APPLICATION NOTES

Setting the laser current

When switching DC currents of up to 150mA or pulse currents of up to 700mA one channel is sufficient (Example 1). Input ENx of the unused channel should be jumpered to GND and pin AGNDx left open. Higher currents or several different current levels can be obtained by using both channels (Example 2 and 3).

Example 1: Switching a current of 100mA

1. 100mA < 150mA ⇒ one channel
2. Switching on and off only ⇒ RK can be omitted (RK = 0Ω)
3. As shown in Figure 1 (cf. data sheet, Figures 2..4), the required voltage V(CI) for RK = 0Ω is read off at I(LDK) = 100mA as V(CI) = 1.75V

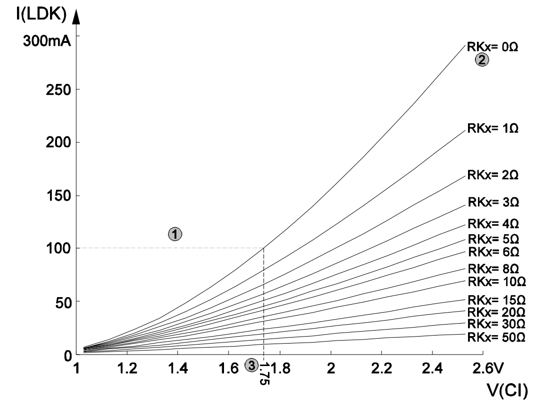

Fig. 1: Determining V(CI) for Example 1 - pulse current of 100mA

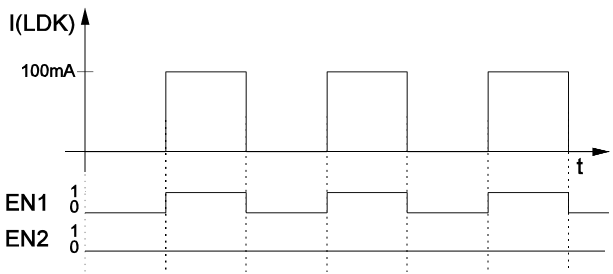

Fig. 2: Signal patterns for Example 1 - pulse current of 100mA

With the circuit shown in Figure 3 and a voltage of 1.75V at pin CI the laser current can be switched between typically 0mA and 100mA by applying an appropriate pulse pattern to EN1.

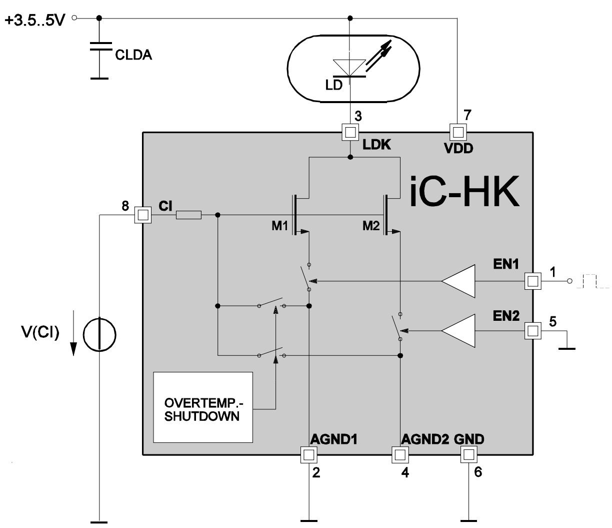

Fig. 3: Circuit with iC-HK for Example 1 - pulse current of 100mA

Example 2: Switching between 50mA and 250mA

1. More than two current levels ⇒ both channels are required
2. The lower DC current level of 50mA is provided by channel 1 and the remaining 200mA pulse current by channel 2
3. As shown in Figure 4 (cf. data sheet, Figure 3), an RK2 value is selected for I(LDK) = 200mA and the corresponding voltage V(CI) then determined - e.g. RK2 = 2Ω und V(CI) = 2.75V
4. Again as shown in Figure 4, the appropriate value of RK1 is determined for I(LDK) = 50mA and V(CI) = 2.75V as RK1 = 20Ω

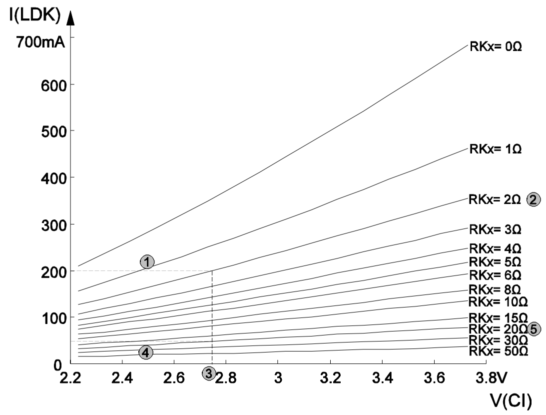

Fig. 4: Determining V(CI) for Example 2 and 3

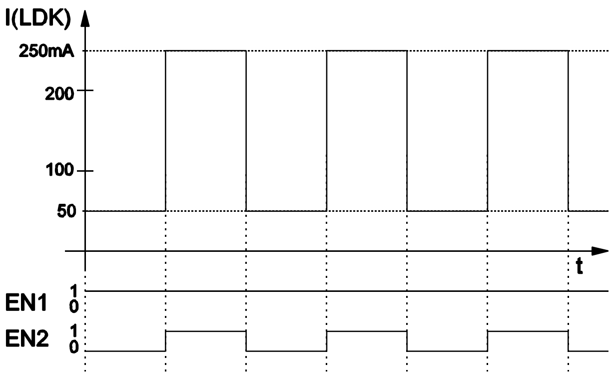

Fig. 5: Signal patterns for Example 2

With the circuit shown in Figure 6, a voltage of 2.75V at pin CI, RK1 = 20Ω, RK2 = 2Ω and EN1 = VDD the laser current can be switched between typically 50mA and 250mA by applying an appropriate pulse pattern to EN2.

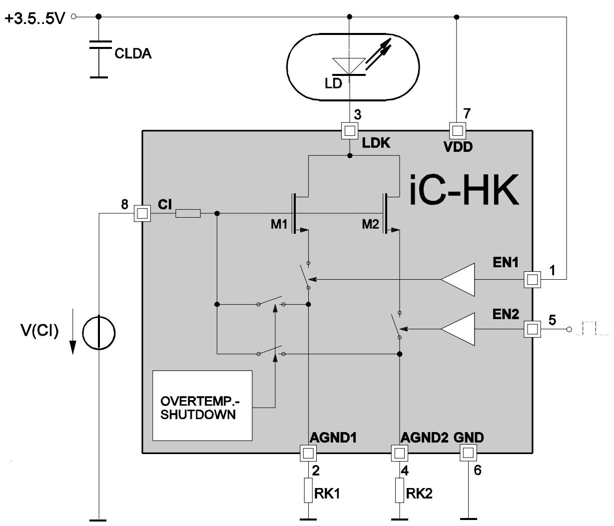

Fig. 6: Circuit with iC-HK for Example 2

Example 3: Switching the laser current between 0mA, 100mA, 200mA and 300mA

1. More than two current levels ⇒ both channels are required
2. 100mA are provided by channel 1, 200mA by channel 2 and 300mA by both channels together
3. Similar to Example 2, here RK2 is chosen to 3Ω and V(CI) to 3V for I(LDK) = 200mA
4. As shown in Figure 3 of the data sheet the corresponding value of RK1 is read off at ca. 9Ω for I(LDK) = 100mA and V(CI) = 3V

With the circuit shown in Figure 8, a voltage of 3V at pin CI, RK2 = 3Ω and RK1 = 9Ω a pulse pattern similar to the one shown in Figure 7 can be obtained.

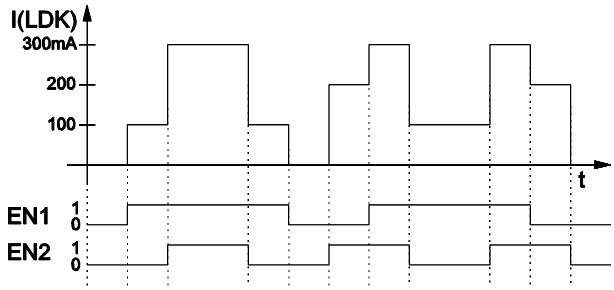

Fig. 7: Signal patterns for Example 3

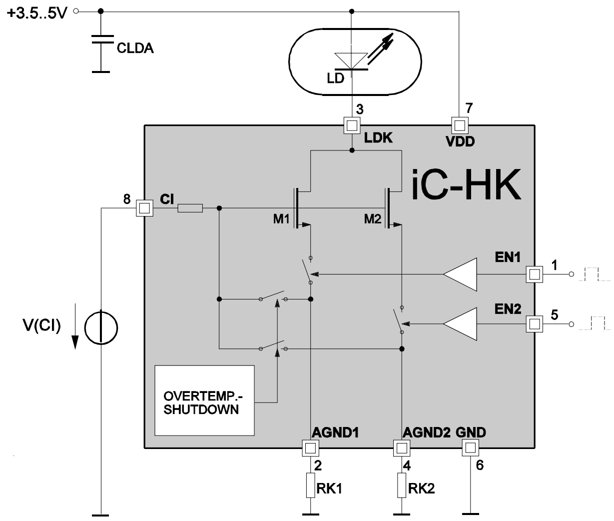

Fig. 8: Circuit with iC-HK for Example 3

Controlling the laser power in conjunction with iC-WK
iC-HK operates as a voltage-controlled current source. Canges in temperature, ageing and reflections from attached lenses will alter the power/current ratio of the laser diode in such a way that the emitted laser power differs from the adjusted bias point. The laser power thus has to be monitored and the laser current readjusted accordingly. This can be achieved by using laser driver iC-WK; this device has the added advantage of an integrated soft start facility which protects the laser diode when the power supply is switched on.

When using laser diodes with integrated monitor diodes (all pin configurations are possible) iC-WK can monitor the emitted laser power and control the voltage at pin CI in such a way that the mean value of the monitor current Im_{av} - and thus the mean value of the emitted optical laser power - remains constant. For iC-WK to achieve a proper control to the mean the pulse frequency has to be higher than 100kHz. Otherwise iC-WK will try to readjust with every pulse.
It is imperative that the pulse signals are available at ENx when the power supply is switched on! Otherwise, as a monitor signal is then lacking, iC-WK will set the voltage at CI to maximum which might damage the laser diode with the first high pulse at ENx.

Example 4: Switching a current of 100mA with control to the mean value by iC-WK

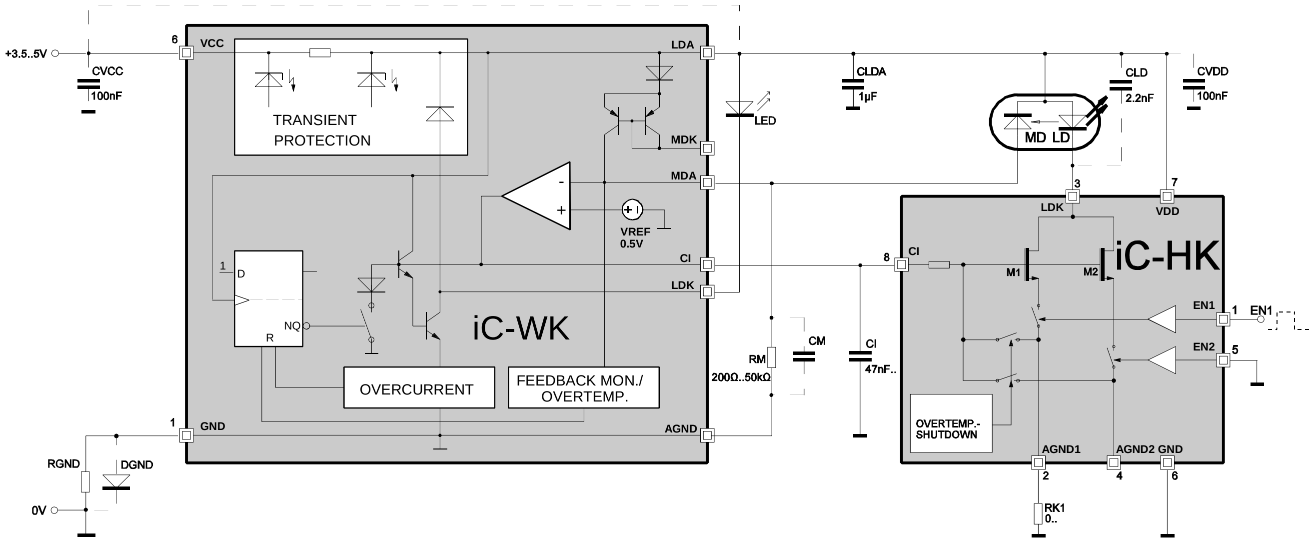

Fig. 9: Controlled laser power with iC-HK in conjunction with iC-WK

The typical monitor current (Im_{hi}) for the chosen laser power is determined from the laser diode data sheet. Since iC-WK controls the mean value of the monitor current this has to be calculated from the duty cycle:

$$Im_{av} = Im_{hi} \times t_{hi} / T$$

The value of RM is calculated from the internal reference voltage of iC-WK (Item No. 101, iC-WK data sheet: typically 500mV) as

$$RM = 500\ mV / Im_{av}$$

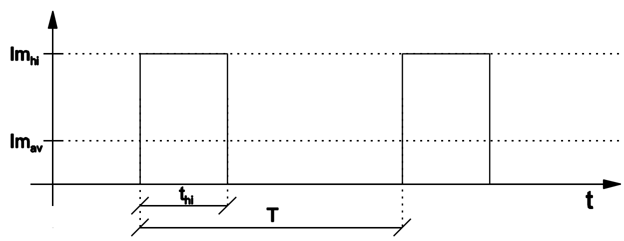

Fig. 10: Pulse pattern for Example 4 - laser power controlled by iC-WK

iC-WK sets voltage V(CI) so that the mean value of the monitor current matches the target current Im_{av}.

iC-WK's modulation range is at its maximum when for a current I(LDK) of ca. 45mA the voltage at pin CI vs. pin GND of iC-WK is approximately 1.7V (min 1.1V, max 2.2V - limited by the saturation of the output stage or by the overcurrent shutdown). The voltage across pin VCC and pin GND of iC-WK has to be sufficiently high so that 45mA through LDK will not drive the output stage into saturation.
A voltage of 1.7V at CI with RKx = 0Ω produces a current of approximately 150mA per channel through iC-HK's pin LDK. For higher laser currents the voltage at CI can be increased by virtually raising iC-WK's pin GND. This can be achieved by inserting a diode (DGND) or a resistor (RGND) between iC-WK's GND pin and the system ground. The forward voltage of the diode V_{fw}(DGND) should satisfy the following condition:

$$V_{fw}(DGND) \approx V(CI) - 1.7V$$

Resistor RGND should be set to:

$$RGND \approx (V(CI) - 1.7V) / 45mA$$

Resistors RKx are not usually required. However for laser diodes operating on very low currents RKx might be necessary due to the lower voltage limit of iC-WK at pin CI. When dimensioning the resistors Figures 2..4 from the data sheet should be refered to as shown in Example 1. Furthermore, the use of resistors RKx can be useful when implementing protection against overcurrent (see page 8, 'Overcurrent shutdown/Laser current limitation').

The value of capacitor CI depends primarily on the pulse frequency. If CI is too small iC-WK would try to readjust during a clock cycle and thus no control to the mean would occur. Since iC-WK controls the optical power by setting the voltage at pin CI, overcurrent shutdown or - even worse - laser damage might occur if the voltage at CI is too high with the next high pulse. Capacitor CI must thus be sufficiently large so that the voltage at CI remains more or less constant during the low pulse. The following equation is helpful when estimating a value for CI:

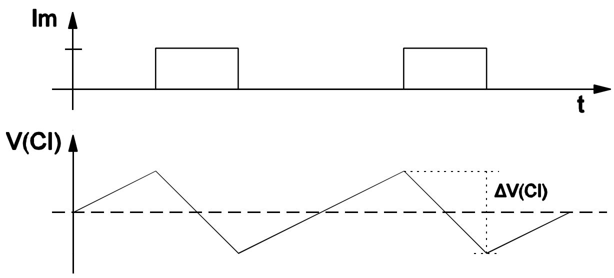

Fig. 11: Ripple at CI with respect to Im

$$CI \geq (100\ \mu A / f) / \Delta V(CI)$$

Here, ΔV(CI) is the permissible ripple at CI and f the clock frequency. The permissible ripple depends on the laser diode used; this is typically 2mV. For diodes with an extremely steep characteristic the permissible ripple has to be reduced even further.

At low clock frequencies (<100kHz), high laser currents or with an excessively high-resistance RM the voltage at MDA may rise above ca. 0.7V during a light pulse, thus triggering the permanent overcurrent shutdown. In this instance we recommend using a capacitor CM in parallel with RM. To avoid an overshoot at pin CI when the system is switched on, which can cause hazardous overcurrent to pass through the laser, CM has to be selected so that the time constant at node MDA is approximately 1/10 of the CI control time constant:

$$CM \approx 1 / (10 \times f \times RM)$$

Should the use of CM be necessary capacitor CI has to be increased to reduce a possible tendency towards oscillation.

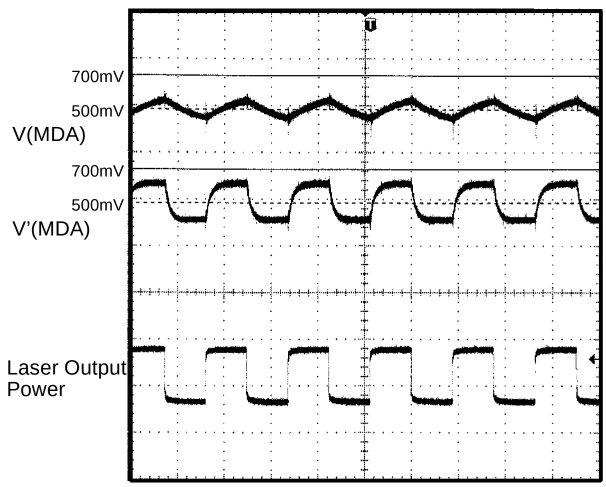

Fig. 12: Voltage at MDA with (V(MDA)) and without (V'(MDA)) capacitor CM

For 5mW laser power with a duty cycle t_{hi}/T of 1:10 and f = 100kHz, an Im_{hi} of 0.1mA is yielded for a specific diode type, i.e. the mean monitor current is

Im_{av} = 10µA. RM is thus set to ca. 50kΩ and CI to 50nF. The use of CM is recommended at 100kHz. This is set to 20pF.

The oscillogram on the right gives the probable response of the optical laser power with respect to the power supply and inputs EN1 and EN2.

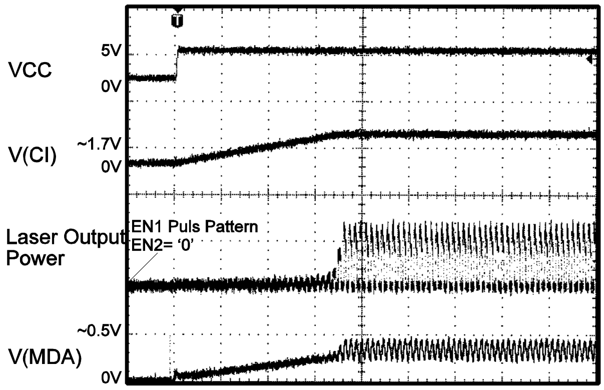

Fig. 13: Optical laser power for Example 4

Example 5: Switching between two levels (50mA and 250mA) with control to the mean by iC-WK

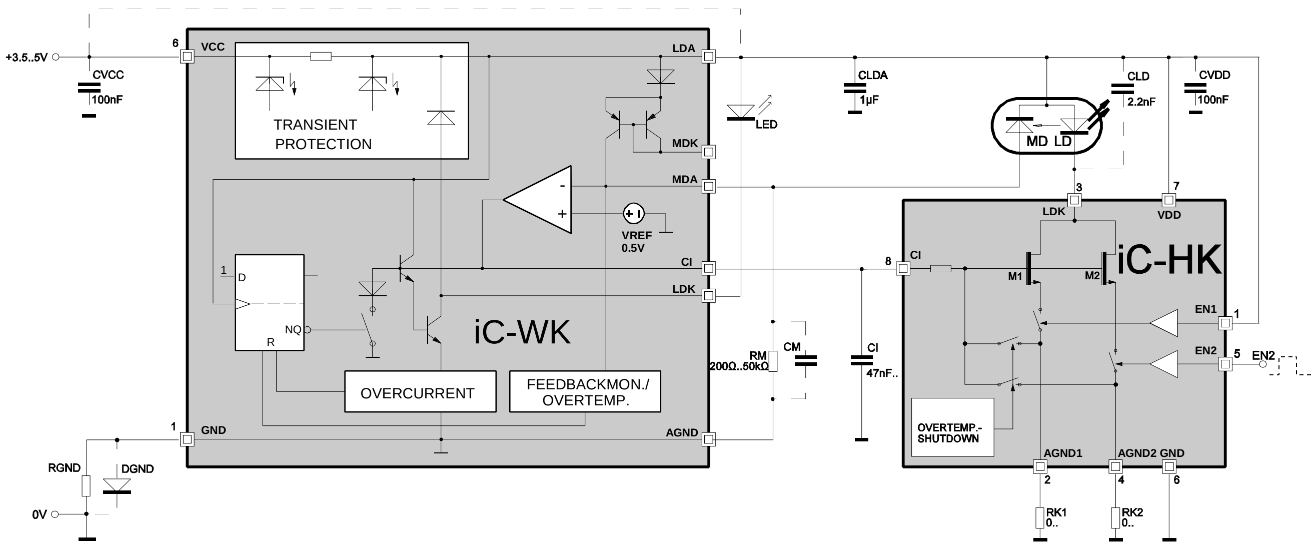

Fig. 14: Switching between two levels with control to the mean by iC-WK

By connecting one of the two ENx inputs (here, EN1) to VDD the corresponding channel is permanently switched on, producing a bias current. Via the second input (EN2) the other channel can be pulsed. The bias and the pulse currents cumulate at pin LDK. Figure 15 gives the possible response of the optical laser power and the voltages at CI and MDA with reference to the power supply and inputs EN1 and EN2.

The dimensioning of RK1, RK2 and voltage V(CI) is similar to Example 2.

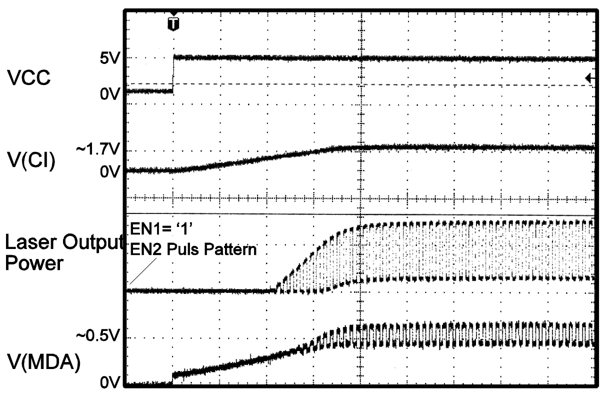

Fig. 15: Optical laser power for Example 5

iC-WK controls the mean value of the monitor current. This thus has to be calculated from the high and low level and the duty cycle of the monitor current as follows:

$$Im_{av} = Im_{hi} \times t_{hi} / T + Im_{lo} \times t_{lo} / T$$

For a current ratio of $k = Im_{hi} / Im_{lo}$ it follows that

$$Im_{av} = Im_{lo} \times (t_{lo} + k\, t_{hi}) / T$$

or

$$Im_{av} = Im_{hi} / k \times (t_{lo} + k\, t_{hi}) / T$$

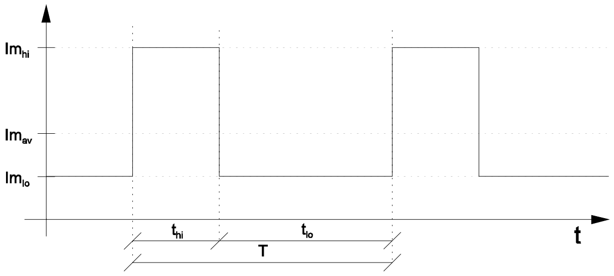

Fig. 16: Pulse pattern for Example 5 - power control for pulse and bias current

Resistor RM is calculated as

$$RM = 500mV / Im_{av}$$

The optimum operating point for iC-WK is if the voltage across CI and GND is approximately 1.7V. With the aid of resistor RGND or diode DGND the ground potential of iC-WK can thus be raised with respect to the system ground. RGND is typically set to

$$RGND = (V(CI) - 1.7V) / 45mA$$

Diode DGND should be selected so that the forward voltage $V_{fw}(DGND)$ is

$$V_{fw}(DGND) = V(CI) - 1.7V$$

Overcurrent protection through permanent shutdown of iC-WK

To protect the laser diode the additional circuitry shown in Figure 17 can be applied. The permanent shutdown of iC-WK prevents overcurrent.

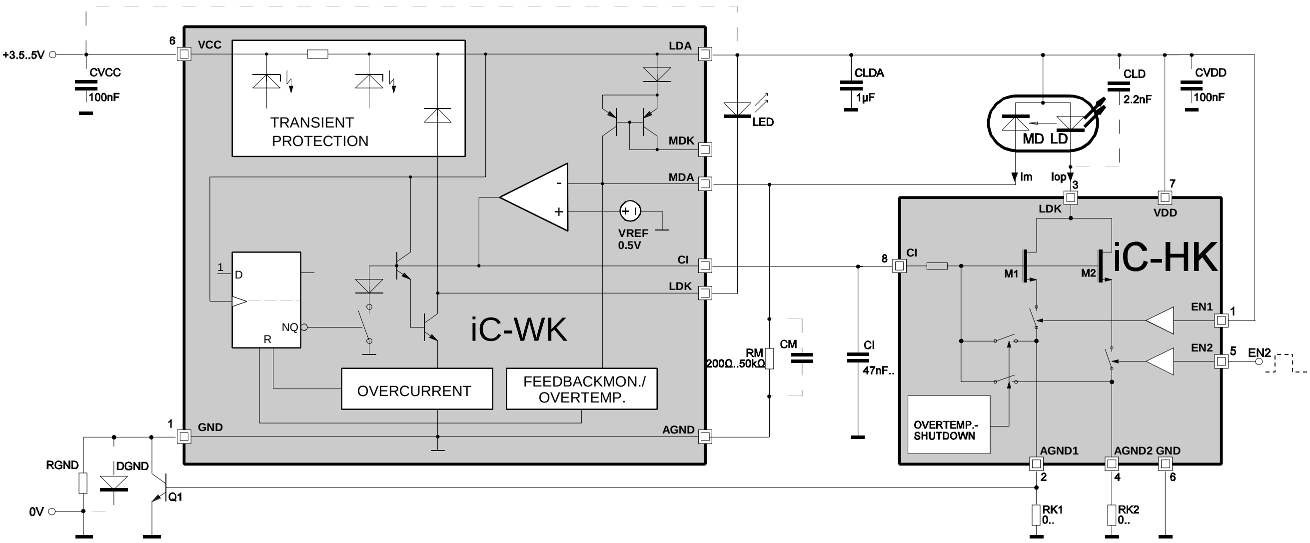

Fig. 17: Overcurrent protection by permanent shutdown of iC-WK

If for a given laser current Iop the overcurrent threshold Iop_{max} is a certain percentage higher than the desired high level Iop_{hi}, then this also applies to each of the partial currents for the two channels. It is thus sufficient when monitoring the laser current to monitor a single channel only. To keep the requirements on the specification of the switching transistor Q1 relatively low it is advisable to monitor the channel with the lower frequency. The shutdown/limitation threshold is calculated as

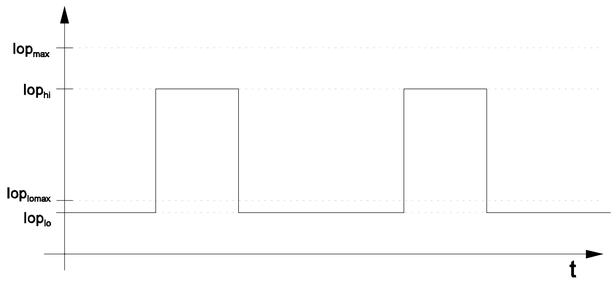

Fig. 18: Puls pattern for overcurrent shutdown

$$Iop_{lomax} = Iop_{lo} \times Iop_{max} / Iop_{hi}.$$

The required RKx for the bias channel is calculated as

$$RKx = U_{BE} / Iop_{max}$$

The value for the other RKx and voltage V(CI) can be determined using Figures 2..4 from the data sheet.

With excessive laser current the voltage drop across RKx exceeds U_{BE}(Q1). Transistor Q1 is switched on, thus lowering the voltage at pin GND on iC-WK and therefore the voltage at CI. iC-WK tries to compensate for this, resulting in a higher current in LDK which activates iC-WK‘s permanent overcurrent shutdown.

Laser current limitation without an iC-WK shutdown

Another way of providing protection against overcurrent is illustrated in Figure 19. With increasing current through RK1 transistor Q1 is switched on, lowering the voltage at CI and thus reducing the laser current without triggering iC-WK's overcurrent shutdown.

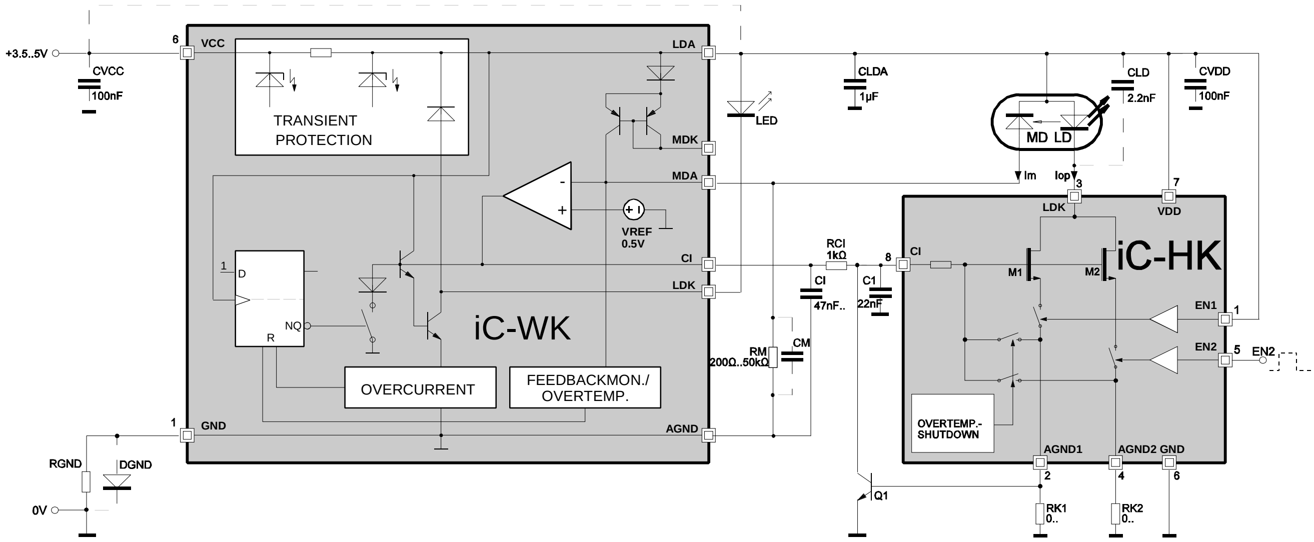

Fig. 19: Laser current limitation without an iC-WK shutdown

Caution: Due to the direct feedback of the controlled current through RKx to the control voltage at CI there is a certain tendency towards oscillation. This can be counteracted by experimenting with the settings of the components involved.

Hint: Please bear in mind that the laser characteristic of most laser diodes has a strong temperature dependency, in particular with regard to threshold current (I_{th}) and efficiency. To avoid damage to the laser diode sufficient cooling has to be provided and/or protection against overcurrent implemented as shown above.

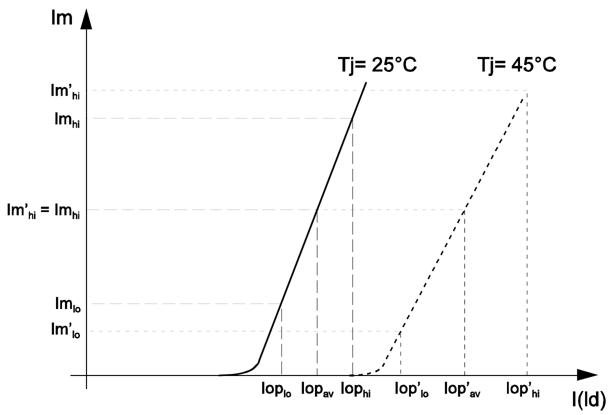

Fig. 20: Temperature dependency of the laser bias

Layout advise

iC-HK can be used in a wide range of applications from CW to over 150 MHz. Very fast switches have thus been integrated, which have to be properly blocked to prevent ringing. A small blocking capacitor is therefore required for iC-WK between pin 2 (CI) and 3 (AGND) and also at pin 4 (CI) of iC-HK (cf. Figure 19). Increasing capacitor CLDA might also help to suppress ringing.
If the connection between the laser diode and iC-HK (LDK Pin 7) is loaded inductively, a small capacitor CLD in parallel with the laser diode is recommended to suppress current spikes.
With higher pulse frequencies it is advisable to use separate grounds for iC-WK, iC-HK, capacitor C1 and resistors Rkx respectively.
The connection between VCC and LDA (dashed line) is necessary for laser currents >70mA.

Device	Typical value	Comment
CVCC	100nF	Power supply blocking capacitor for iC-WK
CVDD	100nF	Power supply blocking capacitor for iC-HK
CLDA	1µF	Laser diode supply smoothing capacitor
CLD	2.2nF	Laser diode ESD protection, filtering with inductive loads; to be mounted directly across the laser diode
CI	47nF..	Averaging capacitor for V(CI)-control by iC-WK
CM		MDA smoothing capacitor, has to be calculated
C1	22pF	CI smoothing capacitor (used with current limitation)
LED	V_{fw} < V(VCC_{WK}) - V(GND_{WK}) -1V	Load for iC-WK output stage; LED must be capable of 45mA; may be replaced by a resistor or even jumpered
DGND	V_{fw} ≈V(CI) - 1.7V	Ground shift at iC-WK to increase V(CI)
RGND	0Ω .. 100Ω	Ground shift at iC-WK to increase V(CI)
RM	200Ω .. 50kΩ	Set point of monitor current (mean value)
RK1	0Ω ..	Set point of current through channel 1
RK2	0Ω ..	Set point of current through channel 2
RCI	1kΩ	Decoupling of pin CI at iC-WK and iC-HK for laser current limitation

APPLICATION EXAMPLES

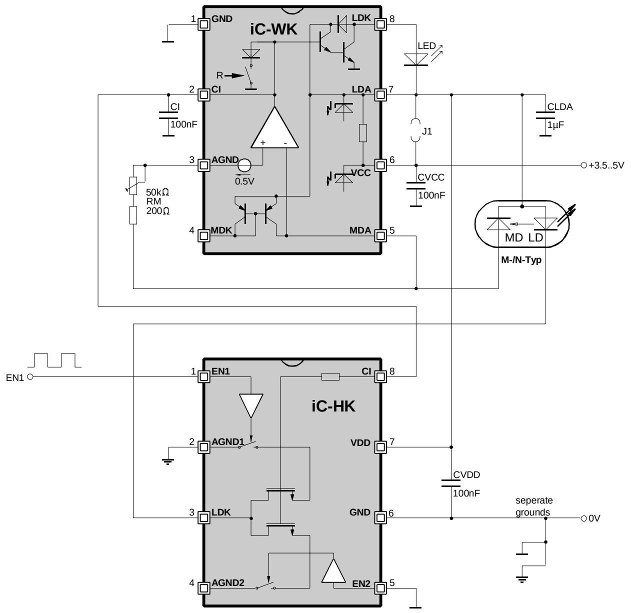

Fig. 21: Minimum circuit for M- or N-type laser diodes; jumper J1 for I(LDK) > 70mA

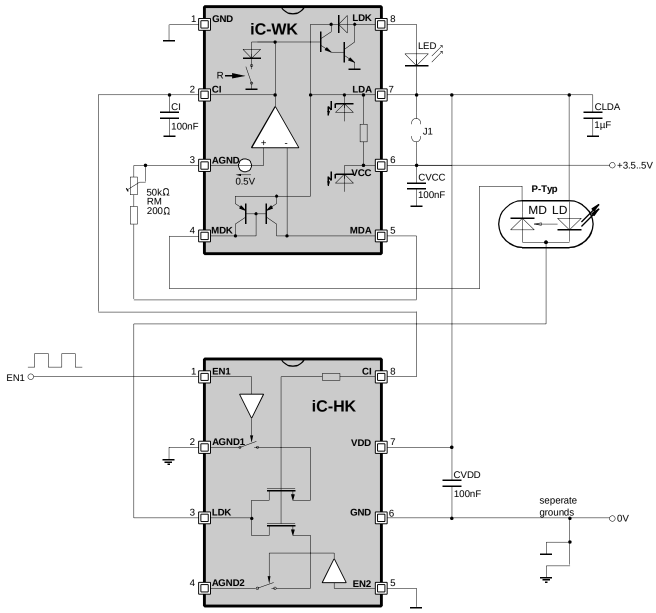

Fig. 22: Minimum circuit for P-type laser diodes; jumper J1 for I(LDK) > 70mA

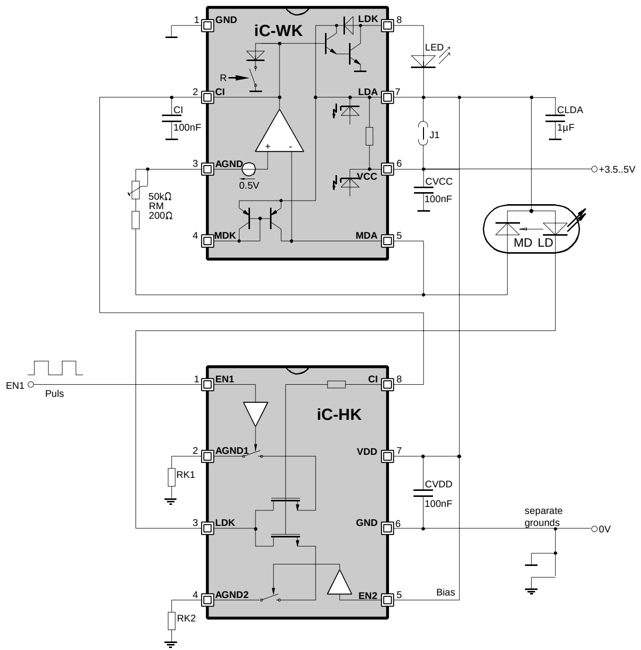

Fig. 23: Circuit for switching between two current levels (e.g. 50mA and 220mA)

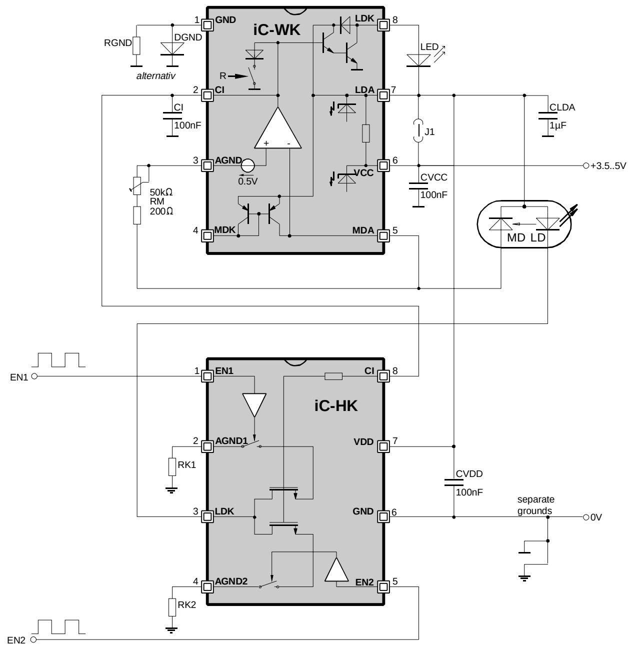

Fig. 24: Circuit for switching between two current levels with GND shift for iC-WK via RGND or DGND

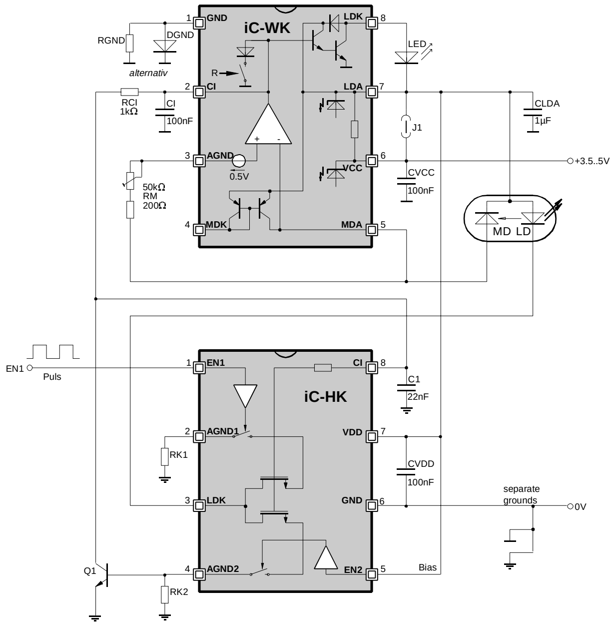

Fig. 25: Same as Figure 24; with laser current limitation by monitoring the bias current and reducing V(CI)

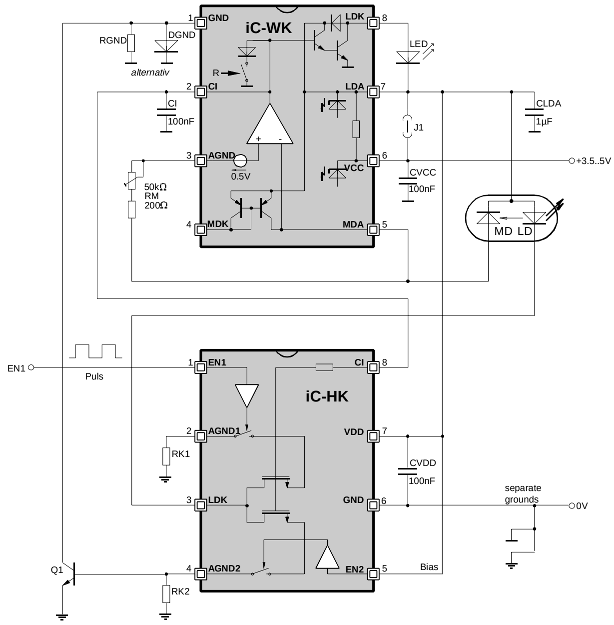

Fig. 26: Same as Figure 24; with permanent overcurrent shutdown of iC-WK by monitoring the bias current

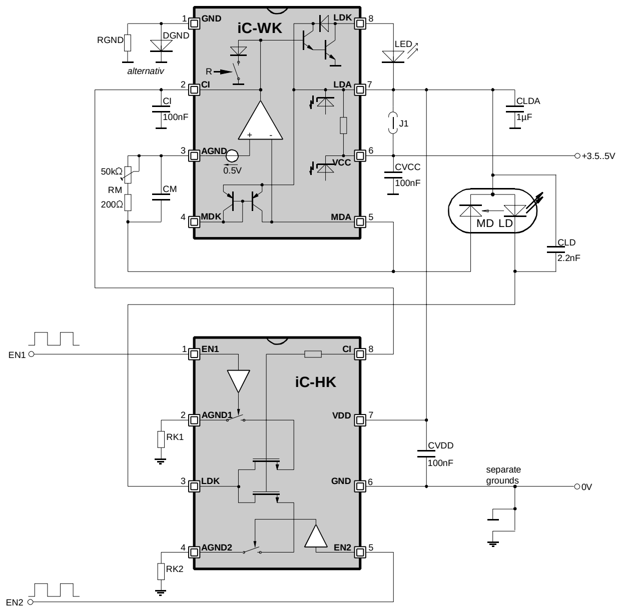

Fig. 27: Same as Figure 24; with additional components to reduce oscillation tendency and ringing (dimensioning has to be determined by experiment)

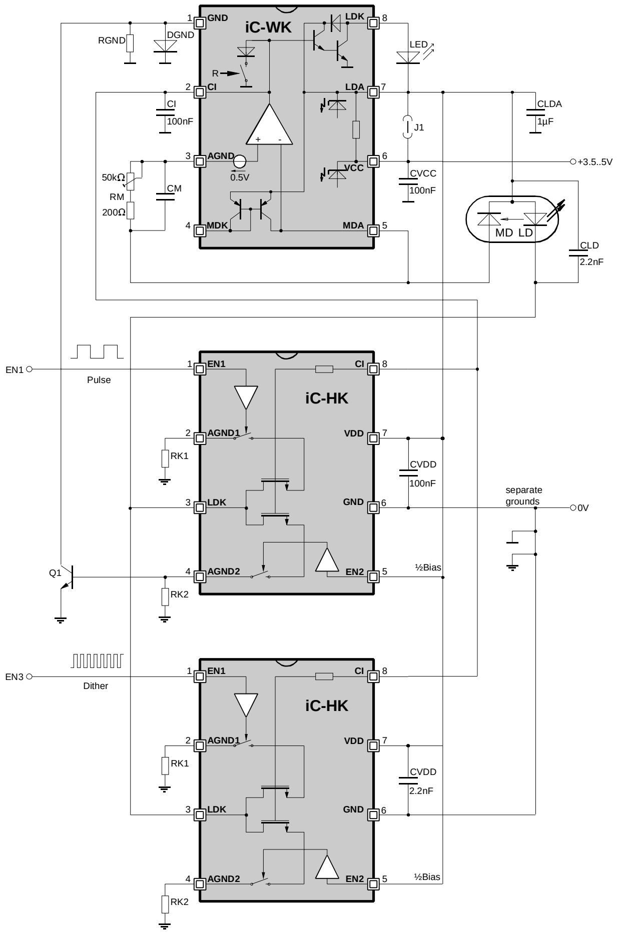

Fig. 28: Use of two iC-HKs to enlarge the bias current and to allow dithering