Semiconductor Laser Diodes

Application Notes

Rev.001

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1, Precautions for Laser Diodes

1-1 Absolute Maximum Ratings

If an excessive current flows in a laser diode, a large optical output is generated occur and the emitting facet may be damaged. This optical damage can happen even with a momentary over-current. Therefore, it specifies the largest current that must not be exceeded even for a moment. In particular, please pay attention to excessive currents when a power supply is applied and excessive currents caused by static electricity. Although an use within the absolute maximum ratings is guaranteed, the values are specified in the condition of 25°C. As the temperature of the laser diode rises, its maximum output power and power dissipation decreases and its operating range is reduced. Even within the absolute maximum ratings, the life becomes shorter by using at high temperatures. For this reason, the design should include sufficient margin for heat radiation and light output.

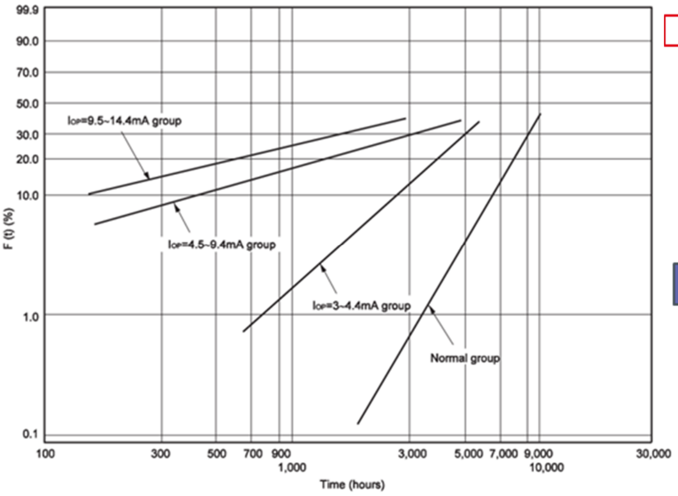
1-2 About Heat radiation

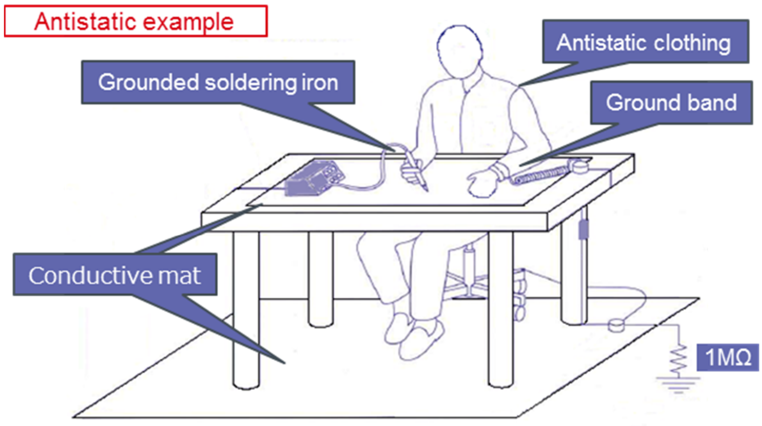
A laser diode generates some heat at the junction points with a long time of electric current like general semiconductors. As a result, the temperature of the element increases. Without an enough heat dissipation, the case temperature rises, and the light output is reduced, so a more current must be needed to maintain the light output. An increase in the forward current causes a further rise temperature of the case, and then that requires a more forward current. It seems a negative spiral. Therefore, please use a heat sink (30x30x3 mm or larger) of aluminum or similar materials in close contact with the steam of the laser diodes.

1-3 Protection against damage due to electrostatic discharge and other current surges

Electrostatic discharge and other current surges can cause deterioration and damage in a laser diode, resulting in reduced reliability (Fig.1). Please note the following.

a. Ground equipment and circuits. Do not allow a noise into the ground line. Please implement countermeasures such as noise filters or noise-cut transformers for each power input section.
b. Wear anti-static clothing, hat and shoes when working. Always use a grounding band to ground the human body through a high resistance 1MΩ, especially while working.
c. Use an antistatic case for transport and storage.
d. Note that if an excessive surge current flows through the laser diode when the power is turned on and off, it may damage and deteriorate.
e. Nearby equipment that generates high-frequency surges, induced surges may degrade and destroy a laser diode. Therefore, avoid using it near something like fluorescent glow lamps.





(Fig.1) Effect of electrostatic discharge on LD life

1-4 About Soldering

When soldering to the laser lead, the soldering iron must be grounded and the soldering conditions must be the following;

- ・temperature : 350℃ or below
- ・time : 3 seconds or shorter
- ・distance : at least 2 mm away from the root of the lead

Do not solder the lead edge as the plating may be thin. Please be careful with below points.

a. The adhesiveness of the die-bonding paste drastically declines at a high temperature; thus, entire temperature of the package must be careful to prevent increasing. **We don't recommend heating the whole package such as reflow soldering.**
b. Partial heating of the lead terminals one by one is recommended. (Please avoid simultaneous heating of multiple leads.)
c. Even if only the leads are heated, the package will become hot due to heat conduction, so it is recommended to use a heat sink or other means to dissipate heat before soldering.
d. It is recommended to solder the GND lead first to restrain the heat conduction from the lead frame.

1-5 About the use of the glue

There is the possibility that the volatilization component of the glue exerts the influence on the characteristic of laser diode.　Please use it after checking sufficiently.

1-6 About handling packages

Do not drop from a height or apply excessive pressure to the package. Please be careful to ensure that the forming process that bends the leads does not damage the glass seal or cut the wire by applying stress to the leads in the package.

For products with glass windows

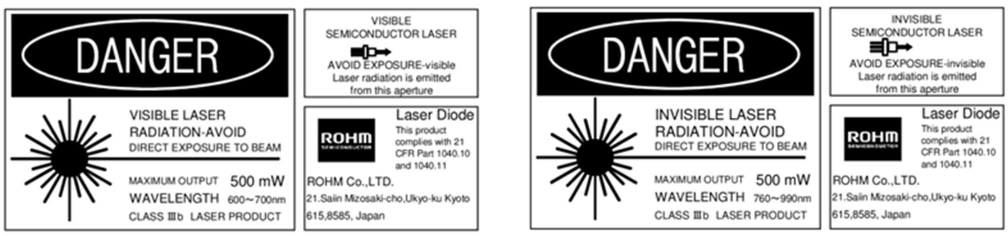
Never touch the glass part of the laser. Any scratches or stains on the glass window will alter the optical characteristics of the laser.

For open package products

The external environment may degrade the characteristics and reliability. Please take enough measures against toner, human foreign objects, foreign objects including cigarette smoke, corrosion by ions, effects of volatile components of adhesives and flux, condensation, optical tweezers effect, etc. Also, be careful not to touch the components inside the cap, including the laser chip.

1-7 About Safety

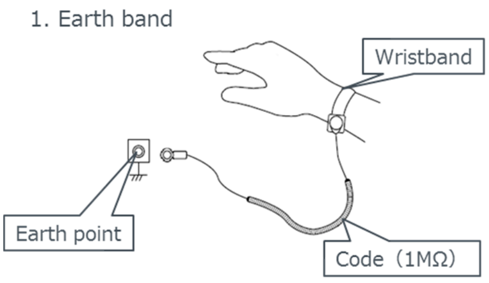
Viewing the light emitted from a laser diode directly or through the lens is very dangerous. Use a TV camera or other similar device to adjust the optical axis. The laser diodes package has a warning label as shown below.



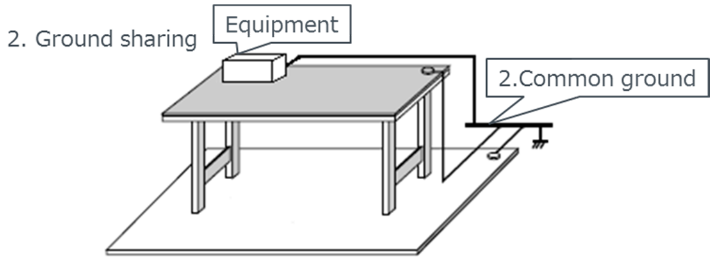
2, Surge prevention for laser diodes

2-1 Examples of surge prevention

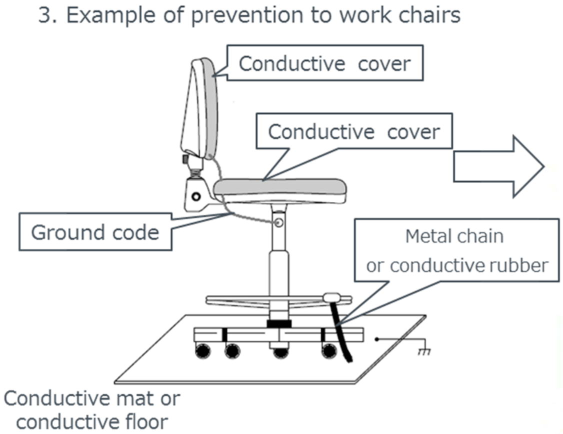
Category	No.	contents	example
Work environment	1	Secure the grounding properly by oneself.	Attach the grounding band through 1Ωresistor.
	2	Standardize the grounding for workbench, inspection equipment and mounting platform.	Standardize the grounding for shield room when using there.
	3	Secure the grounding for the work chair which is electrically charged.	Cover the work chair with the electrostatic cover and attach the ground chain.
	4	Wear the conductive clothing.	
	5	Install the conductive mat in the product rack.	
	6	Use the conductive material to made the trays used in the process.	resistance value（10^6～10^9Ω/□）
	7	Use ion blowing or work in a weak ion atmosphere in conductive environment.	
	8	Control the humidity of the room atmosphere	Target 50±10% RH.
equipment	9	Wire to each measurement power supply through noise filters.	
	10	Install a static eliminator on the belt that touches the equipment to prevent it from being charged.	
	11	Secure the grounding of the product suction pads.	
	12	Prevent chatter from occurring in a relay that connects to the power supply.	
	13	Use a power supply with no ripple.	
Operation	14	Do not turn the power supply ON/OFF while the specified voltage is applied, when measuring electrical characteristics.	Turn off the power supply by dropping the volume resistors, turn it on and then raise it to the specified voltage.
	15	Do not turn ON/OFF the power to the lines or lights in the same room when assembling Laser Diode and adjusting operations.	
	16	Adjust initially the voltage of the volume resistance which controls the power supply voltage to the lowest point. （Volume resistance is often set at an intermediate value.）	
other	17	Use the conductive gloves and finger sacks.	
	18	Connect the end of the soldering iron to the ground.	Use a soldering iron with three-terminal.
	19	Check the effectiveness of static elimination if iron blowing is used.	
	20	Use the volume resistors with no entanglement.	Replace the volume resistors on a regular basis.



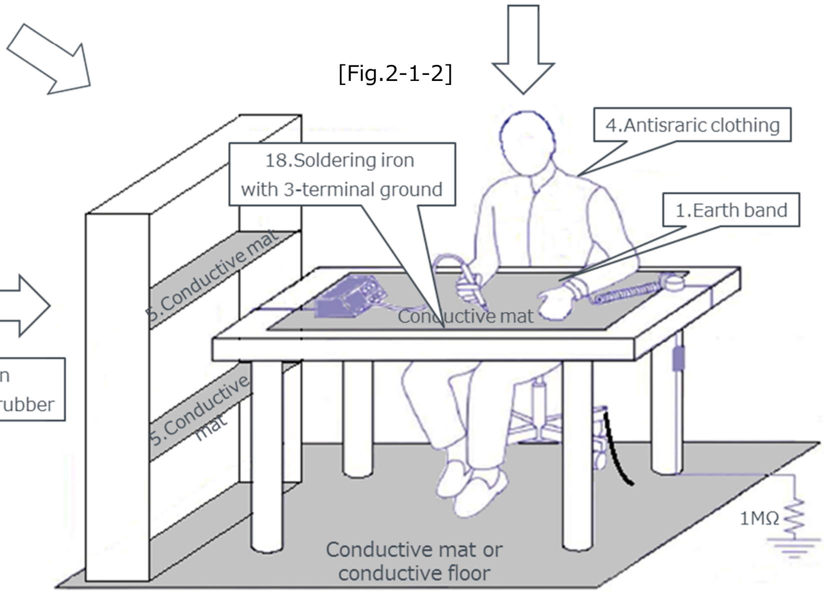
[Fig.2-1-1]



[Fig.2-1-2]



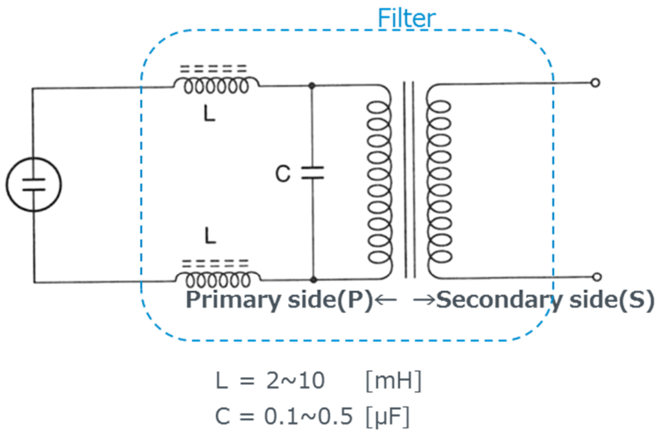
[Fig.2-1-3]



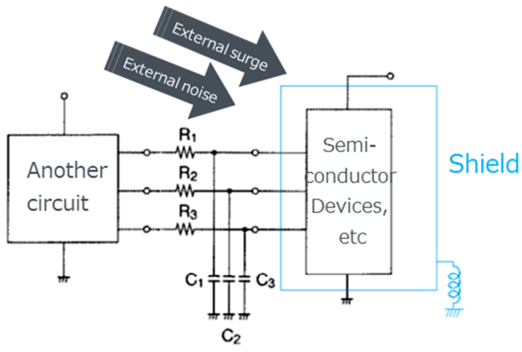
[Fig.2-1-4]

2-2 Measures against noise and surge voltage

Generally, the electronic devices are designed including about 10% increase or decrease as changes of the consumer power. However, if a machine that generates surge voltage is used in the vicinity, malfunctions or malfunctions caused by fluctuations in the power supply voltage may occur. This is due to a surge superimposed on the power lines and a surge of impulse state can be induced in case of lightning, etc. In response to that, it could be reduced by inserting the filter like [Fig.2-2-1] into the AC line side. Even if a surge and static electricity do not indirectly enter from the AC line, if there is a risk of direct application to components including semiconductor devices in the circuit board, the shield is required to be attached and the ground impedance to the shield is also required to be low value. [Fig. 2-2-2]
In case that static electricity or surge pulse may be applied directly as noise, as a special case, a protective circuit may be inserted as shown in the figure. The time constant of Rx × Cx should be set to the range suitable for absorbing surge pulse without affecting the operation.



[Fig.2-2-1]



[Fig.2-2-2]

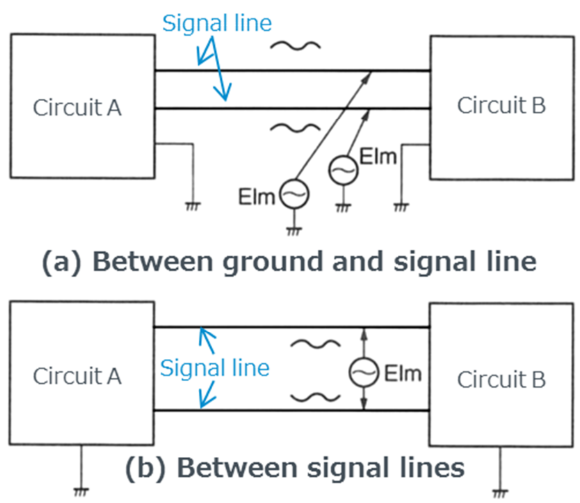
2-3 Variety of noises

Some of the noise that can cause implementation problems is (a) generated between the ground and signal lines and (b) induced between the signal lines. [Figure 2-3-1]

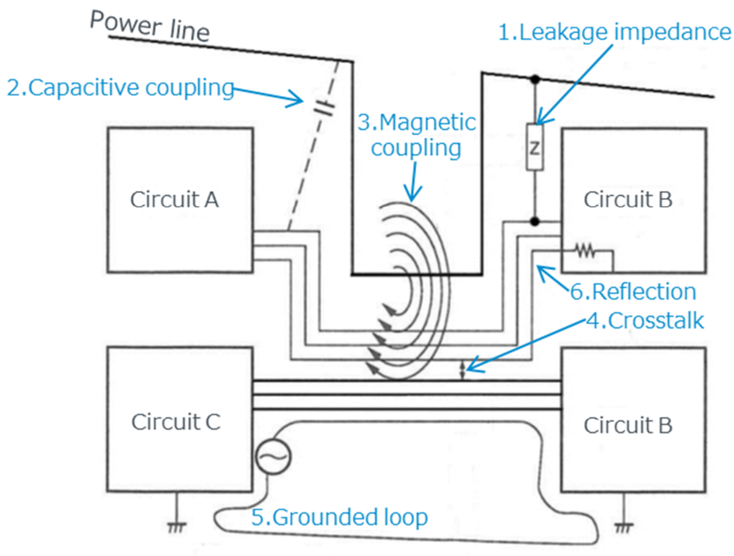
These have different effects on the devices and how to deal with them. The following is examples of coupling a noise source and a signal line. (The conceptual diagram of a power line as a noise source is shown

in [Fig. 2-3-2].)

1、By conduction	The leakage impedance between noise source and signal line.
2、By electrostatic induction	The capacitive coupling between noise source and signal line.
3、By magnetic induction	The mutual conductance between noise source and signal line.
4、By crosstalk	When two or more signal lines are adjacent to each other, electrostatic or electromagnetic induction induces a noise voltage on one of the signal lines.
5、By grounded loop	The potential difference between two points becomes a noise when the signal Lines are installed for transmission and reception.
6、By reflection	Reflected waves due to impedance mismatch in signal lines are superimposed on the signal.



[Fig.2-3-1]



[Fig.2-3-2]

2-4 Noise Reduction

To create a noise-free system, find the source of the noise and eliminate or reduce it. Try not to pick up noise. Use a circuit with a large noise margin. Provide protection circuits.

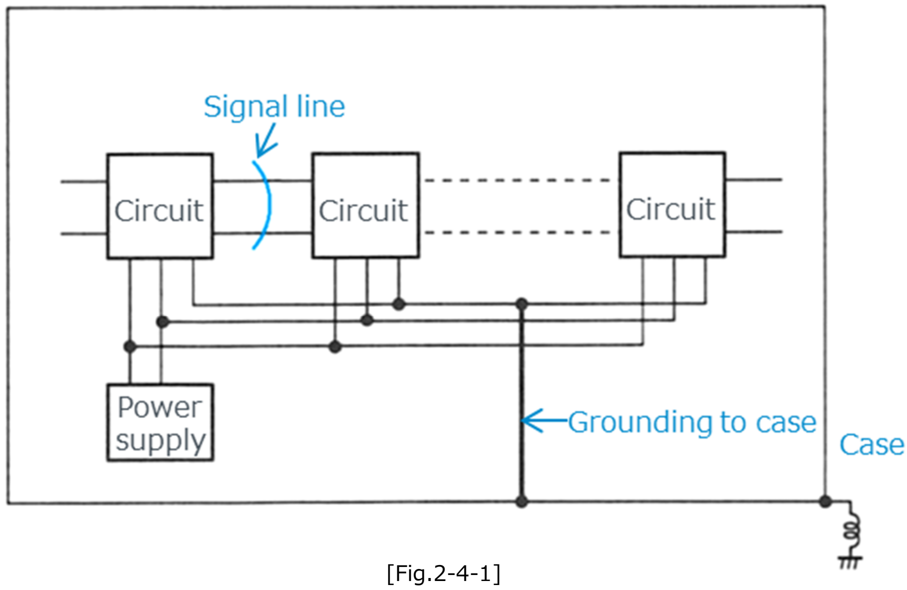
1. Countermeasures at the noise source

The most effective countermeasure is to treat the source of the noise. This can be done by using diodes, or resistors, capacitors, and capacitors in parallel with the relay coil. The surge voltage can be reduced by inserting a filter. Also, for noise passing through the AC power supply line, a filter can be inserted into the source power line. For devices that generate a strong electric field, if a countermeasure is implemented on the source side, such as applying a shield to the device that generates a strong electric field, the disturbed device will be subjected to a disturbance.

No system-wide measures are required. Other measures, such as separating it from the source of the problem, are also possible.

2. Grounding line measures

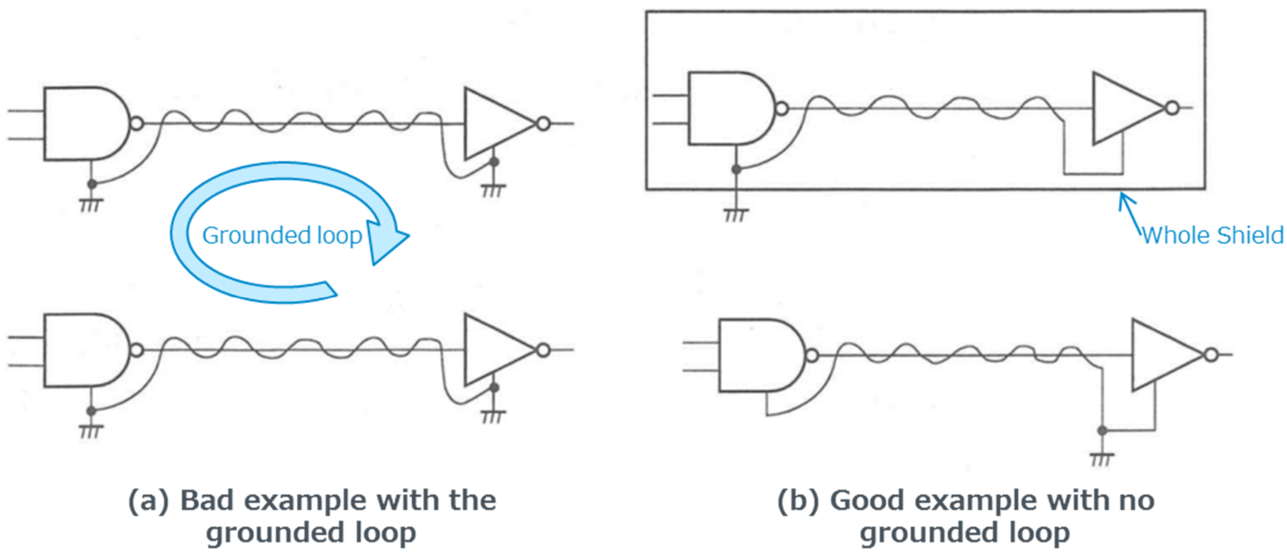
The circuit system grounding line should be dedicated and completely separated from the other power lines and other grounding systems to eliminate the current flowing through the grounding system to the circuit system. In addition, only one point of grounding between the circuit system and the enclosure is required, and the circuit system and the enclosure must be do not form a closed loop. [Figure 2-4-1]



[Fig.2-4-1]

3. Shield measures

Shielding the signal lines, and the entire system, is a good way to reduce the impact of external noise. In case of noise due to electrostatic coupling, cover it with a good conductor and ground it. This allows noise that would be included on the signal line in the absence of shielding to be induced in the shielded line and it is bypassed to ground. Other examples of shielding are the commonly used twisted-pair wires. Noise is reduced if the two signal lines are symmetrical in terms of signal source, receiver circuit and ground noise source. If the twisted-bitch of the signal line is also made smaller than the transmission distance, it can be balanced and external noise is reduced. In the case of twisted pair wires, a grounding loop may occur, but it can be eliminated as shown in [Fig. 2-4-2].



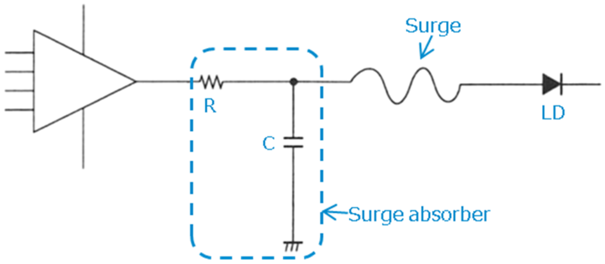
[Fig.2-4-2]

4. Filter measures

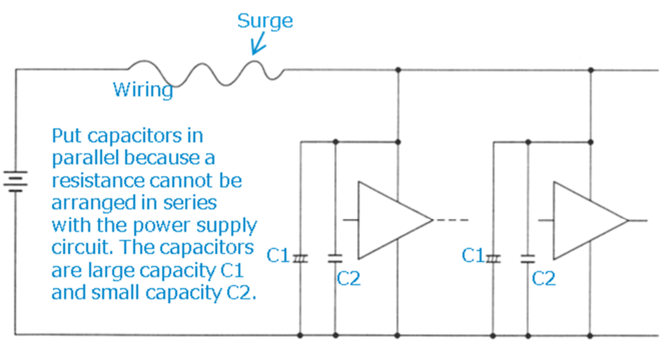
Generally, power supply noise tends to enter through the AC lines, so AC line filters are installed on the source side or the AC power supply side of the circuit system. It is also necessary to reduce the power supply impedance from the circuit system side as much as possible, so capacitors are inserted at each point of the power supply line to reduce the impedance to noise. In this case, it is desirable to insert in parallel a large capacitor as a bypass for relatively low frequencies and a small capacitor with low impedance for high frequencies.

5. Surge Protection

Circuit systems can be subjected to surge voltage effects. The main examples are listed here. When an LD is used in the same set as an oscilloscope, if the high voltage circuits are close to each other, surge voltages may be applied due to discharge. [Fig.2-7] and [Fig.2-8] show examples of LDs with resistors and capacitors between their terminals to absorb and reduce surge voltage. How to reduce the surge voltage is a major factor for improving reliability. [Fig. 2-7] is an example where a capacitor and a resistor are inserted to protect the output end of the LD to reduce the surge induced in the lead wire. [Fig. 2-8] shows an example of absorbing a surge entering the power supply, and to prevent the surge destruction of LDs, it is necessary to search for the surge penetration path and the penetration terminal and take the measures described above. The next thing that is often overlooked is that there is a case where a potential difference is caused by a surge on the line of the power supply line that is originally thought to be equipotential, and the LD may be destroyed. In this case, it is necessary to take measures to prevent surge-induced damage to the line by using an arrangement and wiring system that does not cause a surge, by applying a shield, and by considering the ground point.



[Fig.2-4-3]

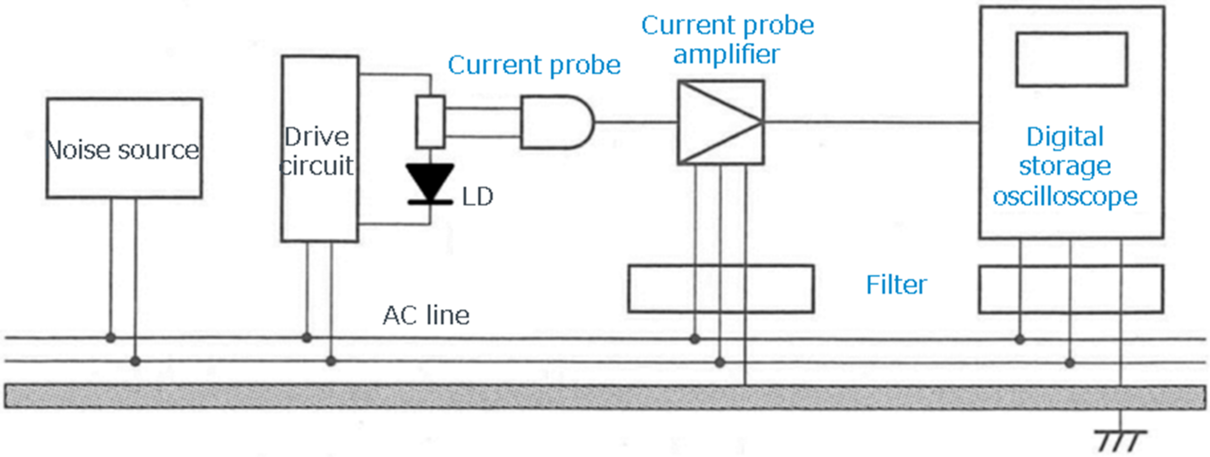


[Fig.2-4-4]

6. Surge measurement method

In the previous section, we have discussed how to remove noise that causes surges.

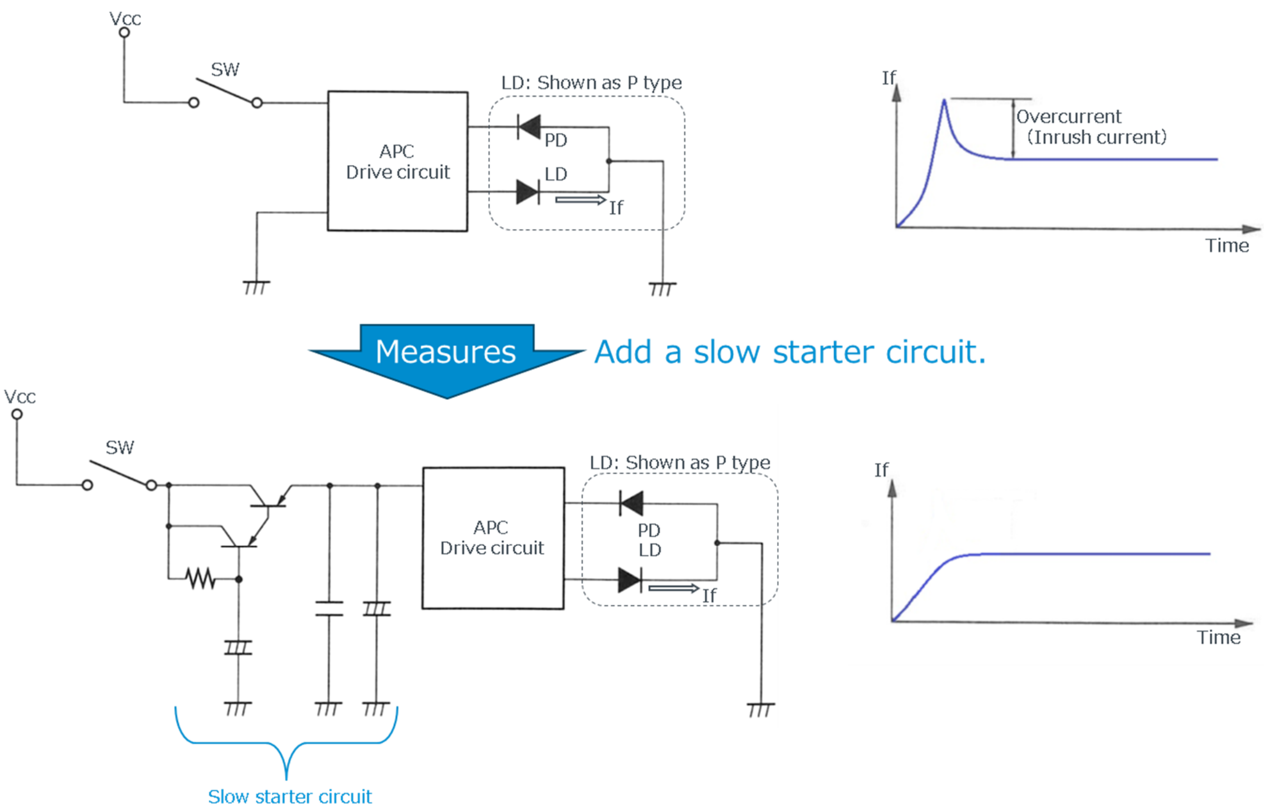
Please design and develop your circuits and systems with these measures in mind. After the circuit and system are decided, it is necessary to check the current in the LD drive circuit for actual surges, as close as possible to the actual drive conditions. For this purpose, as shown in [Fig. 2-4-5], use a rolling mode with a current probe and a digital storage oscilloscope to confirm that no surge is generated during actual operation. (The figure assumes a noise source, but there are many cases where surges are generated by the drive circuit. In this case, you can still detect the surge with this method.)



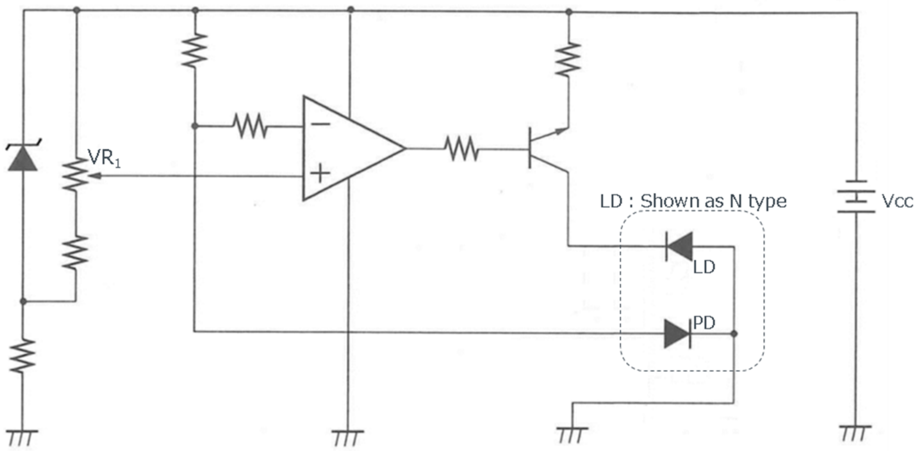
[Fig.2-4-5]

2-5 Examples of surge destruction and measures

1.Overcurrent (inrush current) breakdown at the time of APC circuit mounting : Breakdowns due to transient characteristics at the rise of power supply



2. During the exchange of samples in the APC circuit, VR1 was lowered and LDs were exchanged in order to reduce the optical output to zero, but the exchanged LDs were destroyed by an overcurrent. When the previous LD was removed, the circuit became open and the output voltage rose to Vcc, which caused an overcurrent to flow to the next LD and destroy it.

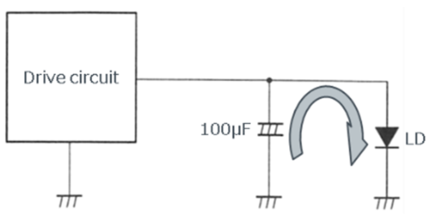


Measures — Reduce output voltage before setting LD.

After lowering VR1 so that the light output becomes 0, Vcc is lowered so that the output voltage becomes 0, and then the LD is set.

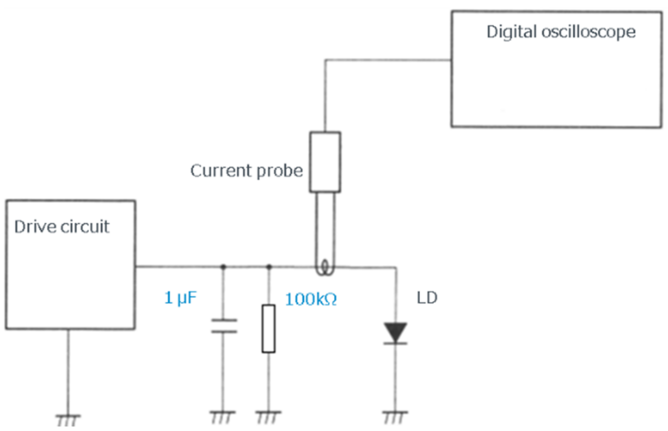
3. Destroyed because a large capacitor was connected to the drive power supply terminal.

：The voltage charged to the capacitor when the power supply is turned off causes current to be applied to the LD drive power supply terminals in reverse, resulting in an overcurrent breakdown.



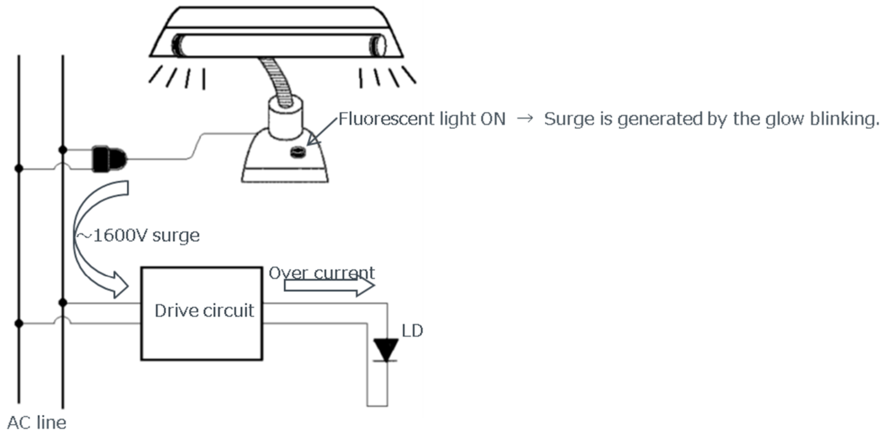
Measures

Optimize capacitor capacity.
Put a resister in parallel with the capacitor.
Check if transient surge is applied when the circuit is ON/OFF.



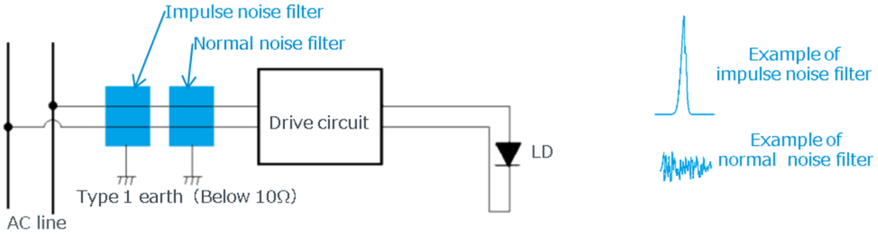
4. LDs were destroyed the moment the fluorescent lamp on the next seat was turned on during LD characteristics measurement.

: This is due to a surge of ~ 1,600 V in the common AC line when the fluorescent lamp is turned on and enters the AC input of the LD drive circuit.

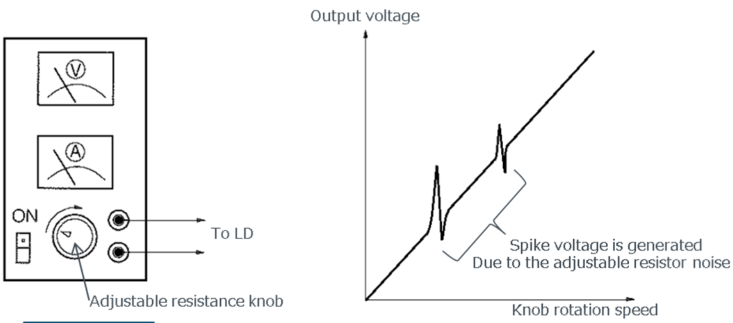


Measures

Put both impulse and normal noise filters between the AC line and the drive circuit.
Separate the noise source and the AC line of drive circuit.

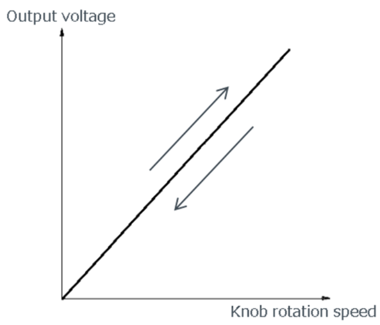


5. LDs were broken when the variable resistor was turned during the output adjustment of LDs. Overcurrent flowed and destroyed due to the skinny variable resistor.



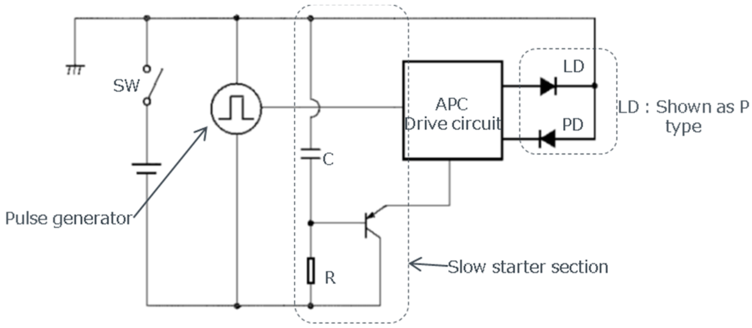
Measures

Replace the adjustable resistor regularly.
Check that there is no spike voltage by the oscilloscope.
Keep the process clean to avoid dust on the adjustable resistor

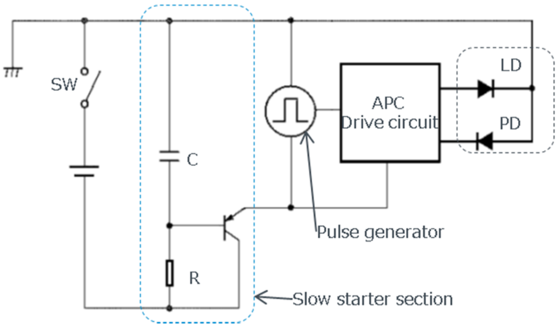


6. LDs were destroyed when the power SW was turned on in the circuit below.

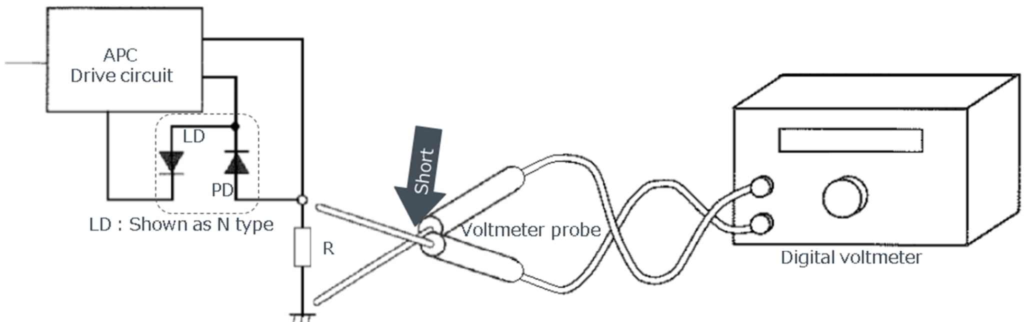
A large time constant of the slow starter causes a delay in the rise of the APC, resulting in an overcurrent that destroys it.



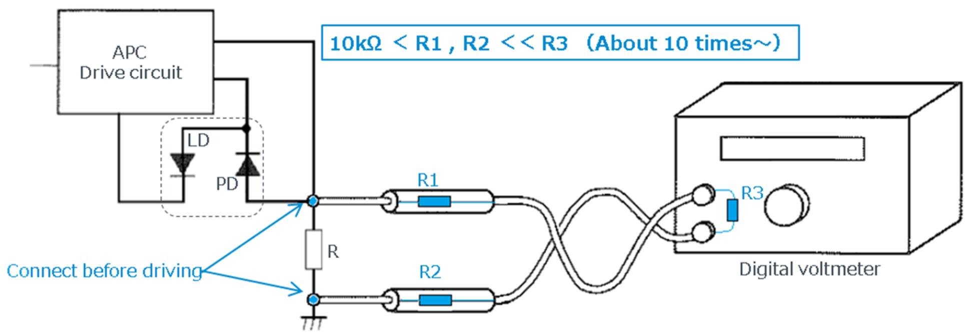
Measures Pulse generator is set behind the slow starter section, and rise and APC are occurred at the same time.



7. The LD was destroyed while measuring the monitor voltage in the APC circuit to check the light output. The probe of the voltmeter short-circuited each other and the monitor voltage became 0, which caused an overcurrent to flow to the LD. (In the figure below) A surge from the voltmeter may cause a decrease in the monitor voltage and an overcurrent to occur even without a short circuit.



Measures Don't check by external contact while the APC circuit is driving. Connect to the appropriate pins before driving.



3, Laser Diode Drive Circuit Design Method and Spice Model

ROHM offers laser diodes (LDs) for Light Detection and Ranging (LiDAR). This application note will introduce ROHM's LD line-up and show how to design the drive circuits of ROHM LDs. In addition, ROHM provides an evaluation board and a Spice model for evaluating LDs and will show how to use them and some important points.

3-1 The Lineup and Features of ROHM's Pulse LD

Pulse laser diodes are LDs that produce high optical output power with short current application time (pulse width). In recent years, many applications, such as distance measurement, have emerged.

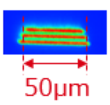
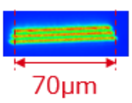
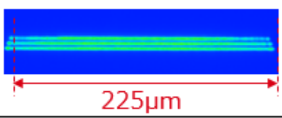
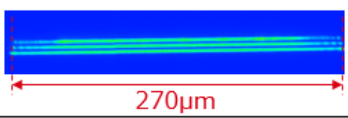
Many LDs are designed with continuous wave (CW) drives that produce optical output from a few mW to several W. When such LDs try to output higher optical output power than a specific optical output power, even if the pulse width is short, the optical cavity is damaged, and the optical output cannot be generated.

However, pulse LDs are designed to produce high optical output power with short pulse widths. The drive of the pulse LD must be determined by the pulse width and duty cycle. In order to achieve high optical output power, the duty cycle must be very small. For example, a duty cycle of 0.05% (100 µs per cycle, 50 ns pulse width) means that very short pulse currents are repeatedly applied in the kHz range. The applied current to the LDs is from several A to several tens of A to produce high optical output power pulses.

The wavelength of pulse LDs is material-dependent, and ROHM can offer 905 nm. 905 nm wavelength range is made up of AlGaAs, a material with high reliability, high beam quality and stable temperature characteristics. Pulse laser diodes use a stack structure consisting of multiple light-emitting layers to achieve high optical output power. ROHM's three-layered stacks are used to achieve Up to 120 W optical output can be provided.

ROHM's pulse LDs are characterized by a narrow luminescence width and good wavelength temperature dependence. Table.1 shows the emission images for the optical output lineup. The narrower the luminescence width, the higher the optical density, and the longer the distance can be measured with the same optical output power. In addition, the narrower the luminescence width, the smaller the beam area can be when irradiating an object, which enables a higher resolution LiDAR module to be used.

Table 1. Luminescent Images for Optical Output Lineup

output※	25W		75W	120W
model	RLD90QZW6	RLD90QZW5	RLD90QZW3	RLD90QZW8
Emitting width (Physical size)	**50µm**×10µm	**70µm**×10µm	**225µm**×10µm	**270µm**×10µm
Emitting width (FWHM)	**44µm**×10µm	**64µm**×10µm	**170µm**×10µm	**210µm**×10µm
Emitting figure				

※ Optical output with a pulse width of 50 ns

Improving Signal to Noise (S/N) ratio in LiDAR's optical system, put in a band-pass filter to cut other than required wavelength range. The wavelength temperature dependence of ROHM's pulse LDs have an outstanding wavelength temperature dependence of 0.15 nm/℃. This makes it possible to design a narrower wavelength range for the band-pass filter to cut, thus improving the S/N ratio of LiDAR modules.

3-2 LiDAR and ToF method

LiDAR is an abbreviation for "Light Detection and Ranging" and has been attracting attention in various fields such as automobiles, robots, drones, surveillance cameras, etc. Time of Flight (ToF) method is the most used distance measurement method in LiDAR. In the ToF method, as shown in Fig. 3-2-1, the distance is calculated by measuring the time it takes for the light emitted from the light source to be reflected by the object and returned to the detector (flight time).

The distance between the light source and the object is defined by the following equation, where *d* is the distance between the light source and the object and t_f is the time of flight.

$$d = \frac{c \cdot t_f}{2} \quad \cdots (2\text{-}1)$$

c is the speed of light in above equation.

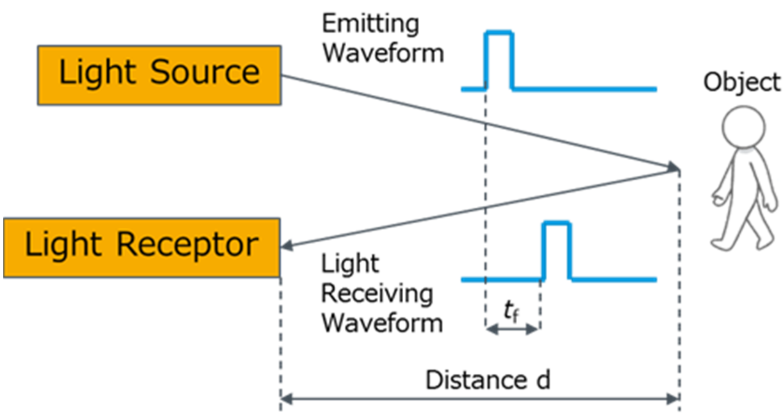


Fig. 3-2-1. Conceptual diagram of the Time of Flight(ToF) method.

Higher optical output power is required to improve the measuring distance. The farther away the distance is, the lower the rate of return of the optical output power. That is caused by light attenuation in the air. *1 For this reason, higher optical output power is required to view objects over long distances.

In order to improve the distance resolution, the pulse width must be made shorter. When the pulse width is longer, the light pulses received by the detector tend to overlap, making it difficult to distinguish between two or more objects that are close to each other. For this reason, shorter pulses are required to improve distance accuracy. Shorter pulses can also increase the maximum optical output power from an eye safe standpoint.

The required distance resolution and distance range are different for each application, as shown in Fig. 3-2-2. Therefore, the required optical output power and pulse widths are different for each application, and it is important to select the right device and design the circuit for each application.

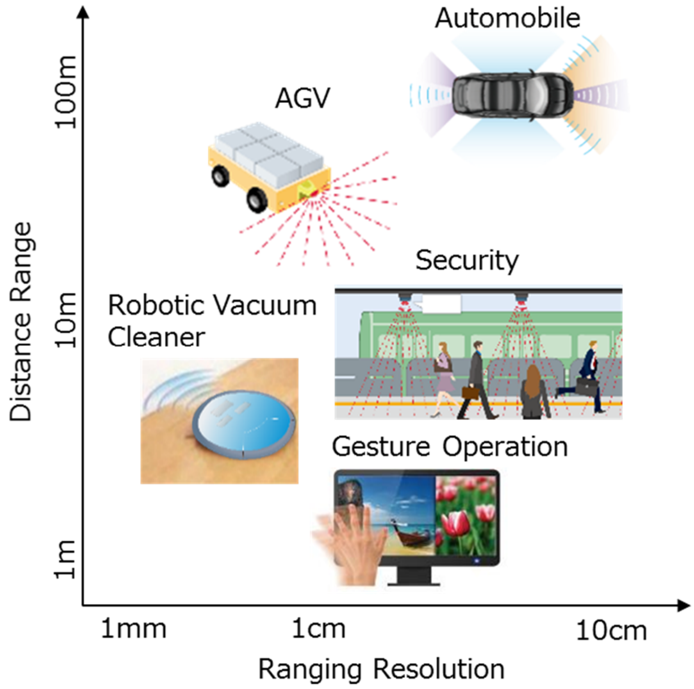


Fig. 3-2-2. Assumed uses of the ToF method.

3-3 LD Drive Circuit Design Method

To output high power with short pulses, not only the selection of the LD, but also the design of the LD drive circuit is important. There are various types of LD drive circuits, and here we will discuss the current resonant circuits. Current-resonant circuits are characterized by high optical output power and short pulses.

The drive circuit is shown in Fig. 3-3-1. The main current paths are the LD, the resonant capacitor C_r and the switching element Q1. When Q1 is switched off, C_r is charged in the I_1 path. The moment Q1 is turned on, current flows in the path from C_r to I_2, allowing light to be output from the LD. If you don't add a resistor R_l to limit the current of I_1, the current of I_2 will be small.

Due to the current in I_2, reverse electric charge gradually builds up in the C_r in the opposite direction. This electric charge in the C_r causes the current to start flowing in the I_3 path. At this time, if a diode D_p is not connected to the LDs, the voltage is applied to the LDs, which may damage the device. (In the resonant wave circuit shown in Fig. 3-3-1, the LDs cannot be driven normally without the D_p because it also serves as a charging path.) If vibration is not suppressed while current is flowing through the I_3 path, current will flow through the I_2 path again, which will generate unnecessary optical output power. Normally, Q1 is turned off at the time when the LDs move from I_2 to I_3, so the second and subsequent currents are less likely to flow. However, even when Q1 is turned off, current flows through the drain-source capacitance of Q1, so the higher the optical output, the more likely it is that unwanted optical output is generated. The second and subsequent optical output can cause false positives, so it is important to suppress vibrations while the current flows back. For this reason, R_D is connected in series with the D_p to suppress the vibration, and when the C_r charge is removed, it is recharged again through I_1.

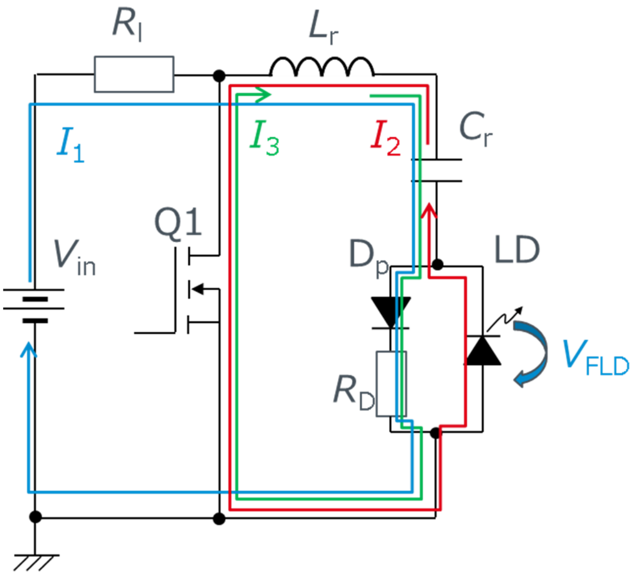


Fig. 3-3-1. Current resonance circuit diagram.

Because the current path of the I_2 shown in Fig. 3-3-1 is a free oscillation circuit of LCR, the current can be defined by the following equation.

$$I_2 = \frac{V_{\rm in}}{\gamma L_r} e^{-\alpha t} \sin(\gamma t) \quad \cdots (3\text{-}1)$$

Here.

$$\alpha = \frac{R}{2L_r} \quad \cdots (3\text{-}2)$$

$$\gamma = \frac{\sqrt{\left(\frac{4L_r}{C_r}\right) - R^2}}{2L_r} \quad \cdots (3\text{-}3)$$

and R is the sum of the on-resistance of Q1, the resistance component (V_{FLD}/I_2) due to the forward drop voltage V_{FLD} of LD, the ESR of C_r, and the wiring resistance of the main current path. V_{in} is the input voltage and L_r is the parasitic inductance of the current path of I_2.

Here, Q1 is assumed to be an ideal switch.

From equation (3-1), the resonant period T_{res} is expressed by the following equation.

$$T_{res} = \frac{2\pi}{\gamma} \quad \cdots (3\text{-}4)$$

Since the maximum current I_{2max} is the current at 1/4 cycle from the beginning of the current flow, I_{2max} can be expressed by the equation (3-5). The larger this I_{2max}, the greater the optical output power can be.

$$I_{2max} = \frac{V_{\rm in}}{\gamma L_r} e^{-\frac{\alpha T_{res}}{4}} \sin\left(\frac{\gamma T_{res}}{4}\right) \cdots (3\text{-}5)$$

The pulse width T_p can be expressed by the equation (3-6).

$$T_p = \frac{T_{res}}{3} = \frac{2\pi}{3\gamma} \quad \cdots (3\text{-}6)$$

Using these equations, Fig. 3-3-2 shows the relationship between the T_p and I_{2max} for C_r and L_r. (Fig. 3-3-2 shows the results for V_{in}=80 V, R=0.3 Ω.) Fig. 3-3-2 shows that the T_p can be shortened by reducing the L_r, while improving the I_{2max}. Although the T_p can be shortened by reducing the C_r, the I_{2max} decreases at the same time, so that the selection of a suitable C_r value for the application is important.

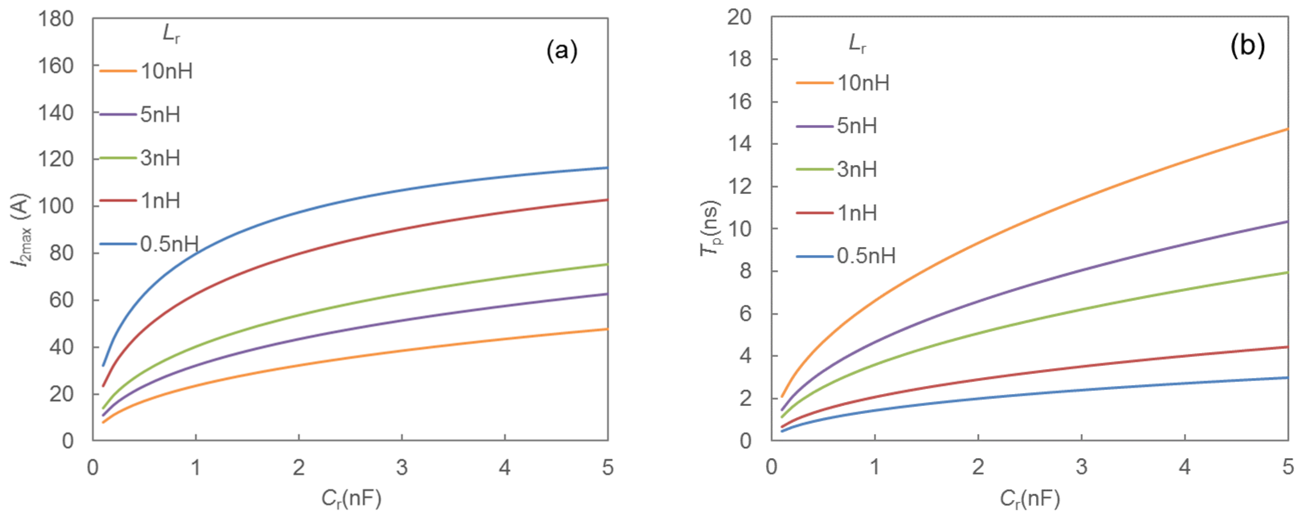


Fig. 3-3-2. Relationship between (a) maximum current I_{2max} and (b) pulse width T_p for resonant capacitor C_r and parasitic inductance L_r.

Impact of layout design

L_r value varies greatly depending on the circuit layout design, so care must be taken when designing. In general, the smaller the area of the closed loop in the current path, the smaller the inductance. Therefore, by reducing the area of the current loop of the I_2 shown Fig 3-3-1, the value of L_r can be reduced. To reduce the area of the current path loops, L_r can be reduced by forming loops in the thickness direction of the substrate rather than forming the loops in a planar shape. *2 In addition to the main current loop, it is also important to reduce the inductance L_g between the gate and source. If the L_g is large, the gate surge voltage becomes large and exceeds the breakdown voltage of the device, so it is important to design the gate-source loop as small as possible so that the L_g is as small as possible.

Effect of LD

As shown in Equation (3-1), it is important to select an element with a small V_{FLD} to increase the output power. Also, the higher the quantum efficiency of the device, the higher the output power can be when the same current is applied.

ROHM's datasheet shows the output power with a pulse width of 50 ns, but the optical output power varies depending on the pulse width. In general, the shorter the pulse width, the less affected by heat, and the more electrons that can contribute to optical coupling, the higher the optical output power tends to be. Therefore, the optical output power may be higher than the data sheet value when using a pulse width shorter than 50ns.

Selection of Resonant Capacitor C_r

Select a capacitor with as small ESR as possible to increase the optical output power from Equation (3-1).
If the capacitance of the capacitor varies according to the input voltage, the results become different from the circuit design conditions. For this reason, it is recommended to use a C0G ceramic capacitor with a small ESR and small capacitance variation.

About Drive Frequency, R_l and R_D

Note that the larger the drive frequency f_{sw}, the shorter the time required to charge the C_r.

If the time to charge the C_r voltage to 99% is defined as T_{charge}, T_{charge} is expressed as

$$T_{charge} = (R_l + R_D)C_r \ln\left(\frac{V_{in}}{V_{in} - 0.99V_{in}}\right) \quad \cdots \text{(3-7)}$$

Where the time discharge until the capacitor is discharged is expressed as

$$T_{discharge} = \frac{T_{res}}{2} = \frac{\pi}{\gamma} \quad \cdots \text{(3-8)}$$

Then R_l and R_D should be selected to meet equation below.

$$\frac{1}{f_{sw}} - T_{discharge} > T_{charge} \quad \cdots \text{(3-9)}$$

Effect of SW element Q1

The package shape also affects the optical output characteristics. In the case of a transistor with a current loop on the front and back sides, the inductance of the main loop tends to be large because it needs to be wired. Therefore, inductance can be reduced by using transistor which pad located on one side only, and it is easier to achieve high optical output power and short pulse. *3 Turning off Q1 in the middle of resonance can make the T_p shorter, in that case, the lower capacity transistor can make turn off faster. Also, to make it difficult to emit unnecessary optical output, a lower-capacity transistor is required.

3-4 Evaluation Board (Resonant Wave Circuit)

ROHM offers a resonant current type evaluation board(Resonant wave B-01).A picture of the evaluation board is shown in Fig. 3-4-1.

The Resonant wave B-01 can be used to evaluate a 5.6Φ CAN package LD and can be installed without soldering. The pulse width and the maximum optical output power P_{peak} can be changed by changing the value of the capacitor C_r for resonance. The total inductance of this evaluation circuit is approximately 4 nH, including the CAN package. (However, the inductance may vary slightly depending on how well the CAN package is inserted, so be sure to insert the CAN package into the circuit firmly.) Please change the capacitance value of the C_r according to the optical output power and pulse width you want. This evaluation board can apply an input voltage of up to 120 V.

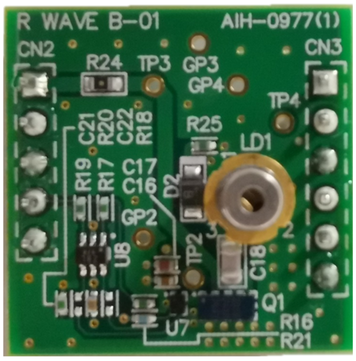


Fig. 3-4-1. Evaluation board Resonant wave B-01.

Actual measurement results

The model number of the measuring instrument used

Oscilloscope: DPO5204B (Tektronix)

Power Meter: S121C (THORLABS)

PD: DET025AL/M (THORLABS)

Function generator: 33250A (Agilent)

How to calculate peak output power

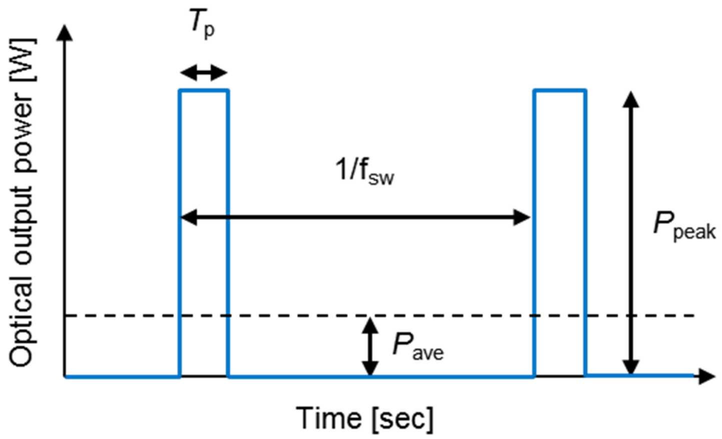


Fig. 3-4-2. Relationship between peak optical output power P_{peak} and average optical output power P_{ave}.

If we set the average optical output power obtained by the power meter be P_{ave}, as shown in Fig. 3-4-2, and the peak optical output power be P_{peak}, the equation of P_{peak} is below.

$$P_{peak} = \frac{P_{ave}}{f_{sw} \times T_p} \quad \cdots \text{(4-1)}$$

Fig. 3-4-3 shows the waveforms of a 100 V V_{in}. The measurement sample is a 120 W ROHM product. This result shows that the T_p is 4.5 ns and the P_{peak} is 120 W. The P_{peak} relative to the V_{in} is shown in Fig. 3-4-4.

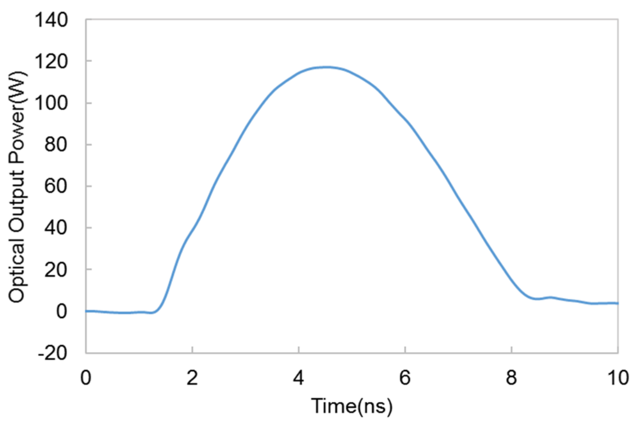


Fig. 3-4-3. Optical output waveform at 100 V input voltage.

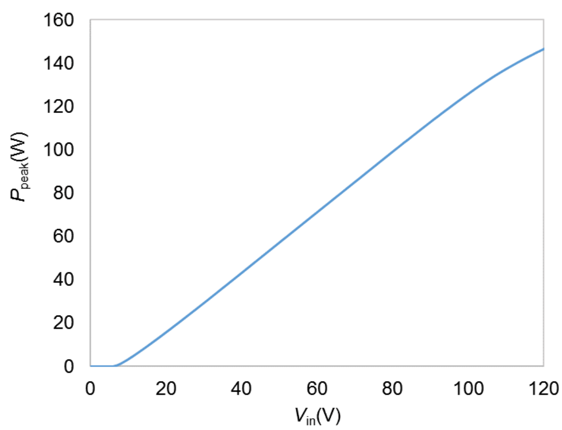


Fig. 3-4-4. Relationship between input voltage and maximum output power.

The current resonant drive circuit is characterized by short pulse widths and high output, but the current cannot be measured correctly because of the resonant waveform. When a shunt resistor is attached to the main current loop to sense the current, while the current is fluctuating, it is electromotive force because of the parasitic inductance of the shunt resistor itself. This is also true for the V_{FLD} measurement of LD. Due to the parasitic inductance of LDs, V_{FLD} cannot be measured correctly. Therefore, the actual measured waveform includes the effect of the electromotive force. In order to measure current and V_{FLD} correctly, it is important to measure in the range where the current does not fluctuate to avoid the influence of electromotive force due to shunt resistance and parasitic inductance of LD. Therefore, a circuit that outputs a square wave is necessary to accurately measure the current and V_{FLD}. In the area where the square wave current is constant, the electromotive component due to parasitic inductance becomes zero, so the current and V_{FLD} can be measured correctly.

3-5 Evaluation Board (Square Wave Circuit)

In order to measure the current and V_{FLD} correctly, ROHM also provides a square wave evaluation circuit (Square wave B-01). A picture of the evaluation board is shown in Fig. 3-5-1.

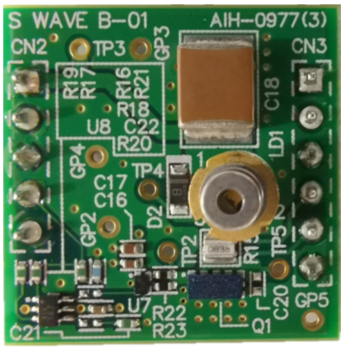


Fig. 3-5-1. Evaluation board Square wave B-01.

Actual measurement results

The model number of the measuring instrument used

Oscilloscope: DPO5204B (Tektronix)

Voltage probe (passive probe): TPP1000 (Tektronix)

Power Meter: S121C (THORLABS)

PD: DET025AL/M (THORLABS)

Function generator: 33250A (Agilent)

Fig. 3-5-2 shows the actual waveform at V_{in} of 50 V. The measurement sample is a 120 W ROHM product. This result shows that the T_p is about 50 ns and P_{peak} is 120 W. In addition, Fig. 3-5-2 shows that the measurement is not affected by parasitic inductance because the current and voltage are constant in some areas. (The surge voltage at the rising and falling edge is due to the parasitic inductance, as described above.) Fig. 3-5-3 shows the relationship between the optical output and V_{FLD} with respect to the current. This waveform was obtained with T_p of about 50 ns. If the T_p is longer, the optical output power may be lowered when compared with the same output current due to heat generation. In addition, the way of heat generation changes depending on the drive frequency and heat dissipation environment, so compare under the same conditions when comparing elements.

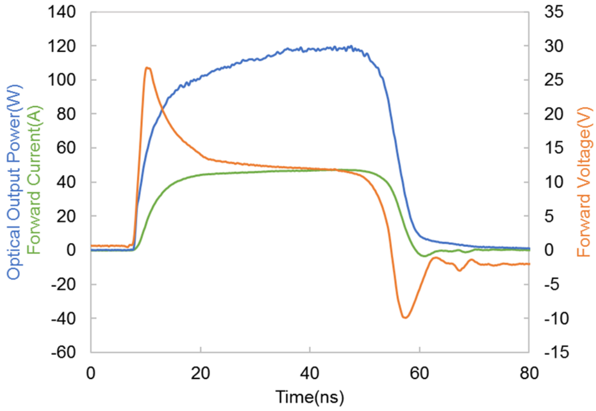


Fig. 3-5-2. Optical output waveform, forward current waveform and forward voltage waveform at 120 W optical output power.

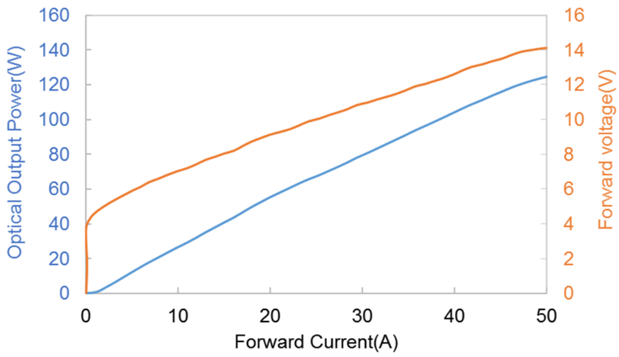


Fig. 3-5-3. Relationship between optical output power and forward voltage in relation to forward current.

In this circuit, as well as the resonant wave circuit, a diode is attached to the LDs for protection. If there is no diode for protection, a reverse surge voltage is generated in the LDs immediately after the circuit is turned off. Moreover, even after the reverse surge voltage, the voltage of the DC component continues to be applied to the LDs in the opposite direction, which may destroy the element. Attaching a protective diode makes it possible to control the reverse surge voltage and stabilize the voltage to almost 0 V even after the surge voltage is generated. For this reason, it is important to connect protective diodes in order to prevent the destruction of the LD elements, for details see Chapter 6, which compares the case with and without protective diodes using simulation.

3-6 Simulation Models and Demo Circuits

ROHM also provides the Spice Model to simplify the preliminary study.
Please refer to the following page for more information on how to use it and download the model.
https://www.rohm.co.jp/products/laser-diodes/high-power-lasers

ROHM's Spice model for LDs not only models the forward current, forward voltage drops, capacitance characteristics and leakage current characteristics, but also the optical output. This makes it possible to design circuits in a simulator and easily predict the optical output. (The optical output can be checked by using the OPT terminal of the optical output model. In this case, connect the GND terminal to GND. The optical output power unit is in V [volts] but multiply the output result by 1 A and convert it to W [watts].) However, this model is modeled on the assumption that the optical output waveform is the same as the forward current waveform, so if you want to make a more accurate calculation, please consider a different method.

Fig. 3-6-1 shows a comparison between the simulation results and the actual measurement results for each characteristic of ROHM's 120 W product. This result confirms that the simulation results are almost identical to the actual measurement results. The simulation results are shown in Fig. 3-6-2, using a demo circuit for the Resonant wave B-01 evaluation board. By using this circuit, we can confirm not only the optical output waveform but also the current that is difficult to measure in the resonant circuit because of inductance electromotive force.

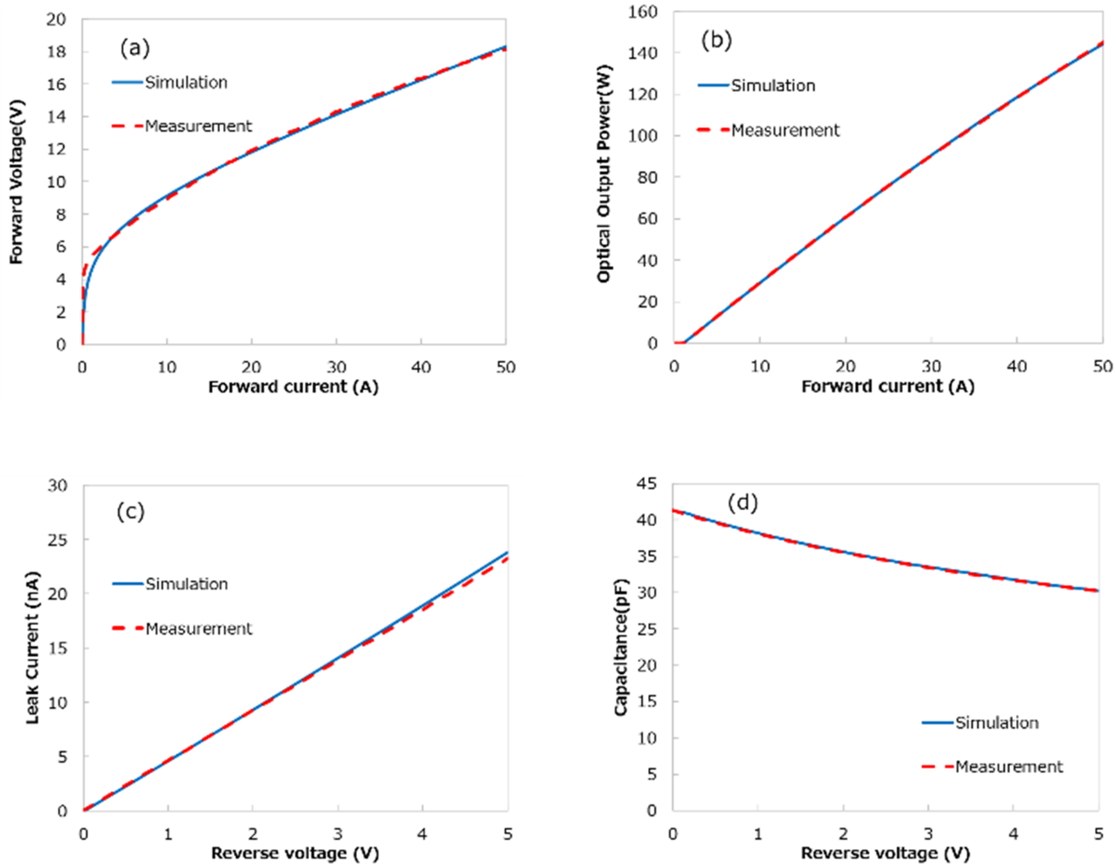


Fig. 3-6-1. Comparison of measured and simulated results (a) Forward voltage characteristics (b) Optical output characteristics (c) Leakage current characteristics (d) Capacitance characteristics.

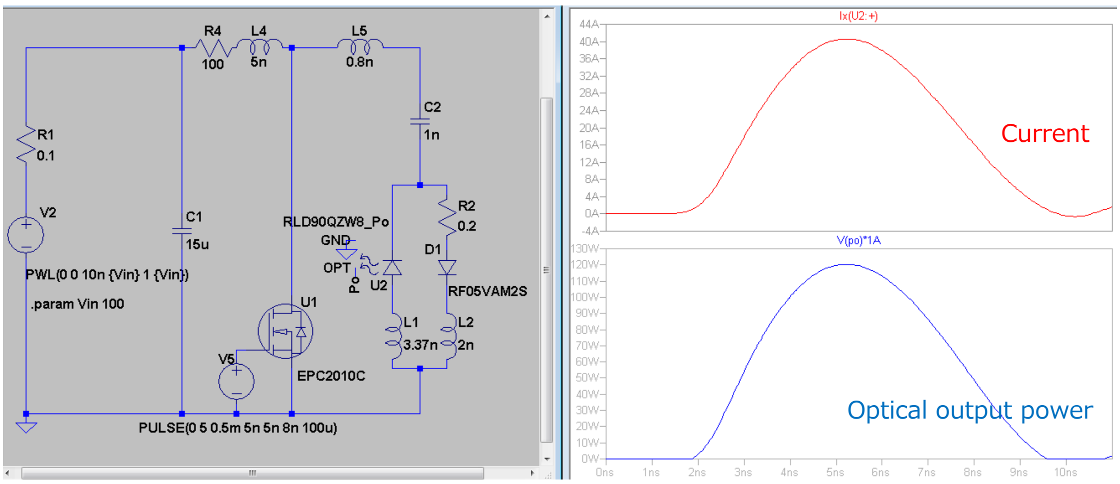


Fig. 3-6-2. Demo circuit for Resonant wave B-01.

About the demonstration circuit corresponding to Square wave B-01's circuit

Fig. 3-6-3 shows the simulation results of the voltage applied to the LDs with and without the protective diode. When we measure applied voltage of LD, the result includes the inductance components of LD, the actual voltage applied to the LD cannot be confirmed. In the simulation, the voltage directly applied to the LD elements is confirmed.

With the protection diode, as shown in Fig. 3-6-3, the voltage becomes close to zero immediately after switching. On the other hand, without the protection diode, the voltage is almost fixed at a negative voltage after switching. Under this simulation conditions, a voltage of about -20 V is applied, and the device is driven under conditions that continue to exceed the reverse voltage withstand voltage of -4 V. As a result, the possibility of element breakage will increase if a protective diode is not installed, so the installation of a protective diode is recommended.

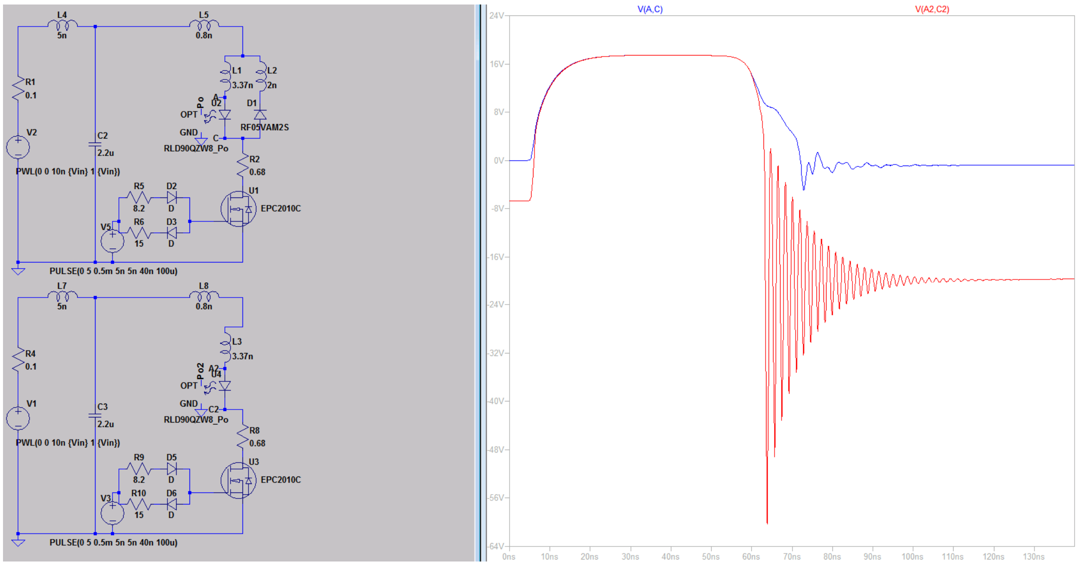


Fig. 3-6-3. Confirmation of the effect of the protection diode by Simulation.

3-7 Reference

*1 G. A. Howe, "Capabilities and performance of dual-wavelength Echidna® lidar," Journal of Applied Remote Sensing 9(1), 095979, Dec 2015

*2 Efficient Power Conversion Corp., “Optimizing PCB Layout,” 2019.

*3 J. Glaser, “High Power Nanosecond Pulse Laser Driver Using an GaN FET,” *PCIM Europe 2018 Proceedings*, 2018

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