

RL78/G11

R01AN3909EC0100

Rev.1.00

Safety Light Curtain

Sep. 15, 2017

Introduction

This user's manual describes a Renesas ultra-low-power microcontroller RL78/G11 application for a safety light curtain (Linear scanning mode), through the PGA, comparator, D/A converter and other functions.

Target Device

RL78/G11

Contents

1. Outline of System Function	3
1.1 Introduction of Safety Light Curtain	3
1.2 Introduction of Safety Light Curtain Theory	4
1.3 Introduction of Scanning Timing of Safety Light Curtain	5
1.4 Main Technical Parameters.....	6
1.5 Introduction of Operation	6
2. Introduction of Hardware	7
2.1 Introduction of PCB	7
2.2 Hardware Block Diagram of Safety Light Curtain.....	9
2.3 Main MCU	11
2.4 Power Supply.....	13
2.5 Infrared Emission Circuit	14
2.6 Analog Multiplexer Control Circuit of Safety Light Curtain Transmitter	15
2.7 Infrared Receiver Circuit	16
2.8 Analog Multiplexer Control Circuit of Safety Light Curtain Receiver	17
2.9 LED Control Circuit of Safety Light Curtain Receiver	18
2.10 External Relay Interface Circuit of Safety Light Curtain Receiver	19
3. Schematic, PCB and Bill of Materials	20
3.1 Schematic	20
3.2 PCB.....	22
3.3 Bill of Materials.....	23
4. Introduction of Software	25
4.1 Integrated Development Environment	25
4.2 List of Option Byte Setting.....	25
4.3 Flow Chart.....	26
4.3.1 Main Program Flow Chart of Safety Light Curtain Transmitter.....	26
4.3.2 Main Program Flow Chart of Safety Light Curtain Receiver	27
5. Sample Code	28
6. Reference Documents	28

1. Outline of System Function

1.1 Introduction of Safety Light Curtain

The safety light curtain is an optoelectronic device that is used to safeguard personnel in the vicinity of moving machinery with the potential to cause harm such as hydraulic presses, filter presses, packaging equipment and winders. The safety light curtain can be used as an alternative to mechanical barriers and other forms of traditional machine guarding. Typically, the safety light curtain is connected to a safety relay which will remove motive power from the hazard in the event when an object is detected. Usually safety light curtain consists of a transmitter and a receiver.

Generally, two ways of scanning (linear scanning and cross scanning) can be used in safety light curtain designing, and this time we use the linear scanning mode for this application and describe the details in this user's manual. The safety light curtain described in this manual is shown in Figure 1.1 and Figure 1.2.

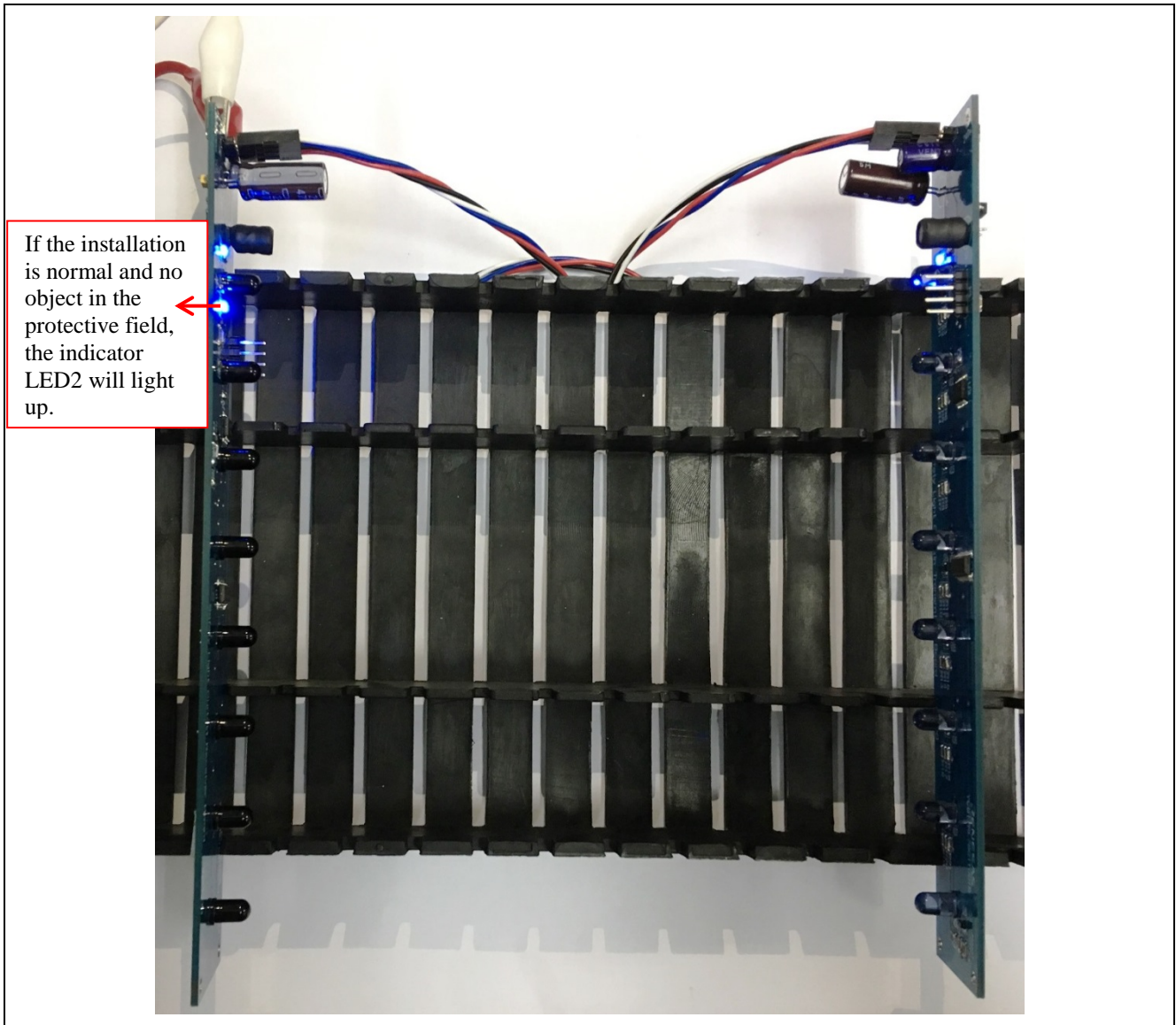


Figure 1.1 Safety Light Curtain without Object in Protective Field

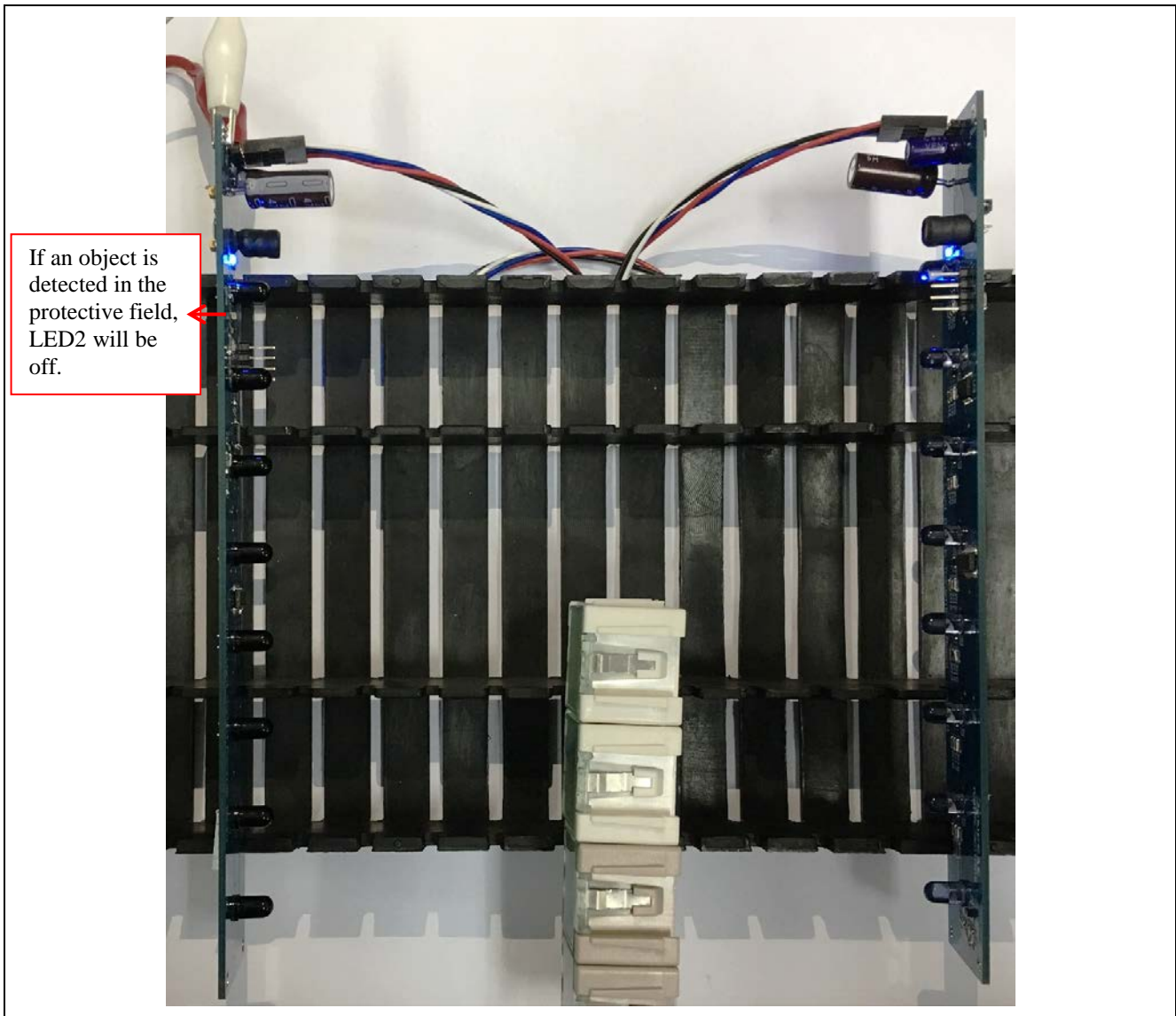


Figure 1.2 Safety Light Curtain with Object in Protective Field

1.2 Introduction of Safety Light Curtain Theory

The safety light curtain includes infrared transmitter unit and infrared receiver unit. The infrared transmitter unit is composed of infrared emitting diodes which are arranged with the equal distance from each other, MCU and other components. The infrared receiver unit is also composed of infrared receiver diodes which are arranged with the equal distance from each other, MCU and other components. The number of infrared emitting diodes and infrared receiver diodes is the same. Transmitter unit projects an array of synchronized, parallel infrared light beams to a receiver unit. When an opaque object interrupts one or more beams, the light curtain controller sends a stop signal to the guarded machine. The transmitter unit contains light emitting diodes which emit pulses of invisible infrared light when energized by the light curtain's timing and logic circuitry. The light pulses are both sequenced – one IRED is energized after another – and modulated – pulsed at a specific frequency. Corresponding supporting circuitry in the receiving unit are designed to detect only the specific pulse and frequency designated for it. These techniques offer enhanced safety and rejection of external light sources.

The principle of safety light curtain detection is shown in Figure 1.3. The red lines represent the infrared lights and the red lines covered areas are protective fields. The left picture is the case where there is no object in the protective field, and the right picture is the condition of detected the object in the protective field.

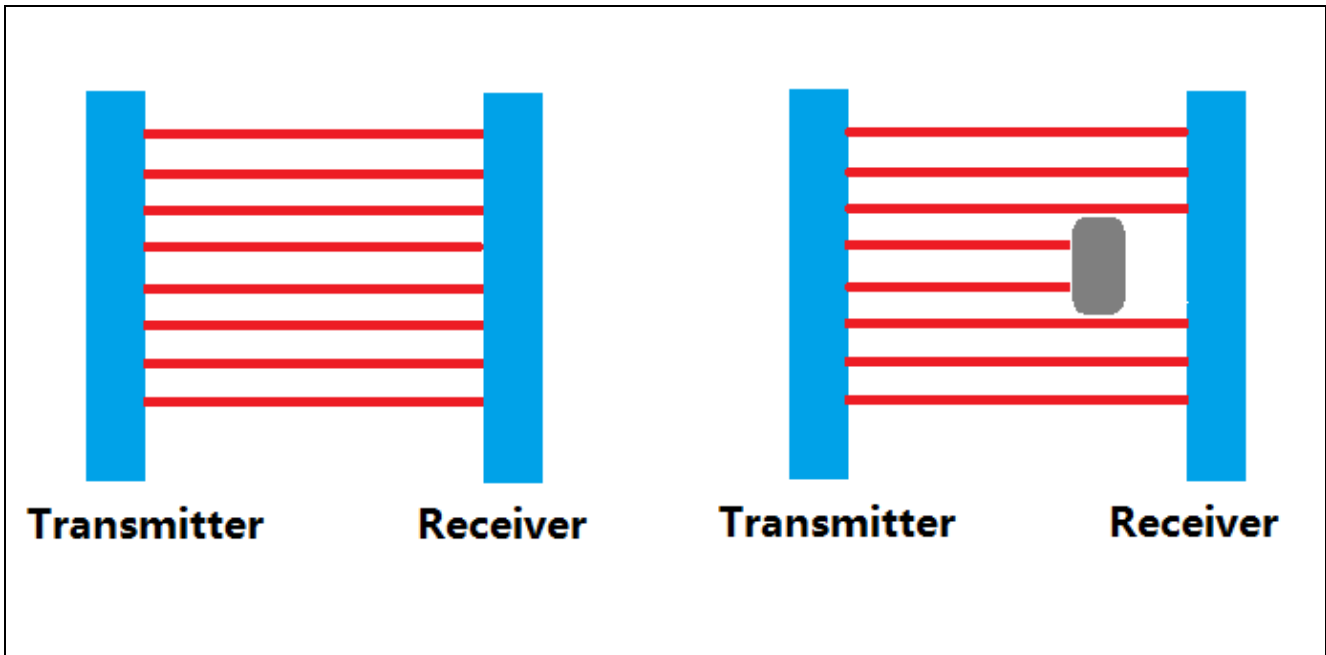


Figure 1.3 Principle of Safety Light Curtain Detection

The modulated infrared signals will be weakened as the distance increasing, in order to increase the detection distance, the received signals will be amplified by MCU internal amplifier in receiver unit. The amplified signals will be input to MCU internal comparator and the output of the comparator will be input to external interrupt pin (INTP) of MCU. Then the program will monitor the INTP signals and calculate the result. Therefore, the detection distance can be changed by configuration of amplifier gain and reference voltage of comparator. The setting values of amplifier gain and reference voltage of comparator in this program have not been tested strictly and are for reference only.

1.3 Introduction of Scanning Timing of Safety Light Curtain

8 pairs of infrared emitting diodes and infrared receiver diodes are used. The infrared emitting diodes emit infrared waves in a particular sequence (linear scanning mode), and the infrared receiver diodes are received in the same order. Linear scanning mode means the infrared emitting diodes will be opened one by one and the infrared receiver diodes have the same movement. MCU controls the analog multiplexers to complete the scanning task.

The scanning timing of safety light curtain is shown in Figure 1.4.

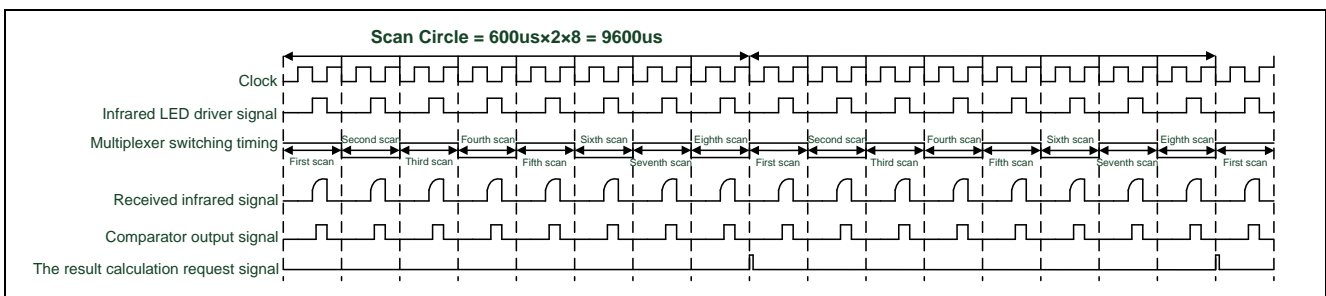


Figure 1.4 Scanning Timing of Safety Light Curtain

1.4 Main Technical Parameters

- Power supply: DC24V
- Protection height: 140mm
- Detecting distance: 1~2000mm (adjustable by configuration parameters)
- Beams: 8
- Gap of optical axis: 20mm
- Resolution: 15mm
- Response time: 10ms
- Output type: NPN

1.5 Introduction of Operation

- (1) The safety light curtain transmitter and receiver are mounted on the workbench and make sure each group of IR (infrared) emitting diode and IR receiver diode must be placed in one-to-one correspondence.
- (2) Connect the transmitter and receiver with a connection cable. Place a 24V relay at JMP1 to control the power supply or working mode of the guarded equipment.
- (3) Connect to the external voltage supply (+24V DC) and power on.
- (4) After power on, if the installation is normal and no object in the protective field, the indicator LED2 will light up.
- (5) Under normal operating conditions, if an object is detected in the protective field, LED2 will be off and external relay control port will output OFF signal to power off the guarded equipment, or stop the guarded equipment. If no object is detected, LED2 will remain in a light state and external relay control port will output ON signal to maintain the power supply or keep guarded equipment in a working state.

2. Introduction of Hardware

2.1 Introduction of PCB

The demo board's top view of the safety light curtain transmitter is shown in Figure 2.1.

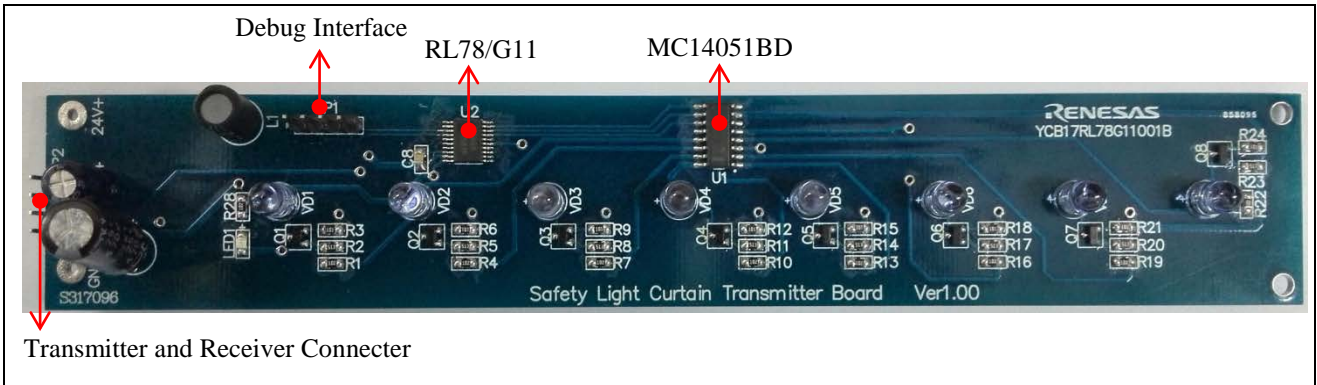


Figure 2.1 Top View of the Safety Light Curtain Transmitter

The demo board's bottom view of the safety light curtain transmitter is shown in Figure 2.2.



Figure 2.2 Bottom View of the Safety Light Curtain Transmitter

The demo board's top view of the safety light curtain receiver is shown in Figure 2.3.

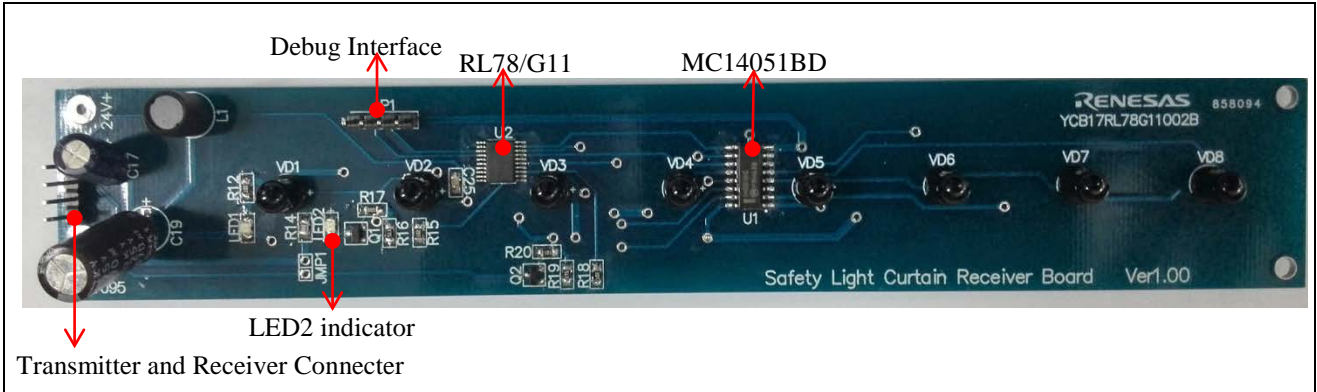


Figure 2.3 Top View of the Safety Light Curtain Receiver

The demo board's bottom view of the safety light curtain receiver is shown in Figure 2.4.

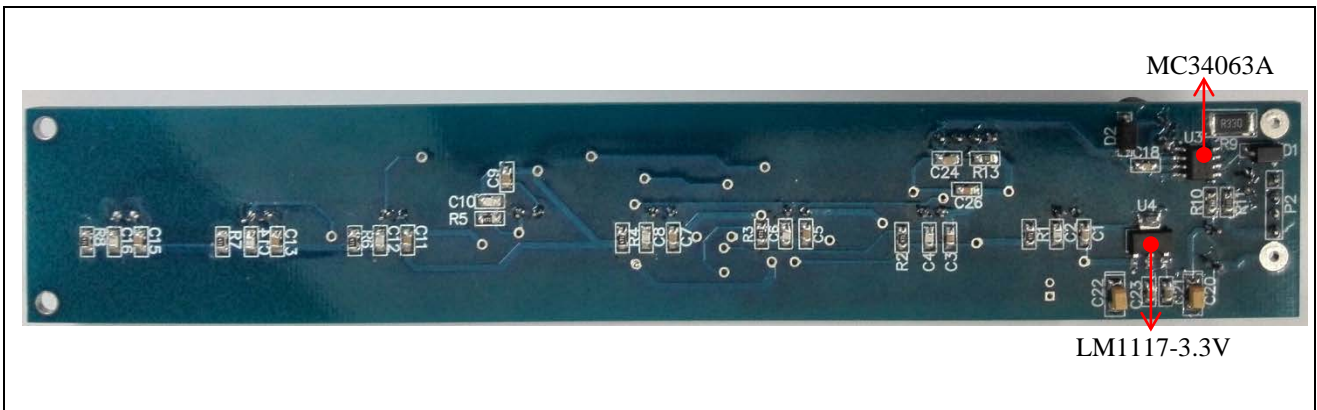


Figure 2.4 Bottom View of the Safety Light Curtain Receiver

2.2 Hardware Block Diagram of the Safety Light Curtain

The safety light curtain transmitter consists of the power supply system, main MCU, infrared emitting diodes, analog multiplexers control circuit and other peripheral components.

The hardware block diagram of the safety light curtain transmitter is shown in Figure 2.5.

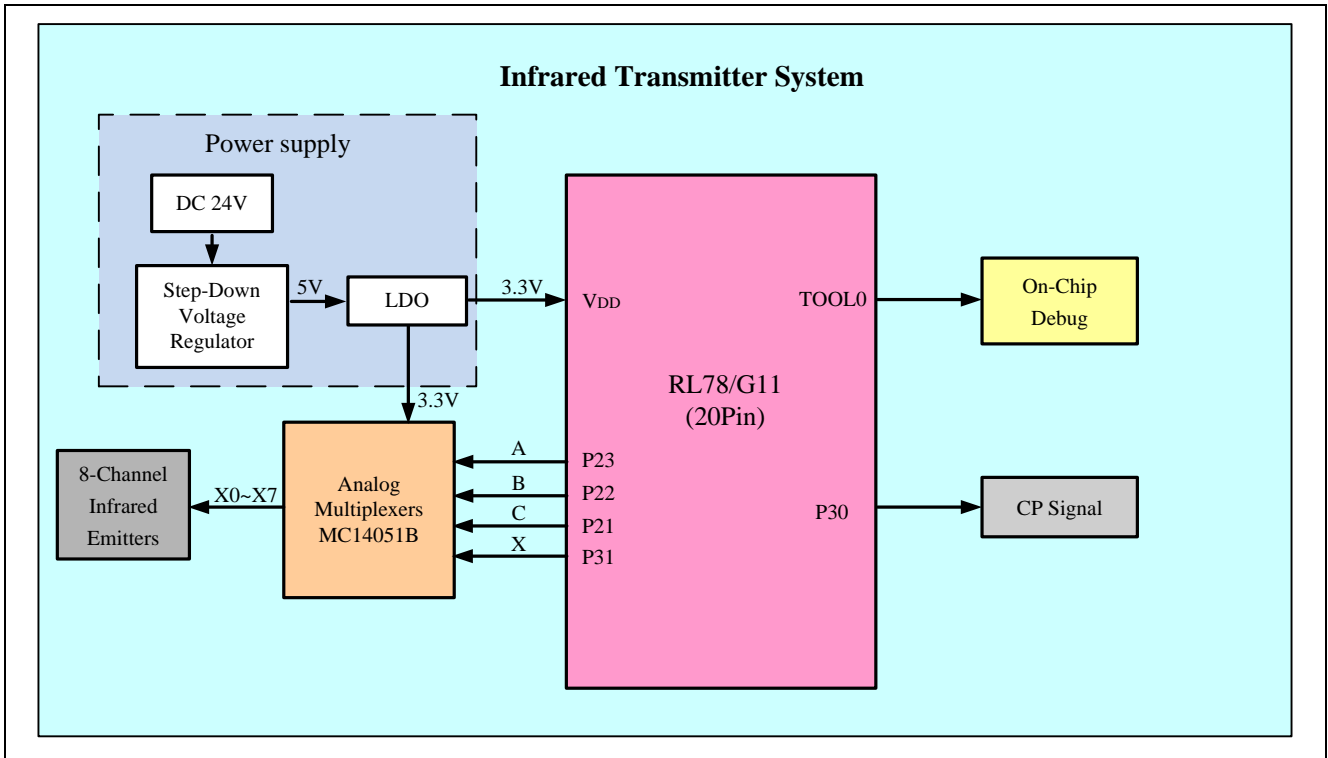


Figure 2.5 Hardware Block Diagram of the Safety Light Curtain Transmitter

The safety light curtain receiver consists of the power supply system, main MCU, infrared receiver diodes, analog multiplexers control circuit and other peripheral components.

The hardware block diagram of the safety light curtain receiver is shown in Figure 2.6.

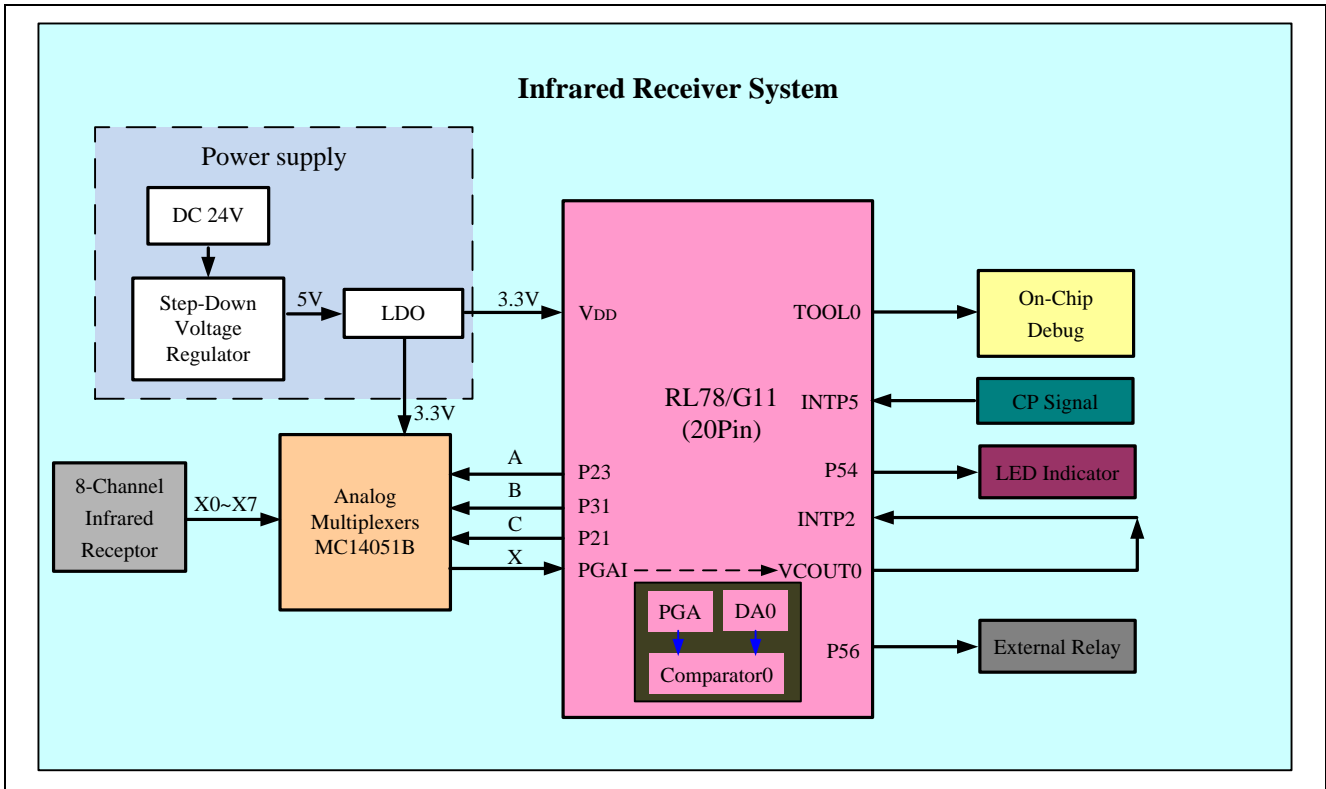


Figure 2.6 Hardware Block Diagram of the Safety Light Curtain Receiver

2.3 Main MCU

The safety light curtain both transmitter and receiver use RL78/G11 (R5F1056A) as main MCU. The Flash ROM size of R5F1176A is 16 KB and the RAM size is 1.5 KB. The package is LSSOP20.

The peripheral functions of R5F1056A and their applications of the safety light curtain transmitter are shown in Table 2.1.

Table 2.1 Peripheral Functions and Their Applications of the Safety Light Curtain Transmitter

Peripheral functions	Usage
TAU03	Generate an interrupt with a period of 300us.
P03	Generate a synchronous signal between the transmitter and receiver, which is flipped every 1200us.
P31	Generate infrared emitting diode driving signal.
P21	Used to control the address C of analog multiplexers.
P22	Used to control the address B of analog multiplexers.
P23	Used to control the address A of analog multiplexers.

The peripheral functions of R5F1056A and their applications of the safety light curtain receiver are shown in Table 2.2.

Table 2.2 Peripheral Functions and Their Applications of the Safety Light Curtain Receiver

Peripheral functions	Usage
PGAI	Used as input port connected with infrared receiver (The amplifier and comparator are connected internally).
VCOUT0	Used as comparator output port.
INTP2	Used to count the number of scanning times.
INTP5	Used to count the number of comparison results.
P21	Used to control the address C of analog multiplexers.
P23	Used to control the address A of analog multiplexers.
P31	Used to control the address B of analog multiplexers.
P54	Used to control the LED2
P56	Used to control the external relay.

RL78/G11 MCU main control circuit and E1 interface of the safety light curtain transmitter are shown in Figure 2.7.

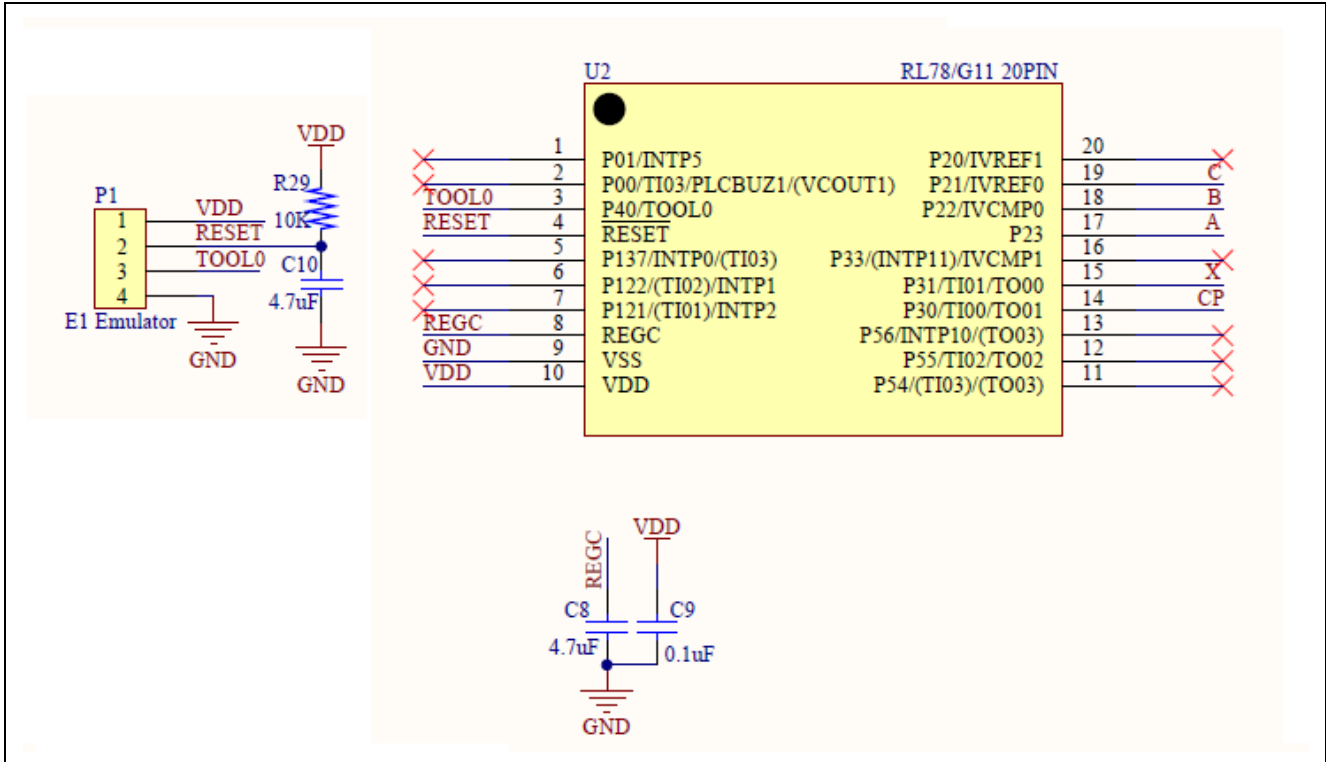


Figure 2.7 MCU Main Control Circuit and E1 Emulator Interface of the Safety Light Curtain Transmitter

RL78/G11 MCU main control circuit and E1 interface of the safety light curtain receiver are shown in Figure 2.8.

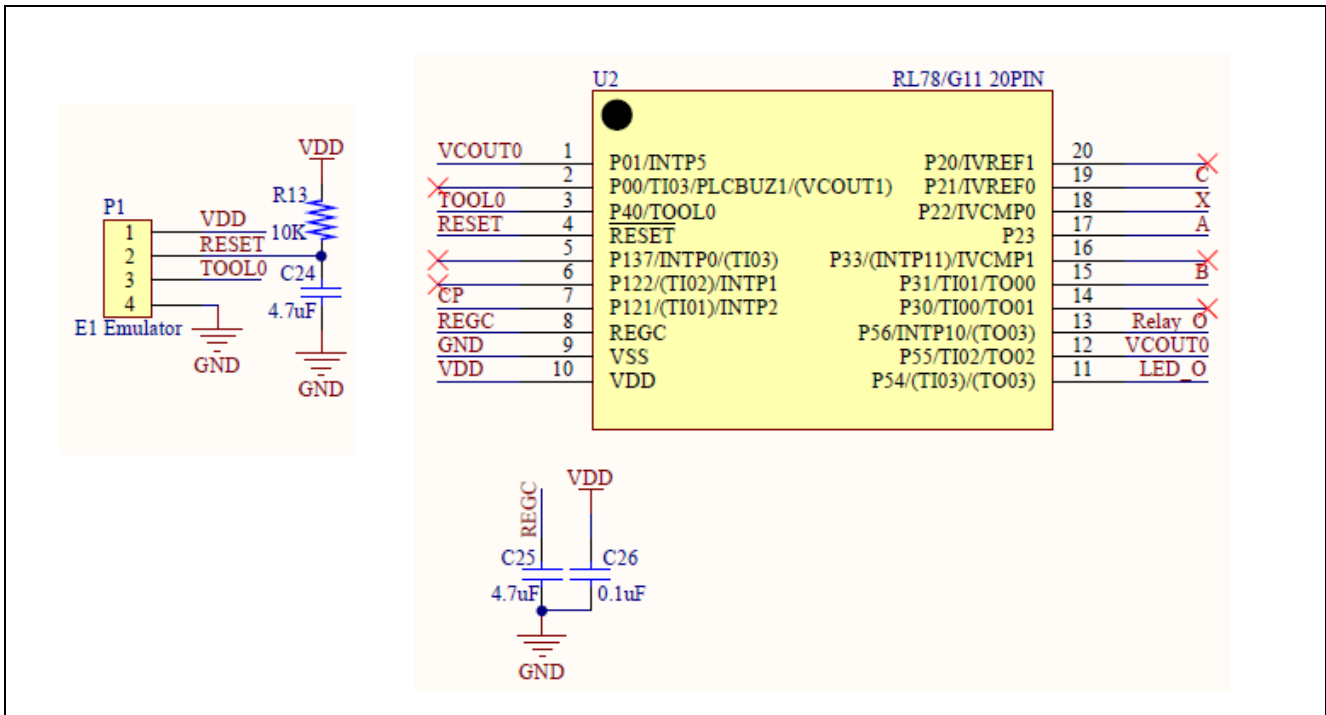


Figure 2.8 MCU Main Control Circuit and E1 Emulator Interface of the Safety Light Curtain Receiver

2.4 Power Supply

The power supply of the safety light curtain transmitter and receiver are both DC 24 V. MCU operating voltage is 3.3V, so the DC 24V has been input to voltage step-down and stabilizing circuit to get 3.3V.

The power supply circuit of the safety light curtain receiver is shown in Figure 2.9.

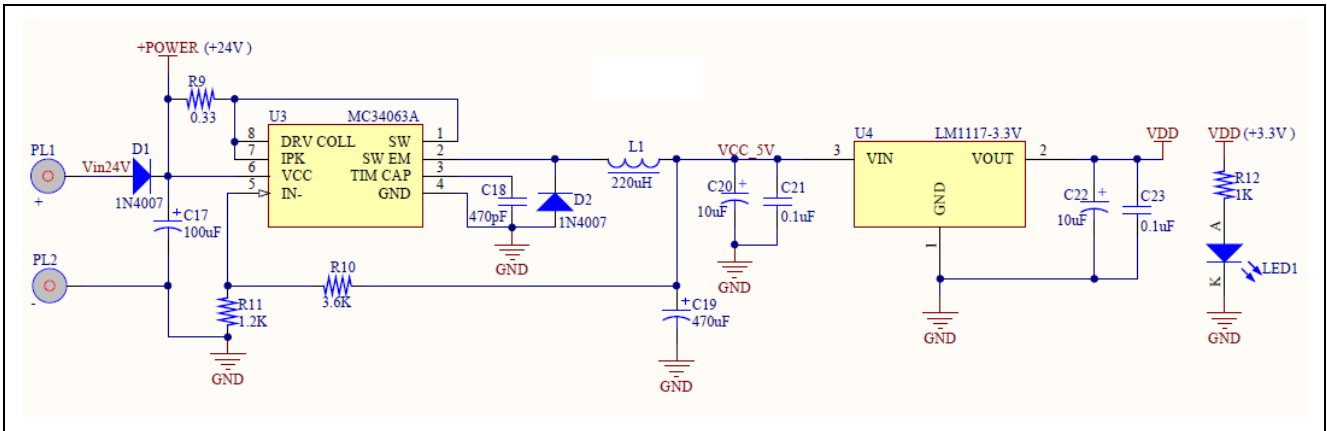


Figure 2.9 Power Supply Circuit of the Safety Light Curtain Receiver

2.5 Infrared Emission Circuit

The infrared emission circuit is composed of infrared emitting diodes, NPN transistor BC817 and other components.

The infrared emission circuit is shown in Figure 2.10.

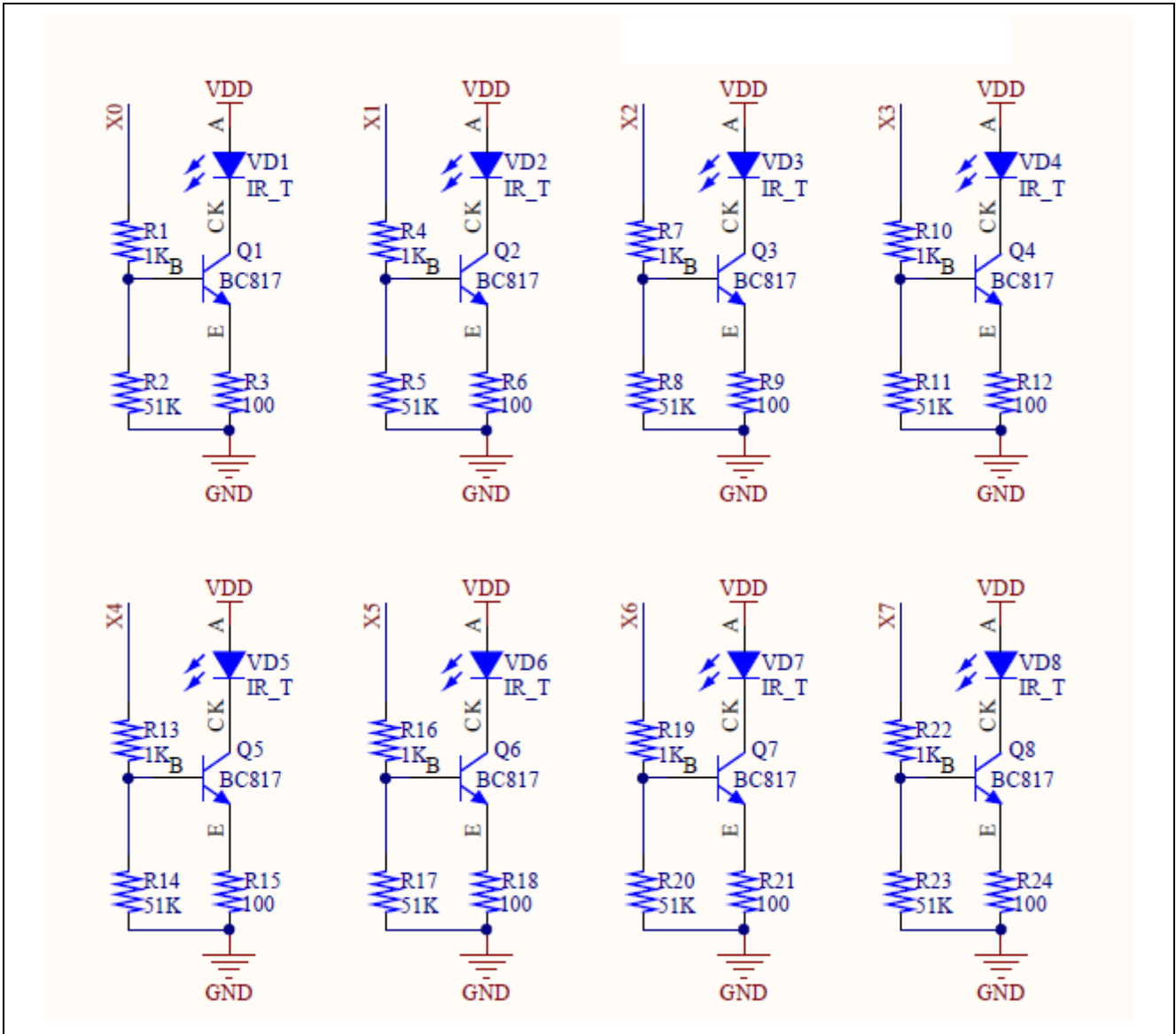


Figure 2.10 Infrared Emission Circuit

2.6 Analog Multiplexer Control Circuit of Safety Light Curtain Transmitter

The analog multiplexers MC14051B has been used to determine which infrared emitting diode will be used to give driver signal.

The analog multiplexer control circuit of the safety light curtain transmitter is shown in Figure 2.11.

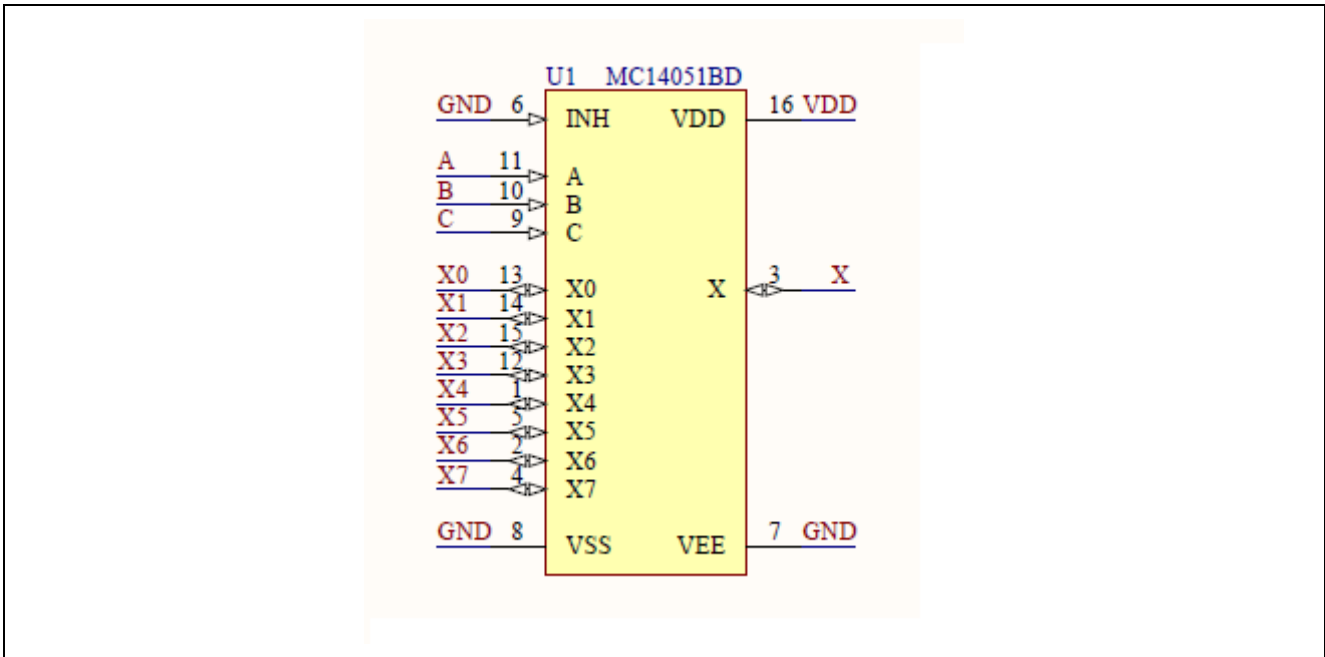


Figure 2.11 Analog Multiplexer Control Circuit of the Safety Light Curtain Transmitter

2.7 Infrared Receiver Circuit

The infrared receiver circuit is composed of infrared receiver diodes, resistances and capacitances.

The infrared receiver circuit is shown in Figure 2.12.

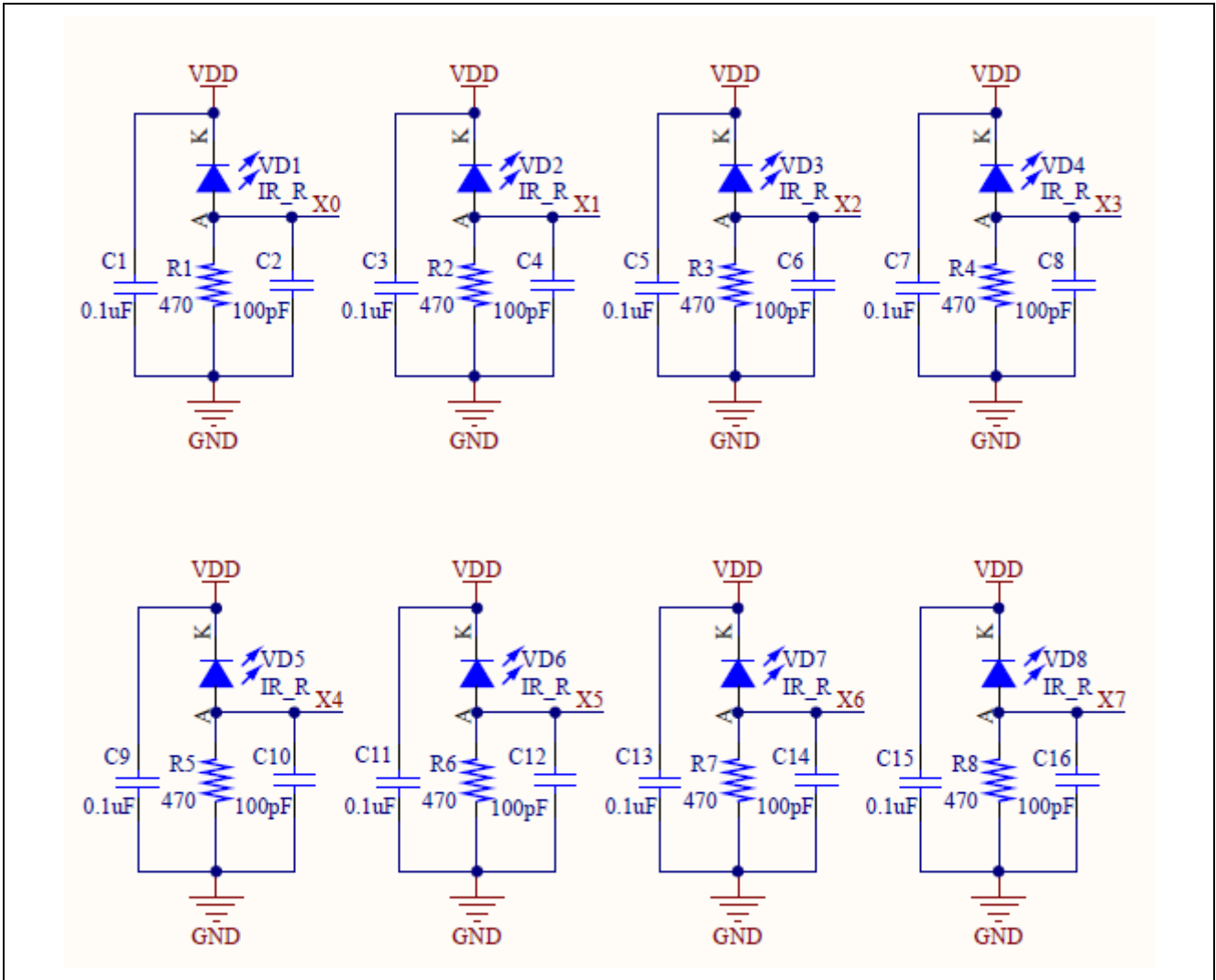


Figure 2.12 Infrared Receiver Circuit

2.8 Analog Multiplexer Control Circuit of Safety Light Curtain Receiver

The analog multiplexers MC14051B has been used to determine which infrared receiver diode will be selected to receive the infrared signal.

The analog multiplexer control circuit of the safety light curtain receiver is shown in Figure 2.13.

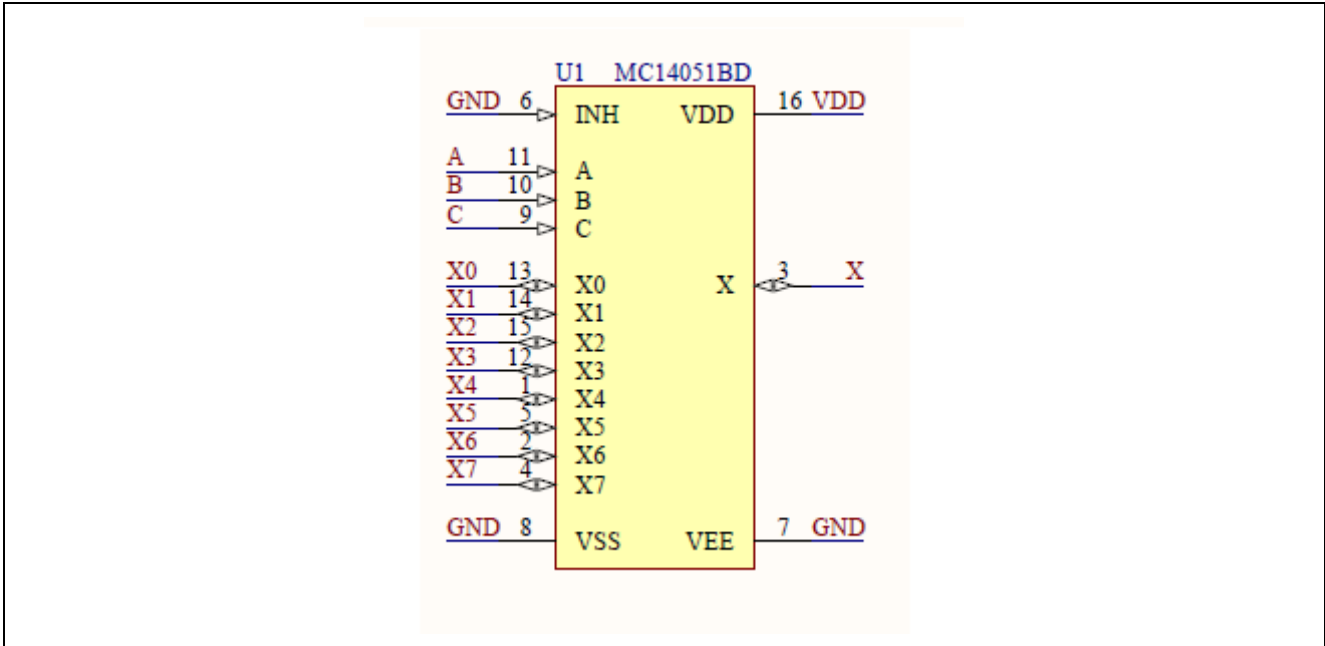


Figure 2.13 Analog Multiplexer Control Circuit of the Safety Light Curtain Receiver

2.9 LED Control Circuit of Safety Light Curtain Receiver

The indicator LED2 is controlled by NPN transistor BC817 and current limiting resistor R14, R17. LED2 is used to indicate whether there is an object in the protective field. If an object is detected in the protective field, LED2 will be off, if not, LED2 will be on. In addition, when installing the safety light curtain, make sure every group of the infrared emitting diodes and the infrared receiver diodes are aligned, after power on, the LED2 will be on.

The LED control circuit of the safety light curtain receiver is shown in Figure 2.14.

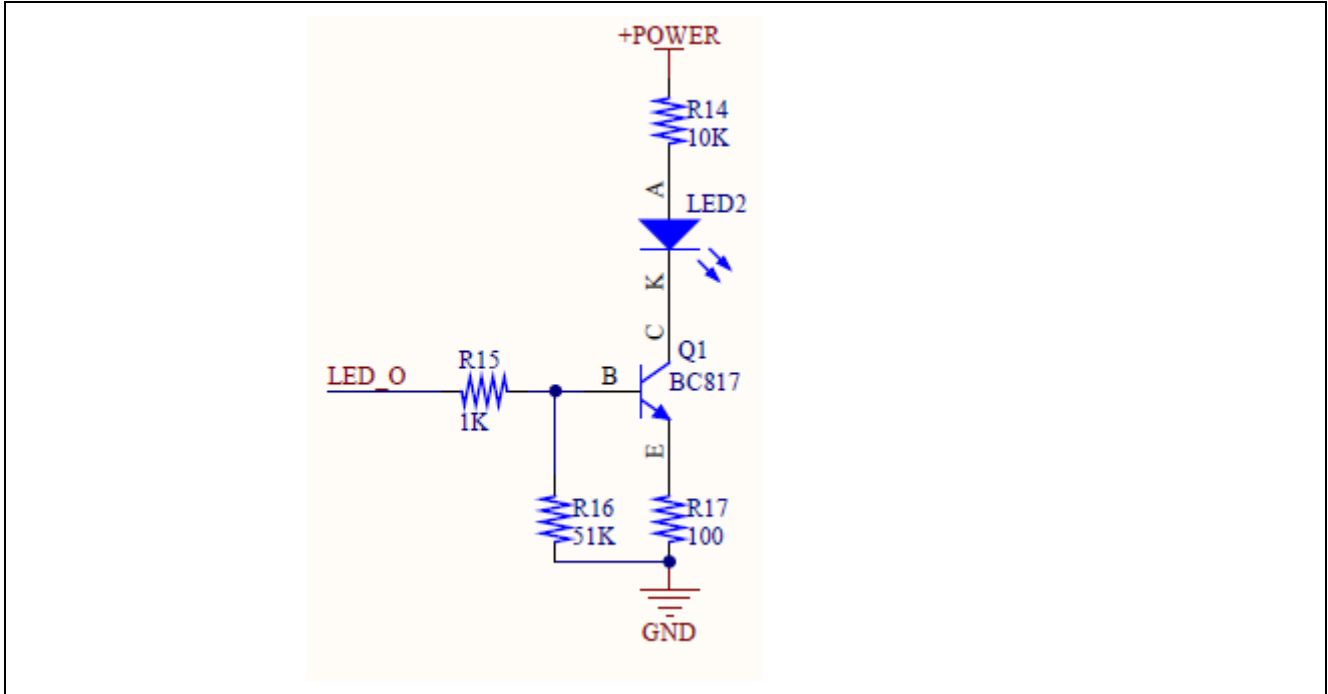


Figure 2.14 LED Control Circuit of the Safety Light Curtain Receiver

2.10 External Relay Interface Circuit of Safety Light Curtain Receiver

The JMP1 can be connected with an external relay which controlled by NPN transistor BC817. The external relay is used to control the power supply or working mode of the guarded equipment.

The external relay interface circuit of the safety light curtain receiver is shown in Figure 2.15.

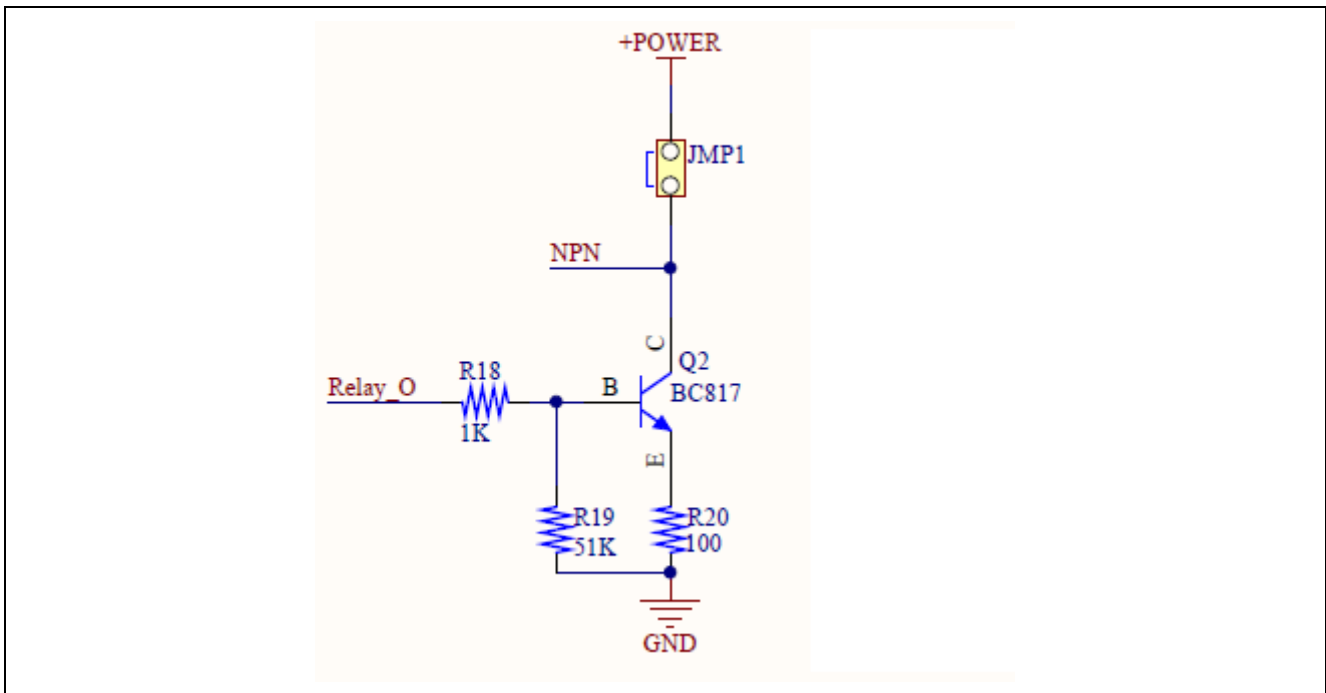


Figure 2.15 The External Relay Interface Circuit of the Safety Light Curtain Receiver

3. Schematic, PCB and Bill of Materials

3.1 Schematic

The schematic of the safety light curtain transmitter is shown in Figure 3.1.

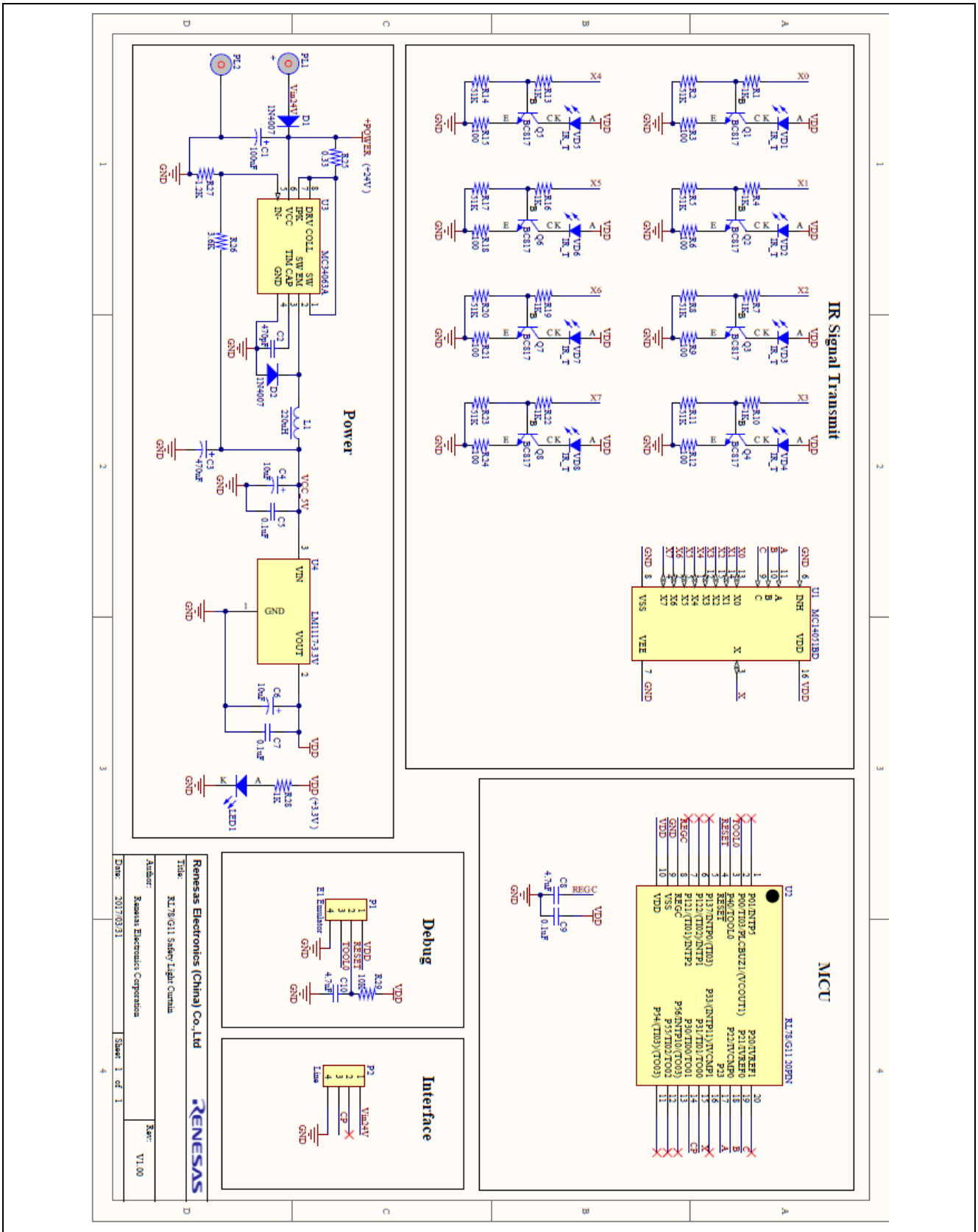


Figure 3.1 Schematic of the Safety Light Curtain Transmitter

The schematic of the safety light curtain receiver is shown in Figure 3.2.

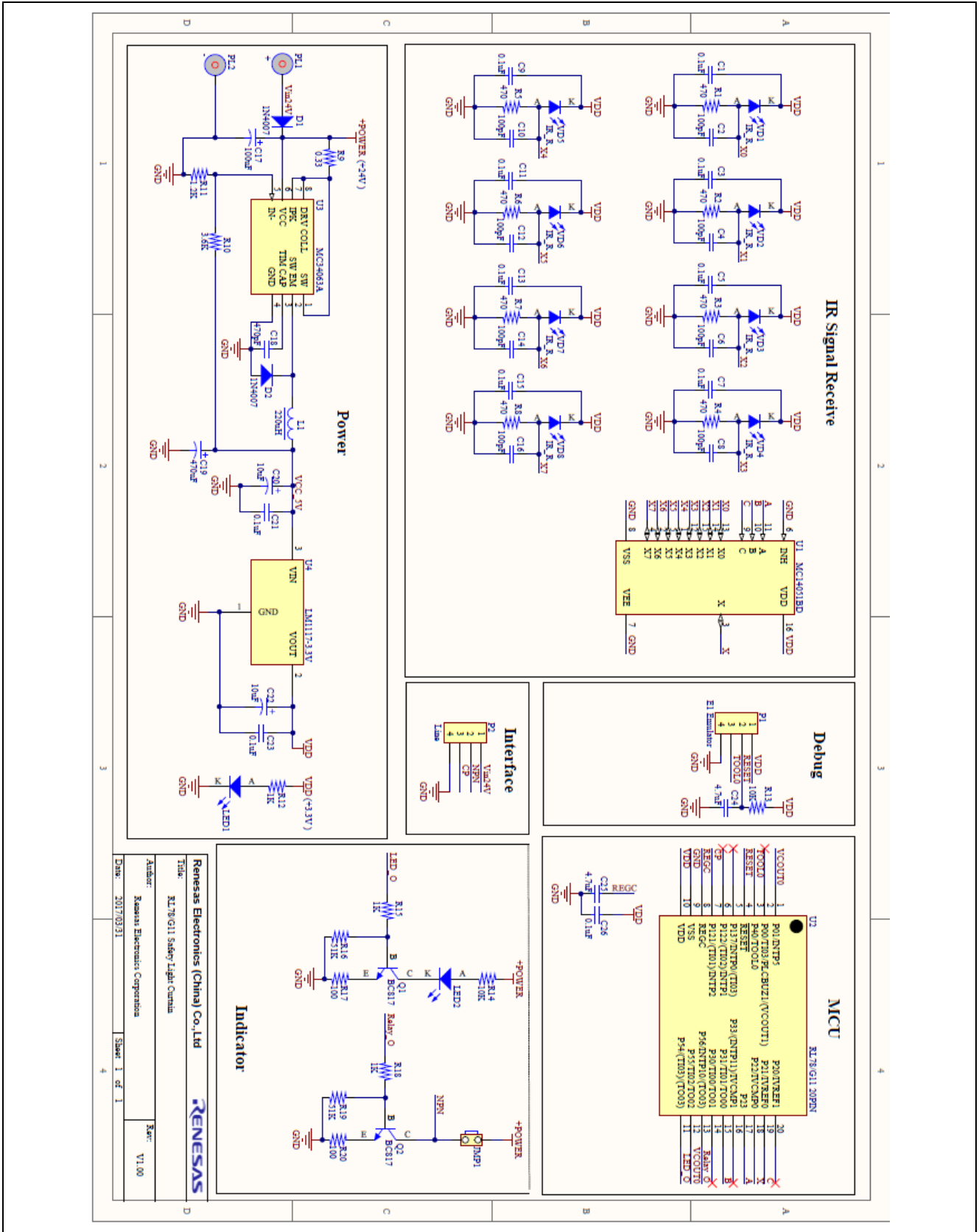


Figure 3.2 Schematic of the Safety Light Curtain Receiver

3.2 PCB

The PCB of the safety light curtain transmitter is shown in Figure 3.3.

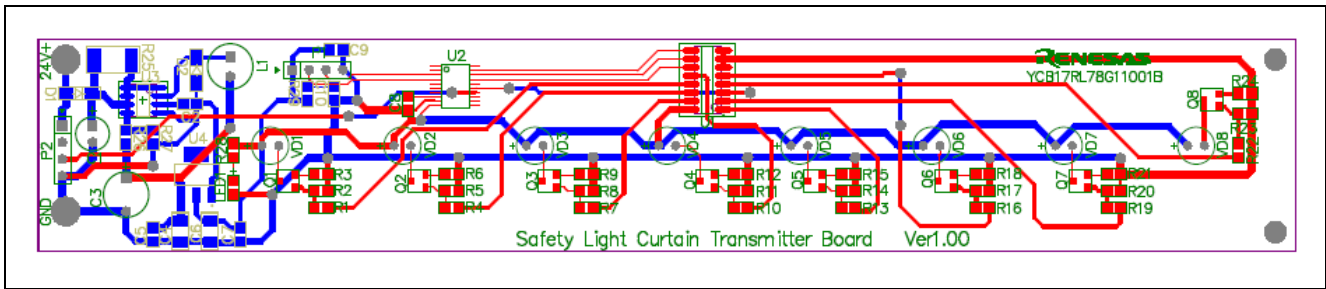


Figure 3.3 PCB of the Safety Light Curtain Transmitter

The PCB of the safety light curtain receiver is shown in Figure 3.4.

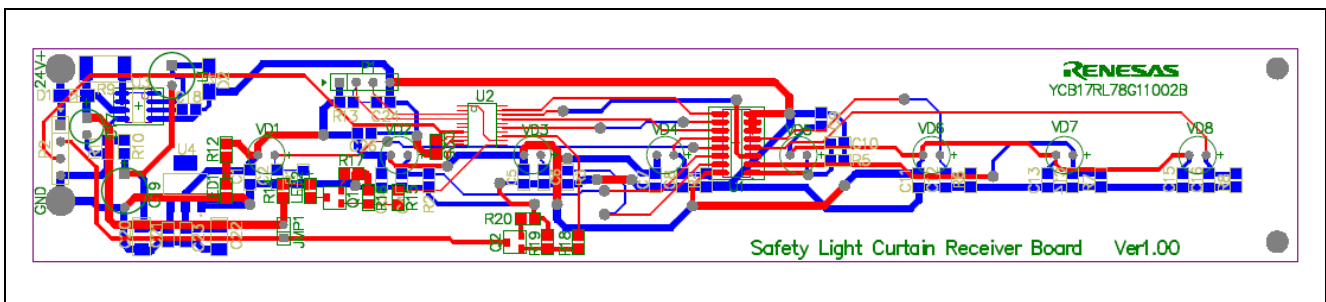


Figure 3.4 PCB of the Safety Light Curtain Receiver

3.3 Bill of Materials

The bill of materials of the safety light curtain transmitter is shown in Table 3.1.

Table 3.1 Bill of Materials of the Safety Light Curtain Transmitter

Designator	Quantity	Part Name	Manufacturer	Description
C1	1	ECA-1EM101I	Panasonic	Aluminum Electrolytic Capacitor 100uF/25V
C2	1	GRM216R71H471KA01D	Murata	Capacitor (470pF, 50VDC, ±10%, 0805)
C3	1	EEU-FM1E471LB	Panasonic	Aluminum Electrolytic Capacitor 470uF/25V
C4, C6	2	TAJA106K016RNJ	AVX	Cap Tant Solid 10uF 16V A CASE 10% (3.2 X 1.6 X 1.6mm)
C5, C7, C9	3	GRM21BR71E104KA01L	Murata	Capacitor (0.1uF, 25VDC, ±10%, 0805)
C8, C10	2	GRM21BR61A475KA73L	Murata	Capacitor (4.7uF, 10VDC, ±10%, 0805)
D1, D2	2	1N4007	TOSHIBA	General Rectifier 50V 1A SMA/DO-214AC
L1	1	—	—	Radial Lead Inductor 220uH(DIP-2, 2.54mm)
LED1	1	XZCBD54W-1	SunLED	Action LED (blue, 0805)
P1	1	146850	TE Connectivity	Connector (CON 4X1 2.54mm)
P2	1	146850	TE Connectivity	Interface (CON 4X1 2.54mm)
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	8	BC817	NXP	TRANS NPN 45V 0.5A SOT-23
R1, R4, R7, R10, R13, R16, R19, R22, R28	9	RC0805JR-071KL	YAGEO	Resistor (1KΩ, ±5% 0805)
R2, R5, R8, R11, R14, R17, R20, R23	8	RC0805FR-0751K1L	YAGEO	Resistor (51KΩ, ±1% 0805)
R3, R6, R9, R12, R15, R18, R21, R24	8	RC0805JR-07100RL	YAGEO	Resistor (100Ω, ±5% 0805)
R25	1	—	—	Resistor (1W,0.33Ω, ±1% 2512)
R26	1	RC0805FR-073K65L	YAGEO	Resistor (3.6KΩ, ±1% 0805)
R27	1	RC0805FR-071K2L	YAGEO	Resistor (1.2KΩ, ±1% 0805)
R29	1	RC0805JR-0710KL	YAGEO	Resistor (10KΩ, ±5% 0805)
U1	1	MC14051BD	ON Semiconductor	Analog Multiplexers 18V 0.025A (SOP-16)
U2	1	R5F1056A	Renesas	MCU RL78/G11 20PIN (LSSOP-20)
U3	1	MC34063ACD-TR	STMicroelectronics	DC/DC, 3-40V, 100KHZ, 1.5A (SOP-8)
U4	1	AMS1117-3.3	Advanced Monolithic Systems	REG LDO 3.3V 1A (SOT23-3)
VD1, VD2, VD3, VD4, VD5, VD6, VD7, VD8	8	IR333C-A	EVERLIGHT	940nm,5mm IR Emitting Diode (DIP-2, 2.54mm)
24V+	1	—	—	DC Power IN +
GND	1	—	—	DC Power IN _

The bill of materials of the safety light curtain receiver is shown in Table 3.2.

Table 3.2 Bill of Materials of the Safety Light Curtain Receiver

Designator	Quantity	Part Name	Manufacturer	Description
C1, C3, C5, C7, C9, C11, C13, C15, C21, C23, C26	11	GRM21BR71E104KA01L	Murata	Capacitor (0.1uF, 25VDC, ±10%, 0805)
C2, C4, C6, C8, C10, C12, C14, C16	8	GRM2165C2A101JA01D	Murata	Capacitor (100pF, 100VDC, ±5%, 0805)
C17	1	ECA-1EM101I	Panasonic	Aluminum Electrolytic Capacitor 100uF/25V
C18	1	GRM216R71H471KA01D	Murata	Capacitor (470pF, 50VDC, ±10%, 0805)
C19	1	EEU-FM1E471LB	Panasonic	Aluminum Electrolytic Capacitor 470uF/25V
C20, C22	2	TAJA106K016RNJ	AVX	Cap Tant Solid 10uF 16V A CASE 10% (3.2 X 1.6 X 1.6mm)
C24, C25	2	GRM21BR61A475KA73L	Murata	Capacitor (4.7uF, 10VDC, ±10%, 0805)
D1, D2	2	1N4007	TOSHIBA	General Rectifier 50V 1A SMA/DO-214AC
JMP1	1	146850	TE Connectivity	External Relay Interface (CON 3X1 2.54mm)
L1	1	—	—	Radial Lead Inductor 220uH (DIP-2, 2.54mm)
LED1, LED2	1	XZCBD54W-1	SunLED	Action LED (blue, 0805)
P1	1	146850	TE Connectivity	Connector (CON 4X1 2.54mm)
P2	1	146850	TE Connectivity	Interface (CON 4X1 2.54mm)
Q1, Q2	2	BC817	NXP	TRANS NPN 45V 0.5A SOT-23
R1, R2, R3, R4, R5, R6, R7, R8	8	RC0805JR-07470RL	YAGEO	Resistor (470Ω, ±5% 0805)
R9	1	—	—	Resistor (1W, 0.33Ω, ±1% 2512)
R10	1	RC0805FR-073K65L	YAGEO	Resistor (3.6KΩ, ±1% 0805)
R11	1	RC0805FR-071K2L	YAGEO	Resistor (1.2KΩ, ±1% 0805)
R12, R15, R18	3	RC0805JR-071KL	YAGEO	Resistor (1KΩ, ±5% 0805)
R12, R14	2	RC0805JR-0710KL	YAGEO	Resistor (10KΩ, ±5% 0805)
R16, R19	2	RC0805FR-0751K1L	YAGEO	Resistor (51KΩ, ±1% 0805)
R17, R20	2	RC0805JR-07100RL	YAGEO	Resistor (100Ω, ±5% 0805)
U1	1	MC14051BD	ON Semiconductor	Analog Multiplexers 18V 0.025A (SOP-16)
U2	1	R5F1056A	Renesas	MCU RL78/G11 20PIN (LSSOP-20)
U3	1	MC34063ACD-TR	STMicroelectronics	DC/DC, 3-40V, 100KHZ, 1.5A (SOP-8)
U4	1	AMS1117-3.3	Advanced Monolithic Systems	REG LDO 3.3V 1A (SOT23-3)
VD1, VD2, VD3, VD4, VD5, VD6, VD7, VD8	1	PT333-3B	EVERLIGHT	940nm, 5mm IR Receiver Diode (DIP-2, 2.54mm)
24V+	1	—	—	DC Power IN +
GND	1	—	—	DC Power IN _

4. Introduction of Software

4.1 Integrated Development Environment

The integrated development environments of the safety light curtain are shown in Table 4.1 and Table 4.2.

Table 4.1 Integrated Development Environments for CS+

Item	Contents
Integrated development environment	CS+ for CC V5.00.00 (Renesas Electronics Corporation)
C complier	CC-RL V1.04.00 (Renesas Electronics Corporation)
Debugger	E1 (Renesas Electronics Corporation)

Table 4.2 Integrated Development Environments for e2 Studio

Item	Contents
Integrated development environment	e2 studio V5.3.1.002 (Renesas Electronics Corporation)
C complier	CC-RL V1.04.00 (Renesas Electronics Corporation)
Debugger	E1 (Renesas Electronics Corporation)

4.2 List of Option Byte Setting

The option byte setting of the safety light curtain is shown in Table 4.3.

Table 4.3 Option Byte Setting

Address	Setting	Description
000C0H/010C0H	11101111B	Watchdog timer operation is stopped (Count is stopped after reset).
000C1H/010C1H	11111111B	LVD mode: OFF P125/RESET pin: use as reset input
000C2H/010C2H	11110000B	HOCO: 48 MHz, Operation voltage range: 2.7 V~5.5 V
000C3H/010C3H	10000100B	On-chip debugging is enabled.

4.3 Flow Chart

4.3.1 Main Program Flow Chart of the Safety Light Curtain Transmitter

The flow chart of the safety light curtain transmitter's main program is shown in Figure 4.1.

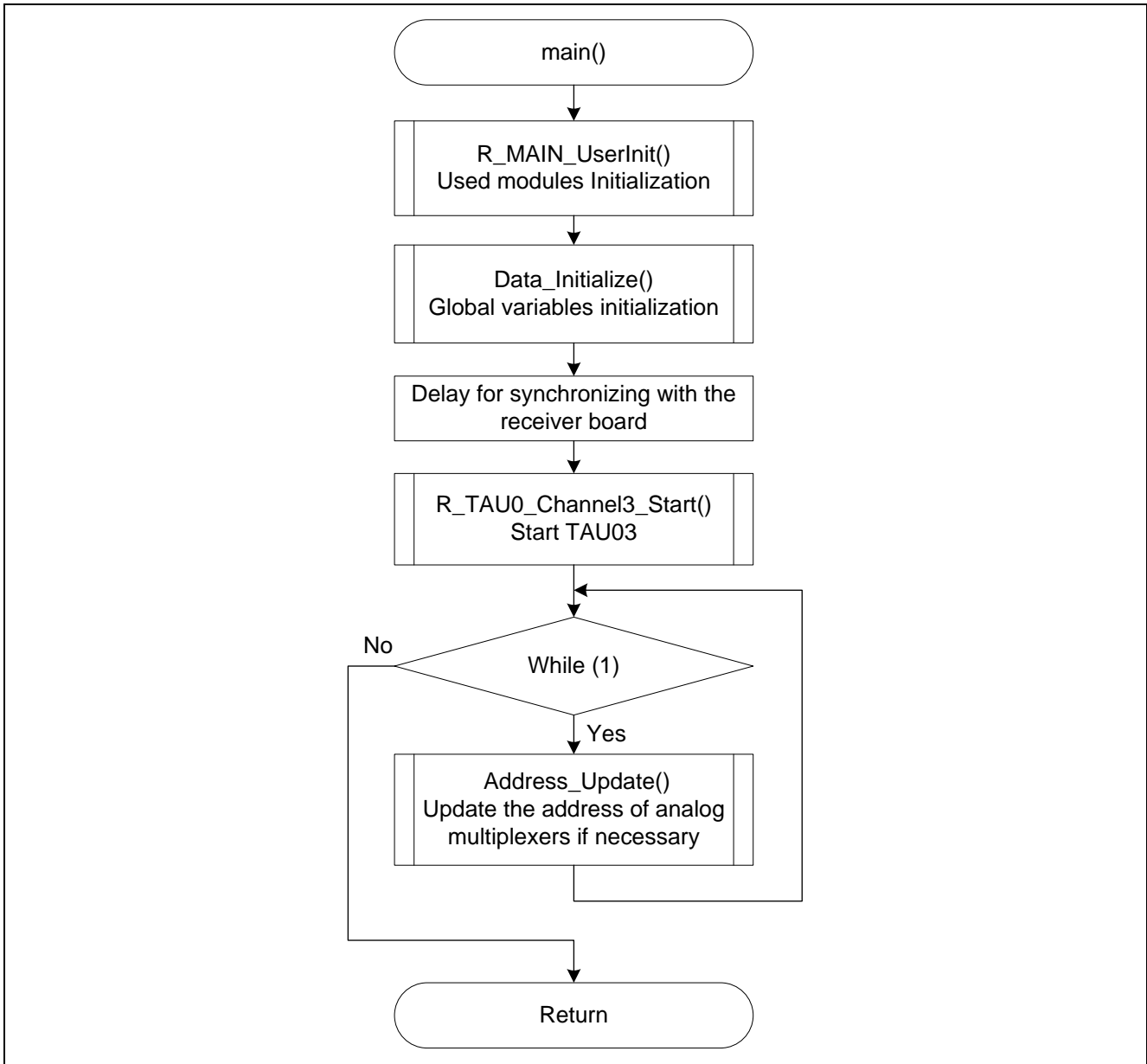


Figure 4.1 Main Program Flow Chart of the Safety Light Curtain Transmitter

4.3.2 Main Program Flow Chart of the Safety Light Curtain Receiver

The flow chart of the safety light curtain receiver's main program is shown in Figure 4.2.

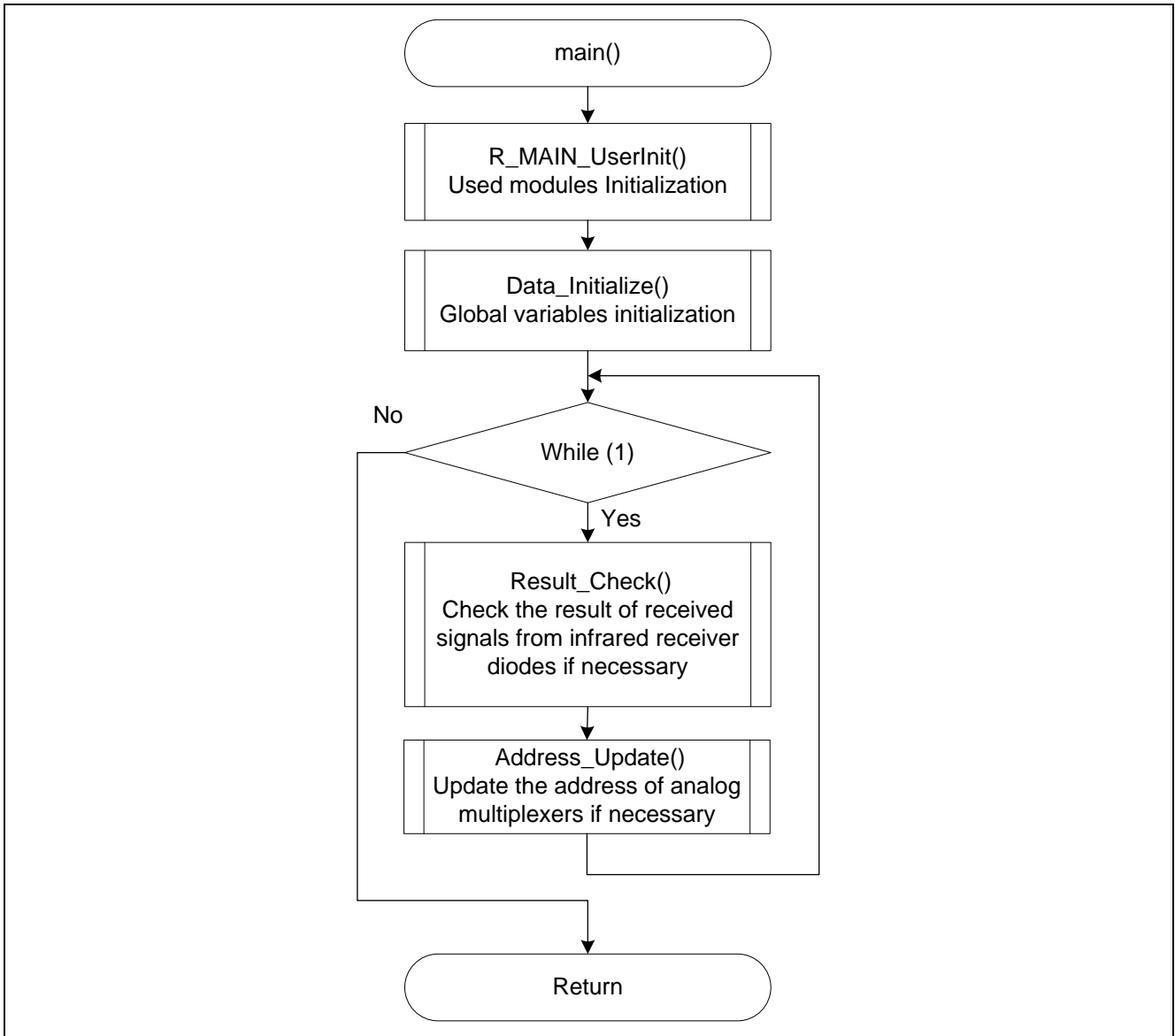


Figure 4.2 Main Program Flow Chart of the Safety Light Curtain Receiver

5. Sample Code

The sample code is available on the Renesas Electronics Website.

6. Reference Documents

User's Manual

RL78/G11 User's Manual: Hardware (R01UH0637EJ)

RL78 Family User's Manual: Software (R01US0015E)

The latest versions of the documents are available on the Renesas Electronics Website.

Technical Updates/Technical News

The latest information can be downloaded from the Renesas Electronics website.

Website and Support

Renesas Electronics Website

<http://www.renesas.com/>

Inquiries

<http://www.renesas.com/contact/>

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Revision History

Rev.	Date	Description	
		Page	Summary
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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. 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

Access to reserved addresses is prohibited.

- The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

5. Differences between Products

Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

- The characteristics of Microprocessing unit or Microcontroller unit products in the same group but having a different part number may differ in terms of the 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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