# Operating Sanyo laser diodes with integrated drivers

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**Abstract**

The following describes application circuitry built with laser diode drivers by iC-Haus to operate the most commonly used Sanyo laser diodes in both CW and pulse mode.

## CONTENT

## GENERAL INFORMATION

The advantages of integrated driver components as opposed to discrete circuitry are obvious. Compared to the typical suggestions for circuits integrated solutions only require about one quarter of the components, thus requiring less space, and are significantly more reliable. Integrated drivers usually also have a considerably higher degree of accuracy. Most discrete solutions have just one specific basic function. Temperature-stable voltage references (band-gap references), for example, cannot be implemented discretely; ICs must be used for this purpose anyway.

In selecting suitable driver modules for a laser diode the following criteria must be taken into consideration:

- Is a monitor diode present?
- Pin configuration (N, M or P type*)
- Maximum laser diode current
- Monitor current range
- CW or pulse operation
- Pulse frequency (range)
- Fixed or variable duty cycle

Laser diode drivers from iC-Haus have been designed for operation with monitor diodes (regulation of the optical output power = APC or automatic power control). With the exception of iC-HK, an integrated monitor diode is thus imperative.

Not every device supports all three pin configurations.

The maximum laser diode current determines the necessary driving capability which each individual device should have.

The monitor current within the required setup range must also be able to be processed by the selected driver device. Exceeding this permissible monitor current range damages neither the laser diode nor the device; the control accuracy will, however, decrease and the susceptibility to interference rise.

Figure 1 shows the monitor and laser current range covered in CW operation.

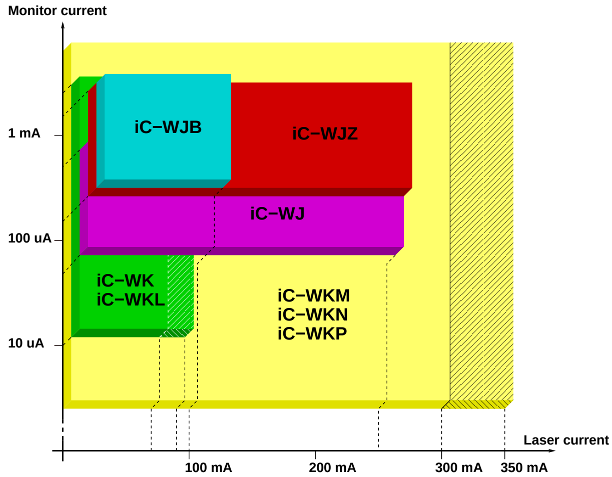


Figure 1: Monitor / laser current range in CW operation

The operating mode (CW or pulse), pulse frequency (fixed or variable) and duty cycle (fixed or variable) determine whether a simple averaging control is sufficient or whether each individual pulse has to be controlled separately.

Figure 2 describes the frequency and laser current range covered by iC-Haus laser diode drivers.

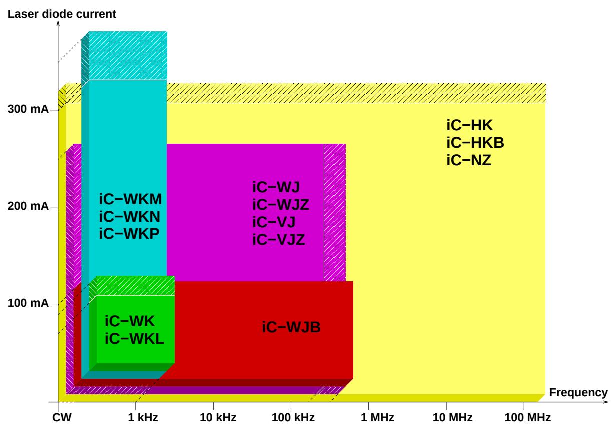


Figure 2: Frequency / current range

The following examples are geared towards some of the most commonly used Sanyo laser diodes.

* Also often referred to as types I, II and III.

## CW OPERATION

In plain CW operation an averaging control unit is totally sufficient. Stability is provided when the optical output signal does not exhibit any notable overshoot for the set operating point when switched on.

**DL-3147-260**

The **DL-3147-260** is a P-type laser diode with a maximum of 45 mA at a maximum output power of 7 mW. Here, either the *Universal Laser Saver* iC-WK/L can be used (Figure 3) or, if the laser diode casing is to be connected to ground for improved thermal dissipation or easier assembly in a module, iC-WKP (Figure 4).

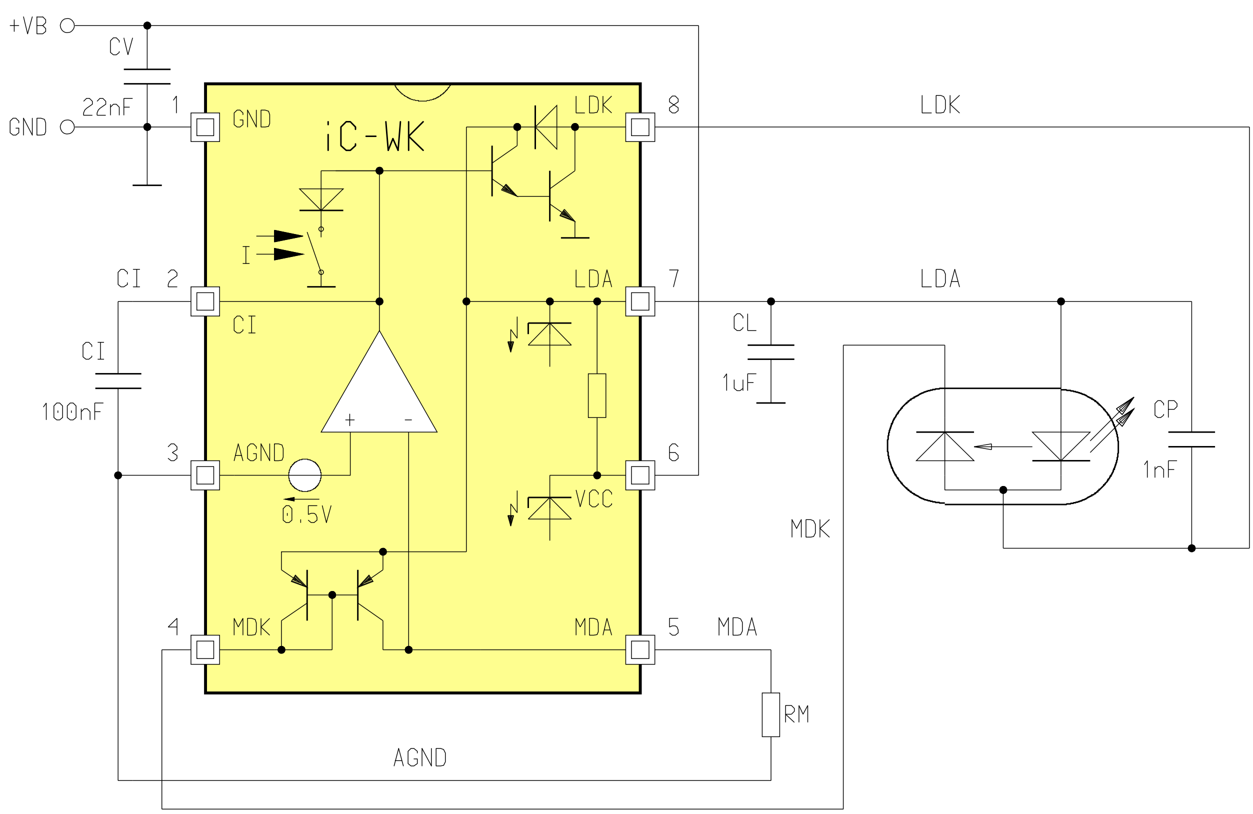


Figure 3: iC-WK/L with a DL-3147-260

### Dimensioning information for iC-WK/L

**CI:** integration capacitor; value must be determined empirically; size is sufficient if the optical output does not exhibit any overshoot when switched on

**CL:** back-up capacitor, absolute value not critical; can be increased for greater stability

**CP:** optional; only necessary with longer connections between the driver output and laser diode

**CV:** blocking capacitor, absolute value not critical

**RM:** power setting: RM = 0.5 V / Im, with Im = monitor current of the laser diode with the required output power.

Resistance RM, used to set the operating point, is always calculated according to the same principle, as given in the following formulae:

$$RM_{min} = \frac{V(MDA)}{Im_{nom_{max}}} * \frac{P_{nom}}{P_{set}} \quad (1)$$

$$RM_{max} = \frac{V(MDA)}{Im_{nom_{min}}} * \frac{P_{nom}}{P_{set}} \quad (2)$$

where $Im_{nom_{min}}$ and $Im_{nom_{max}}$ represent the monitor current range at nominal output power $P_{nom}$, as given in the laser diode data sheet, and $P_{set}$ is the laser power to be set.

At 3 mW output power and using the information given in the **DL-3147-260** and iC-WK/L data sheets this amounts to:

$$RM_{min} = \frac{0.5V}{0.4mA} * \frac{5mW}{3mW} = 2083.33\,\Omega$$

$$RM_{max} = \frac{0.5V}{0.08mA} * \frac{5mW}{3mW} = 10416.67\,\Omega$$

It is prudent here to divide resistor RM into a fixed resistor ($RM_{min} \geq RM_{fix} \widehat{=} P_{out_{max}}$) and a trimmer ($RM_{var}$) for the setup process:

$$RM_{min} \geq RM_{fix} = 2k\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 10k\Omega$$

If the output power is to be set within a range of 3 to 5 mW, for example, the following applies:

$$RM_{min} = \frac{0.5V}{0.4mA} * \frac{5mW}{5mW} = 1250\,\Omega$$

$$RM_{max} = \frac{0.5V}{0.08mA} * \frac{5mW}{3mW} = 10416.67\,\Omega$$

$$RM_{min} \geq RM_{fix} = 1.2k\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 10k\Omega$$

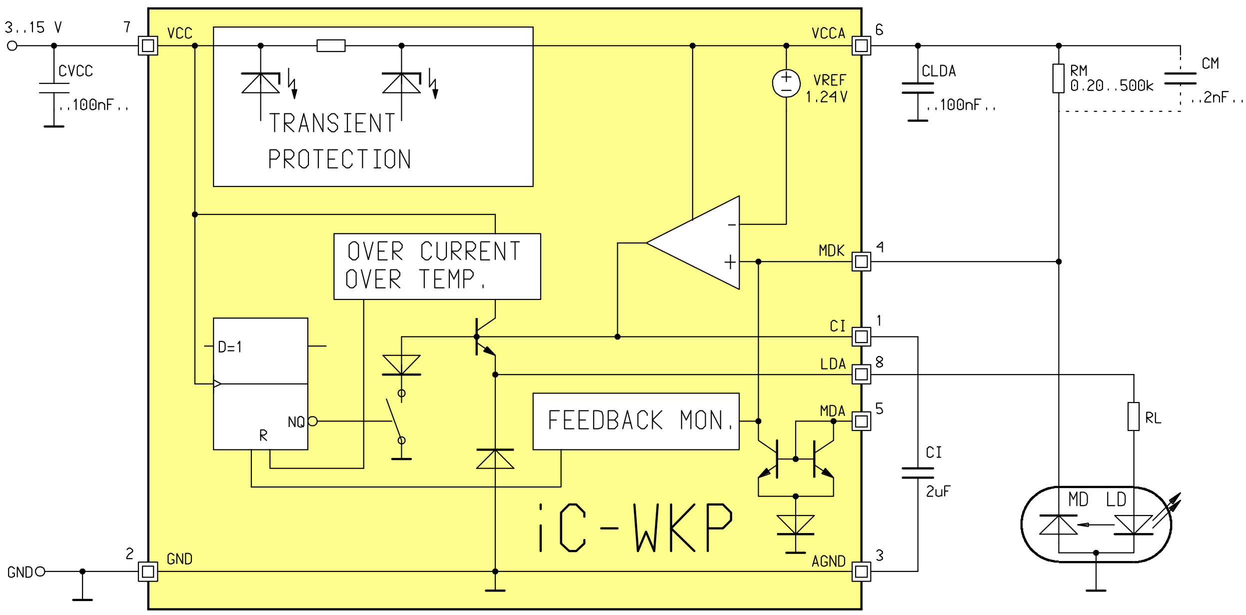


Figure 4: iC-WKP with a DL-3147-260

**Dimensioning information for iC-WKP**

**CI:** integration capacitor; value must be determined empirically; size is sufficient if the optical output does not exhibit any overshoot when switched on

**CLDA:** back-up capacitor, absolute value not critical; can be increased for greater stability

**CM:** optional; reduces susceptibility of spike detection at pin MDK

**CVCC:** blocking capacitor, absolute value not critical

**RL:** reduces the power dissipation in the IC and improves the stability of the control unit; absolute value not critical provided LDA does not saturate

**RM:** power setting: RM = 1.24 V / Im, with Im = monitor current of the laser diode with the required output power.

Using the information given in the **DL-3147-260** data sheet RM is calculated as shown in Equations 1 and 2.

At 3 mW this amounts to:

$$RM_{min} = \frac{1.24V}{0.4mA} * \frac{5mW}{3mW} = 5166.67\,\Omega$$

$$RM_{max} = \frac{1.24V}{0.08mA} * \frac{5mW}{3mW} = 25833.33\,\Omega$$

Division of resistor RM into a fixed resistor ($RM_{min} \geq RM_{fix} \hat{=} P_{out_{max}}$) and a trimmer ($RM_{var}$):

$$RM_{min} \geq RM_{fix} = 5.1k\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 22k\Omega$$

If the output power is to be set within a range of 3 to 5 mW, for example, the following applies:

$$RM_{min} = \frac{1.24V}{0.4mA} * \frac{5mW}{5mW} = 3100\,\Omega$$

$$RM_{max} = \frac{1.24V}{0.08mA} * \frac{5mW}{3mW} = 25833.33\,\Omega$$

$$RM_{min} \geq RM_{fix} = 3k\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 22k\Omega$$

**DL-4148-021, DL-4148-031**
**DL-4148-021** and **DL-4148-031** are N-type laser diodes with a maximum of 80 mA at a maximum output power of 12 and 10 mW respectively. Here, either iC-WJ (Figure 5) or iC-WKN can be used. If the laser diode casing is to be connected to ground for improved thermal dissipation or easier assembly in a module, in both cases the voltage must be supplied from -5 V (Figure 6).

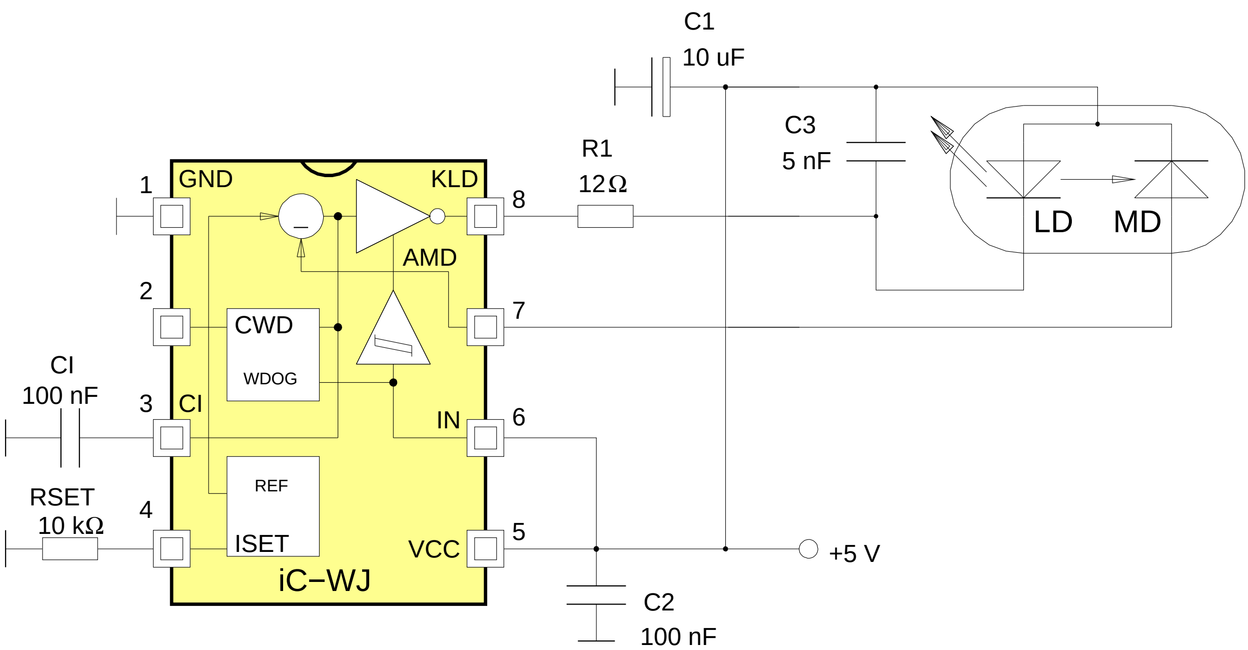


Figure 5: DL-4148-021 or DL-4148-031 with iC-WJ

### Dimensioning information for iC-WJ

**C1, C2:** blocking capacitors, absolute value not critical

**C3:** optional; only necessary with longer connections between the driver output and laser diode

**CI:** integration capacitor; value must be determined empirically; size is sufficient if the optical output does not exhibit any overshoot when switched on

**R1:** reduces the power dissipation in the IC; output KLD must not saturate!

**RSET:** power setting: RM = 1.22 V / Im, with Im = monitor current of the laser diode with the required output power.

Using the information given in the **DL-4148-021** and **DL-4148-031** data sheets the following formulae are calculated for RM in keeping with Equations 1 and 2:

$$RM_{min} = \frac{V(ISET)}{Im_{nom_{max}}} * \frac{P_{nom}}{P_{set}} \quad (3)$$

$$RM_{max} = \frac{V(ISET)}{Im_{nom_{min}}} * \frac{P_{nom}}{P_{set}} \quad (4)$$

At 8 mW this amounts to:

$$RSET_{min} = \frac{1.22\,V}{0.4\,mA} * \frac{10\,mW}{8\,mW} = 3812.5\,\Omega$$

$$RSET_{max} = \frac{1.22\,V}{0.05\,mA} * \frac{10\,mW}{8\,mW} = 30500\,\Omega$$

Division of resistor RSET into a fixed resistance ($RSET_{min} \geq RSET_{fix} \widehat{=} P_{out_{max}}$) and a trimmer ($RSET_{var}$):

$$RSET_{min} \geq RSET_{fix} = 3.6\,k\Omega$$

$$RSET_{max} - RSET_{fix} \leq RSET_{var} = 33\,k\Omega$$

If the output power is to be set within a range of 5 to 10 mW, for example, the following ratios apply:

$$RSET_{min} = \frac{1.22\,V}{0.4\,mA} * \frac{10\,mW}{10\,mW} = 3050\,\Omega$$

$$RSET_{max} = \frac{1.22\,V}{0.05\,mA} * \frac{10\,mW}{5\,mW} = 48800\,\Omega$$

$$RSET_{min} \geq RSET_{fix} = 3\,k\Omega$$

$$RSET_{max} - RSET_{fix} \leq RSET_{var} = 47\,k\Omega$$

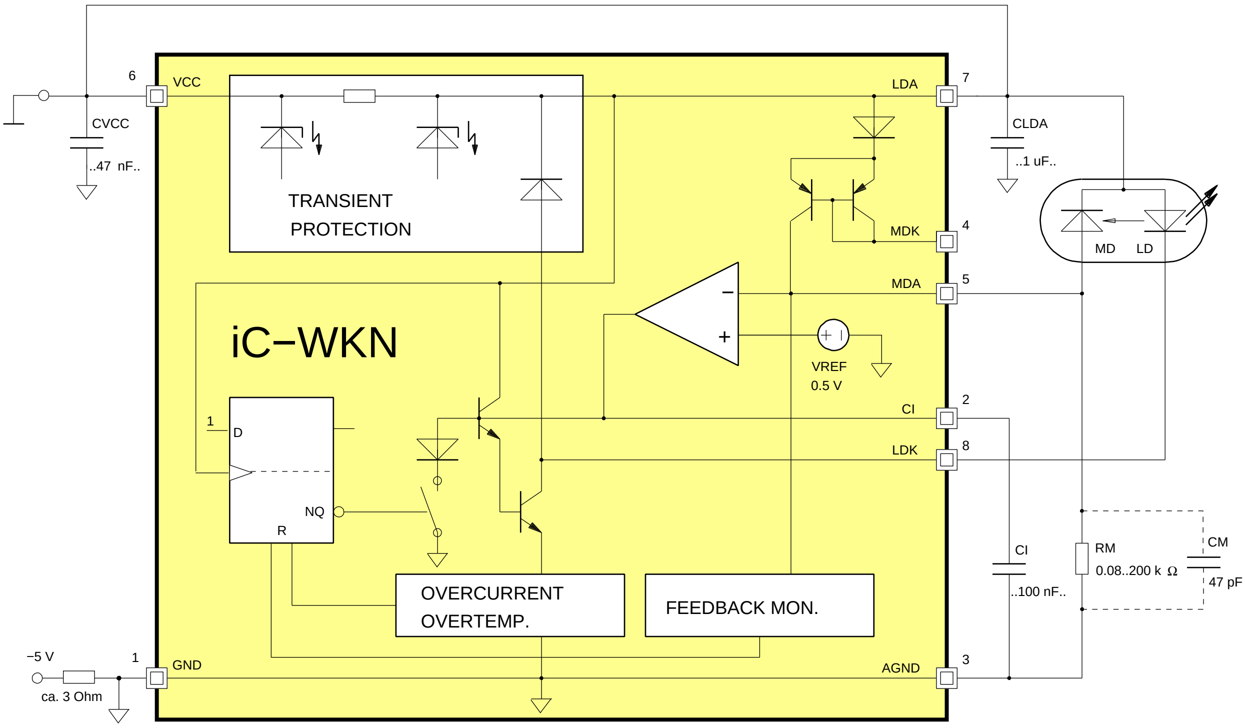


Figure 6: DL-4148-021 or DL-4148-031 with iC-WKN

**Dimensioning information for iC-WKN**

**CI:** integration capacitor; value must be determined empirically; size is sufficient if the optical output does not exhibit any overshoot when switched on

**CLDA:** back-up capacitor, absolute value not critical; can be increased for greater stability

**CM:** optional; reduces susceptibility of spike recognition at pin MDA

**CVCC:** blocking capacitor, absolute value not critical

**RM:** power setting: RM = 0.5 V / Im, with Im = monitor current of the laser diode with the required output power.

Using the information given in the **DL-4148-021** and **DL-4148-031** data sheets RM is calculated as shown in Equations 1 and 2.

At 8 mW this amounts to:

$$RM_{min} = \frac{0.5\,V}{0.4\,mA} * \frac{10\,mW}{8\,mW} = 1562.5\,\Omega$$

$$RM_{max} = \frac{0.5\,V}{0.05\,mA} * \frac{10\,mW}{8\,mW} = 12500\,\Omega$$

Division of resistor RM into a fixed resistance ($RM_{min} \geq RM_{fix} \mathrel{\widehat{=}} P_{out_{max}}$) and a trimmer ($RM_{var}$):

$$RM_{min} \geq RM_{fix} = 1.5\,k\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 15\,k\Omega$$

If the output power is to be set within a range of 5 to 10 mW, for example, the following ratios apply:

$$RM_{min} = \frac{0.5\,V}{0.4\,mA} * \frac{10\,mW}{10\,mW} = 1250\,\Omega$$

$$RM_{max} = \frac{0.5\,V}{0.05\,mA} * \frac{10\,mW}{5\,mW} = 20000\,\Omega$$

$$RM_{min} \geq RM_{fix} = 1.2\,k\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 20\,k\Omega$$

**DL-3149-057**

The **DL-3149-057** is an N-type laser diode with a maximum of 45 mA at a maximum output power of 7 mW. Here, universal *Laser Saver* iC-WK/L can be used. If the laser diode casing is to be connected to ground, the voltage can also be supplied from -5 V as with iC-WKN (see Figure 6).

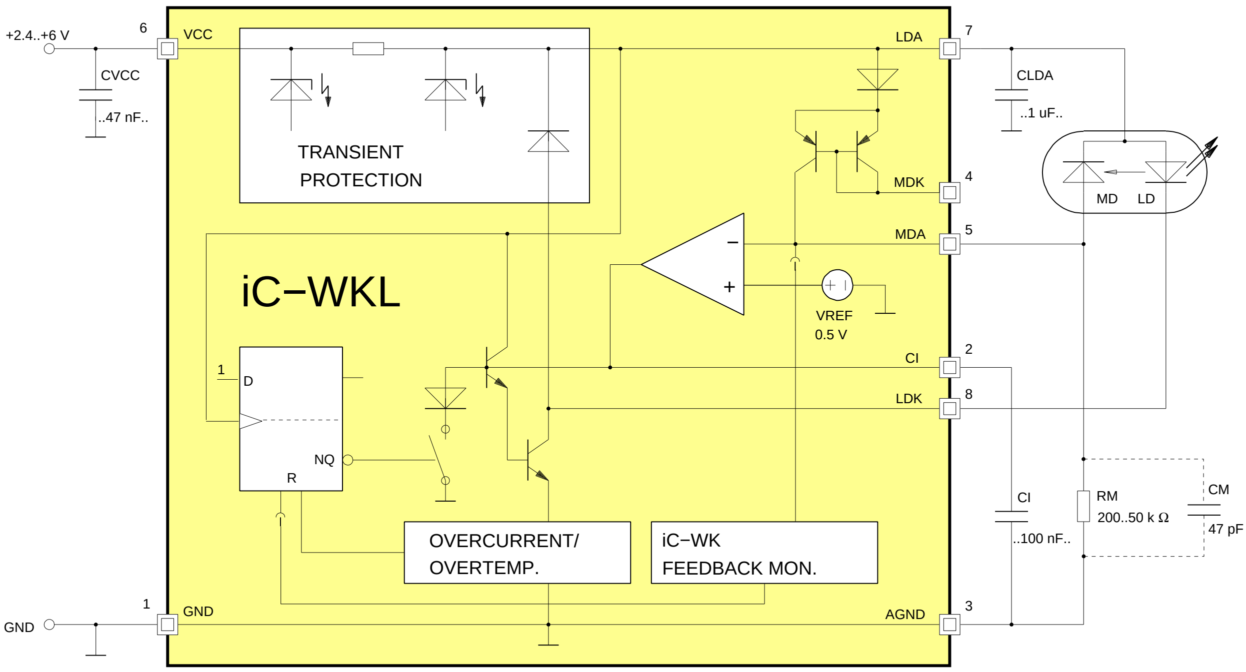


Figure 7: DL-3149-057 with iC-WK/L

**Dimensioning information for iC-WK/L**

Using the information given in the **DL-3149-057** data sheet RM is calculated as shown in Equations 1 and 2.

At 3 mW this amounts to:

$$RM_{min} = \frac{0.5V}{2mA} * \frac{5mW}{3mW} = 416.67\,\Omega$$

$$RM_{max} = \frac{0.5V}{0.5mA} * \frac{5mW}{3mW} = 1666.67\,\Omega$$

It is prudent here to divide resistor RM into a fixed resistor ($RM_{min} \geq RM_{fix} \,\hat{=}\, P_{out_{max}}$) and a trimmer ($RM_{var}$):

$$RM_{min} \geq RM_{fix} = 390\,\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 1.5k\Omega$$

If the output power is to be set within a range of 3 to 5 mW, for example, the following ratios apply:

$$RM_{min} = \frac{0.5V}{2mA} * \frac{5mW}{5mW} = 250\,\Omega$$

$$RM_{max} = \frac{0.5V}{0.5mA} * \frac{5mW}{3mW} = 1666.67\,\Omega$$

$$RM_{min} \geq RM_{fix} = 240\,\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 1.5k\Omega$$

**DL-3146-151, DL-3146-152**

**DL-3146-151** and **DL-3146-152** are 405 nm M-type laser diodes with a maximum of 70 mA and 110 mA at a maximum output power of 7 and 35 mW respectively. The higher forward voltage (ca. 5.5 V) and the necessary connection of the laser diode casing to ground for improved thermal dissipation mean that only iC-WKM can be used here (Figure 8). This device also permits the operation of an M-type laser diode (whose casing is connected to ground) from a single supply.

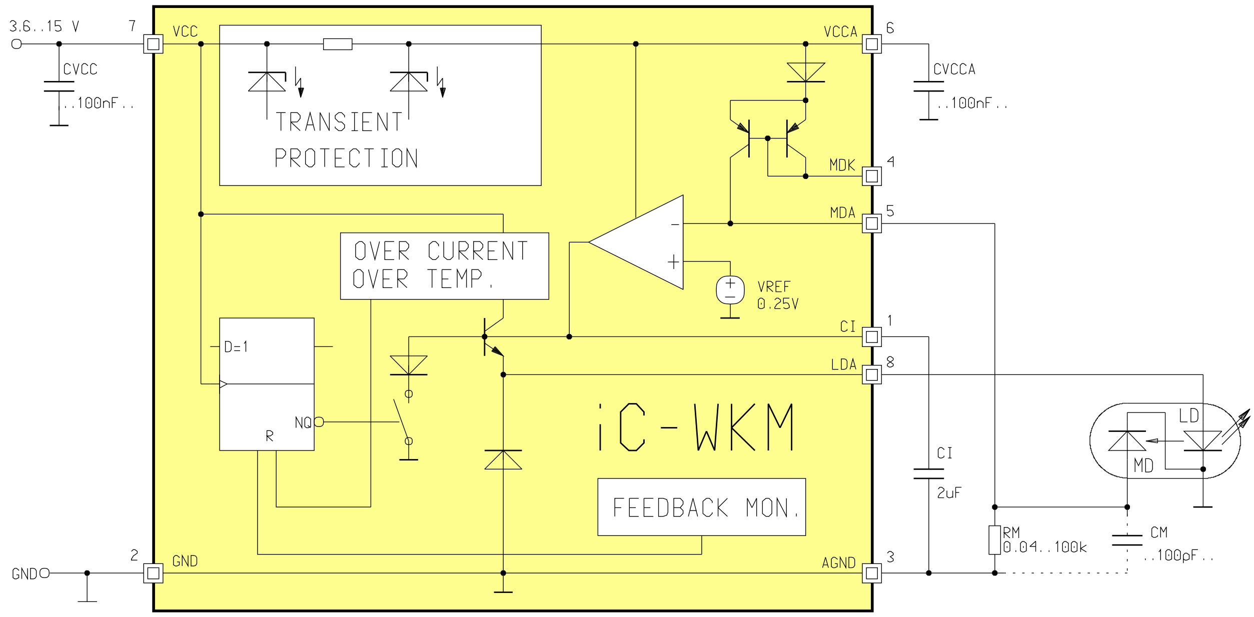


Figure 8: DL-3146-151 or DL-3146-152 with iC-WKM

**Dimensioning information for iC-WKM**

**CI:** integration capacitor; value must be calculated empirically; size is sufficient if the optical output does not exhibit any overshoot when switched on; larger values are necessary if CM is used

**CM:** optional; reduces sensitivity of spike recognition at pin MDA

**CVCC:** blocking capacitor, absolute value not critical

**CVCCA:** back-up capacitor, absolute value not critical; can be increased for greater stability

**RM:** power setting: RM = 0.25 V / Im, with Im = monitor current of the laser diode with the required output power.

Using the information given in the **DL-3146-151** data sheet RM is calculated as shown in Equations 1 and 2.

At 3 mW this amounts to:

$$RM_{typ} = \frac{0.25\,V}{0.2\,mA} * \frac{5\,mW}{3\,mW} = 2083.33\,\Omega$$

$$RM_{max} = \frac{0.25\,V}{0.05\,mA} * \frac{5\,mW}{3\,mW} = 8333.33\,\Omega$$

As the data sheet only gives the typical value for the monitor current and no maximum value the division of resistor RM into a fixed resistor ($RM_{min} \geq RM_{fix} \mathrel{\hat{=}} P_{out_{max}}$) and a trimmer ($RM_{var}$) could be as follows:

$$RM_{typ} \geq RM_{fix} = 390\,\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 10\,k\Omega$$

If the output power is to be set within a range of 3 to 5 mW, for example, the following ratios apply:

$$RM_{typ} = \frac{0.25\,V}{0.2\,mA} * \frac{5\,mW}{5\,mW} = 1250\,\Omega$$

$$RM_{max} = \frac{0.25\,V}{0.05\,mA} * \frac{5\,mW}{3\,mW} = 8333.33\,\Omega$$

$$RM_{typ} \geq RM_{fix} = 240\,\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 10\,k\Omega$$

RM can be calculated using the information given in the **DL-3146-152** data sheet.

At 25 mW this amounts to:

$$RM_{min} = \frac{0.25\,V}{1\,mA} * \frac{35\,mW}{25\,mW} = 350\,\Omega$$

$$RM_{max} = \frac{0.25\,V}{0.1\,mA} * \frac{35\,mW}{25\,mW} = 3500\,\Omega$$

Division of resistor RM into a fixed resistance ($RM_{min} \geq RM_{fix} \mathrel{\widehat{=}} P_{out_{max}}$) and a trimmer ($RM_{var}$):

$$RM_{min} \geq RM_{fix} = 330\,\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 3.3\,k\Omega$$

If the output power is to be set within a range of 5 to 35 mW, for example, the following ratios apply:

$$RM_{min} = \frac{0.25\,V}{1\,mA} * \frac{35\,mW}{35\,mW} = 250\,\Omega$$

$$RM_{max} = \frac{0.25\,V}{0.1\,mA} * \frac{35\,mW}{5\,mW} = 17500\,\Omega$$

$$RM_{min} \geq RM_{fix} = 240\,\Omega$$

$$RM_{max} - RM_{fix} \leq RM_{var} = 22\,k\Omega$$

**Analogue modulation**

With regard to all of the driver devices described herein, in principle analog modulation (modulation depth $\ll$ 100%) is possible up to a specific cutoff frequency which is determined by the integration capacitor (CI). This can either be achieved through direct modulation at the operating point adjusting resistor (see Figures 9 and 10) or, with devices in the iC-WK product range, at the second monitor current input (Figure 11).

Taking the operating point set using RSET (cf. Equations 3 and 4), the output power is calculated thus:

$$P_{OUT} = P_{nom} + P_{mod} \quad (5)$$

$$P_{OUT} = P_{nom} + P_{nom} * \frac{\frac{V(ISET)-VMOD}{R2}}{\frac{V(ISET)}{RSET}} \quad (6)$$

Parallel to this the output power for iC-WK is calculated as shown in Figure 10.

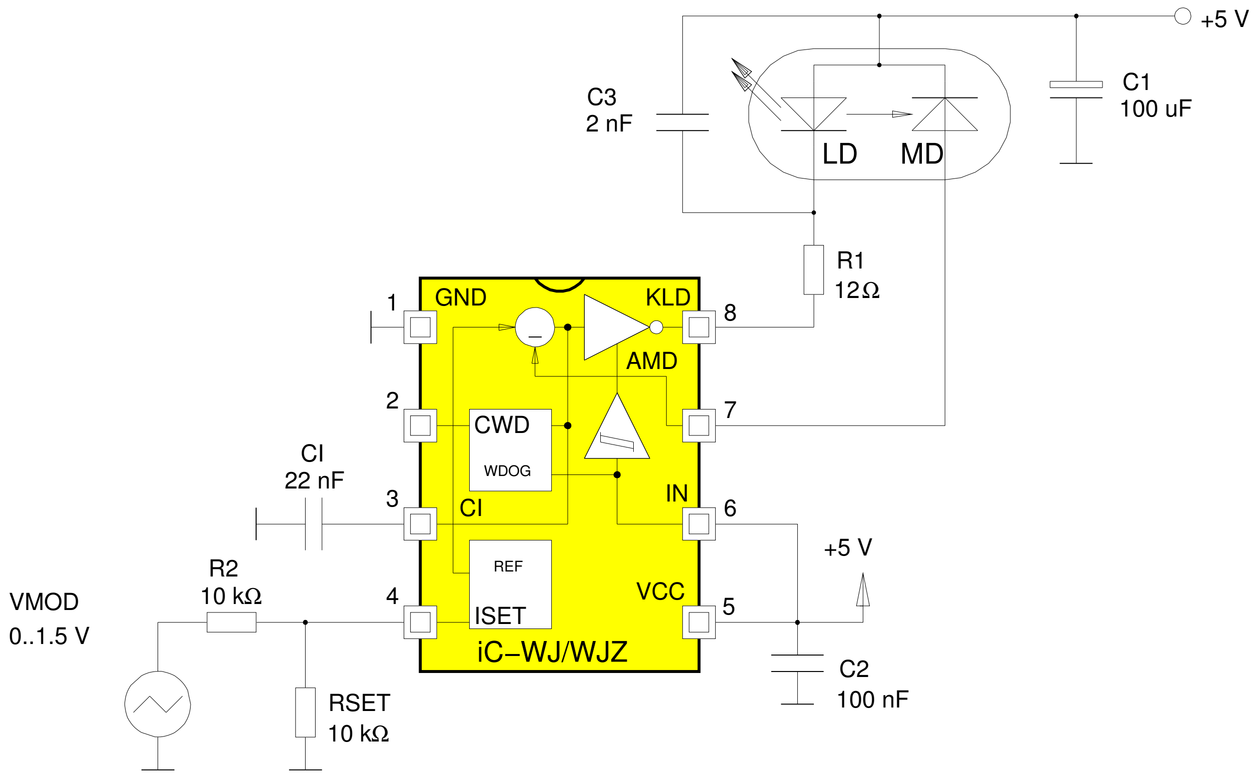


Figure 9: Analogue modulation in the iC-WJ product range

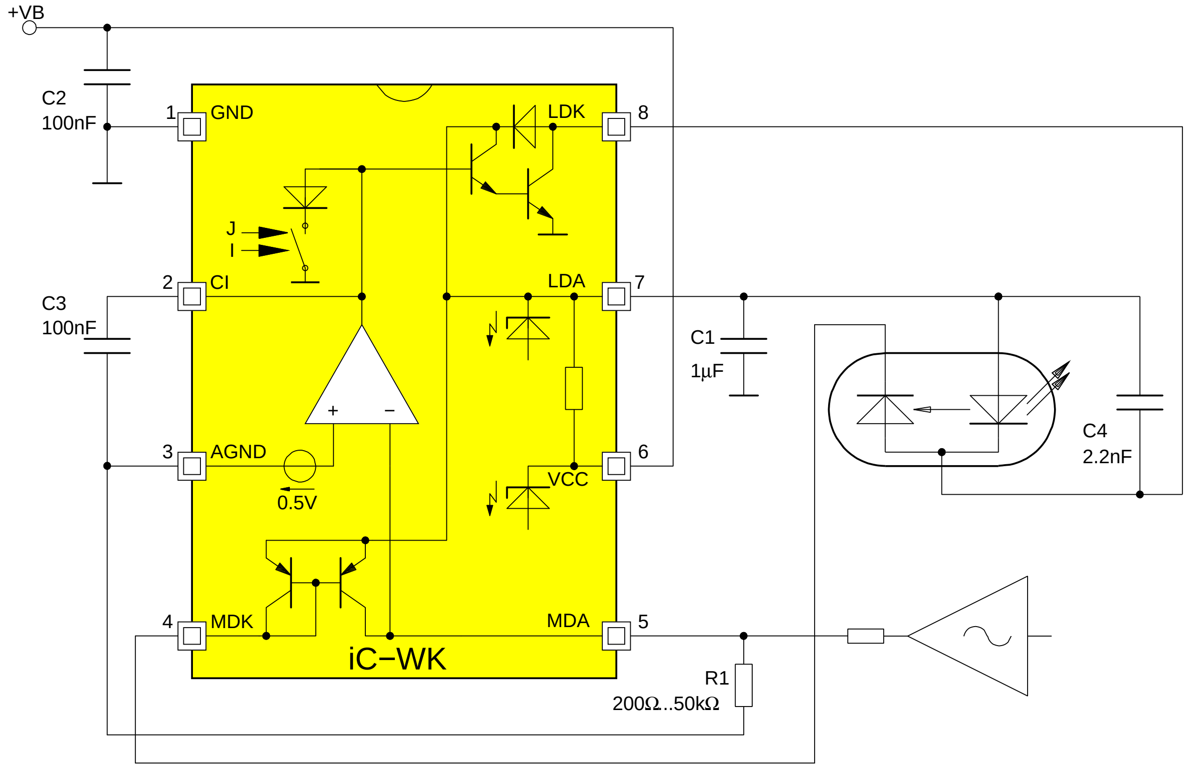


Figure 10: Analogue modulation in the iC-WK product range

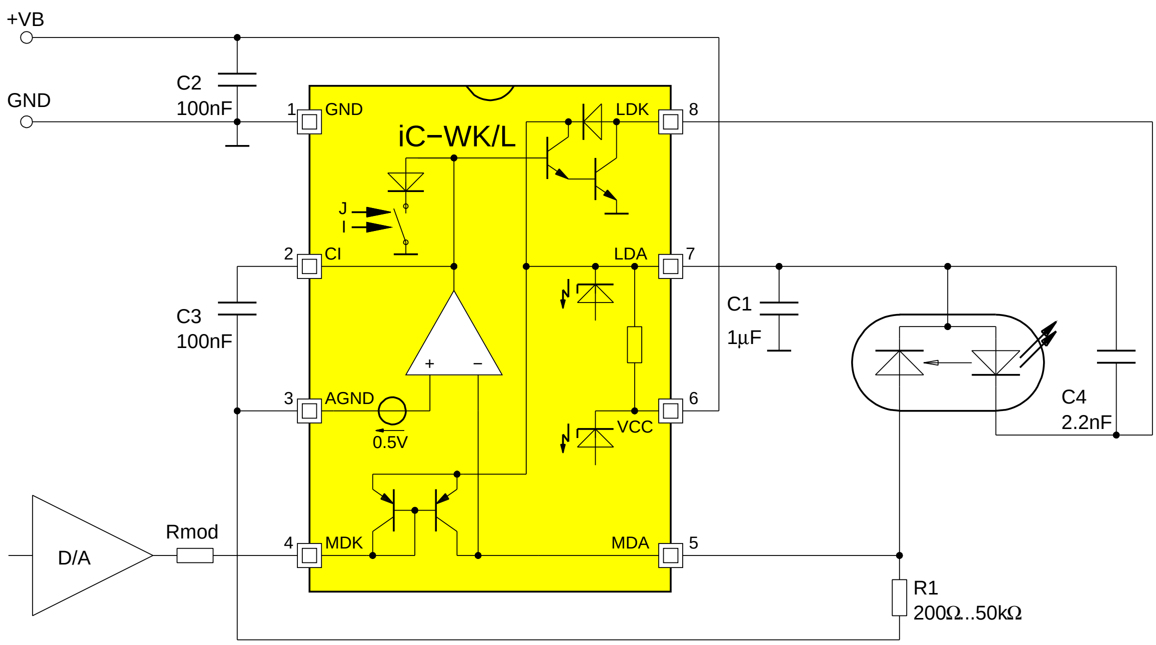


Figure 11: Analogue modulation in the iC-WK product range using the second monitor input

Pin MDK is a current input. A controlled current sink is thus ideal for modulation. If modulation occurs from a voltage source (such as a D/A converter, for example), the current- and temperature-dependent voltage at pin MDK must be taken into consideration when calculating the percentage of modulation according to Equation 5.

$$P_{OUT} = P_{nom} + P_{nom} * \frac{\frac{VMOD - V(MDK)}{Rmod}}{\frac{V(MDA)}{R1}}$$

## PULSE OPERATION

In pulse operation a distinction must be made between devices with an averaging control unit, where only the average optical output power is kept constant (iC-VJ and iC-WJ products), and those with a peak optical power control unit (iC-NZ), where each individual pulse is controlled (with limitations).

As a matter of principle the averaging control unit requires a fixed duty cycle. In addition the regulating constant must be adjusted so that it tarries with the lowest occurring pulse frequency which in general constitutes a useful low pulse frequency of several 10 kHz. For frequencies below this the integration capacitor would have to be disproportionately large which also considerably increases the start-up time. However, CW-like operation can be more or less achieved with the aid of a watchdog (iC-WJ products) at low pulse frequencies. In this instance a certain pulse delay must be reckoned with.

Here, peak optical power control is substantially more flexible, permitting variable pulse widths and pulse frequencies within broad margins. At low frequencies or with long pulse intervals, however, pulse delays can be caused by settling processes.

### DL-3147-260

The **DL-3147-260** is a P-type laser diode with a maximum of 45 mA; only iC-NZ can thus be used here for pulse operation. The circuitry illustrated in Figure 12 enables pulse operation of a P-type laser diode with up to 320 mA and up to three separately regulated output levels.

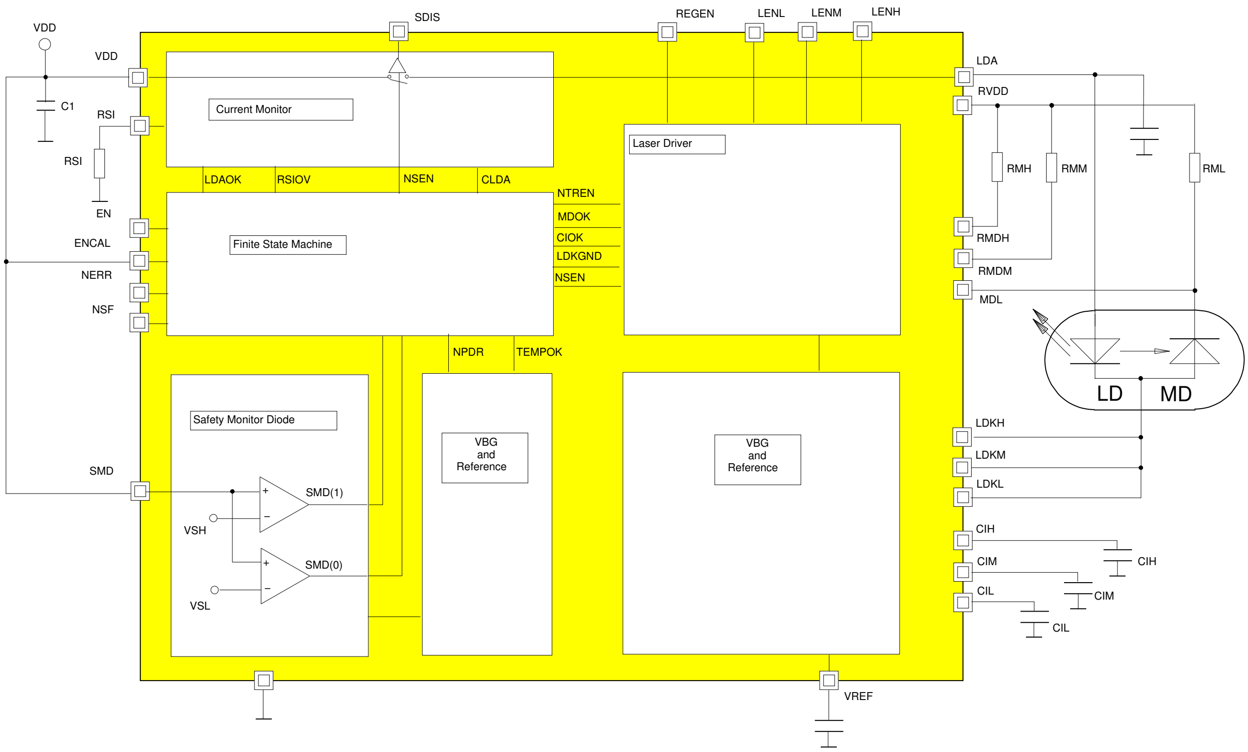


Figure 12: DL-3147-260 in pulse operation with iC-NZ

A detailed description of the setup procedure can be found in the iC-NZ data sheet which also goes into detail about the optional single-failure-proof feature of the device.

### DL-4148-021, DL-4148-031

**DL-4148-021** and **DL-4148-031** are N-type laser diodes with a maximum of 80 mA. Depending on the pulse frequency and duty cycle required, here either iC-WJ (Figure 13) or iC-NZ (Figure 14) can be used. In applications with a fixed pulse frequency, such as light barriers, for example, iC-VJ is also a possible option (Figure 15).

Detailed instructions for dimensioning can be found in the relevant data sheets.

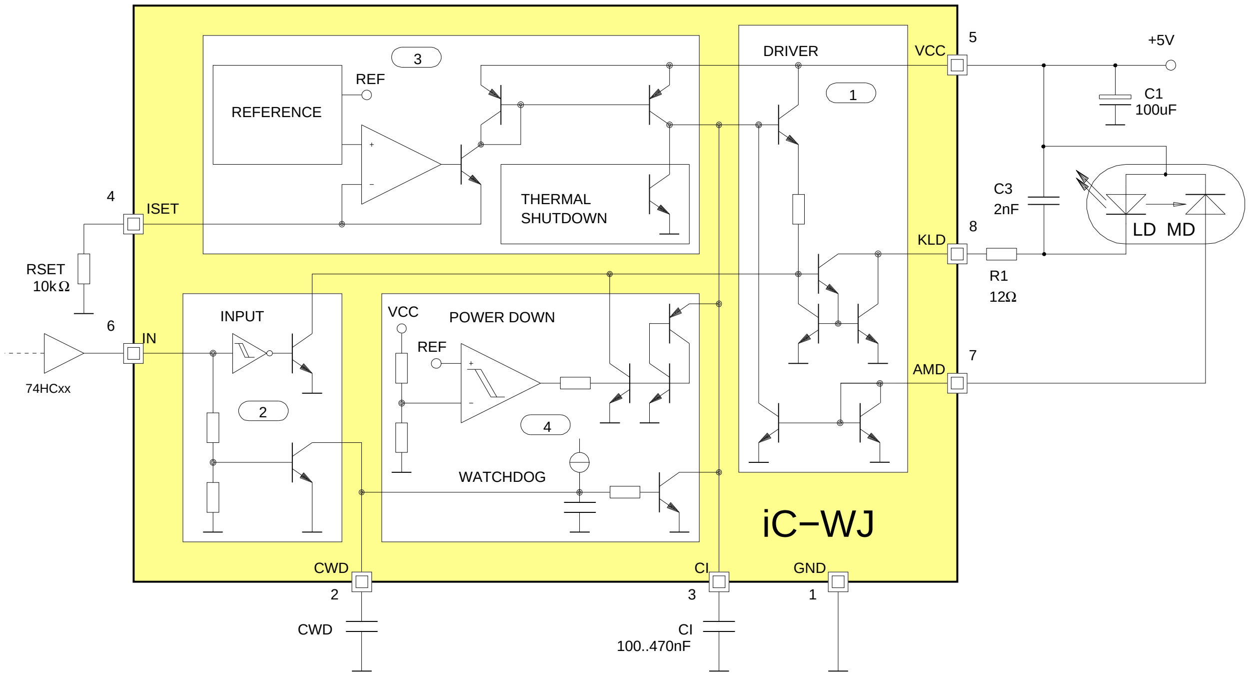


Figure 13: DL-4148-021 or DL-4148-031 in pulse operation with iC-WJ

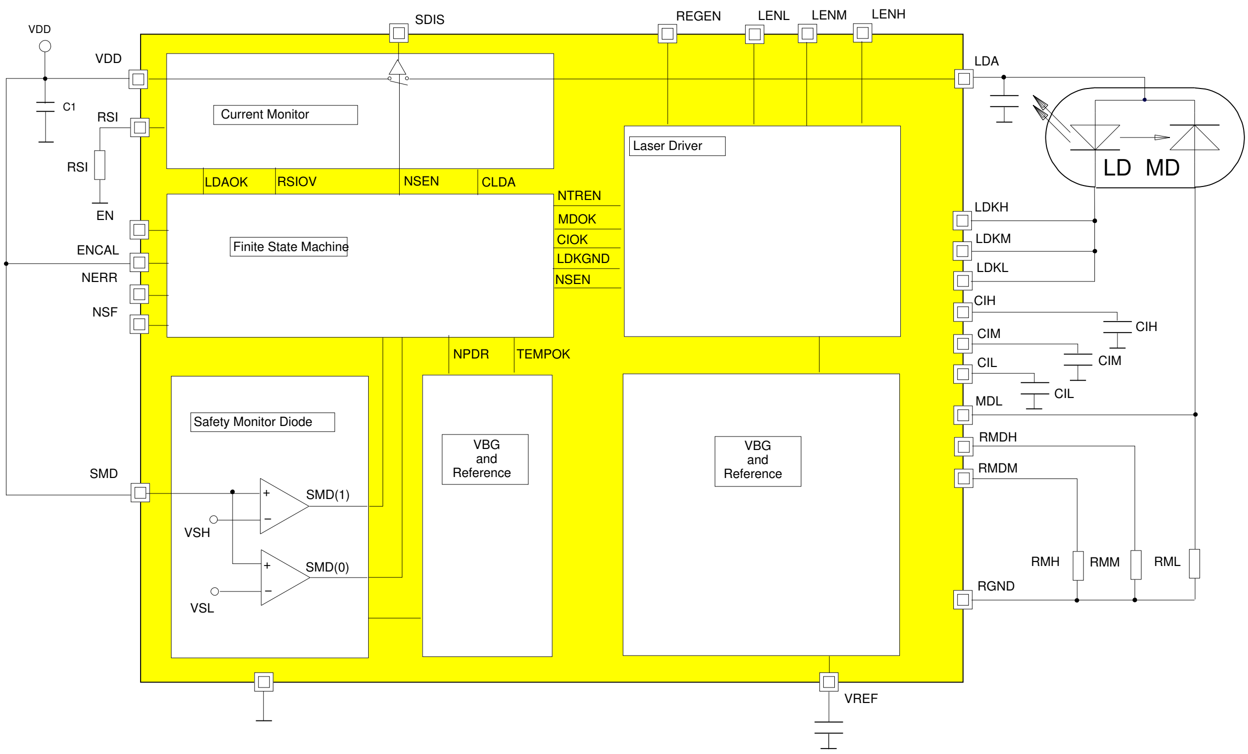


Figure 14: DL-4148-021 or DL-4148-031 in pulse operation with iC-NZ

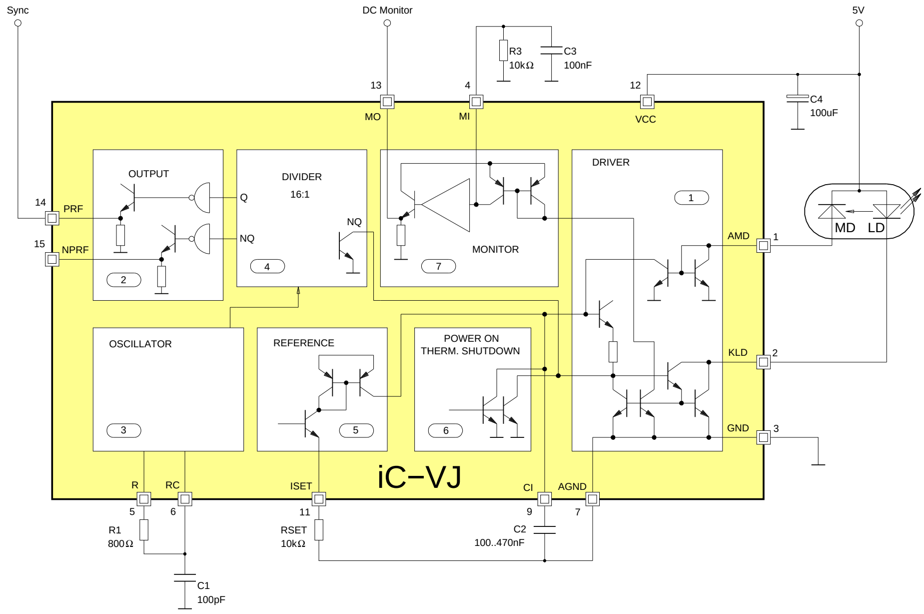


Figure 15: DL-4148-021 or DL-4148-031 in pulse operation with iC-VJ

### DL-3149-057

The **DL-3149-057** is an N-type laser diode with a maximum of 45 mA. Here the same applies as for DL-4148-021 and DL-4148-031.

### DL-3146-151, DL-3146-152

**DL-3146-151** and **DL-3146-152** are 405 nm M-type laser diodes with a maximum of 70 mA and 110 mA respectively. The considerably higher forward voltage of ca. 5.5 V means that only iC-NZ can be used here (Figure 16). The laser diode is then powered separately from a higher voltage.

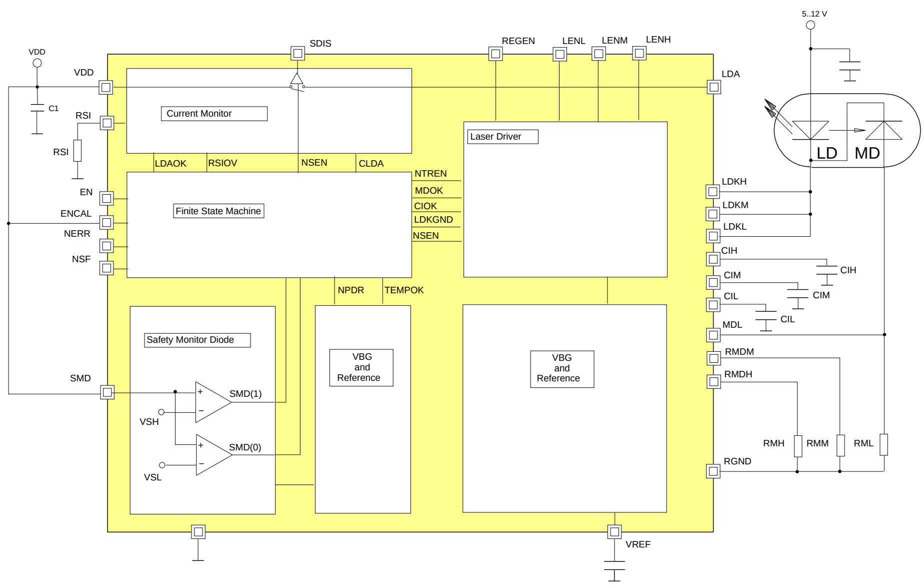


Figure 16: DL-3146-151 and DL-3146-152 in pulse operation with iC-NZ