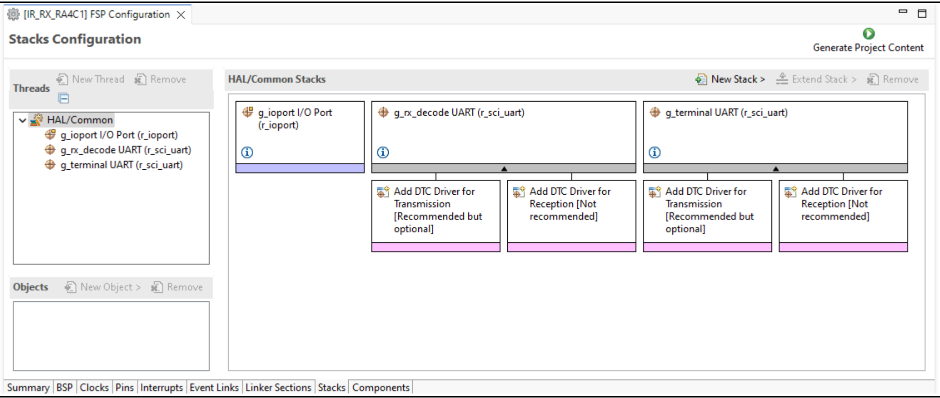


Figure 21. Stack configurations

3.3.3.1 RX Decoder SCI UART Configuration

The IR messages are encoded using the **r_sci_uart** module instance named **g_rx_decode**.

Table 5. RX Project configurations for the g_rx_encode that differ from the default.

Configuration	Default Value	Project Value	Reason
Module → General → Name	g_uart0	g_rx_encode	Name the SCI UART module.
Module → Baud → Baud Rate	115200	2400	Either 2400 or 1200 is acceptable for TSOP38238. Value must match the TX project's UART's baud rate.
Module → Interrupts → Callback	NULL	decode_callback	Callback sends events when a message is input by the TSOP38238 or if a runtime module error occurs.

3.3.3.2 Serial Terminal SCI UART Configuration

The serial terminal interface is managed by a second **r_sci_uart** module instance named **g_terminal.**

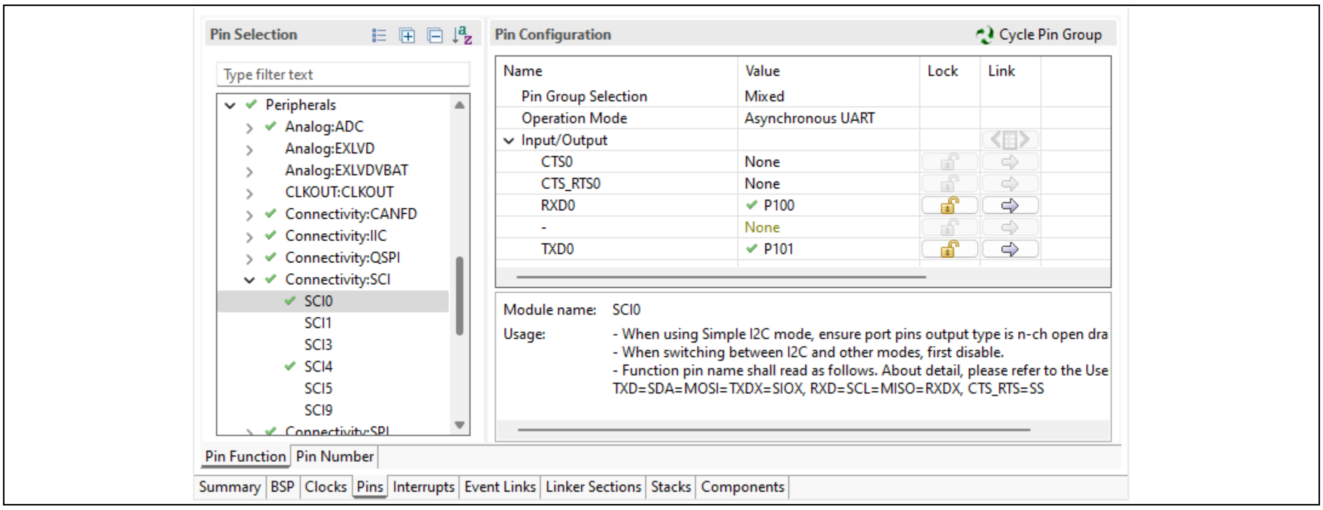
Table 6. RX Project configurations for the g_terminal that differ from the default.

Configuration	Default Value	Project Value	Reason
Module → General → Name	g_uart0	g_terminal	Name the SCI UART module.
Module → General → Channel	0	4	The USB over VCOM routes to channel 4 of the SCI peripheral.
Module → Interrupts → Callback	NULL	terminal_callback	Callback sends events when serial messages are transmitted and received or if a runtime module error occurs.

3.3.4 Pin Settings

Navigate to the FSP Configuration Pin Tab to view the IO configuration for the TX project.

Under **Peripherals** → **Connectivity: SCI**, the **SCI0** is used to access the SCI channel 0 pin configurations. The **Operation Mode** is set to **Asynchronous UART** with IO signals routing **RXD5** to **P100** and **TXD5** to **P101**. TXD must be routed to an MCU pin, but it is not connected to the TSOP sensor.



Name	Value	Lock	Link
Pin Group Selection	Mixed		
Operation Mode	Asynchronous UART		
Input/Output			
CTS0	None		
CTS_RTS0	None		
RXD0	✓ P100		
-	None		
TXD0	✓ P101		

Module name: SCI0

Usage: - When using Simple I2C mode, ensure port pins output type is n-ch open dra
- When switching between I2C and other modes, first disable.
- Function pin name shall read as follows. About detail, please refer to the Use
TXD=SDA=MOSI=TXDX=SIOX, RXD=SCL=MISO=RXDX, CTS_RTS=SS

Figure 22. SCI channel 0 pin configurations for the RX project

The peripheral operation mode for **HMI: SLCDC** had to be **Disabled** to avoid pin conflicts.

3.3.5 Invert SCI RXD Signal

To enable the SCI mask function at runtime in code, the RINV bit of the SPTR register needs to be set to 1 when the module is open. The FSP does not yet provide an API to set and clear the bitfield.

The **R_SCI0** struct defines all special function register addresses for SCI channel 0. The SPTR register can be accessed with **R_SCI0->SPTR,** and the bitfield RINV is accessed with the **R_SCI0_SPTR_RINV_Pos** macro.

```
void sci_rx_invert(void)

{

    R_SCI0->SPTR =  SCI_RX_INV_EN << R_SCI0_SPTR_RINV_Pos;

}
```

4. Running the Application Project

This section gives steps to run and validate the application project where 2 EK-RA4C1 boards communicate with modulated IR over an external interface.

The project is in the folder "Modulated_IR_SCIMask" and consists of a transmission project "IR_TX_RA4C1" and a reception project "IR_RX_RA4C1".

4.1 Required Resources

The following resources are required to run the example:

4.1.1 Software

- e^2 studio v2025-10
- FSP v6.4.0
- Tera Term or other serial terminal software

4.1.2 Hardware

4.1.2.1 General

- 2x EK-RA4C1
- Breadboard

- Jumper cables

Transmission

- High Power IR LED (Vishay TSAL6200)
- Current-limiting resistor (300-400 Ohm resistor)

Reception

- IR Receiver Module (Vishay TSOP382)

4.2 Steps to Build and Run

On both EK-RA4C1 boards, ensure SW4 has all switches 1-8 set to OFF except 4, which is ON.

Follow the steps to run the application:

4.2.1 Connections and workspace setup

1. Set up the transmission circuit with board 1, the LED, resistor, jumper cables, and breadboard.

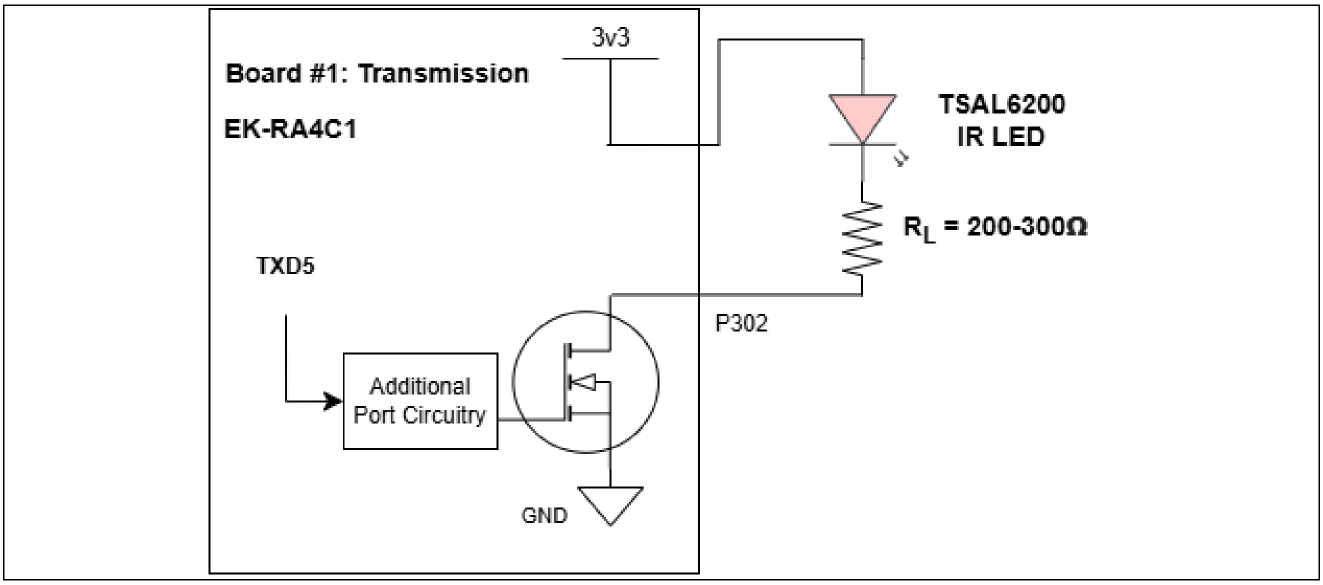


Figure 23. Transmission circuit setup

2. Set up the reception circuit with board 2, the sensor, jumper cables, and breadboard.

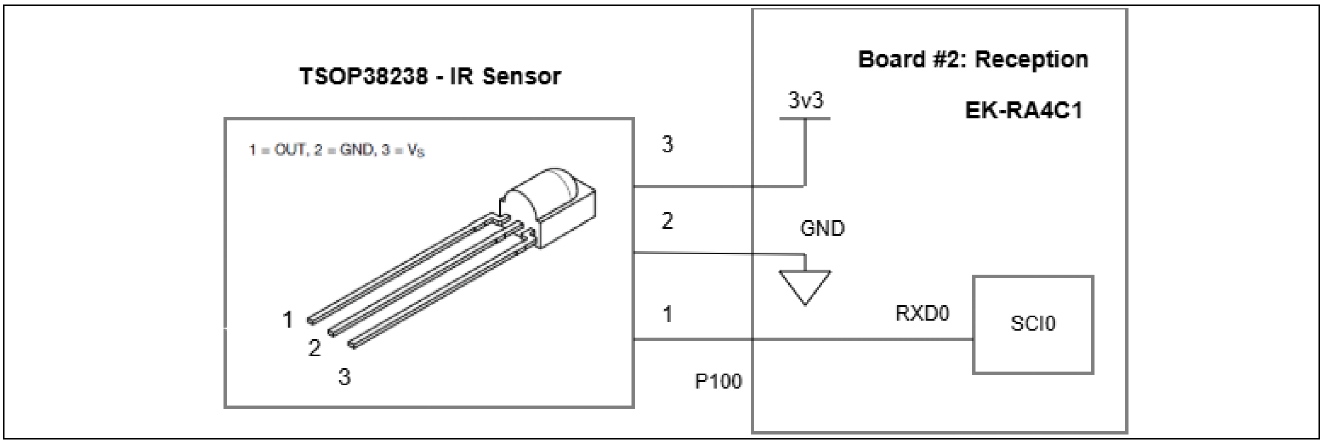


Figure 24. Reception circuit setup

3. Make sure the IR LED and IR sensor are aligned and in close proximity for the strongest connection.

4. In e^2 studio navigate to File > Import > General > Existing Projects and select the folder **Modulated_IR_SCIMask** to import both projects into e^2 studio. Build the projects.

4.2.2 Load TX binary to MCU 1

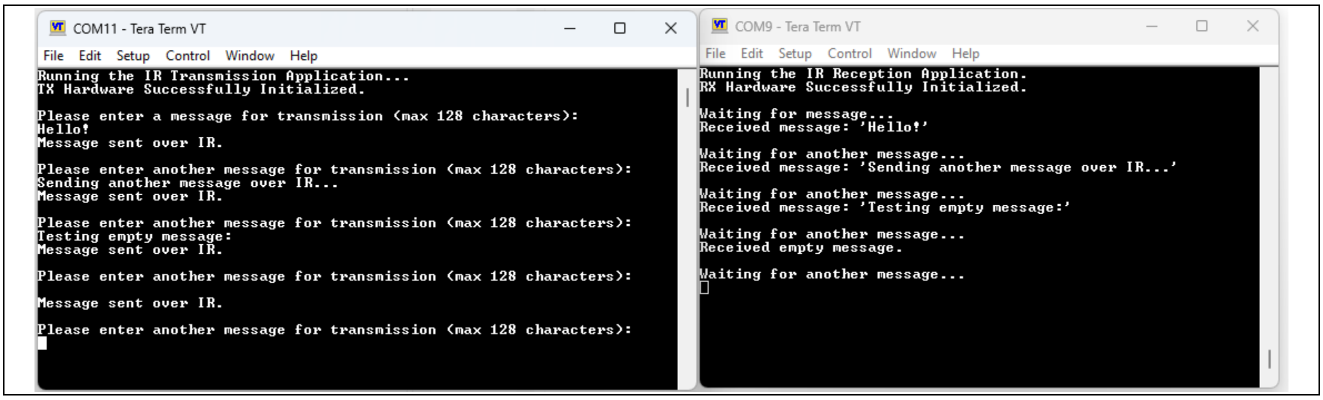
1. Connect only the TX Board #1 to the host PC. Debug the project **IR_TX_RA4C1**.
2. Before running the project, open the serial terminal application and connect to **COM: JLink CDC UART Port**.
3. Ensure settings:
    1. Baud: 115200
    2. Data: 8-bit
    3. Parity: None
    4. Terminal > Local Echo: on
4. Disconnect the TX MCU USB A cable from the PC.

4.2.3 Load RX Binary to MCU 2

1. Make sure board 1 stays disconnected.
2. Connect only the RX Board #2 to the host PC. Debug the project **IR_RX_RA4C1**.
3. Before running the RX project, open a new serial terminal application session instance.
4. Ensure the same data format settings:
    1. Baud: 115200
    2. Data: 8-bit
    3. Parity: None

4.2.4 Run the IR Communication Application

1. Connect both debug cables back to the PC for power.
2. Re-connect the serial terminal sessions if they do not automatically connect.
3. Press the reset button SW3 on both boards to restart the application.
4. Enter messages up to 128 characters into the TX serial terminal.
5. View the message received in the RX serial terminal.



```
Running the IR Transmission Application...
TX Hardware Successfully Initialized.

Please enter a message for transmission (max 128 characters):
Hello!
Message sent over IR.

Please enter another message for transmission (max 128 characters):
Sending another message over IR...
Message sent over IR.

Please enter another message for transmission (max 128 characters):
Testing empty message:
Message sent over IR.

Please enter another message for transmission (max 128 characters):

Message sent over IR.

Please enter another message for transmission (max 128 characters):
```

```
Running the IR Reception Application.
RX Hardware Successfully Initialized.

Waiting for message...
Received message: 'Hello!'

Waiting for another message...
Received message: 'Sending another message over IR...'

Waiting for another message...
Received message: 'Testing empty message:'

Waiting for another message...
Received empty message.

Waiting for another message...
```

Figure 25. IR Communication Application

5. Next Steps

1. Design your own encoding/decoding method:
    - External IR peripherals will have specific timing requirements for IR messages. Create a custom encoding method to match and communicate with a peripheral of choice, like a remote-controlled device.
    - Create a custom encoding/decoding scheme for IR communication between 2 RA4C1 MCUs.
2. Integrate the IR TX code into an existing carrier IR application.
    - If you have an existing application that drives an IR LED, replace this code with an application that needs to drive an IR LED.

5.1 Design Considerations

- **Matching frequencies:** Ensure the carrier frequency of the transmission matches the IR receiver's specifications.
- **Distance and angle:** Consider the effective range and angle between the IR LED and IR sensor for reliable operation.
- **Interference avoidance:** Minimize interference from ambient light or other IR sources.
- **Line of Sight:** Maintain a direct line of sight between the transmitter and receiver.
- **Driving a Different LED:** Follow the steps to determine the current-limiting resistor value. Analyze the TX circuit diagram for a different external IR LED.

6. Website and Support

Visit the following URLs to learn about key elements of the RA family, download components and related documentation, and get support:

RA Product Information	www.renesas.com/ra
RA Product Support Forum	https://community.renesas.com/mcu-mpu/ra/
RA Flexible Software Package	www.renesas.com/FSP
Renesas Support	www.renesas.com/support

Revision History

Rev.	Date	Description	
		Page	**Summary**
1.00	May.18.26	—	Initial release

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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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