

**S1C17W23**  
**EL Lamp**  
**Application Notes**

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## Summary

This document is intended to provide a reference document in order to generate signals for an EL lamp driver in S1C17W23 by using IR remote controller (REMC) and turn on the EL lamp.

## Operating Environment

- S5U1C17W23T (Software Evaluation Tool for S1C17W23, "SVT17W23" below)  
A dedicated cable is necessary to connect to ICDmini.
- PC
  - GNU17 (S5U1C17001C) development tool already installed\*
  - ICDmini USB driver already installed
- ICDmini (S5U1C17001H)  
A USB cable is necessary to connect to PC.
- Programming package (this package) for S1C17W23 EL lamp driver
  - Programming package for conditional running in RAM
  - Programming package including a test assembler

\*Note: This package has been evaluated in GNU17 v2.4.0/v3.0.5.

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## 1. Specification

In this application notes, the signals for the EL lamp driver are generated by using an IR remote-controller (REMC) built in S1C17W23. The signals generated for the EL lamp driver are input into high voltage DC-DC converter circuit mounted on a separate board to generate high voltage to turn on the EL lamp.

Of all programs, W23\_REMC\_RAM\_gnu17vx, which runs on RAM in order to set wave conditions for EL drive signals and make an experiment of REMC, is to generate signals for the EL lamp driver continuously during the operation.

Also, W23\_REMC\_ASM\_gnu17vx including a test assembler out of all sample programs is to generate signals for the EL lamp driver for one of turn-off/turn-on/blink operation modes.

The figure 1 shows how to connect the circuit.

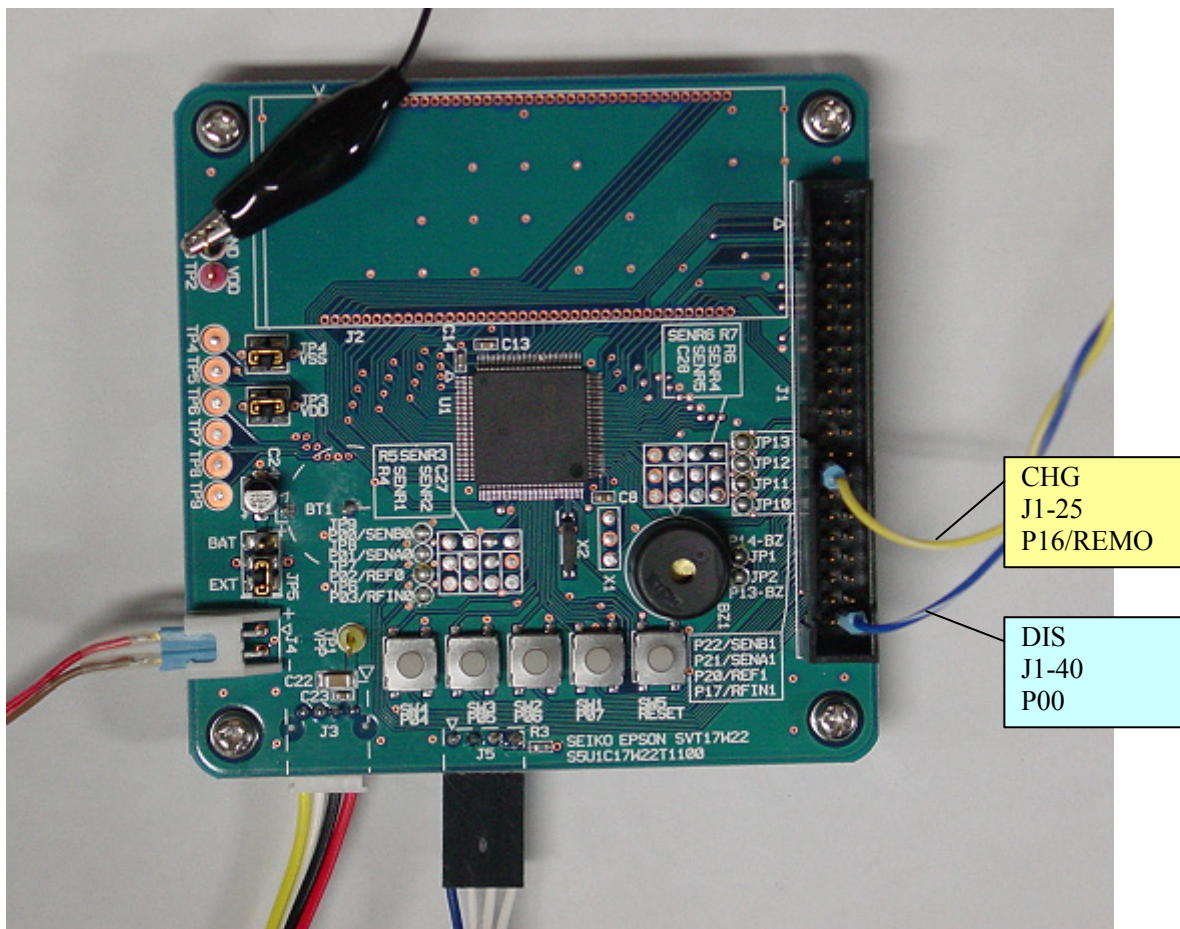


Figure 1 How to connect SVT17W23 - High voltage DC-DC converter circuit

## 2. Feature Description

### 2. Feature Description

|                |  |
|----------------|--|
| Output pin     | REMC's REMO: CHG signal (for generating charging pulses)<br>GPIO's P00: DIS signal (for generating discharging pulses)                                 |
| Operation mode | REMC: Controls when to restart REMC in one-shot mode in order to invert DIS signals and output CHG signals by using compare AP/DB interrupt functions. |
| System clock   | The system clock uses OSC1 (32.768kHz).  |
| Interrupt      | The REMC's vector number and vector address are as follows:  |

REMC    Vector No.: 21 (0x15)  
           Vector address: 0x1054 (W23\_REMC\_RAM\_gnu17vx),  
                           0x8054 (W23\_REMC\_ASM\_gnu17vx)

This sample uses the following two types of interrupts.  
 - Compare AP interrupt  
 - Compare DB interrupt

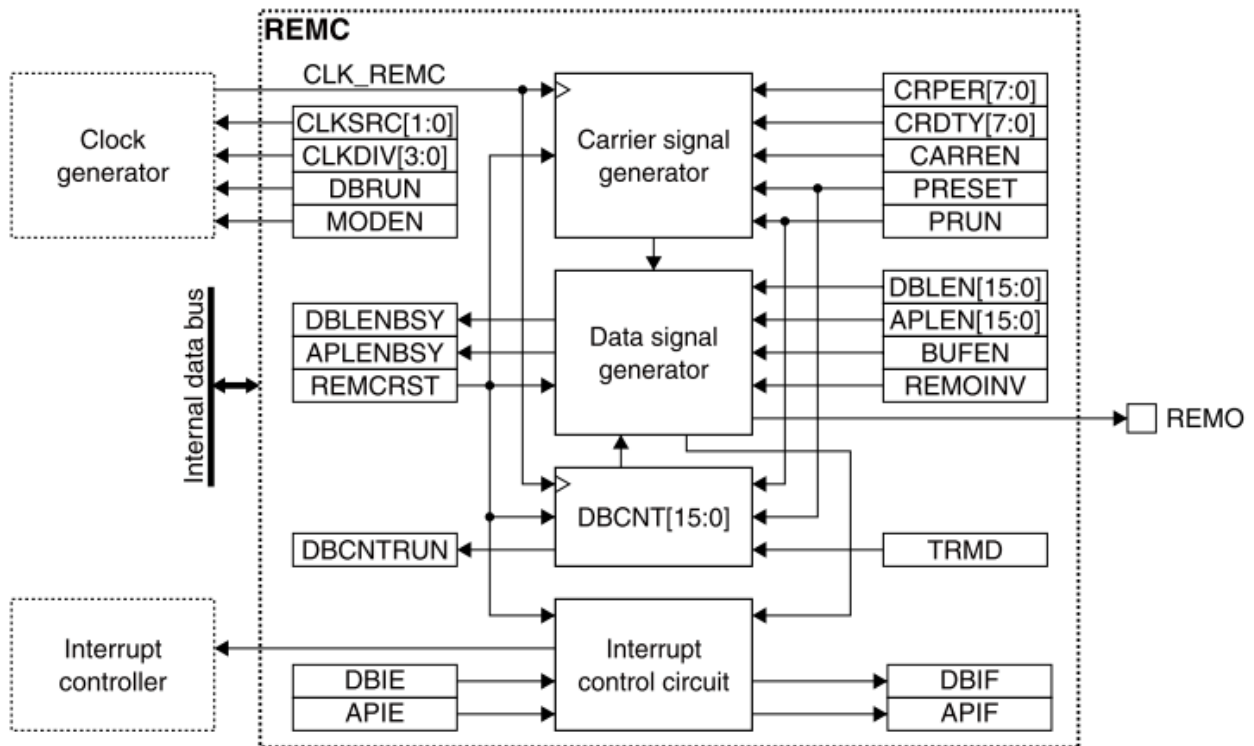


Figure 2 REMC configuration

### 3. Operating Principle

#### (1) EL

EL stands for Electro-Luminescence, a luminous phenomenon caused when a substance is excited by energy. The phenomenon is called luminescence that emits the energy as light which a fluorescent substance received from excitation source. The luminescence is, according to types of excitation sources, classified into electro-luminescence (EL) excited by electric field, photo-luminescence (PL) excited by light, and cathode-luminescence (CL) excited by electron beam.

EL is classified into injection and intrinsic ELs according to luminescent principle. And, strictly speaking, intrinsic EL may be called EL. The injection EL (distributed EL) emits light when electrons and holes injected into semiconductor element recombine near the junction surface by applying a voltage to electric field. The light emitting diode (LED) is an example of injection EL. The intrinsic EL (thin film EL) emits light when electrons accelerated by electric field collide with luminescent center and luminescent center is excited in semiconductor element. The thin film EL element is classified into this.

The thin film EL elements are characterized by the fact that they emit light evenly and extensively over the entire surface of luminous plate of approximately 0.5mm thickness. The study of EL for lighting use and EL display is growing. The EL which uses organic substance including diamines as a luminous object is called organic EL and the EL which uses inorganic substance including zinc sulfide is called inorganic EL.

The organic EL emits light at 5 to 10 VDC, but inorganic EL needs 50 to 200 VAC. This application notes describe how to generate necessary high voltage AC in order for inorganic EL to emit light.

### 3. Operating Principle

#### (2) Principle of high voltage DC-DC converter

The high voltage to activate EL is generated by applying driving waveform shown in Figure 4 to high voltage DC-DC converter circuit shown in Figure 3. In particular, two operating phases are repeated: the phase charging the EL lamp EL1 with high voltage generated in coil L1 by inputting CHG signals (signals for generating charging pulses) and the phase discharging the EL lamp EL1 by inputting DIS signals (signals for generating discharging pulses).

Deliberately select the inductance of coil L1 and frequency of charge waveform input into CHG so that the luminescence intensity of EL lamp EL1 is maximized.

When the current flowing in coil L1 increases from zero to I [A], the energy U [J] stored in coil L1 can be derived from the equation below based on the self-induction principle:

$$U = \frac{1}{2} LI^2 \dots\dots (1)$$

$$I = \frac{V_{CC} - IR - V_{Q1}}{R} \dots\dots (2)$$

Where, L is the inductance of coil L1, R is the resistance of coil L1, V<sub>Q1</sub> is voltage between the collector and emitter when transistor Q1 is turned on.

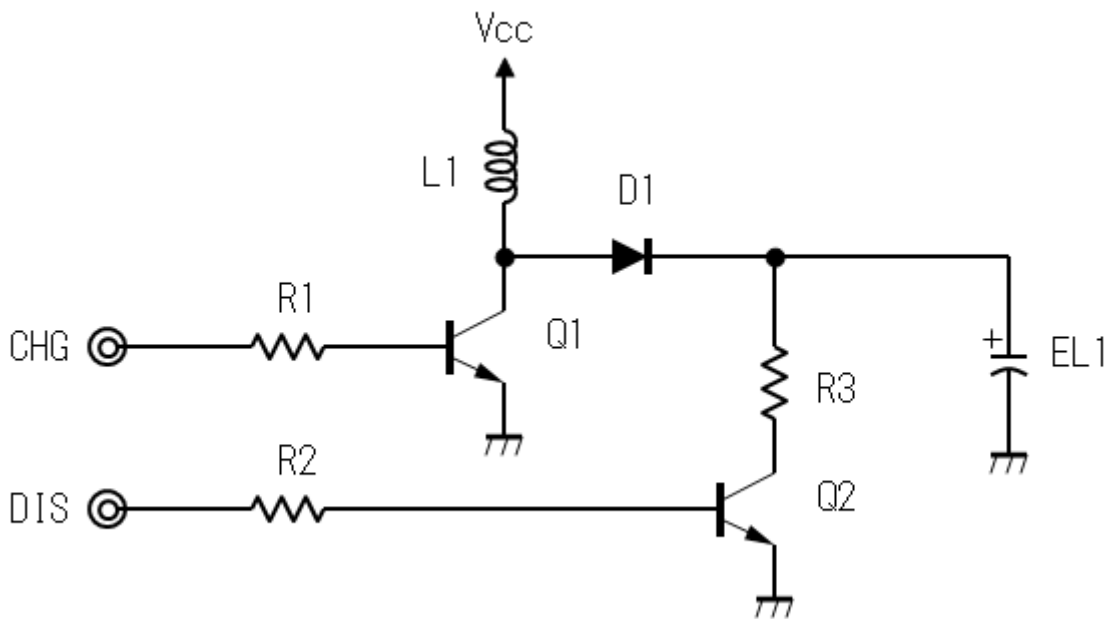


Figure 3 High voltage DC-DC converter circuit

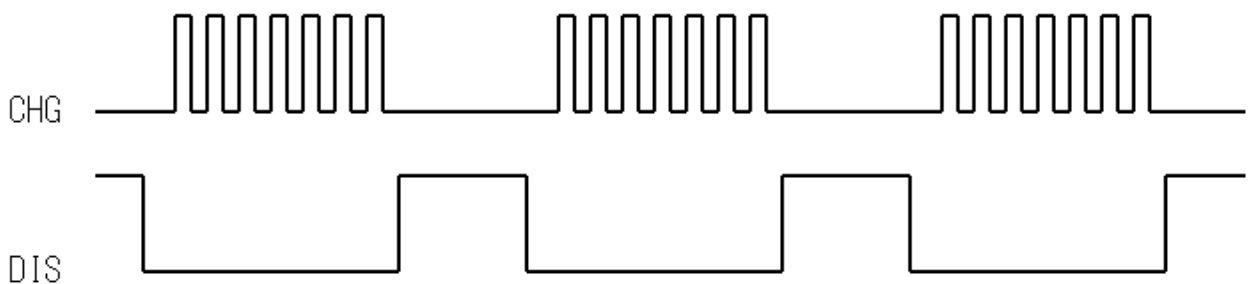


Figure 4 Driving waveform of high voltage DC-DC converter



As shown in this equation, in order to maximize the energy generated from coil L1, it is necessary to increase supply voltage Vcc as much as possible and reduce resistance R of coil L1 as low as possible.

The current flowing in a coil changes according to time and is determined by the turn-on time tON of a switch between the coil and power source as shown in the equation below:

$$I = \frac{V_L}{L} \cdot t_{ON} \dots\dots (3)$$

Where, VL is the voltage applied to coil L1.

The current I flowing in a coil is zero at the moment when the switch is closed, and the voltage Vcc-VQ1 is applied to the coil. The current flowing in the coil increases linearly according to time from the switch-on. As the current flowing in the coil increases, the voltage applied to the inductor decreases due to the resistance of coil and switch's on-resistance, as shown in the equation 4 below:

$$V_L = V_{CC} - IR - V_{Q1} \dots\dots (4)$$

Thus, in order to generate high voltage for activating EL lamp without loss, it is necessary to select those high-voltage transistors and diodes which are sufficient for the drive voltage.

## 4. Software Description

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### 4. Software Description

#### 4.1 W23\_REMC\_RAM\_gnu17vx

This section describes W23\_REMC\_RAM\_gnu17vx, the software running on RAM, in order to make an experiment on REMC by setting the waveform conditions of the EL drive signals.

##### 4.1.1 File Configuration

| File name        | Function   |
|------------------|--|
| src/boot.c       | Startup module   |
| src/main.c       | Main function  |
| src/osc.c        | OSC driver file  |
| src/osc.h        | OSC driver header file   |
| src/remc_out.c   | Initialize and interrupt functions of REMC waveform output                     |
| src/remc_out.h   | Header file for the initialize and interrupt functions of REMC waveform output |
| src/remc.c       | REMC driver file   |
| src/remc.h       | REMC driver header file  |
| src/crt0.h       | Boot processing definition file (for GNU17 Version 3)                          |
| inc/c17w23_reg.h | Header file for peripherals  |
| inc/reg          | The header file which defined the bit assignment every peripheral circuits     |

##### 4.1.2 Module Description

This section describes non-generic setting mainly of function names and functions out of all modules in the files.

File name: boot.c

| Function name | Function   |
|---------------|--|
| boot          | In order to store programs in the RAM area with start address 0x1000, the Vector Table Address Low value is changed to 0x1000. |

File name: remc\_out.c

| Function name | Function  |
|---------------|---|
| remcInt       | REMC interrupt function. It handles the compare AP/DB interrupts. |
| initStartRemc | Initializes REMC.   |

### 4.1.3 Operating Procedures

The sample software includes two projects for GNU17 Version 2 (hereinafter referred to as GNU17v2) and GNU17 Version 3 (hereinafter referred to as GNU17v3).

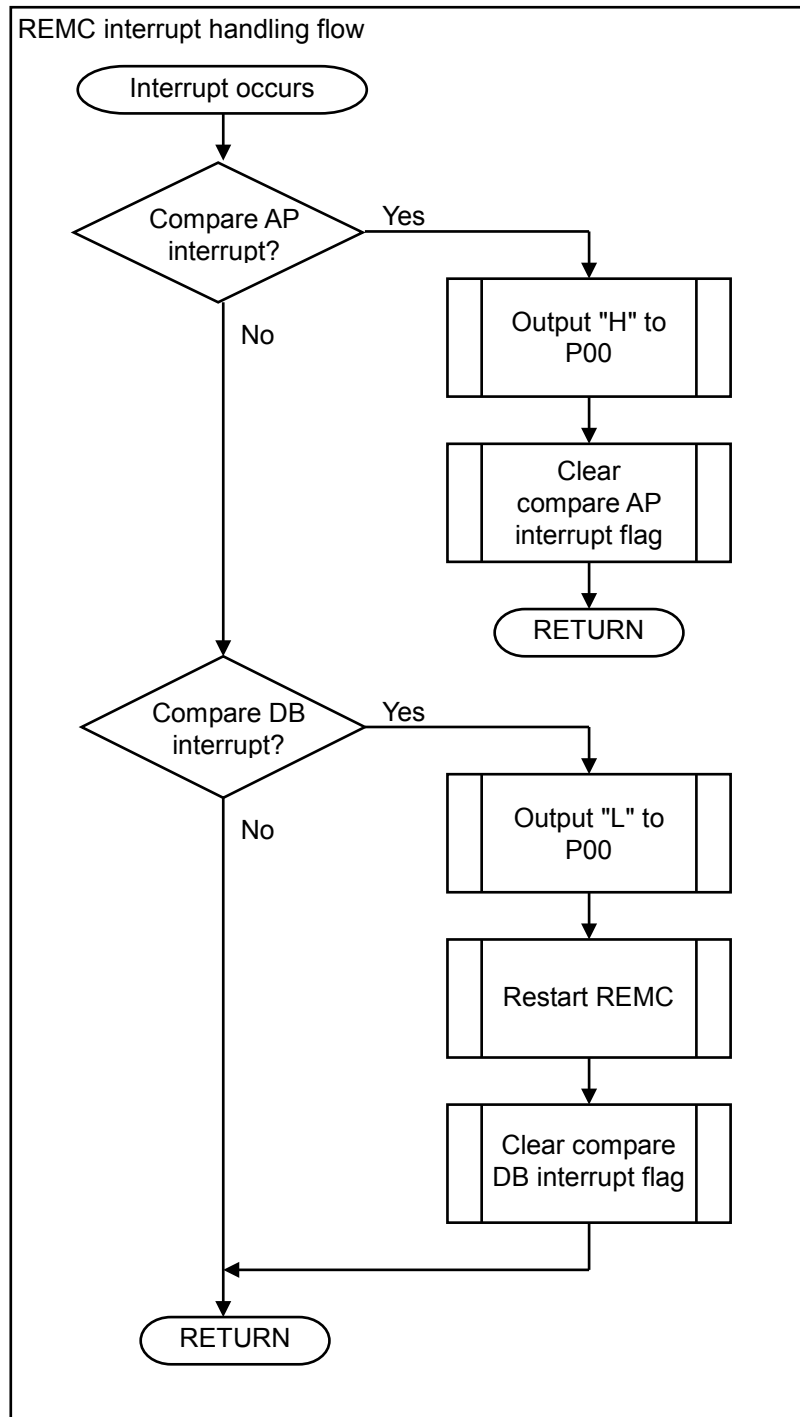
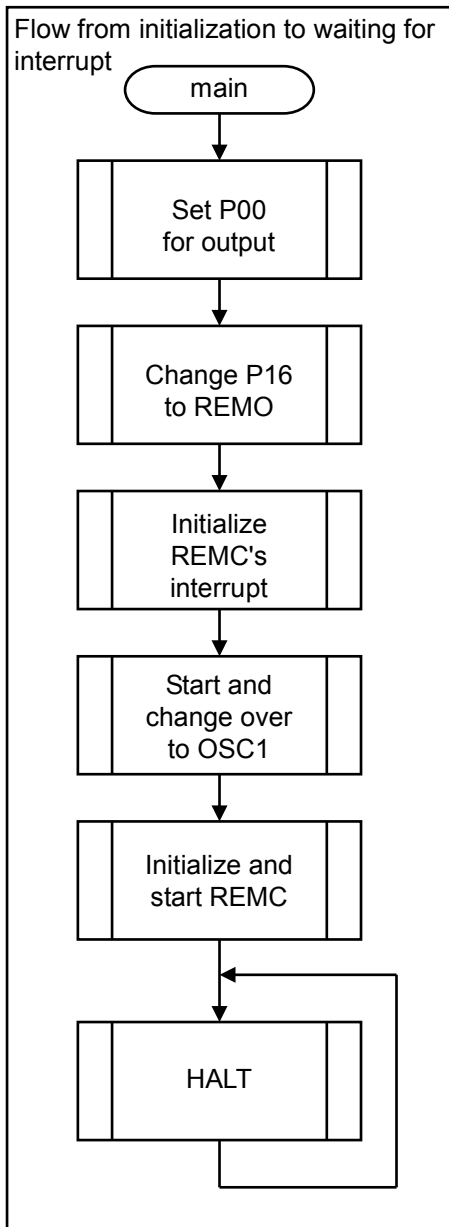
- (1) Select [Import...] from the [File] menu to start the Import Wizard, then select [General] > [Existing Project to Workspace] (GNU17v2) or [General] > [Existing Projects into Workspace] (GNU17v3).
- (2) Select the project folder that contains the sample program:  
W23\_REMC\_RAM\_gnu17v2 folder (GNU17v2) or  
W23\_REMC\_RAM\_gnu17v3 folder (GNU17v3).
- (3) Select [Copy projects into workspace] and then click the [Finish] button to exit the Import Wizard.
- (4) Change the target CPU.  
(GNU17v2)
  1. Select the imported project in the [C/C++ project] view and select [Properties] from the [Project] menu.
  2. Select [GNU17 General] from the property list in the [Properties] dialog box that appears.
  3. Select the target CPU from the [Target CPU Device] drop-down list.
  4. Click the [OK] button to close the dialog box.(GNU17v3)
  1. Select the imported project in the [Project Explorer] view and select [Properties] from the [Project] menu.
  2. Select [GNU17 Setting] from the property list in the [Properties] dialog box that appears.
  3. Select the target CPU from the [Target CPU] drop-down list.
  4. Click the [OK] button to close the dialog box.
- (5) Build the project.  
Use IDE to build the W23\_REMC\_RAM\_gnu17vx project.
- (6) Connect the equipment and turn on the power.
  1. Connect high voltage DC-DC converter, SVT17W23, ICDmini, USB cable, and PC.
  2. Reset SVT17W23 and ICDmini.
- (7) Run the sample software.
  1. Use IDE to run the W23\_REMC\_RAM\_gnu17vx project.
  2. After starting W23\_REMC\_RAM\_gnu17vx, the EL lamp turns on.

## 4. Software Description

### 4.1.4 Sample Program Operation Overview

- (1) Initialize the system.
- (2) REMC starts to oscillate in a one-shot mode.
- (3) The program halts to wait for an interrupt from REMC.
- (4) When an interrupt occurs from REMC, the program outputs a signal to P00 or restart REMC in a one-shot mode according to interrupt causes.

The figure below shows the flow chart:



#### 4.1.5 Parameters and Output Waveforms

The file `remc_out.c` defines constants to determine output waveforms. These constants can change the count values of REMC's timer as shown in the table below:

| Definition name | Setup counter                                      |
|-----------------|--|
| DIS_CYCLE       | REMC's DBLEN (cycle length of data signal)         |
| DIS_LO          | REMC's APLEN (high level period of data signal)    |
| CHG_CYCLE       | REMC's CRPER (carrier signal period)               |
| CHG_HI          | REMC's CRDTY (high level period of carrier signal) |

The correspondence may be wrong because the DIS\_LO's setup counter indicates high level period of data signal in the description above. But, since the DIS signal controls, through GPIO's P00 pin, the time when to invert the DIS signal by using the REMC's compare match interrupt function, the DIS signal has nothing to do with the REMC's internal state.

REMC's REMO output is for outputting CHG signals.

Therefore, the DIS signal, timing of CHG signal, and relationship between frequencies are uniquely determined as follows by using the MCU's clock frequency  $\Phi = 32.768\text{kHz}$ :

$$(1) (\text{DIS\_CYCLE} + C1) / \Phi \quad C1=40 \quad \text{DIS\_CYCLE} \geq \text{DIS\_LO} + 44$$

$$(2) (\text{DIS\_LO} + C2) / \Phi \quad C2=35$$

$$(3) \text{CHG\_CYCLE} / \Phi$$

$$(4) \text{CHG\_HI} / \Phi$$

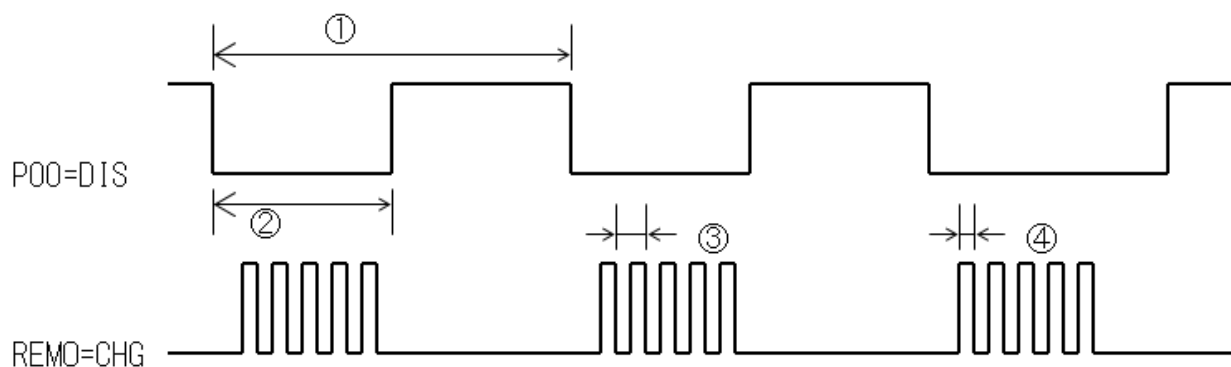


Figure 5 Relationship between output signal waveform and parameter

It is recommended to determine the definition values by checking waveforms with an oscilloscope lest disadvantageous waveforms including beard-like waveform are generated.

## 4. Software Description

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### 4.2 W23\_REMC\_ASM\_gnu17vx

This section describes the software W23\_REMC\_ASM\_gnu17vx including a compact program written in assembler language in order to test EL drive signals. Note that, if not otherwise specified, this application notes describe the blink operation.

#### 4.2.1 File Configuration

| File name        | Function  |
|------------------|---|
| src/boot.c       | Startup module  |
| src/main.c       | Main function   |
| src/osc.c        | OSC driver file   |
| src/osc.h        | OSC driver header file  |
| src/remc_asm.s   | Start, stop, and interrupt functions of REMC waveform output (assembler language) |
| src/t16_ch0.c    | T16 Ch0 driver file   |
| src/t16_ch0.h    | T16 Ch0 driver header file  |
| src/crt0.h       | Boot processing definition file (for GNU17 Version 3)                             |
| inc/c17w23_reg.h | Header file for peripherals   |
| inc/reg          | The header file which defined the bit assignment every peripheral circuits        |

#### 4.2.2 Module Description

This section describes non-generic setting mainly of function names and functions out of all modules in the files.

File name: remc\_asm.s

| Function name | Function   |
|---------------|--|
| startRemcAsm  | Initializes and activates REMC, and accepts an interrupt.                                |
| stopRemcAsm   | Stops REMC, clears interrupt accepted, and sets the outputs to P00 and P16 to "L" level. |
| intRemcAsm    | REMC interrupt function. It handles the compare AP/DB interrupts.                        |

File name: t16\_ch0.c (the description is provided only for functions used in this software)

| Function name | Function                            |
|---------------|-------------------------------------|
| initT16Ch0    | Initializes T16 Ch0.                |
| startT16Ch0   | Starts T16 Ch0.                     |
| intT16Ch0     | Interrupts T16 Ch0. Repeats blinks. |

### 4.2.3 Global Variable

This section describes global variables used in the sample program.

| Variable name | Type           | Function   |
|---------------|----------------|--|
| blink         | unsigned short | Used in a blink mode. 0: turned off, 1: turned on. |

### 4.2.4 Compile Switch

This section describes compile switches used in the sample program.

Switch a definition in main.c to change turned-off, turned-on, or blink mode.

| Variable name | Function                               |
|---------------|--|
| EL_LAMP_MODE  | 0: turned-off, 1: turned-on, 2: blink. |

The blink frequency can be changed with the parameter `BLINK_INTERVAL_COEF` in `t16_ch0.c`, and the value can be calculated in the equation below (unit: second).

$$\text{Turn-off time} = \text{Turn-on time} = \text{BLINK\_INTERVAL\_COEF} / 32768$$

That is, if `BLINK_INTERVAL_COEF` = 16384 by default, EL lamp repeats to turn on/off in 0.5 sec cycle.

## 4. Software Description

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### 4.2.5 Operating Procedures

The sample software includes two projects for GNU17 Version 2 (hereinafter referred to as GNU17v2) and GNU17 Version 3 (hereinafter referred to as GNU17v3).

- (1) Select [Import...] from the [File] menu to start the Import Wizard, then select [General] > [Existing Project to Workspace] (GNU17v2) or [General] > [Existing Projects into Workspace] (GNU17v3).
- (2) Select the project folder that contains the sample program:  
W23\_REMC\_ASM\_gnu17v2 folder (GNU17v2) or  
W23\_REMC\_ASM\_gnu17v3 folder (GNU17v3).
- (3) Select [Copy projects into workspace] and then click the [Finish] button to exit the Import Wizard.
- (4) Change the target CPU.  
(GNU17v2)
  1. Select the imported project in the [C/C++ project] view and select [Properties] from the [Project] menu.
  2. Select [GNU17 General] from the property list in the [Properties] dialog box that appears.
  3. Select the target CPU from the [Target CPU Device] drop-down list.
  4. Click the [OK] button to close the dialog box.  
(GNU17v3)
  1. Select the imported project in the [Project Explorer] view and select [Properties] from the [Project] menu.
  2. Select [GNU17 Setting] from the property list in the [Properties] dialog box that appears.
  3. Select the target CPU from the [Target CPU] drop-down list.
  4. Click the [OK] button to close the dialog box.
- (5) Build the project.  
Use IDE to build the W23\_REMC\_ASM\_gnu17vx project.
- (6) Connect the equipment and turn on the power.
  1. Connect high voltage DC-DC converter, SVT17W23, ICDmini, USB cable, and PC.
  2. Reset SVT17W23 and ICDmini.
- (7) Run the sample software.
  1. Use IDE to run the W23\_REMC\_ASM\_gnu17vx project.
  2. After starting W23\_REMC\_ASM\_gnu17vx, the EL lamp blinks.

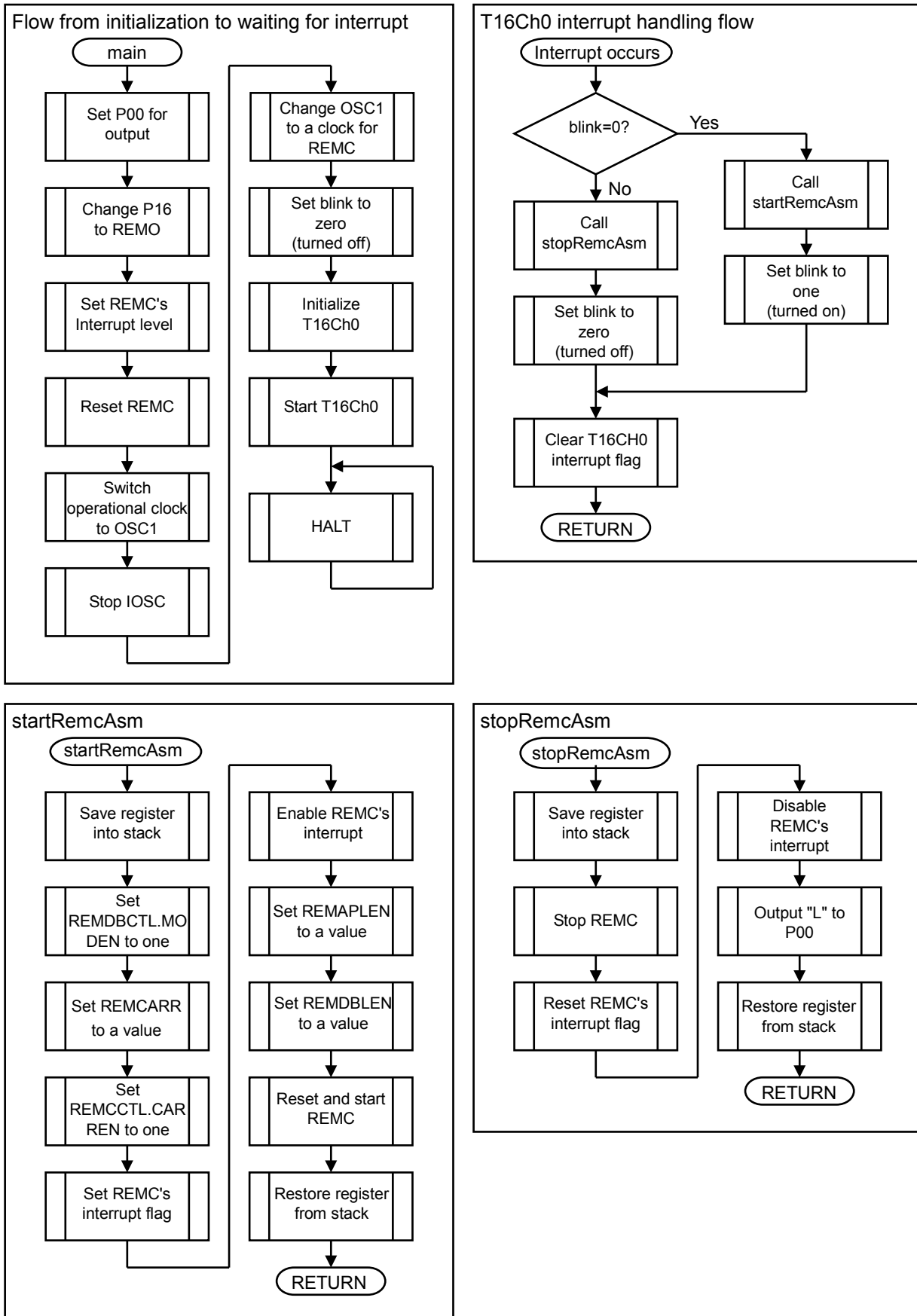


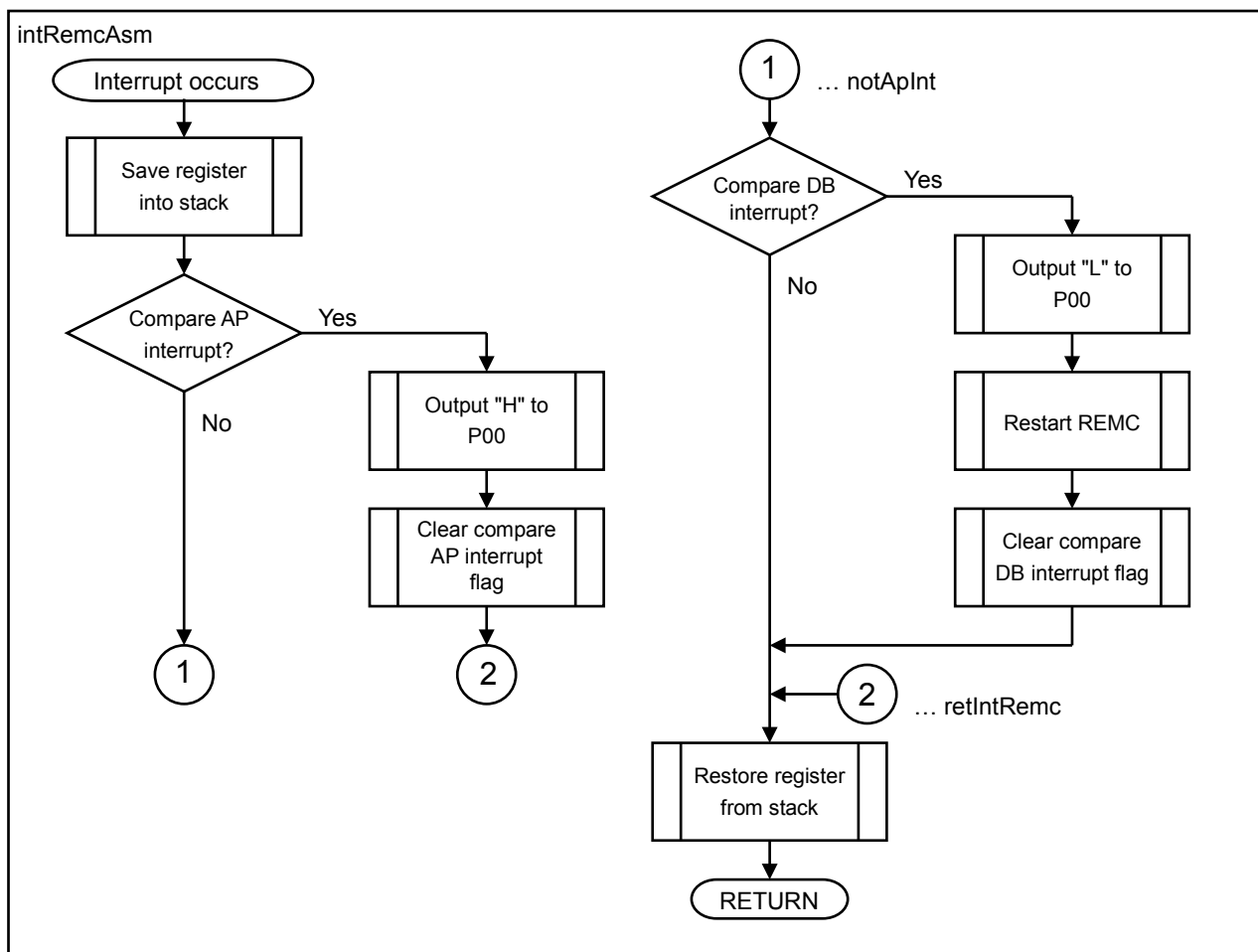
### 4.2.6 Sample Program Operation Overview

- (1) Initialize T16 Ch0, GPIO, and REMC.
- (2) Start T16 Ch0.
- (3) The program halts to wait for an interrupt from T16 Ch0.
- (4) When an interrupt from T16 Ch0 occurs, REMC is restarted or stopped to blink according to blinking state.
- (5) When REMC is running, an interrupt occurs regularly for modulating output waveforms, so that a signal is output to P00 or REMC is restart according to the interrupt cause.

## 4. Software Description

The figure below shows the flow chart:





**4.2.7 Parameters and Output Waveforms**

The file remc\_asm.s defines constants to determine output waveforms. The constants can change the counter value of REMC timer and have the same specification as described in "4.1.5 Parameters and Output Waveforms." However, C1=37 and C2=32.

**4.2.8 Sample Program Size**

Of all files of this sample program, remc\_asm.s provides three functions which enables REMC to operate EL driver: startRemcAsm, stopRemcAsm, and intRemcAsm. So, in order to use remc\_asm.s for general purpose, its size is shown below:

| File name  | ROM size used |
|------------|---------------|
| remc_asm.s | 170Byte       |

## APPENDIX A. Experiment Example to Turn on EL Lamp

### APPENDIX A. Experiment Example to Turn on EL Lamp

This chapter describes an example which examined how the brightness and various characteristics of an EL lamp may actually change according to waveforms.

First, this chapter describes the circumstance to evaluate luminescence intensity.

The luminescent intensity of the EL lamp can be measured in  $\text{cd}/\text{m}^2$  as a light source. A dedicated meter including a photometer is required for this purpose. But, due to the constraint of available meters and flat light source, available light meter is used as the alternative means.

The specification of the light meter used is as follows:

- Minolta digital light meter T-1

Now, we have examined the change of luminescence intensity of the EL lamp caused by the change of waveforms by using BOM components listed in Table 1 in the high voltage DC-DC converter circuit shown in Figure 3, so we determined two typical conditions for evaluation.

Table 1 BOM of high voltage DC-DC converter circuit shown in Figure 3

| Name       | Symbol | Manufacturer         | Product number    | Specification                              |
|------------|--------|----------------------|-------------------|--|
| EL Lamp    | EL1    | -                    | -                 | Custom-made                                |
| Transistor | Q1     | Micro Commercial Co. | MMBT5551-TPCT-ND  | $I_c=600\text{mA}$ , $V_{ce0}=160\text{V}$ |
|            | Q2     |                      |                   |  |
| Diode      | D1     | ON Semicon.          | BAS21LT3GOSCT-ND  | 250V, 200mA                                |
| Inductor   | L1     | Abracon Corporation  | ASPI-0403S-332M-T | 3.3mH, 80mA, $R_{DC}\leq 11\Omega$         |
| Resistor   | R1     | ROHM                 | MCR01 Series      | 1k $\Omega$ , Size=1005(0402), Tol=F       |
|            | R2     |                      |                   | 1k $\Omega$ , Size=1005(0402), Tol=F       |
|            | R3     |                      |                   | 10k $\Omega$ , Size=1005(0402), Tol=F      |

Table 2 lists the meaning of symbols below:

Table 2 Description of symbols

| Symbol              | Meaning   |
|---------------------|---|
| $V_{\text{peak}}$   | Peak voltage value applied to the EL lamp.  |
| $I_{\text{meas}}$   | Total current flowing in the driver circuit ( $V_{cc}$ in Figure 3) and S1C17W23. |
| Illuminance         | Measured illuminance of luminescent EL surface.                                   |
| Luminous efficiency | Value of the illuminance divided by $V_{cc}$ multiplied by $I_{\text{meas}}$ .    |

## APPENDIX A. Experiment Example to Turn on EL Lamp

Figure 6 shows the dependency of various characteristics on applied voltage when using setting values under two typical conditions.

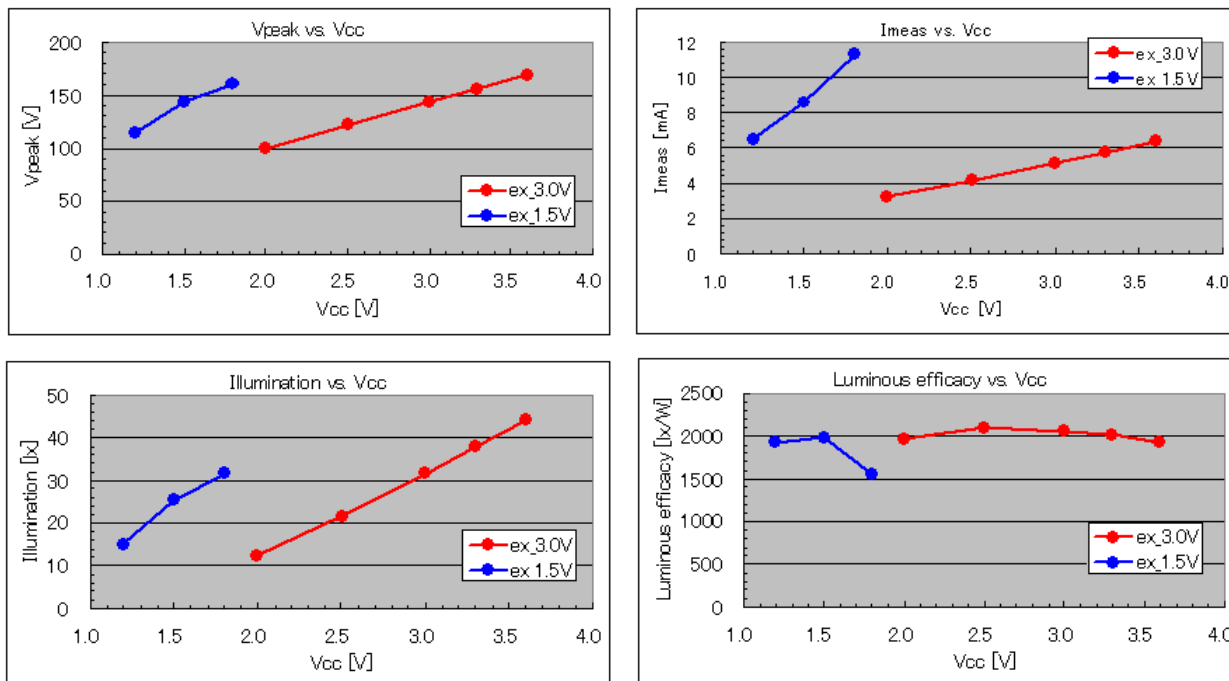


Figure 6 Dependency of various characteristics on applied voltage under two typical conditions

In addition, the meters used in the experiment are as follows:

- Ammeter: Agilent, 34401A, 6 1/2 Digit Multimeter
- Oscilloscope: Tektronix TDS3014
- Stabilized power supply: HP E3631A, DC Power Supply

Finally, Figure 7 shows how the lamp emits light when the supply voltages (3.0V, 1.5V) are applied under two typical conditions.

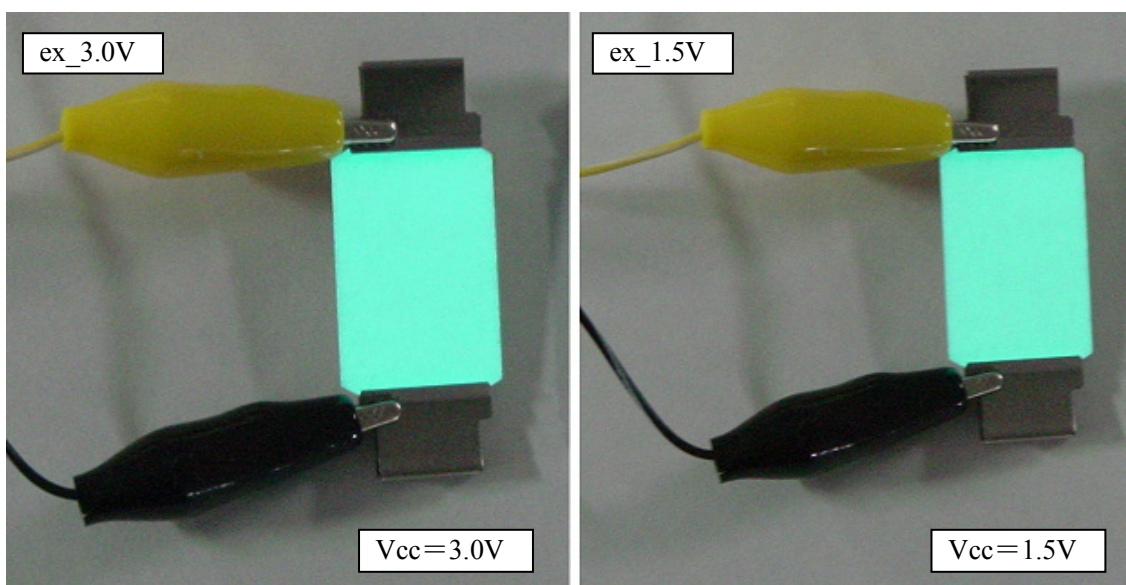


Figure 7 How EL lamp emits light under two typical conditions

## Revision History

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### Revision History

Attachment-1

| Rev. No. | Date       | Page                        | Category | Contents  |
|----------|------------|-----------------------------|----------|---|
| Rev. 1.0 | 2013/08/20 | All                         | New      | New establishment   |
| Rev. 1.1 | 2016/03/31 | i, 1, 2,<br>6, 7,<br>10, 12 | Addition | Descriptions for the contents that were added or modified to support the new operating environment (GNU17 Ver. 3) have been appended. |
|          |            |                             |          |   |
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