NIPPON PRECISION CIRCUITS INC.

SM8143

Application Note

EL Driver IC

OVERVIEW

The SM8143 has independent inductor drive oscillator circuit (OCL) and EL drive oscillator circuit (OCE) built-in. Accordingly, the frequency of oscillation can be individually changed to control the brightness, current consumption, and frequency over a wide range.

The SM8143 has an EL ON/OFF control pin, ENA (ON when HIGH, and OFF when LOW).

DESCRIPTION

The SM8143 comprises an oscillator, booster, and high voltage switching circuit functional blocks.

Block Diagram

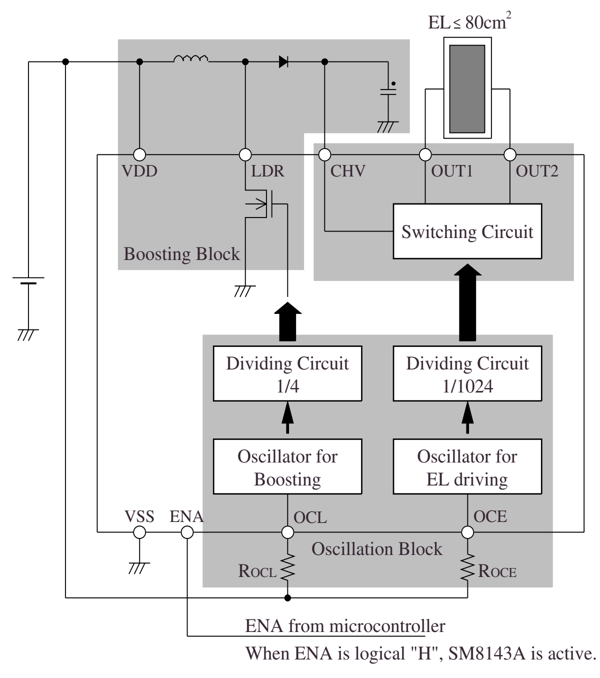


Figure 1. SM8143 Block Diagram

Oscillator

The built-in oscillator circuits require only the connection of an external resistor to form RC oscillator circuits. Changing the value of the external resistor causes the frequency of the oscillator to change. When the resistance is increased, the frequency of oscillation decreases and, conversely, when the resistance is decreased, the frequency of oscillation increases.

The frequency of the oscillator is divided to form two frequency signals, f_{LDR} and f_{OUT}. The f_{LDR} frequency is derived from a 1/4 divider, and f_{OUT} is derived from a 1/1024 divider. The relationship between resistance values and f_{LDR} and f_{OUT} is shown in figures 2 to 5. Note that the measurements shown in the characteristics diagrams were measured using an NPC standard PCB, and that capacitance due to different wiring patterns may have a small effect on these values.

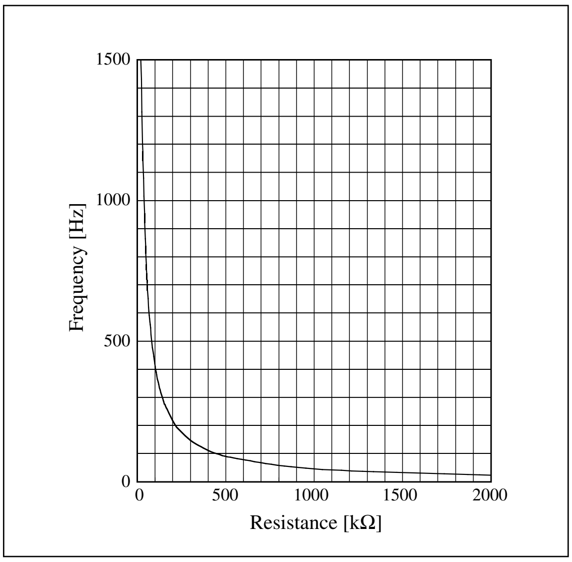


Figure 2. $R_{OCE} - f_{OUT}$

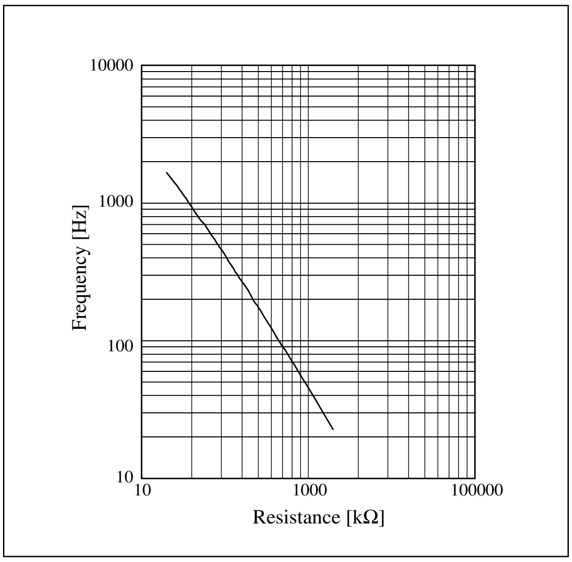


Figure 3. $R_{OCE} - f_{OUT}$ (LOG)

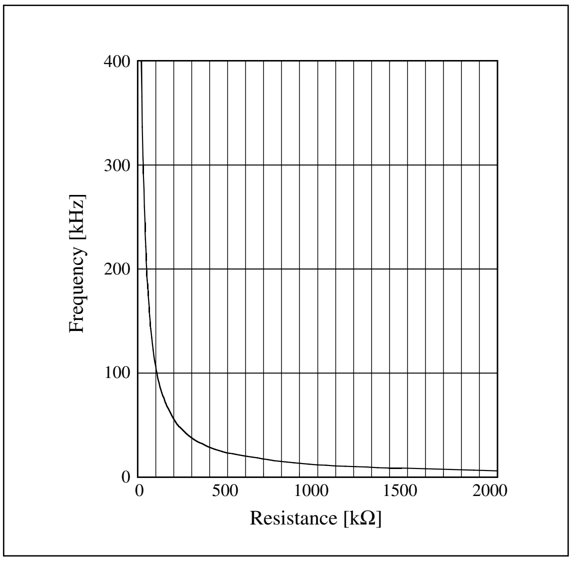


Figure 4. $R_{OCL} - f_{LDR}$

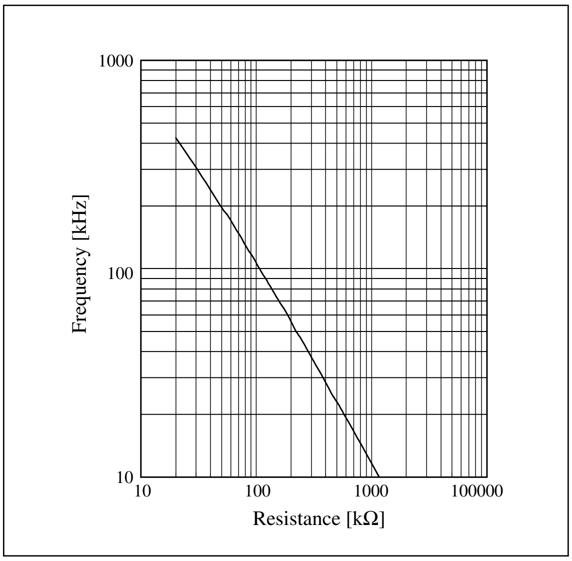


Figure 5. $R_{OCL} - f_{LDR}$ (LOG)

Booster

The oscillator frequency is divided by 4 to form the inductor drive clock (f_{LDR}), which is used to switch the inductor drive transistor to boost the voltage from battery-level voltages up to a maximum of 100V DC. The switching duty ratio is fixed with a cycle of 75% ON and 25% OFF. When the inductor drive transistor is ON, the inductor current flows through the inductor drive transistor, as shown in the following figure.

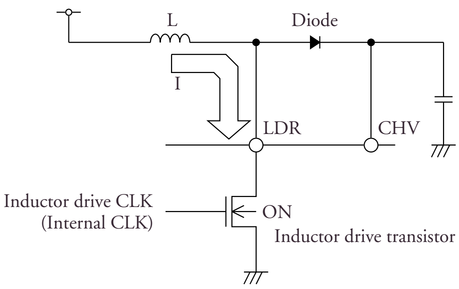


Figure 6. Boost circuit (transistor ON)

The current I [A] is a function of the coil inductance L [H], the voltage across the inductor V [V], and the inductor drive transistor ON time t_{ON} [sec], given by:

$$I = \left(\frac{V}{L}\right) \times t_{ON} \text{ [A]}$$

and the inductor stores this energy as magnetic energy. When the inductor drive transistor is OFF, the current in the inductor drive transistor necessarily reduces to zero. However, the inductor current naturally continues to flow and is redirected through the diode and capacitor, which stores the energy as electric energy. At this point, a counter emf appears on pin LDR.

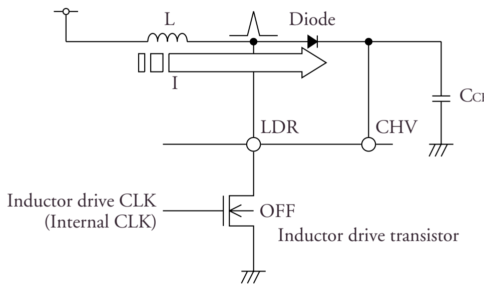


Figure 7. Boost circuit (transistor OFF)

This operation repeats as the transistor is switched ON and OFF, thereby boosting the voltage on pin CHV to stabilize the power consumption in the EL output stage. Note that the rating for the voltage on CHV is 100V maximum, so care should be taken not to exceed this value.

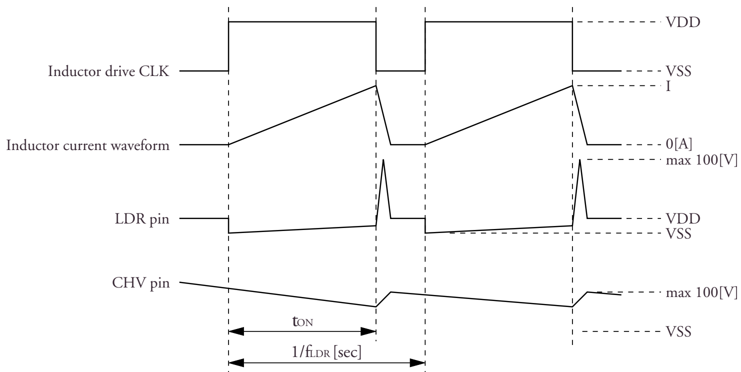


Figure 8. Boost circuit timing

The inductor drive clock duty ratio is 75%, and therefore the voltage is applied to the inductor for time t_{ON}, given by:

$$t_{ON} = 0.75 \times \frac{1}{f_{LDR}} \text{ [sec]}$$

and the energy stored in the inductor (E) is given by:

$$E = \frac{1}{2} \times f_{LDR} \times L \times I^2 \approx 0.28 \times \frac{V^2}{f_{LDR} \times L}$$

For example, if the frequency is halved, then the ON time for which current flows through the inductor is doubled, the current through the inductor is also doubled, and the energy stored in the inductance coil is also doubled. Also, if the coil inductance is halved, then the current and energy are doubled. If the voltage is doubled, then the current is doubled and the energy is quadrupled.

The booster energy can be adjusted by controlling the coil inductance drive frequency, the inductance of the coil, and the voltage across the inductor to meet the desired application.

Output Stage

The high voltage created in the booster stage is passed to the output stage and two signals OUT1 and OUT2 from a bridge circuit are output at a frequency f_{OUT} generated by the oscillator. The output frequency can be adjusted using the external resistance values of R_{OCE} and R_{OSC}.

Output Waveform

Ideally, the SM8143 output waveform for efficient EL illumination is a rectangular-like drive waveform as shown in figure 10. If the EL element oscillates in a particular application, then the output waveform can be slightly smoothed by adjusting an output resistor R_{OUT} shown in figure 9. The output waveform is smoother for higher values of resistance for R_{OUT}, which will help control noise but at the expense of higher loss.

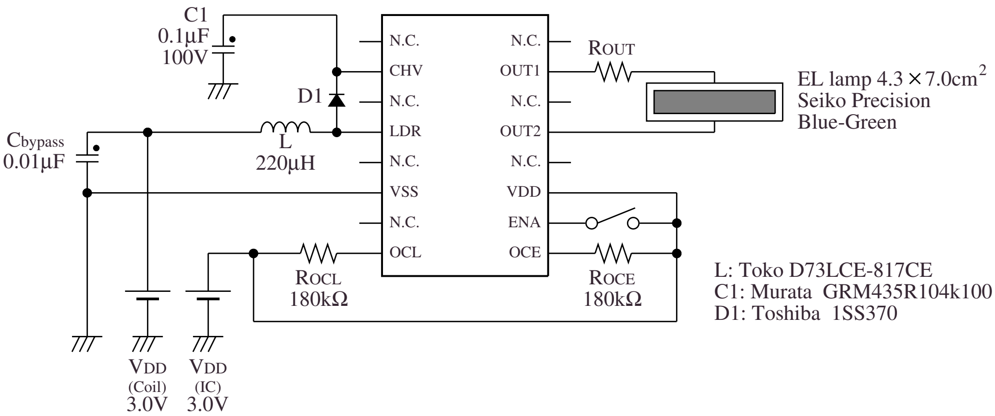


Figure 9. Output waveform adjustment circuit

The effect of R_{OUT} for values of 0, 5.1kΩ, 10kΩ, and 20kΩ are shown in the following table and figures.

R_{OUT} [kΩ]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]	Waveform
0.0	180	180	55.5	225	194	27.7	Figure 10
5.1	180	180	56.1	227	182	22.4	Figure 11
10.0	180	180	56.2	227	176	19.9	Figure 12
20.0	180	180	56.1	227	168	17.1	Figure 13

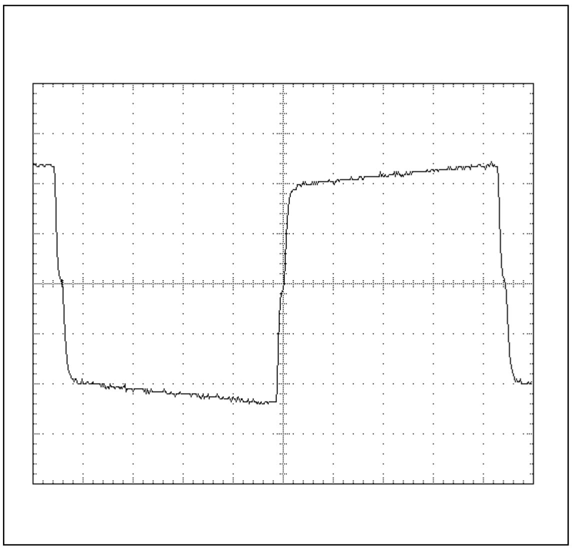


Figure 10. R_{OUT} = 0

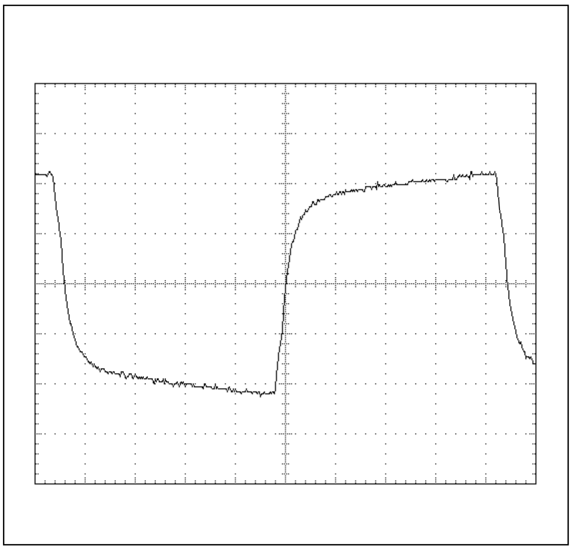


Figure 11. R_{OUT} = 5.1kΩ

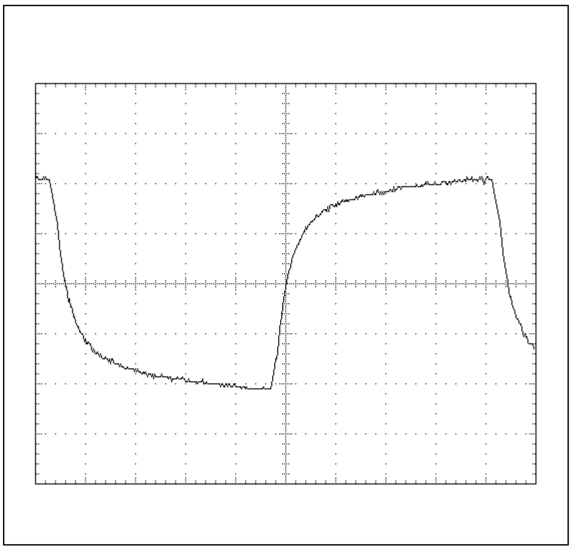


Figure 12. R_{OUT} = 10kΩ

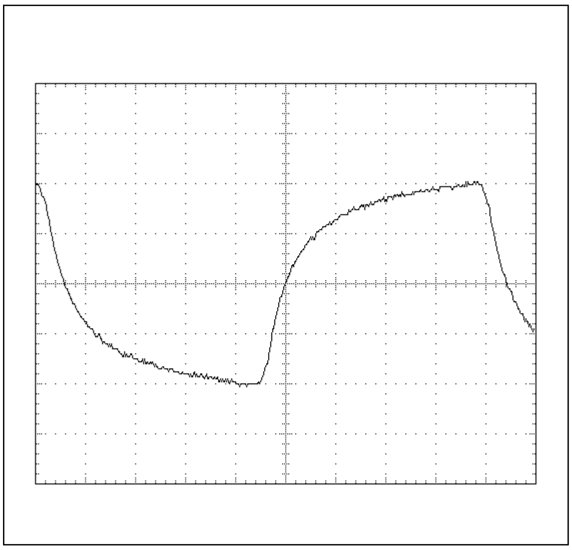


Figure 13. R_{OUT} = 20kΩ

TYPICAL APPLICATION CIRCUIT

V_{DD}: 3.0 [V], EL size: 30 [cm^2] – (1)

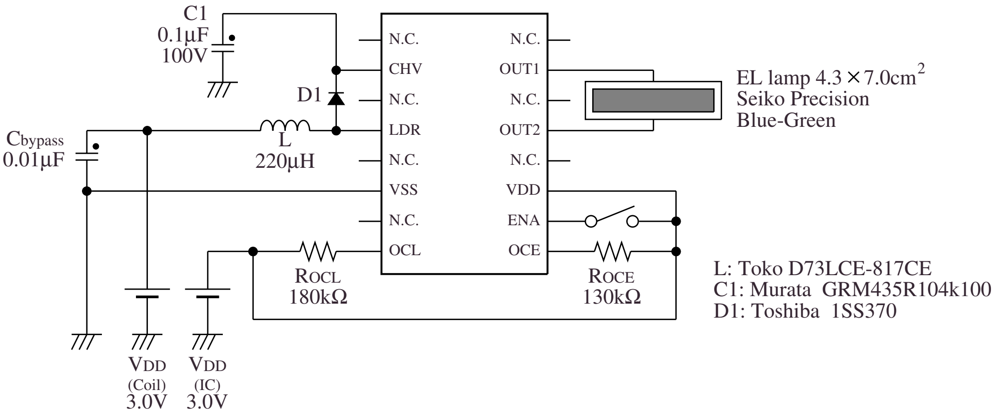


Figure 14. Application circuit

The inductance, R_{OCL}, and R_{OCE} can all be adjusted to control the brightness and current consumption required in a particular application, as summarized in the following table.

EL size [cm^2]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
30.1	470	91	270	13.4	172	126	8.6
30.1	470	180	270	25.7	174	168	15.8
30.1	330	180	180	41.3	256	172	22.8
30.1	220	180	130	56.5	345	168	27.6
30.1	220	470	91	119.1	471	180	39.7

The characteristics using the circuit in figure 14 for different values of coil inductance, R_{OCL}, and R_{OCE} are shown in figures 15 to 23. Figures 15 to 17 show the relationship between current consumption and R_{OCL}, figures 18 to 20 show the relationship between brightness and R_{OCL}, and figures 21 to 23 show the relationship between brightness and R_{OCE}, provided for reference.

Measurement conditions

V_{DD}: 3.0V, EL size: 30cm^2 (refer to figure 14)

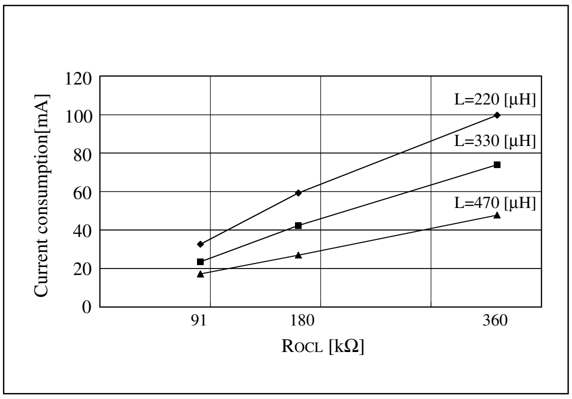


Figure 15. Current consumption – R_{OCL}
(R_{OCE} = 24kΩ)

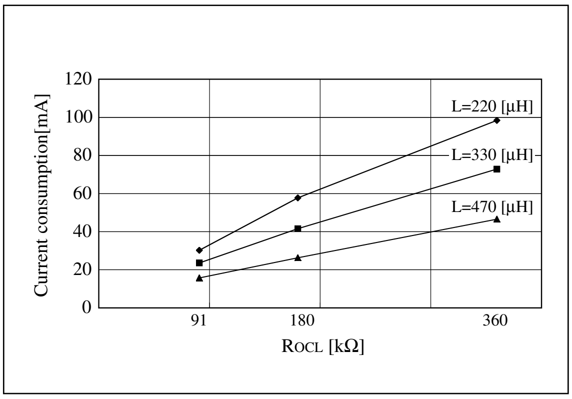


Figure 16. Current consumption – R_{OCL}
(R_{OCE} = 91kΩ)

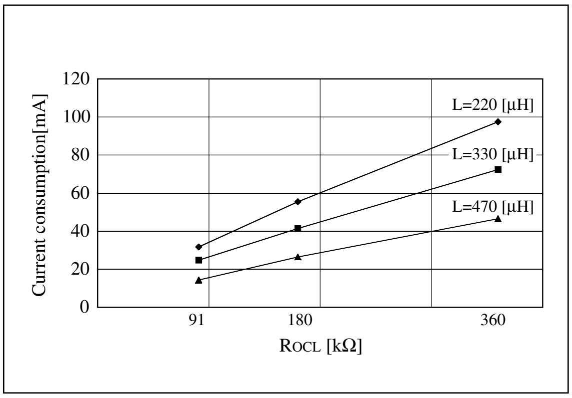


Figure 17. Current consumption – R_{OCL}
(R_{OCE} = 180kΩ)

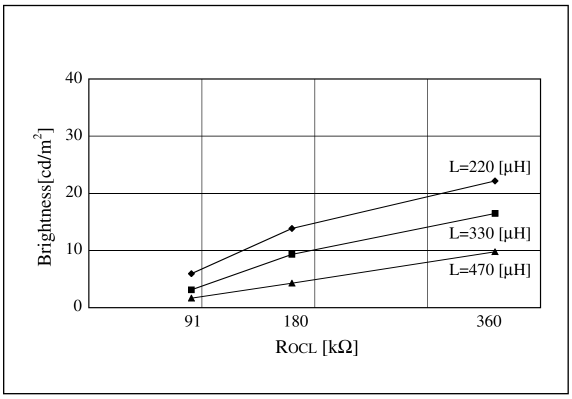


Figure 18. Brightness – R_{OCL}
(R_{OCE} = 24kΩ)

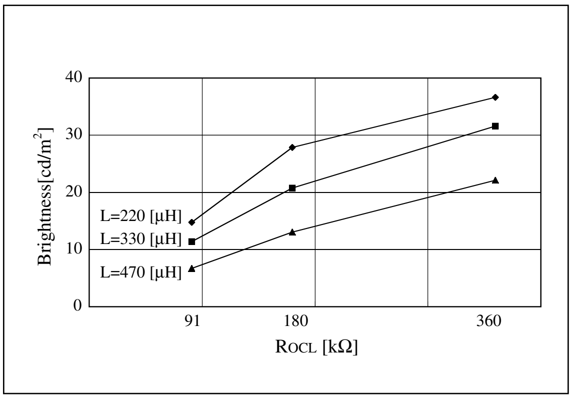


Figure 19. Brightness – R_{OCL}
(R_{OCE} = 91kΩ)

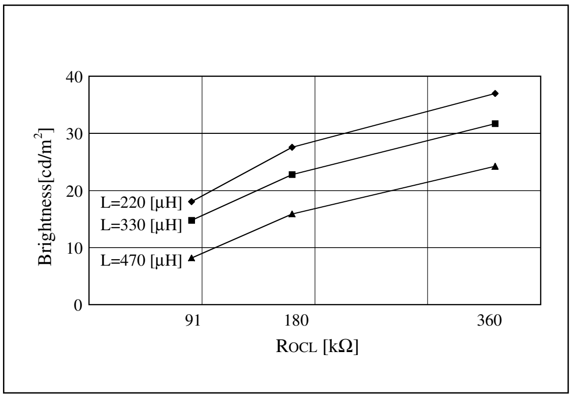


Figure 20. Brightness – R_{OCL}
(R_{OCE} = 180kΩ)

R_{OCL} is the resistor connected to pin OCL. Changing the resistance changes the inductor switching frequency, which also changes the inductor current and EL brightness. Values should be within the range 24kΩ to 1000kΩ. A high resistance reduces the inductor switching frequency and increases the current. Care should be taken not to exceed the rated maximum inductor current for high values of R_{OCL} resistance.

V_{DD}: 3.0V, EL size: 30cm^2 (refer to figure 14)

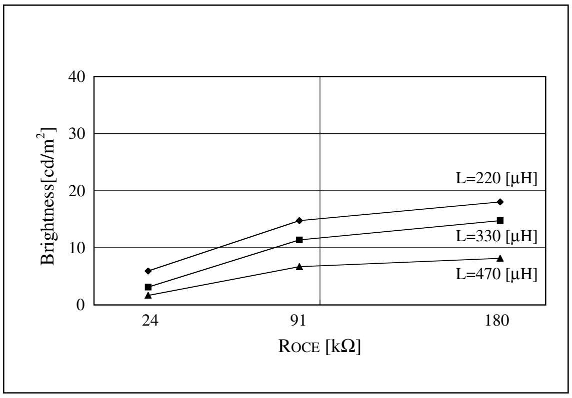


Figure 21. Brightness – R_{OCE}
(R_{OCL} = 91kΩ)

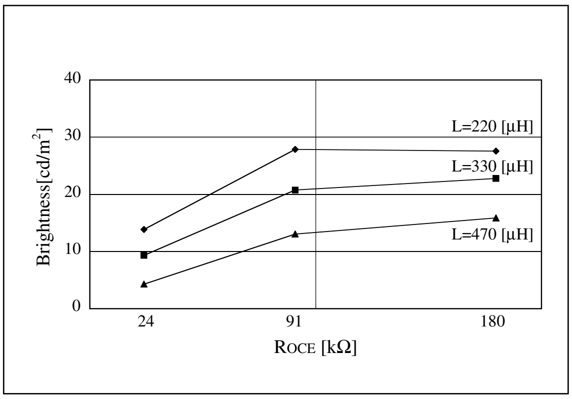


Figure 22. Brightness – R_{OCE}
(R_{OCL} = 180kΩ)

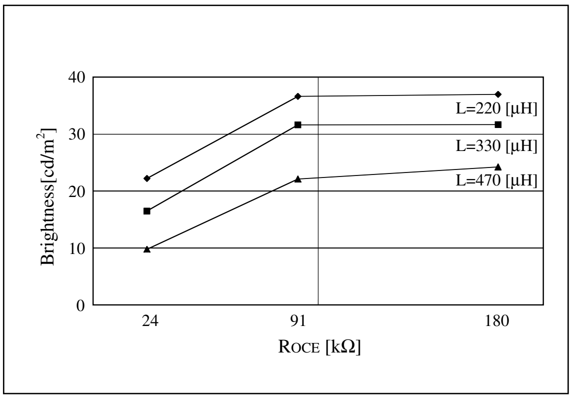


Figure 23. Brightness – R_{OCE}
(R_{OCL} = 360kΩ)

R_{OCE} is the resistor connected to pin OCE. Changing the resistance changes the output frequency. Values should be within the range 24kΩ to 1000kΩ. A high resistance reduces the output frequency. Care should be taken not to exceed the maximum rating as the output voltage will be high level if the output frequency is set to low, even if the brightness or the current through the inductor is fixed.

V_{DD}: 3.0 [V], EL size: 30 [cm^2] – (2)

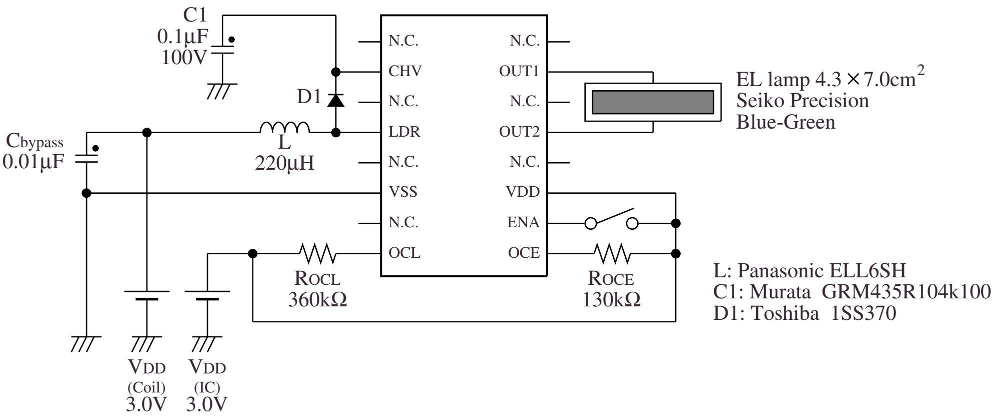


Figure 24. Application circuit

EL size [cm^2]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
30.1	470	470	180	55.7	256	182	26.5
30.1	470	130	270	17.9	171	142	11.3
30.1	330	270	130	41.4	346	146	20.9
30.1	220	360	130	76.9	346	180	31.7
30.1	220	470	130	94.6	344	188	34.4

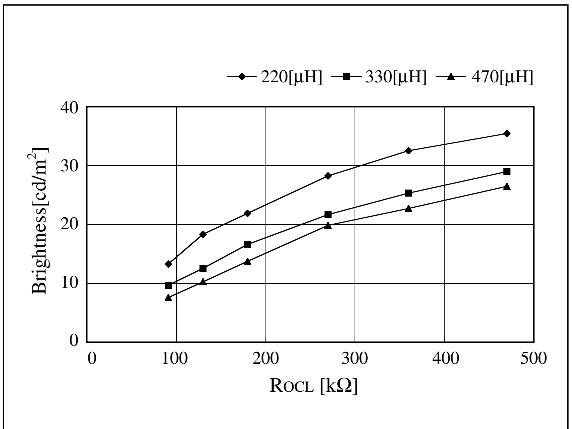


Figure 25. Brightness – R_{OCL}
(R_{OCE} = 180kΩ)

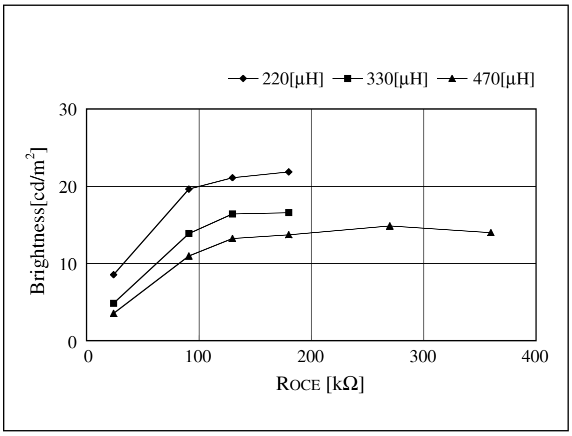


Figure 26. Brightness – R_{OCE}
(R_{OCL} = 180kΩ)

V_{DD}: 3.0 [V], EL size: 50 [cm^2] – (1)

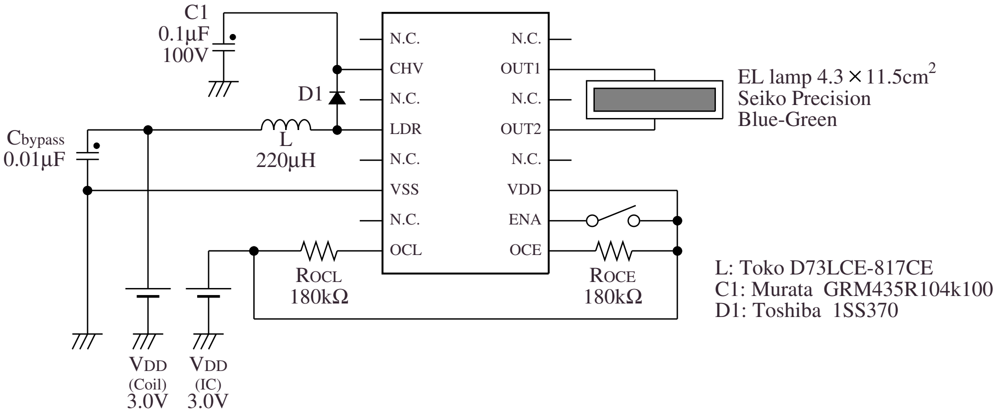


Figure 27. Application circuit

EL size [cm^2]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
49.5	470	130	360	19.7	132	140	8.2
49.5	470	270	360	35.5	131	176	13.7
49.5	330	180	360	41.0	132	184	15.0
49.5	220	180	180	57.3	250	162	19.3
49.5	220	470	130	119.8	345	170	27.1

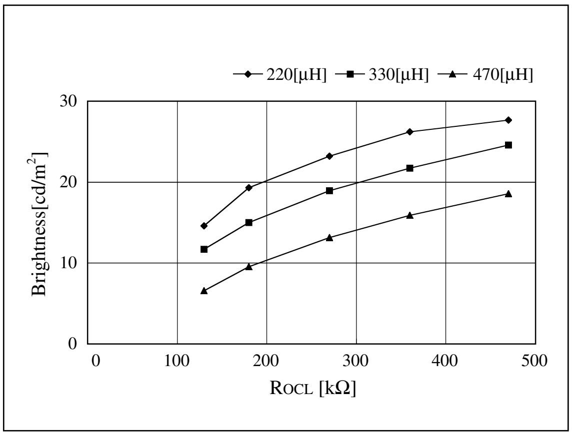


Figure 28. Brightness – R_{OCL} (R_{OCE} = 180kΩ)

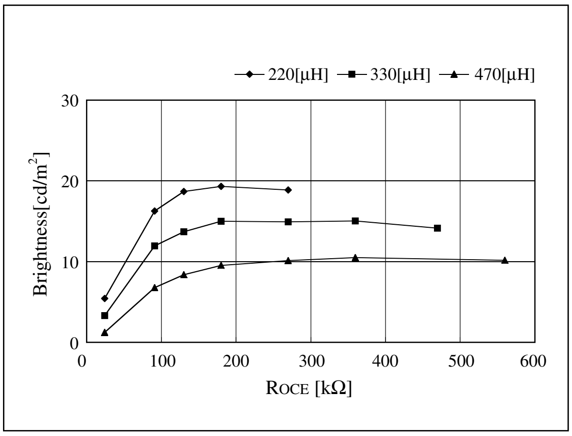


Figure 29. Brightness – R_{OCE} (R_{OCL} = 180kΩ)

V_{DD}: 3.0 [V], EL size: 50 [cm^2] – (2)

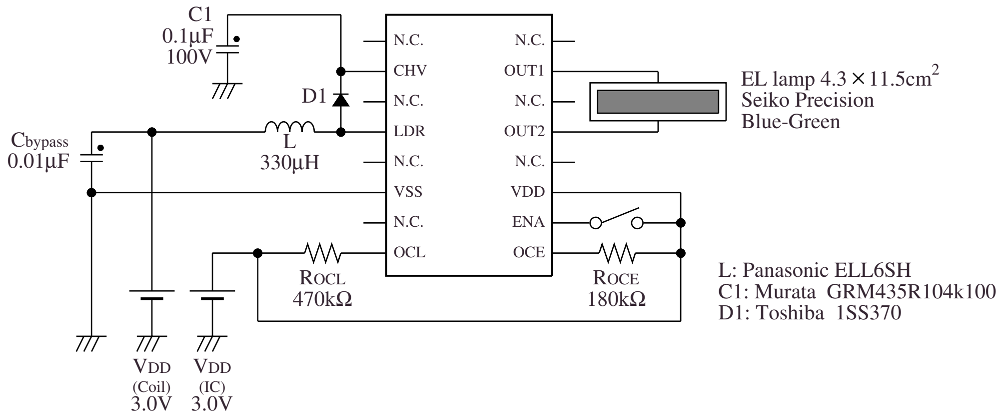


Figure 30. Application circuit

EL size [cm^2]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
49.5	470	470	270	55.9	174	182	17.5
49.5	470	180	360	24.4	132	146	9.7
49.5	330	470	180	67.5	255	162	19.7
49.5	330	270	270	41.3	171	162	14.7
49.5	220	360	180	78.2	255	170	22.3

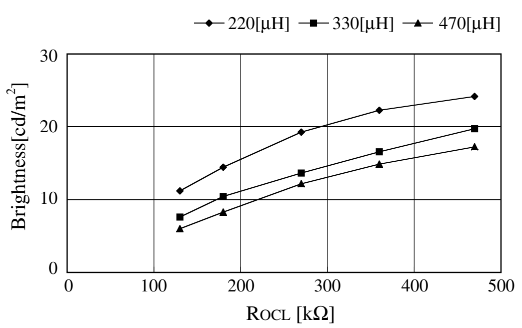


Figure 31. Brightness – R_{OCL}
(R_{OCE} = 180kΩ)

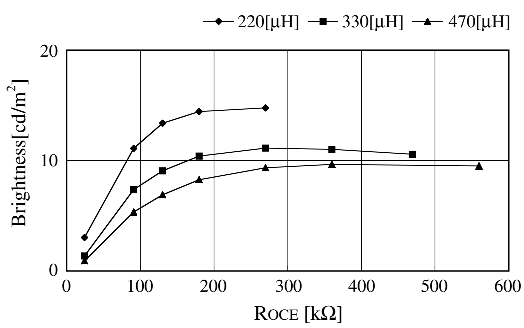


Figure 32. Brightness – R_{OCE}
(R_{OCL} = 180kΩ)

V_{DD}: 5.0 [V], EL size: 30 [cm^2]

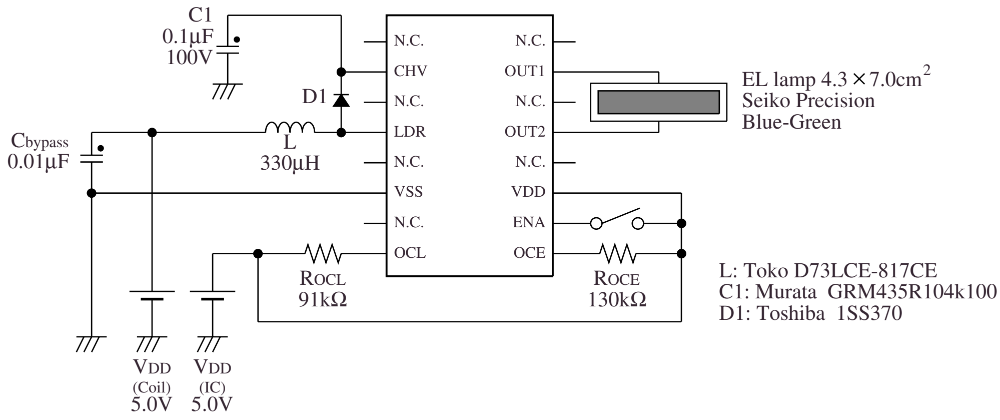


Figure 33. Application circuit

EL size [cm^2]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
30.1	470	91	150	25.5	313	166	25.8
30.1	470	130	130	30.8	355	172	30.1
30.1	470	180	91	42.4	513	168	36.0
30.1	330	91	130	38.4	353	184	35.3
30.1	220	91	91	53.4	503	184	44.3

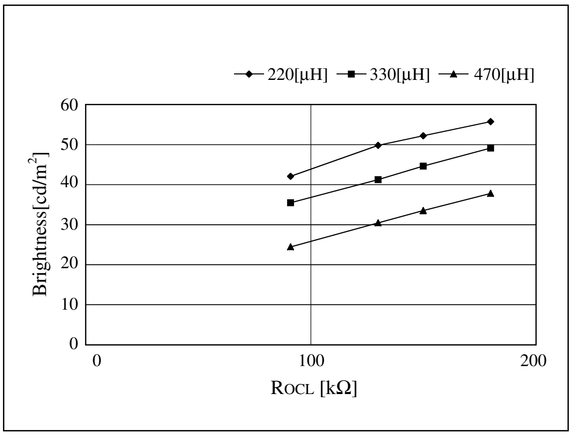


Figure 34. Brightness – R_{OCL}
(R_{OCE} = 180kΩ)

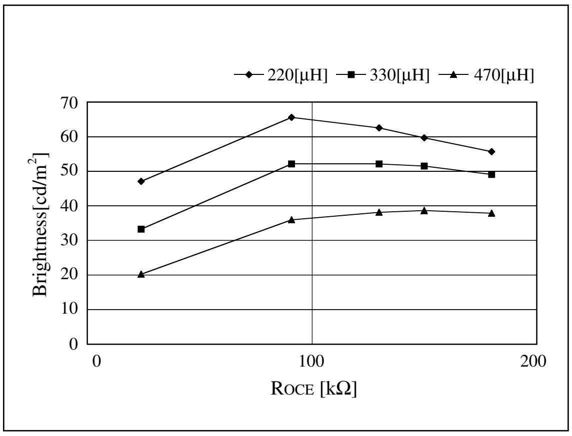


Figure 35. Brightness – R_{OCE}
(R_{OCL} = 180kΩ)

V_{DD}: 5.0 [V], EL size: 50 [cm^2]

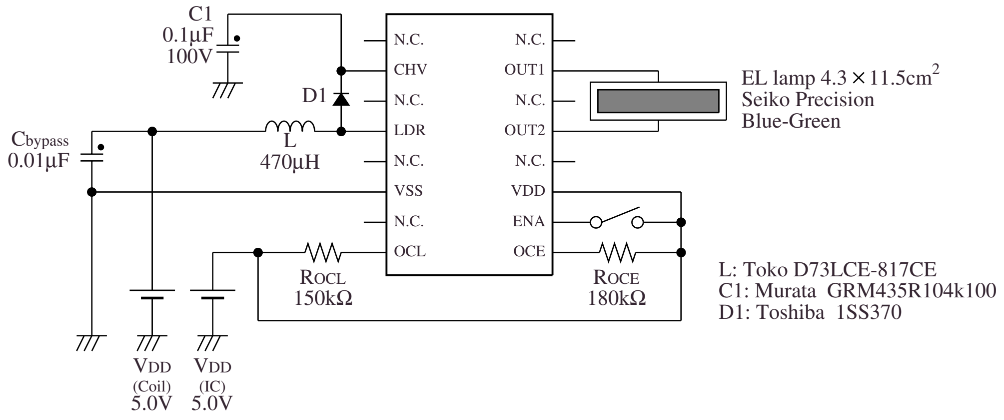


Figure 36. Application circuit

EL size [cm^2]	Inductance [μH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
49.5	470	91	270	25.2	177	176	16.9
49.5	470	150	180	36.9	225	176	23.1
49.5	330	130	150	53.3	314	186	30.8
49.5	330	180	91	68.2	511	168	35.0
49.5	220	150	91	82.9	495	182	40.6

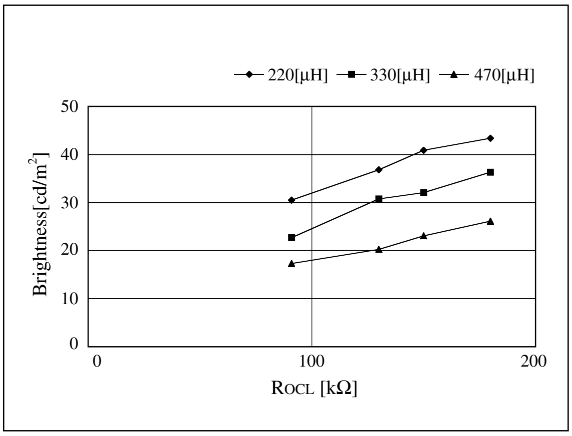


Figure 37. Brightness – R_{OCL}
(R_{OCE} = 180kΩ)

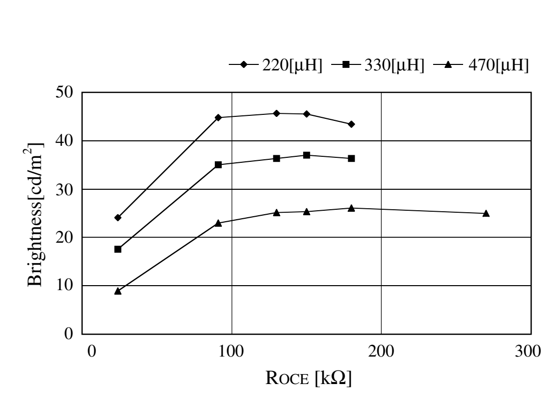


Figure 38. Brightness – R_{OCE}
(R_{OCL} = 180kΩ)

V_{DD}: 5.0 [V], EL size: 80 [cm^2]

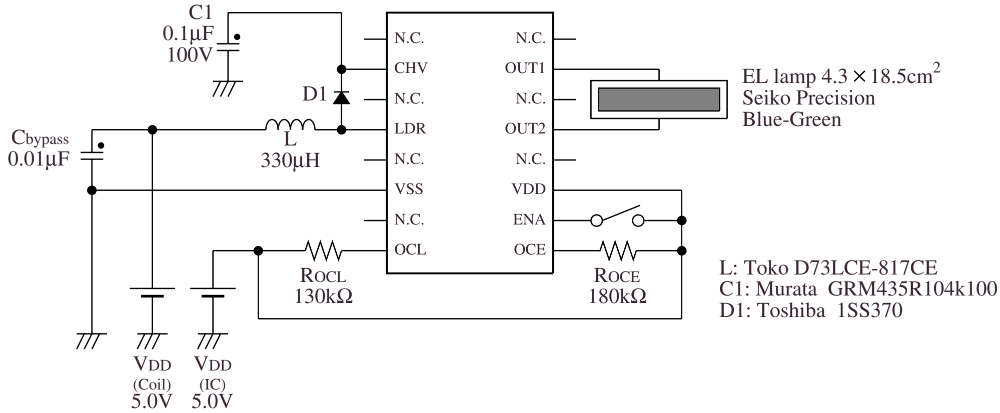


Figure 39. Application circuit

EL size [cm^2]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness [cd/m^2]
79.6	470	91	360	25.9	135	166	11.7
79.6	330	91	270	38.3	177	172	16.1
79.6	330	130	180	53.9	262	168	20.6
79.6	330	180	150	68.5	314	174	24.3
79.6	220	150	130	82.8	355	174	27.7

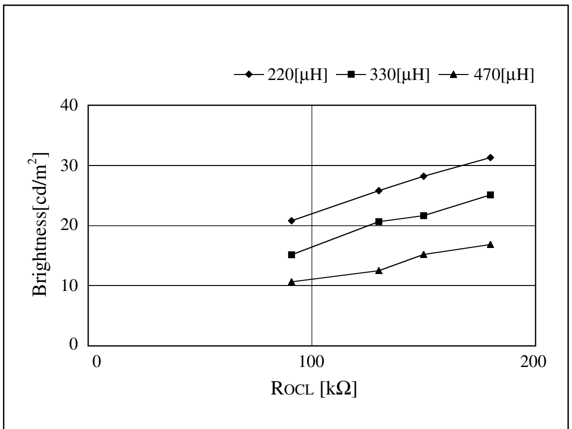


Figure 40. Brightness – R_{OCL}
(R_{OCE} = 180kΩ)

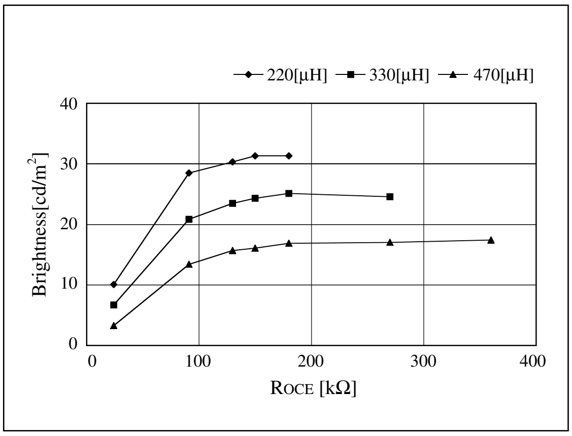


Figure 41. Brightness – R_{OCE}
(R_{OCL} = 180kΩ)

White EL lamp (color LCD) application

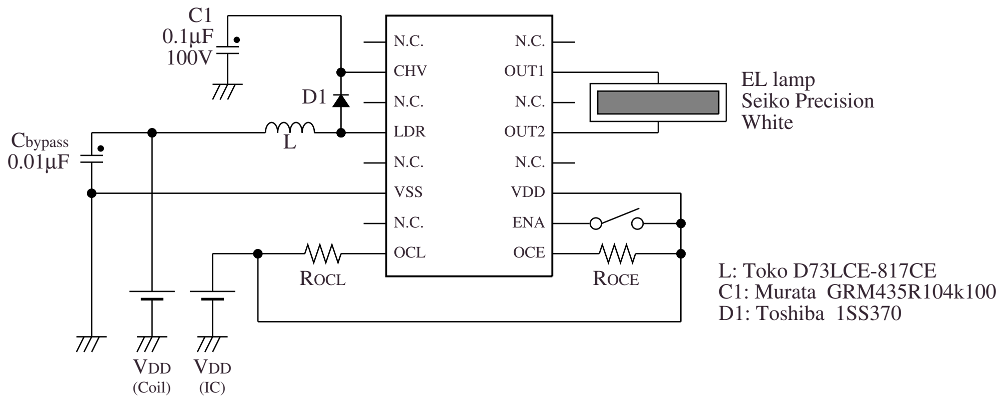


Figure 42. Application circuit

VDD [V]	EL size [cm²]	Inductance [µH]	R_{OCL} [kΩ]	R_{OCE} [kΩ]	Current consumption [mA]	f_{OUT} [Hz]	V_{OUT} [Vp-p]	Brightness enhancement film*1 (none) Brightness [cd/m²]	Brightness enhancement film*1 (1 sheet) Brightness [cd/m²]	Brightness enhancement film*1 (2 sheets) Brightness [cd/m²]
5.0*2	20.0	220	180	39	95.2	1060	196	102.2	143.9	175.9
3.0	20.0	220	180	91	85.8	488	190	56.7	81.2	101.0
3.0	10.0	220	180	39	85.6	1020	184	89.6	127.2	156.5

*1. 3M Brightness Enhanced Film (BEF) is employed.
*2. This setting is around the ratings. Please consider the margin for the actual design.

Note: Current (Power) consumption and Output voltage should NOT be over the ratings.
Please be careful about the design for high brightness.

CONSIDERATIONS SEVERAL TYPES of NOISE

This section considers several types of noise subdivided into audible noise, electromagnetic noise, and supply wraparound noise. Please refer to datasheet for details.

Audible Noise

Audible noises (or ringing) are mainly caused by the capacitor (C_{CHV}) and the EL panel itself. In addition to the noise from these sources is resonant noise from the case, PCB and other components (especially the capacitor).

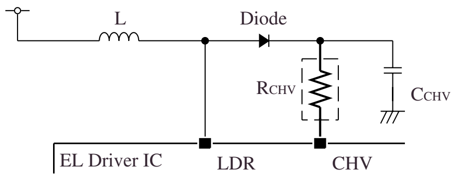
Capacitor (C_{CHV})

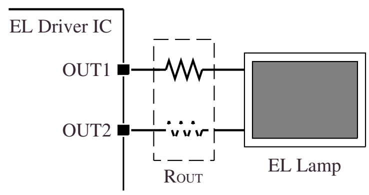
Electrical Considerations

The capacitor (C_{CHV}) connection is very susceptible to ringing noise generation due to voltage fluctuations caused by the EL driver. Generally speaking, high-withstand voltage type capacitors generate less ringing noise.

Relatively high ringing output ceramic chip capacitors can be replaced with low ringing output mylar chip capacitors, and further benefit can be obtained if mounting and cost aspects allow.

If the range of devices available for selection is small, electrically reducing the effect of voltage fluctuations will reduce the ringing noise generated. Specifically, R_{CHV} should be inserted (10 to 20kΩ) and R_{OUT} should be increased (50kΩ max).

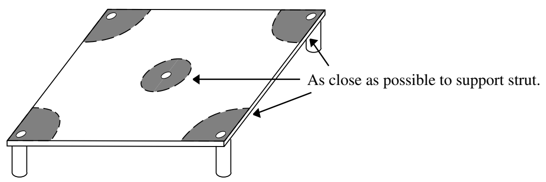




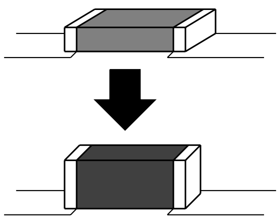
The reduction in C_{CHV} ringing noise is the same in both cases, but making R_{OUT} larger does have an unfavorable result on efficiency. Inserting R_{CHV}, however, is an effective way of reducing only the C_{CHV} ringing noise.

Physical Considerations

The capacitor, which generates the ringing noise, should be mounted as close as possible to the support struts to reduce PCB and case resonant noise. If possible, a more sturdy PCB construction should also be considered.



Furthermore, if the chip capacitor is mounted laying on its side, then the contact area with the PCB is minimized which will also help reduce noise.

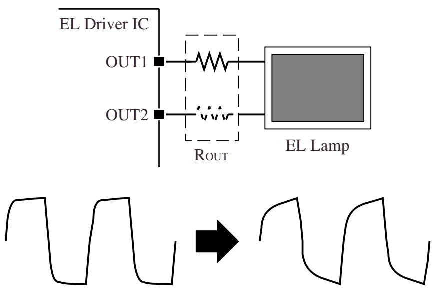


EL Lamp

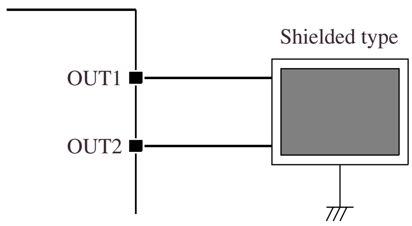
The EL display has a piezoelectric characteristic, which may generate output noise. There is generally 2 sources that can cause noise, the potential difference between the EL display electrodes and the potential difference between the EL display and other components, such as a ground plane.

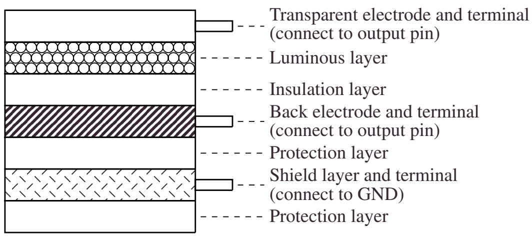
Electrical Considerations

The EL lamp noise can be reduced by inserting R_{OUT} (50kΩ max) which causes the output waveform to be modified such that the high-frequency components are reduced (see page 4, Output Waveform).



A shielded (3-pin type) EL display is effective in preventing noise between the EL display and other components. Also, the piezoelectrice effect can be prevented by avoiding potentials on plane surfaces, such as VDD or ground planes.





Construction of shielded EL

Physical Considerations

The most effective means of protecting the EL display physically is by using non-woven fabric cloth or PET (plastic) film for absorbing and limiting vibration.

Electromagnetic Noise

In addition to the EL lamp acting as an antenna, the driver circuit with its high-voltage booster circuit that uses an inductor and capacitor generates radiated noise caused by the current and capacitive noise induced by the voltage.

Wiring and Layout

In particular, all circuit wiring between the high-voltage inductor, capacitor (C_{CHV}), diode and EL driver LDR pin should be as thick and as short as possible.

Also, the wiring between the outputs (OUT1, OUT2) and EL lamp should be as thick and as short as possible.

EL Lamp

The EL lamp can act as an antenna and emit noise, so, where possible, a shielded EL lamp should be used to reduce the emitted noise.

Components easily affected by induced noise should have their wiring located well away from the EL lamp wiring to prevent induced noise.

Resistor R_{OUT} can be inserted to reduce the high-frequency component of the EL driver waveform. Resistors can be inserted at one or both outputs to the EL lamp. If a single resistor is inserted, it can be inserted in the output closest to components affected by induced noise, or in the output furthest from components affected by induced noise. Generally, it is not possible to definitively say which method is the most effective. The best result is obtained by trial-and-error.

Inductor

The inductor is a source of electromagnetic noise, so peripheral components should have high impedance and wiring layout to avoid induced noise. If possible, the inductor should be a closed-magnetic type, such as a toroid.

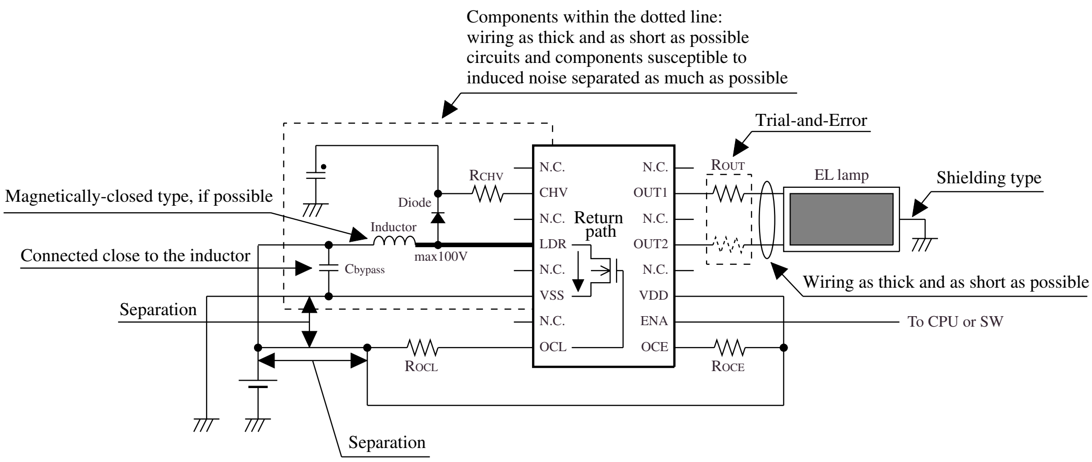
Supply Wraparound Noise

In the booster circuit, the inductor drive transistor switches ON/OFF, generating a sawtooth waveform (see page 3, Figure 8) whose pulse travels from the EL driver LDR pin through to the VSS pin, thereby forming a return path back to the supply. Accordingly, a bypass capacitor (C_{Bypass}) should be connected, adjacent to the inductor, between the inductor and the EL driver VSS pin to absorb the pulses.

Note that the LDR pin voltage is boosted by the inductor and can have amplitudes up to 100V.

The supply system connected to the inductor should also be separated as much as possible from the supply lines for other components.

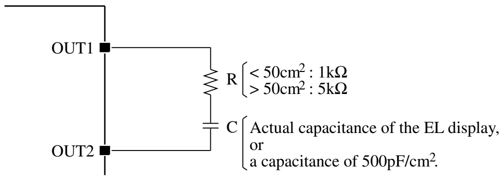
Notice to Application Circuit



Component	Description	Value
Inductor	Booster inductor. The current flowing through the inductor is a triangular waveform, and care should be taken so that the peak current does not exceed the maximum current. An inductor with low resistance will help reduce loss.	0.15 to 0.68mH
Diode	A fast recovery diode with short reverse recovery time at peak reverse voltages exceeding 100V.	
C_{CHV}	Capacitor rated at ≥ 100V	0.1μF (100V)
R_{OCL}	Inductor drive frequency control resistor	51 to 1000kΩ
R_{OCE}	EL drive frequency control resistor	51 to 1000kΩ
C_{Bypass}	Supply bypass capacitor (noise cut)	0.01μF
R_{CHV}	Optional. Reduces the output waveform rise time, and reduces noise.	10 to 20kΩ
R_{OUT}	Optional. Reduces noise emitted by the EL element.	≤ 50kΩ

EQUIVALENT CIRCUIT

The EL display driver must not be operated without an output load as this may damage the IC. For testing purposes, including testing during the manufacturing process, where the IC cannot be connected to an EL display, the following equivalent circuit should be used.

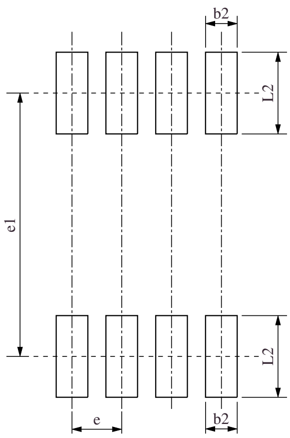


FOOTPRINT

The optimum footprint varies depending on the board material, soldering paste, soldering method, and equipment accuracy, all of which need to be considered to meet design specifications.

(Unit: mm)

Package	b2	L2	e	el
VSOP-16	0.55	0.95	0.65	5.90



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