

## iC-NZ FAIL-SAFE LASER DIODE DRIVER

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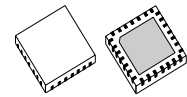
### FEATURES

- ◆ Peak value controlled three level laser switch for operation from CW up to 155 MHz
- ◆ Spike-free switching of laser currents of ca. 100 mA per channel (320 mA total) from 3.5 to 5 V supply voltage
- ◆ Single-failure-proof
- ◆ System-enable with self test
- ◆ Separate setting of laser power for each channel via external resistors
- ◆ Strong suppression of transients with very small external capacitors
- ◆ Adjustable laser current monitor
- ◆ Safety shutdown with overcurrent, overtemperature and undervoltage
- ◆ Autonomous safety circuit for a second photo diode monitoring the laser power
- ◆ All current LD types can be used (M/P/N configurations)
- ◆ Error signal output at shutdown

### APPLICATIONS

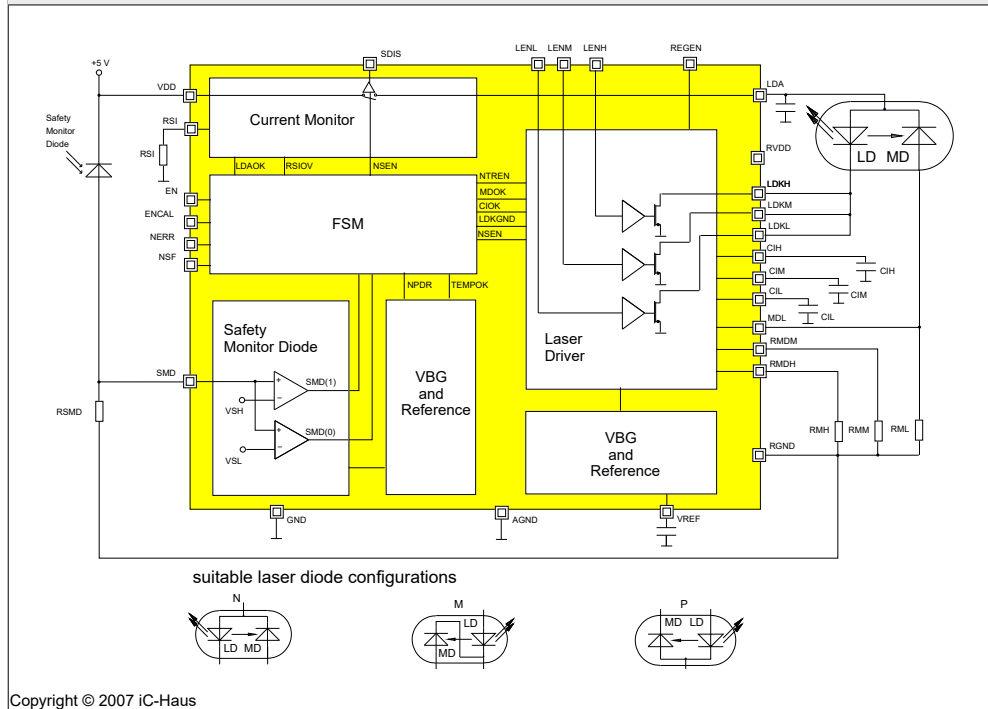
- ◆ Pulsed LD modules for safety applications
- ◆ Distance measurement

### PACKAGES



QFN28 5 mm x 5 mm

### BLOCK DIAGRAM



## iC-NZ

### FAIL-SAFE LASER DIODE DRIVER

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#### DESCRIPTION

Three-channel laser diode pulse regulator iC-NZ enables the continuous wave operation of laser diodes and spike-free switching with defined current pulses in a frequency range of up to 155 MHz. The three channels can be accumulatively pulsed via inputs LENL, LENM and LENH. The peak optical power of the laser diodes is regulated separately for high, middle and low levels and adjusted using the three external resistors RMH, RMM and RML.

The iC is activated via pin EN which triggers a self-test of the device. The system is enabled if no errors are detected. Any errors are signaled at pin NERR.

The (average) current monitor can be set using external resistor RSI. Overcurrent is signaled at NERR, causing the iC to be shut down.

To ensure that the selected laser class is maintained a second monitor input SMD (*safety monitor diode*) is needed. This optional photo diode monitors the laser power. Exceeding the monitor window, set-up by RSMD, triggers a permanent reset. This is re-

ported at output NERR and can be deleted when the system is restarted at EN.

For high pulse frequencies the device can be switched into controlled *burst mode* at input REGEN. A previously settled operating point is maintained throughout the burst phase.

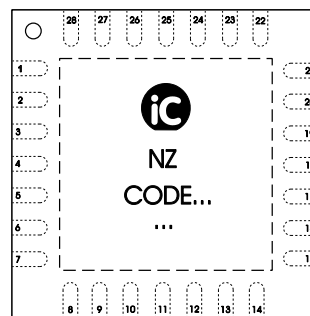
When the iC is switched on all safety-relevant signals pertinent to the current monitor, SMD and control unit are checked. These units are in turn monitored for the following: overcurrent, short circuits, open pins and whether the laser is switched off in terms of output power. With the exception of the latter these checks are carried out intermittently during operation. So that the device is single-failure-proof various safety check routines are also implemented. To this end a second SMD (*safety monitor diode*) monitoring the laser power is required. The laser power must stay within a defined range during operation (thus maintaining the laser class). If this range is left, the system is shut down and an error message is generated.

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PACKAGES QFN28 5 mm x 5 mm to JEDEC Standard (MO-220-VHHD-1)

### PIN CONFIGURATION QFN28 5 mm x 5 mm (top view)



### PIN FUNCTIONS

| No. | Name | Function                        |
|-----|------|---------------------------------|
| 1   | RMDH | APC Setup, Monitor Input Hi     |
| 2   | RVDD | Reference (P-type laser diodes) |
| 3   | RMDM | APC Setup, Monitor Input Mid    |
| 4   | NSF  | No-Safety Signal                |

### PIN FUNCTIONS

| No. | Name  | Function                    |
|-----|-------|-----------------------------|
| 5   | MDL   | APC Setup, Monitor Input Lo |
| 6   | ENCAL | Enable Calibration          |
| 7   | RGND  | Internal Ground             |
| 8   | SMD   | Safety Monitor Diode        |
| 9   | GND   | Ground                      |
| 10  | VREF  | Reference Voltage           |
| 11  | CIL   | Power Control Capacitor Lo  |
| 12  | REGEN | Regulator Enable            |
| 13  | CIM   | Power Control Capacitor Mid |
| 14  | LENL  | Enable Laser Channel Lo     |
| 15  | LENM  | Enable Laser Channel Mid    |
| 16  | GND   | Ground                      |
| 17  | LDKM  | Cathode Laser Diode Mid     |
| 18  | AGND  | Analog Ground               |
| 19  | LDKL  | Cathode Laser Diode Lo      |
| 20  | LDKH  | Cathode Laser Diode Hi      |
| 21  | LENH  | Enable Laser Channel Hi     |
| 22  | NERR  | Error Output                |
| 23  | EN    | Enable Input                |
| 24  | CIH   | Power Control Capacitor Hi  |
| 25  | LDA   | Anode Laser Diode           |
| 26  | RSI   | Current Monitor Setup       |
| 27  | SDIS  | External Current Limitation |
| 28  | VDD   | Power Supply                |

The *Thermal Pad* is to be connected to a Ground Plane (GND) on the PCB. Pins 9, 16 (GND) and 18 (AGND) must be connected externally, e.g. to a Ground Plane.

Orientation of package label (⊙ NZ CODE ...) may vary.

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### ABSOLUTE MAXIMUM RATINGS

Beyond these values damage may occur; device operation is not guaranteed.

| Item No. | Symbol  | Parameter   | Conditions                            |      |      | Unit |
|----------|---------|---|---------------------------------------|------|------|------|
|          |         |   |                                       | Min. | Max. |      |
| G001     | VDD     | Supply Voltage VDD Current  |                                       | -0.7 | 6    | V    |
| G002     | I(VDD)  | Current in VDD  |                                       |      | 400  | mA   |
| G003     | I(Clx)  | Current in Clx  | V(LDA) = 0                            |      | 5    | mA   |
| G004     | I(NSF)  | Current in NSF  |                                       |      | 20   | mA   |
| G005     | I(SMD)  | Current in SMD  |                                       |      | 20   | mA   |
| G006     | I(NERR) | Current in NERR   |                                       |      | 20   | mA   |
| G007     | I(MDL)  | Current in MDL  |                                       |      | 20   | mA   |
| G008     | I(RMDx) | Current in RMDx   |                                       |      | 20   | mA   |
| G009     | I(dig)  | Current in LENL, LENM, LENH, REGEN, NEN, ENCAL  |                                       |      | 20   | mA   |
| G010     | I(LDKx) | Current in LDKx   |                                       |      | 300  | mA   |
| G011     | I(LDA)  | Current in LDA  |                                       |      | 400  | mA   |
| G012     | I(RSI)  | Current in RSI  |                                       |      | 20   | mA   |
| G013     | I(SDIS) | Current in SDIS   |                                       |      | 20   | mA   |
| G014     | I(VREF) | Current in VREF   |                                       |      | 50   | mA   |
| G015     | V()c    | Voltage at RMDH, RVDD, RMDM, NSF, MDL, ENCAL, SMD, VREF, REGEN, Clx, LENx, NERR, LDA, RSI, SDIS |                                       | -0.7 | 6    | V    |
| G016     | V()h    | Voltage at LDKx   |                                       | -0.7 | 15   | V    |
| G017     | Vd()    | ESD Susceptibility at all pins  | HBM, 100 pF discharged through 1.5 kΩ |      | 2    | kV   |
| G018     | Tj      | Operating Junction Temperature  |                                       | -40  | 150  | °C   |
| G019     | Ts      | Storage Temperature Range   |                                       | -40  | 150  | °C   |

### THERMAL DATA

Operating Conditions: VDD = 3.5...5.5V

| Item No. | Symbol | Parameter   | Conditions   |      |      |      | Unit |
|----------|--------|---|--|------|------|------|------|
|          |        |   |  | Min. | Typ. | Max. |      |
| T01      | Ta     | Operating Ambient Temperature Range (extended range on request) |  | -20  |      | 90   | °C   |
| T02      | Rthja  | Thermal Resistance Chip/Ambient                                 | surface mounted, thermal pad soldered to ca. 2 cm <sup>2</sup> heat sink |      | 30   | 40   | K/W  |

All voltages are referenced to ground unless otherwise stated.  
All currents into the device pins are positive; all currents out of the device pins are negative.

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### ELECTRICAL CHARACTERISTICS

Operating Conditions: VDD = 3.5...5.5 V, Tj = -20...85 °C; x: L, M, H, unless otherwise stated

| Item No.                           | Symbol                  | Parameter  | Conditions  | Min. | Typ.       | Max.     | Unit   |
|------------------------------------|-------------------------|--|---|------|------------|----------|--------|
| <b>Total Device</b>                |                         |  |   |      |            |          |        |
| 001                                | VDD                     | Permissible Supply Voltage   |   | 3.5  |            | 5.5      | V      |
| 002                                | I <sub>off</sub> (VDD)  | Supply Current in VDD  | EN = lo   |      | 460        | 600      | µA     |
| 003                                | I <sub>dc</sub> (VDD)   | Supply Current in VDD  | EN = hi, RSI > 780 Ω  |      | 6.4        | 10       | mA     |
| 004                                | Tab                     | Thermal Shutdown Threshold   |   | 110  |            | 150      | °C     |
| 005                                | VDDen                   | Power-On Threshold   |   | 2.1  |            | 2.95     | V      |
| 006                                | V <sub>c</sub> (hi)     | Clamp Voltage hi at REGEN, LENH, LENM, LENL, EN, ENCAL, LDA, NERR, NSF | I() = 1 mA, other pins open, VDD = 0                                | 0.3  |            | 1.5      | V      |
| 007                                | V <sub>c</sub> (hi)     | Clamp Voltage hi at Clx, MDL, RMDH, RMDM SMD                           | I() = 1 mA, other pins open, VDD = 0                                | 0.3  |            | 1.6      | V      |
| 008                                | V <sub>c</sub> (hi)     | Clamp Voltage hi at LDKx   | I() = 1 mA, other pins open   | 12   |            |          | V      |
| 009                                | V <sub>c</sub> (hi)     | Clamp Voltage hi at RSI, VREF  | I() = 1 mA, other pins open, VDD = 0                                | 0.3  | 0.9        | 1.5      | V      |
| 010                                | V <sub>c</sub> (hi)     | Clamp Voltage hi at SDIS   | I() = 1 mA, other pins open   | 6    |            |          | V      |
| 011                                | V <sub>c</sub> (lo)     | Clamp Voltage lo   | I() = 1 mA, other pins open   | -1.5 | -0.65      | -0.3     | V      |
| <b>Reference</b>                   |                         |  |   |      |            |          |        |
| 101                                | V(MDL)                  | Voltage at MDL, VDD - V(MDL) for P-type LD                             | closed control loop   | 440  | 500        | 550      | mV     |
| 102                                | dV(MDL)                 | Temperature Drift of Voltage at MDL                                    | closed control loop   |      | 120        |          | µV/°C  |
| 103                                | I()                     | Current in MDL, RMDM, RMDH   | LENL, LENM, LENH = hi   | -500 |            | 500      | nA     |
| 104                                | V(VREF)                 | Voltage at VREF, VDD - VREF for P-type LD                              | iC active   | 405  | 480        | 550      | mV     |
| <b>Digital Inputs</b>              |                         |  |   |      |            |          |        |
| 201                                | I <sub>pd</sub> ()      | Pull-Down Current in LENx, EN  | V(LDA) = V(VDD)   | 1    | 4          | 10       | µA     |
| 202                                | I <sub>pd</sub> (REGEN) | Pull-Down Current in REGEN   | V(LDA) = V(VDD), V(ENCAL) < V <sub>t</sub> ()                       | 1    | 4          | 10       | µA     |
| 203                                | V <sub>t</sub> ()       | Threshold Voltage at LENx, REGEN, ENCAL, EN                            | VDD = 5 V   | 0.75 | 1.8        | 2.2      | V      |
| 204                                | V <sub>hys</sub> ()     | Hysteresis   |   |      | 800        |          | mV     |
| 205                                | R <sub>pd</sub> (REGEN) | Pull-Down Resistor at REGEN  | V(ENCAL) > V <sub>t</sub> ()  | 4    |            | 20       | kΩ     |
| 206                                | R <sub>pd</sub> (ENCAL) | Pull-Down Resistor at ENCAL  |   | 10   |            | 30       | kΩ     |
| <b>Safety Monitor Diode</b>        |                         |  |   |      |            |          |        |
| 301                                | VSL                     | Monitor Threshold lo, Signal SMD(0)                                    |   | 265  | 300        | 325      | mV     |
| 302                                | VSH                     | Monitor Threshold hi, Signal SMD(1)                                    |   | 615  | 680        | 750      | mV     |
| 303                                | dVS                     | VSH - VSL  |   | 350  | 390        | 430      | mV     |
| 304                                | VCHK                    | Test Voltage for SMD   |   |      |            | 120      | %VSH   |
| 305                                | I(RSMD)                 | Permissible Safety Monitor Diode Current                               |   |      |            | 5        | mA     |
| 306                                | I <sub>pd</sub> (SMD)   | Pull-Down-Current in SMD   |   | 0.2  | 0.6        | 3        | µA     |
| <b>Laser Driver LDKx, Cl, RMDx</b> |                         |  |   |      |            |          |        |
| 401                                | V <sub>s</sub> (LDKx)   | Saturation Voltage at LDKx   | one channel only is activated;<br>I(LDK) = 100 mA<br>I(LDK) = 60 mA |      | 1.2<br>0.8 | 2<br>1.3 | V<br>V |
| 402                                | I <sub>dc</sub> (LDKL)  | Permissible Current  | DC  |      |            | 120      | mA     |
| 403                                | I <sub>dc</sub> (LDKM)  | Permissible Current  | DC  |      |            | 100      | mA     |
| 404                                | I <sub>dc</sub> (LDKH)  | Permissible Current  | DC  |      |            | 100      | mA     |
| 405                                | V <sub>o</sub> ()       | Permissible Voltage at LDKx  |   |      |            | 12       | V      |
| 406                                | V <sub>Cl</sub> ()      | REGOK Monitor Threshold  |   | 100  | 760        | 900      | mV     |

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### ELECTRICAL CHARACTERISTICS

Operating Conditions: VDD = 3.5...5.5 V, Tj = -20...85 °C; x: L, M, H, unless otherwise stated

| Item No.                        | Symbol                        | Parameter  | Conditions   | Min. | Typ. | Max.       | Unit     |
|---------------------------------|-------------------------------|--|--|------|------|------------|----------|
| 407                             | C(ClX)                        | Capacitance at Clx   |  | 100  |      |            | nF       |
| 408                             | I(ClX)                        | Charge Current from Clx                                    | iC active, control unit not yet settled                      | 0.25 | 0.6  | 1          | mA       |
| 409                             | I(ClX)                        | Discharge Current in Clx                                   | iC inactive, V(ClX) > 1 V                                    | 10   |      | 60         | mA       |
| 410                             | Ipd(ClX)                      | Pull-Down Current in Clx                                   | iC active, REGEN = lo  | 25   |      | 150        | nA       |
| 411                             | I(RMDx)                       | Permissible Laser Monitor Diode Current                    | active safety function;<br>VDD = 5 V<br>VDD = 3.3 V          |      |      | 2.5<br>1   | mA<br>mA |
| <b>Status Outputs</b>           |                               |  |  |      |      |            |          |
| 501                             | I(NERR)                       | Current at Error Message                                   | V(LDA) = V(VDD) = V(NERR), error state                       | 1.5  |      | 10         | mA       |
| 502                             | I(NERR)                       | Current in NERR  | V(LDA) = V(VDD) = V(NERR),<br>no error state, V(MDL) < 0.5 V | 0.1  |      | 1          | mA       |
| 503                             | I(NSF)                        | Current at NSF Message                                     | V(LDA) = V(VDD) = V(NSF), V(NSF) > 0.8 V                     | 1.5  |      | 10         | mA       |
| 504                             | I(SDIS)                       | Current at SDIS Message                                    | V(LDA) = V(VDD) = V(SDIS), V(SDIS) > 0.8 V                   | 1.0  |      | 10         | mA       |
| 505                             | Vsat()                        | Saturation Voltage at NERR, NSF, SDIS                      | Isat = 1 mA, NERR in error state                             |      |      | 600        | mV       |
| <b>Current Monitor RSI, LDA</b> |                               |  |  |      |      |            |          |
| 601                             | V(RSI)                        | Controlled Voltage at RSI                                  | EN = hi  | 430  | 490  | 560        | mV       |
| 602                             | RSI                           | Resistor at RSI  |  | 0.78 |      | 9          | kΩ       |
| 603                             | VLDA                          | LDAOK Monitor Threshold<br>VDD – V(LDA)                    |  | 440  | 490  | 550        | mV       |
| 604                             | I <sub>dc</sub> (LDA)         | Current from LDA   | DC   |      |      | 320        | mA       |
| 605                             | R <sub>pd</sub> (LDA)         | Pull-Down Resistor at LDA                                  | Reset  |      |      | 1          | kΩ       |
| 606                             | t <sub>d</sub> (SDIS)         | Overcurrent Shutdown Delay                                 | I(LDA) > I(RSI) * 500  |      |      | 10         | μs       |
| 607                             | r <sub>LDA</sub>              | Current Ratio I(LDA) <sub>max</sub> /I(RSI)                | 780 Ω < RSI < 9000 Ω   | 400  | 500  | 650        |          |
| 608                             | I <sub>pd</sub> (RSI)         | Pull-Down Current in RSI                                   | V(RSI) > 0.5 V   | 1    |      | 10         | μA       |
| <b>Timing</b>                   |                               |  |  |      |      |            |          |
| 701                             | t <sub>en</sub>               | Propagation Time: EN lo → hi<br>system enable              | no error at self test, CLDA = 1 μF                           |      |      | 300        | μs       |
| 702                             | t <sub>r</sub>                | Laser Current Rise Time                                    | see Fig. 2   |      |      | 1.5        | ns       |
| 703                             | t <sub>f</sub>                | Laser Current Fall Time                                    | see Fig. 2   |      |      | 1.5        | ns       |
| 704                             | t <sub>plh</sub>              | Propagation Time:<br>LENx lo → hi to Current lo → hi       | see Fig. 3   |      |      | 10         | ns       |
| 705                             | t <sub>p<sub>h</sub></sub>    | Propagation Time:<br>LENx hi → lo to Current hi → lo       | see Fig. 3   |      |      | 10         | ns       |
| 706                             | t <sub>s0</sub>               | Propagation Time:<br>V(SMD) > VSL to SMD(0) lo → hi        | see Fig. 4<br>Tj = 27 °C<br>Tj = 85 °C                       |      |      | 220<br>240 | ns<br>ns |
| 707                             | t <sub>s0<sub>off</sub></sub> | Propagation Time:<br>V(SMD) < VSL to SMD(0) hi → lo        |  |      |      | 220        | ns       |
| 708                             | t <sub>s1</sub>               | Propagation Time:<br>V(SMD) > VSH to SMD(1) lo → hi        | see Fig. 4   |      |      | 220        | ns       |
| 709                             | t <sub>off</sub>              | Propagation Time:<br>SMD(1) lo → hi until shutdown         | see Fig. 4   |      |      | 10         | ns       |
| 710                             | t <sub>d</sub>                | Propagation Time:<br>SMD(1) lo → hi until error<br>message | see Fig. 4   |      |      | 500        | ns       |

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## ELECTRICAL CHARACTERISTICS: DIAGRAMS

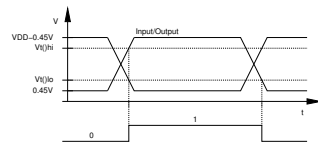


Figure 1: Reference levels

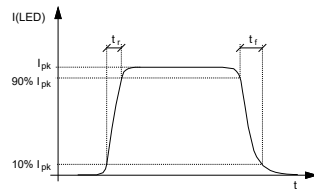


Figure 2: Laser current pulse

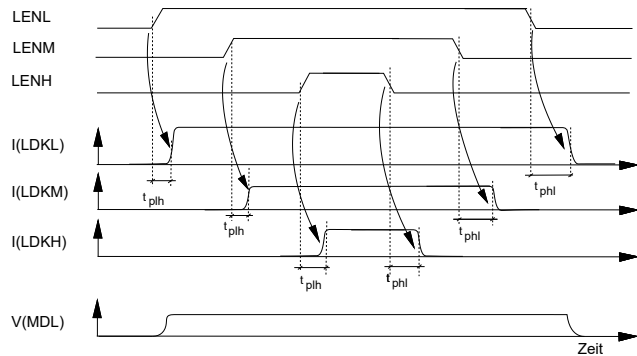


Figure 3: Turn on/turn off behavior of the laser current

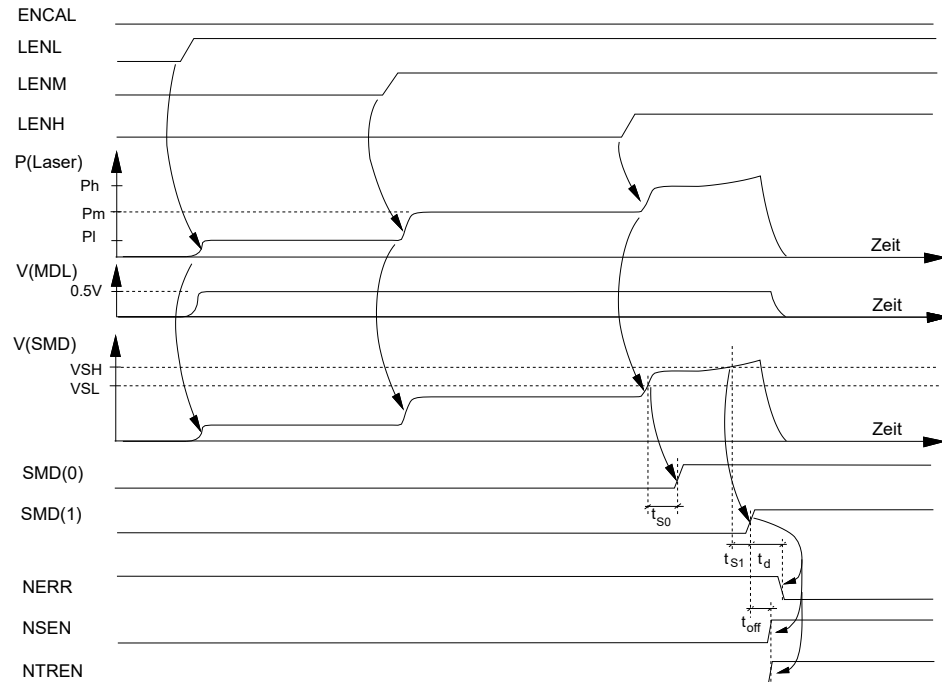


Figure 4: Safety shutdown times with failure of the control unit, for example

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| Demo board . . . . .                                 | 10       | Operation without a second monitor diode . . . . . | 15        |
| Possible sources of error . . . . .                  | 10       | Demo-Board . . . . .                               | 15        |
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| Demo board . . . . .                                 | 10       | Controlled burst mode . . . . .                    | 17        |
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| Demo board . . . . .                                 | 11       | Driving blue laser diodes . . . . .                | 19        |
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| Demo board . . . . .                                 | 11       |  |           |
| Possible sources of error . . . . .                  | 11       |  |           |
| Demo-Board . . . . .                                 | 12       |  |           |



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### DESCRIPTION OF FUNCTIONS

iC-NZ is a three-channel laser diode pulse regulator which is single-failure-proof and able to maintain a selected laser class. The device includes the following functions:

- Monitoring of the laser current
- Switching of three laser light intensity levels which are regulated separately
- Single-failure-proof via laser light monitoring using a second monitor diode and shut-down of the laser in the event of error via three separate, independent switches
- External error messaging
- Pulses of up to 155 MHz in controlled *burst mode*, during which a previously set operating point is maintained

- Extension of the laser current with few external components
- Operation of blue laser diodes possible

To simplify the initial operation of iC-NZ the following passage first outlines the basic steps involved and then goes on to provide details referring to the demo board available for evaluation. A HL6339G HITACHI laser diode has been used here by way of example.

#### Monitoring the laser current

iC-NZ monitors the laser current flowing from pin LDA (Figure 5). The DC current threshold is set using a resistor at pin RSI. If this threshold is exceeded, the device is shut down for safety reasons.

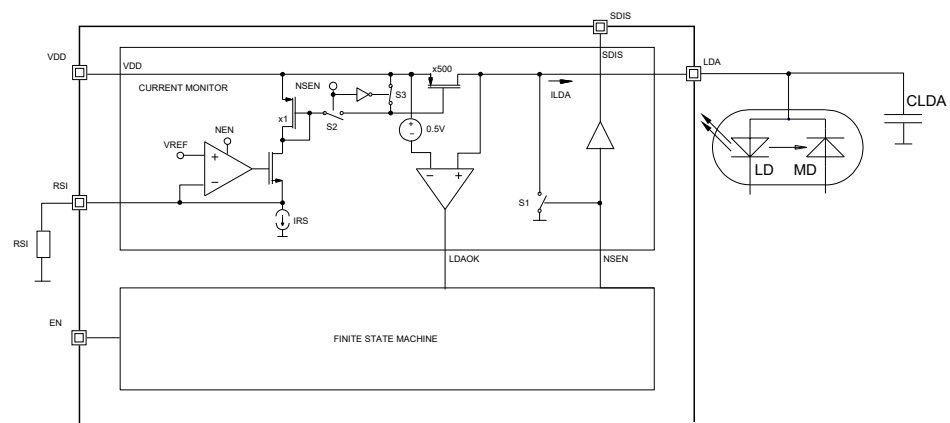


Figure 5: Monitoring the laser current

When dimensioning resistor RSI the following applies:

$$I_{max}(LDA) = 500 \times \frac{0.5 V}{RSI}$$

Short pulses with higher currents are also possible as the DC current is monitored. Capacitor CLDA supplies the current for short, higher pulses.

#### Demo board

According to the manufacturer's specifications laser diode HL6339G requires a maximum current of 70 mA for an optical power of 5 mW. For this maximum 70 mA

current RSI is calculated as:

$$RSI = 500 \times \frac{0.5 V}{70 mA} = 3.5 k\Omega$$

#### Switching up to three laser power levels

The following steps must be taken to set the required optical power:

1. Enabling the system
2. Calibrating the low and middle channels
3. Calibrating the high channel

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#### 1. Enabling the system

Before iC-NZ is put into operation for the first time the external circuitry should be checked for the following (see block diagram):

- Resistor RSMD should be of low impedance. It may not, however, be lower than 250 Ω, otherwise the internal iC check will generate an error message.
- The resistors at pins RMDL, RMDM and RMDH should be of high impedance (low output).
- Inputs LENL, LENM and LENH should be switched to low (the driver stages switched off).

So that iC-NZ can be switched on pin EN must be set to high and pin ENCAL to low. A current in the milliampere range (Electrical Characteristics No. 501) now flows into pin NERR. This indicates that the device is now in its start-up phase. The voltage at pin RSI is set to 0.5 V and capacitor CLDA charged at pin LDA. Once voltage V(LDA) has reached its final value the control unit and safety monitor diode are checked, if the latter is in use (see also *Operation without a second monitor diode*). Following this check the current into pin NERR is lowered (Electrical Characteristics No. 502). The residual current still remaining (ca. 500 μA) indicates that the control unit is not yet in operation (N-type: V(MDL) < 0.5 V, P-type: VDD – V(MDL) < 0.5 V). The entire process is described in Figure 6.

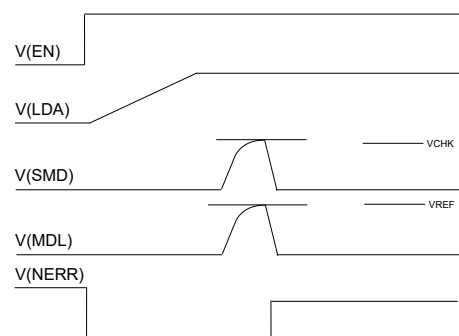


Figure 6: Signal pattern when the system is enabled

#### Demo board

Before the demo board is put into operation trimmers PSMDL, PML, PMM and PMH should be set to the left and trimmer PSMDH to its centre setting.

#### Possible sources of error

- V(NERR) remains at low:
  - Check the current in NERR. Is the impedance of the pull-up resistor too high?
- Too high a current is flowing through pin NERR: An error has occurred during the device self-test. Check the following:
  - Is ENCAL lo?
  - Is RSMD of too low an impedance? RSMD may not be lower than 250 Ω.
  - Is pin SMD open or has it directly short-circuited with VCC?
  - Is there a direct connection between pin LDK and ground?
  - Is there a low-impedance connection between pin LDA and ground?
  - Have all Clx capacitors (x: L, M, H) been properly soldered and placed close to the iC?
  - Is VCC properly back upped?

#### 2. Calibrating the low and middle channels

So that the optical power can be regulated pin REGEN must be set to high. The level at pin ENCAL is of no consequence when setting the low and middle channels.

#### Setting the low output level

Pin LENL is first switched from low to high. The integration capacitor at CIL is then charged. Until the control unit has settled a small amount of current flows in pin NERR. Following this the voltage at pin MDL is 0.5 V for an N-type diode and VDD – 0.5 V for a P-type diode. The required optical power can now be set at resistor RML.

#### Demo board

By way of example, three output levels of 1 mW, 3 mW and 5 mW are to be set. With an optical power of 1 mW laser diode HL6339G has a typical monitor current (IM) of 15 μA. The following value is then obtained for the resistor at pin MDL (RMLn = PML + RML):

$$RMLn = \frac{V(MDL)}{IM} = \frac{0.5 V}{15 \mu A} = 33.34 k\Omega$$

#### Setting the middle channel

Pin LENL must remain at high and LENM be switched from low to high. Following the settling of the control unit at CIM (N-type: V(MDL) < 0.5 V; P-type: VDD – V(MDL) < 0.5 V) the required optical power can be set at resistor RMM.

## IC-NZ

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**Demo board**

With an optical power of 3 mW the monitor current ( $I_M$ ) is 43  $\mu\text{A}$ . This current must flow through the parallel connection of RMLn and RMMn ( $RMMn = PMM + RMM$ ). The following then applies:

$$RMLn || RMMn = \frac{V(MDL)}{I_M} = \frac{0.5 \text{ V}}{43 \mu\text{A}} = 11.62 \text{ k}\Omega$$

$$RMMn = \frac{RMLn || RMMn * RMLn}{RMLn - RMLn || RMMn}$$

$$RMMn = \frac{11.62 \text{ k}\Omega * 33.34 \text{ k}\Omega}{33.34 \text{ k}\Omega - 11.62 \text{ k}\Omega} = 17.84 \text{ k}\Omega$$

**3. Calibrating the high channel**

Here, pins REGEN and ENCAL must be high. This deactivates the monitoring of the optical power, thus enabling the calibration of the high output level. Pins

LENL and LENM must remain at high; pin LENH must also be switched from low to high. Following the settling of the control unit at CIH the required optical power can be set at resistor RMH.

**Demo board**

With an optical power of 5 mW laser diode HL6339G has a typical monitor current ( $I_M$ ) of 80  $\mu\text{A}$ . The following value is then obtained for resistor RMHn = PMH + RMH:

$$RMLn || RMMn || RMHn = \frac{V(MDL)}{I_M} = \frac{0.5 \text{ V}}{80 \mu\text{A}} = 6.25 \text{ k}\Omega$$

$$RMHn = \frac{RMLn || RMMn || RMHn * RMLn || RMMn}{RMLn || RMMn - RMLn || RMMn || RMHn}$$

$$RMHn = \frac{6.25 \text{ k}\Omega * 11.62 \text{ k}\Omega}{11.62 \text{ k}\Omega - 6.25 \text{ k}\Omega} = 13.52 \text{ k}\Omega$$

**Possible sources of error**

- V(NERR) remains at low:
  - Check the current in NERR. Is the impedance of the pull-up resistor too high?
- Too high a current is flowing at pin NERR (ERROR state):
  - Is the laser diode properly connected and the control unit functioning correctly?
  - Are RMDL, RMDM or RMDH of too low an impedance? (Possible shut-down due to overcurrent!)
  - Are all the capacitors at Cix (x: L, M, H) large enough and have they been properly soldered?
  - Is pin AGND connected to ground?
- No laser light:
  - Is pin AGND connected to ground?
  - Is there a short circuit between Cix and ground?
  - Is the laser diode (type N or P) properly connected and the control unit functioning correctly?
  - The laser diode lights up for a few seconds and then turns off:
    - \* Is the laser diode too hot? With insufficient cooling the laser diode power consumption increases which can trigger an overcurrent shut-down.

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### Demo-Board

When using an N-type laser diode jumper J2 must be placed between pins 2 and 3 on the demo board. If a P-type laser diode is used the jumper must be connected between pins 1 and 2.

### Warning!

Following calibration pin EN has to be briefly set to low before actual operation may start with EN set to high again. The following explains why.

When the low channel (LENL → hi) is switched on capacitor CIL is charged. When the middle channel is switched in the internal control unit switches to CIM and starts to charge it. The voltage at CIL is then no longer regulated. As residual current could boost the voltage at CIL, which in turn would increase the current in the low channel, thus the capacitor at CIL is actively discharged with a maximum of 100 nA. The current in the low channel slowly decreases. As the control unit endeavours to keep the optical power constant, the capacitor at CIM is charged at the same rate as CIL is gradually discharged. If the middle channel is now switched off, the control unit switches back to the low channel. Capacitor CIL is regulated again; CIM, however, remains charged. If the middle channel

were then again to be switched on, far too much current would flow; this could destroy the laser diode. The same happens if the low and middle channels are regulated and the high channel switched on for a lengthy period of time. In this instance CIL and CIM are slowly discharged and the voltage at CIH rises in order to maintain a constant optical power. The entire process is illustrated in Figure 7.

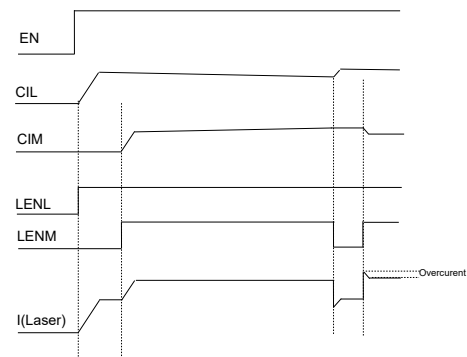


Figure 7: Behavior with very long power-on times

### OPERATION WITH ONE OR TWO CHANNELS

It is of course also possible to operate iC-NZ with one or two levels of light intensity. To make use of the safety functions of the system in one- or two-channel mode, pins LDKx (x: L, M) on the unused channels must be kept unconnected. Nodes Cix should be directly short-

circuited with AGND. To use the safety functions of the safety monitor diode the high channel must always be in use in one- or two-channel mode. Figures 8 to 11 give the configuration of iC-NZ for one- or two-channel operation for both N- and P-type laser diodes.

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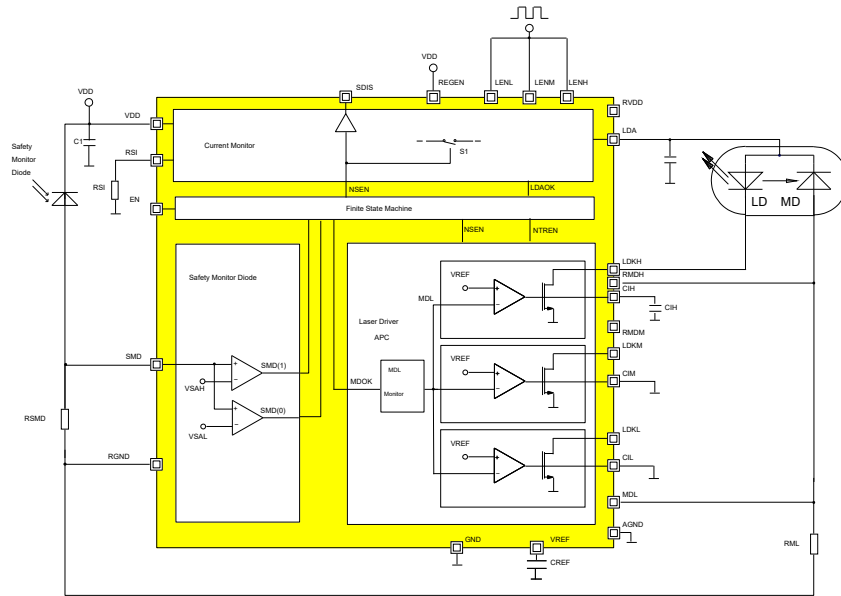


Figure 8: One-channel operation with safety function (N-type laser diode)

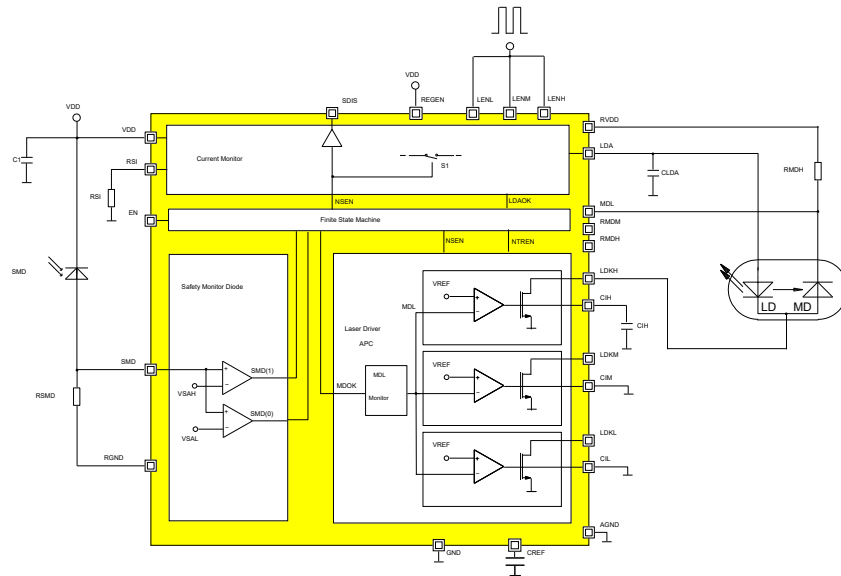


Figure 9: One-channel operation with safety function (P-type laser diode)

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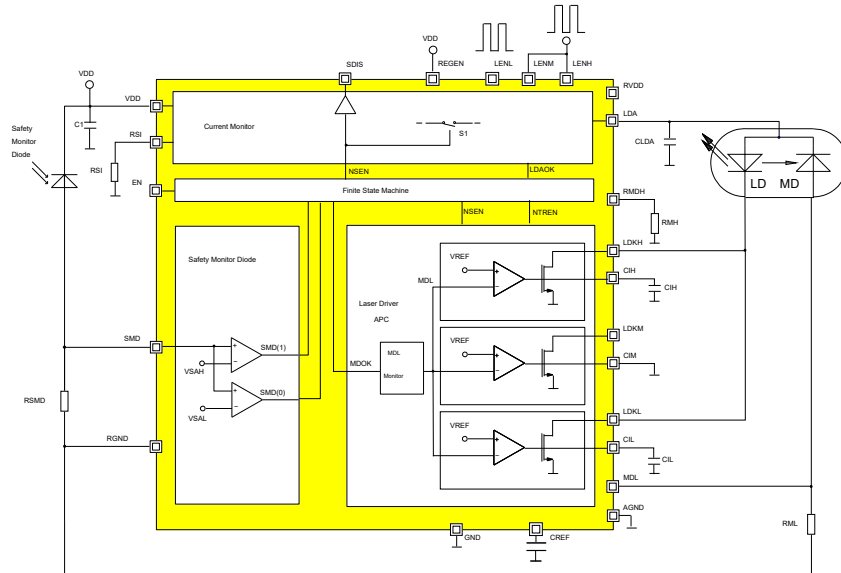


Figure 10: Two-channel operation with safety function (N-type laser diode)

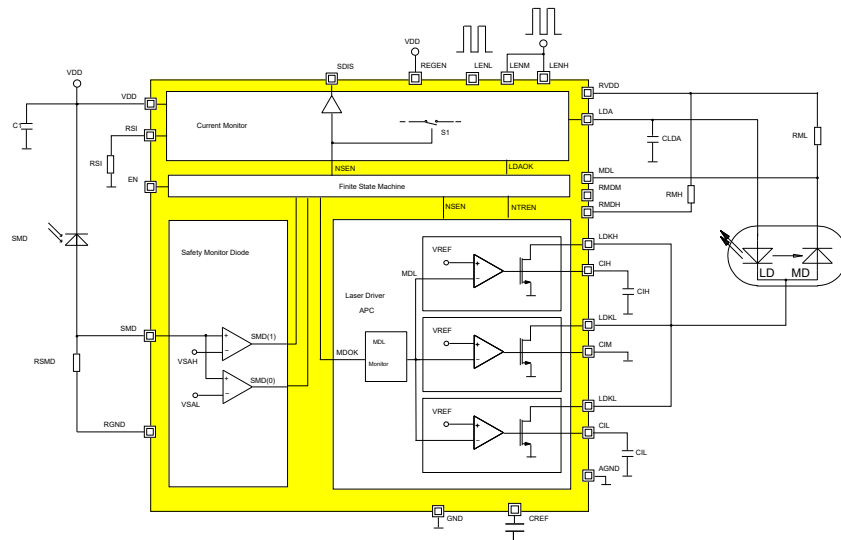


Figure 11: Two-channel operation with safety function (P-type laser diode)

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### SINGLE-FAILURE PROTECTION

Maintaining the laser class and the single-failure protection feature are achieved by means of a second monitor diode and by monitoring the laser current. Further safety is provided by the layout of the laser driver stages. The output stages consist of several identical driver cells where each cell can discharge the integration capacitor  $C_{lx}$  (x: L, M, H) and shut down the laser current. So that the laser can be switched off in the event of error iC-NZ has three completely separate circuits. The second diode monitors whether the laser light is within a predetermined power range or not.

#### Calibrating the safety monitor diode

To calibrate the safety monitor diode iC-NZ is first activated via EN (low → high) with ENCAL at low. Once the device self-test has been successfully carried out (NERR is high) pin ENCAL must be set to high and the system switched to maximum optical power (pins LENL, LENM and LENH switched to high). Resistor

RSMD at pin SMD is now set so that voltage  $V(SMD)$  is inside the monitor window between 0.3V and 0.7V. ENCAL can now be switched back to low.

In applications with a low duty cycle both the peak and average laser power must be monitored to maintain the laser class. To this end the resistor at RSMD is split into RSMD1 and RSMD2 and a capacitor (CSMD) connected in parallel to RSMD1 (see Figure 12). With short laser light pulses capacitor CSMD behaves as if it is a short circuit and bypasses RSMD1. In this instance only RSMD2 is active (higher shutdown threshold). With longer pulses resistors RSMD1 and RSMD2 are in series (lower shutdown threshold). This setup dynamically alters the monitor window. An excess of the maximum permissible laser power through both too high a pulse power or too long a pulse duration is equally detected.

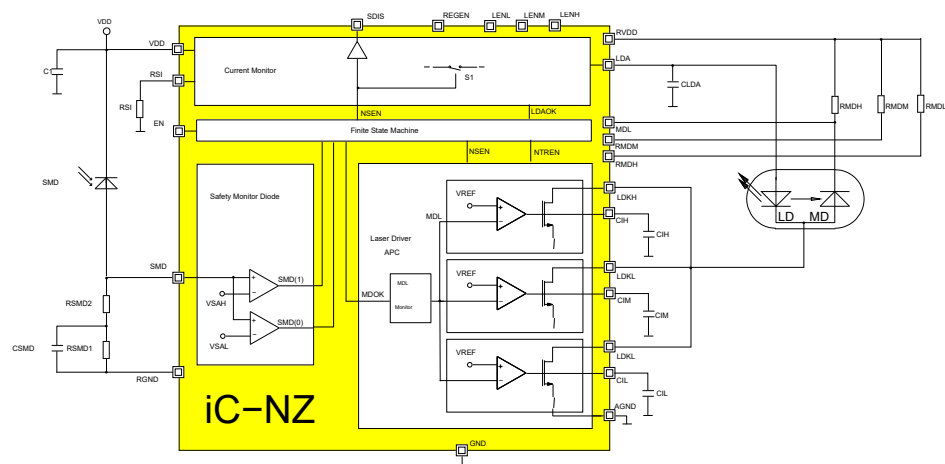


Figure 12: Dynamic adaptation of the monitor window

#### Demo-Board

So that the second monitor diode can be used jumper J1 must be placed between pins 1 and 2 on the demo board. The voltage at SMD is set using the two potentiometers PSMDH (peak) and PSMDL (average).

#### Operation without a second monitor diode

The monitoring function can be disabled for applications which do not require a second monitor diode. To this end pins SMD and ENCAL must be set to high. This *no safety function* (NSF) is signalled at pin NSF.

The overcurrent monitor at LDA is, however, still active in this mode. This ensures safe operation with so called *low-power applications* – even without a second monitor diode. Figures 13 and 14 give the circuitry for N- and P-type laser diodes.

#### Demo-Board

So that the demo board can be operated without a second monitor diode, jumper J1 must be placed between pins 2 and 3.

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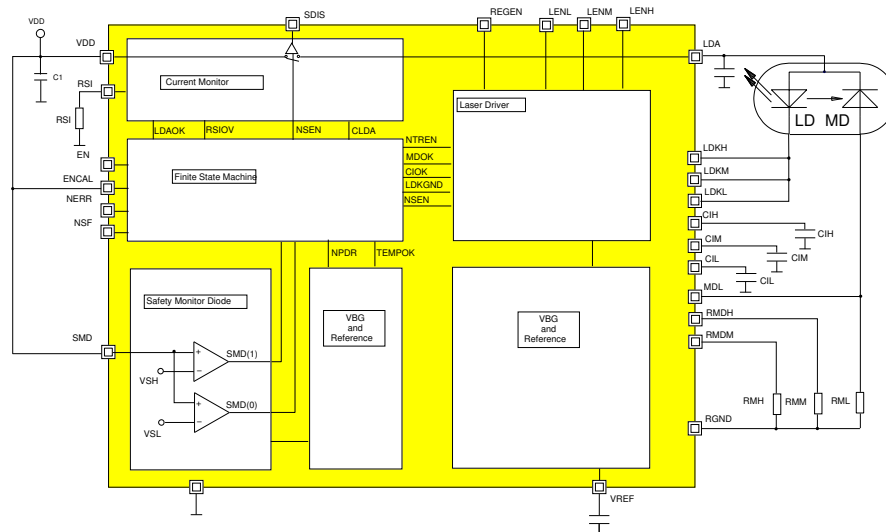


Figure 13: Operation without a second monitor diode (N-type laser diode)

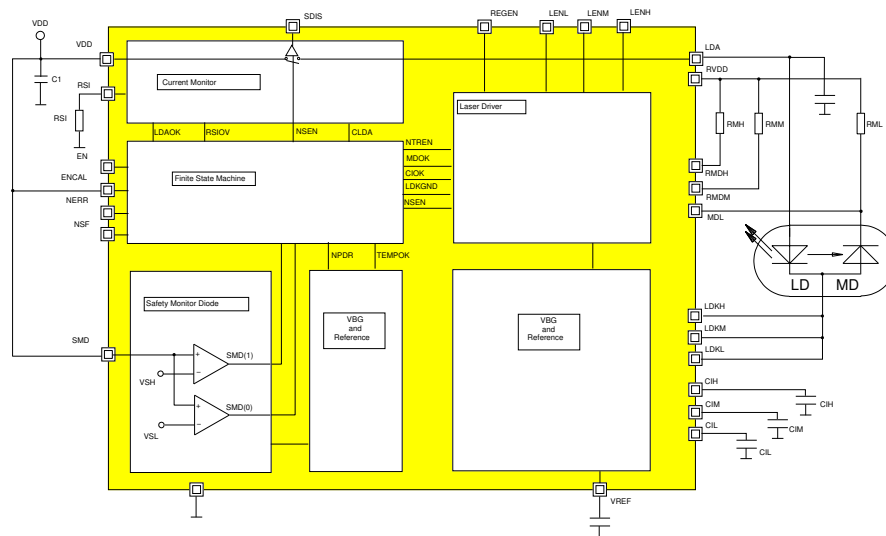


Figure 14: Operation without a second monitor diode (P-type laser diode)



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### MISCELLANEOUS

#### Status outputs NERR, NSF and REGEN

Pin **NERR** is an open-collector output with three states:

|                                       |   |
|---------------------------------------|---|
| $I(\text{NERR}) = 0 \text{ mA}$       | Pin EN is low or the control unit is operational (no error)             |
|                                       | N-type laser diode: $V(\text{MDL}) = 0.5 \text{ V}$                     |
|                                       | P-type laser diode: $V(\text{MDL}) = \text{VDD} - 0.5 \text{ V}$        |
| $I(\text{NERR}) > 1.5 \text{ mA}$     | Error or iC-NZ is still undergoing its self-test                        |
| $0 < I(\text{NERR}) < 1.5 \text{ mA}$ | No error, the control unit is not yet settled or not enough laser light |
|                                       | N-type laser diode: $V(\text{MDL}) < 0.5 \text{ V}$                     |
|                                       | P-type laser diode: $V(\text{MDL}) < \text{VDD} - 0.5 \text{ V}$        |

Pin **NSF** is also an open-collector output and signals the *no safety mode*:

|                                  |                                   |  |
|----------------------------------|-----------------------------------|--|
| $I(\text{NSF}) > 1.5 \text{ mA}$ | iC-NZ is in <i>safety mode</i>    | operation with a second monitor diode    |
| $I(\text{NSF}) = 0 \text{ mA}$   | iC-NZ is in <i>no safety mode</i> | operation without a second monitor diode |

Pin **REGEN**, in addition to its mode select input function (regulated output power  $\leftrightarrow$  *burst mode*), also signals the condition of Pin ENCAL by its pull-down current:

|  |              |                  |
|--|--------------|------------------|
| $I_{pd}(\text{REGEN}) < 10 \mu\text{A}$  | ENCAL = low  | cf. Item No. 202 |
| $I_{pd}(\text{REGEN}) > 100 \mu\text{A}$ | ENCAL = high | cf. Item No. 205 |

#### Controlled burst mode

In controlled *burst mode* iC-NZ can pulse with up to 155 MHz, thus making it suitable for use in laser projection or data transmission. *Controlled* here means that a preset operating point is maintained during fast pulsing or the *burst phase*.

A low power level is first regulated, for which REGEN and LENL must be high. Following this the middle or high power level can be set (LENx  $\rightarrow$  high). The control unit then switches over to the middle or high channel. As only one channel can be regulated at any one time and as the voltage at CIL must not increase by residual current (this could destroy the laser diode) the capacitor at CIL is discharged with a maximum of 100 nA. Once Clx has been regulated LENx can return to low. REGEN at low switches into *burst mode* and thus turns the control unit off. The preset operating point is maintained. To prevent the laser current rising due to residual current the capacitors for the three channels are discharged with a maximum of 100 nA. This process is illustrated in Figure 15. As the capacitors are discharged gradually the output levels must be regulated again after a certain period. With an integration capacitance (Clx) of 100 nF, for example, the level must

again be regulated after 500  $\mu\text{s}$ , with this rising to 1 ms with 200 nF.

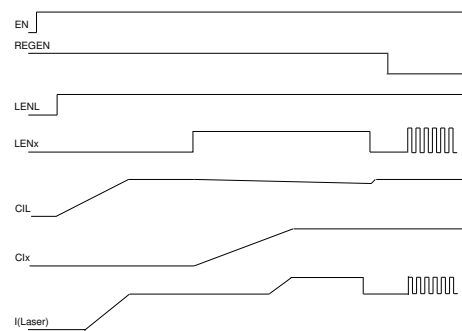


Figure 15: Controlled burst mode

#### Extending the laser current

iC-NZ also has a high-current mode. Here, the laser current no longer flows through the iC but passes instead through the external circuitry (RLDA, Q1, iC-HK); pin RSI is switched to VDD. The current monitor is still active and the shutdown threshold can be set us-

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ing RLDA. iC-HK is a fast, spike-free laser switch with which up to 1.4A can be driven in pulsed operation. An iC-HK can be connected to each channel on iC-NZ so that a maximum laser pulse current of 4.2A can be achieved (depending on pulse frequency, duty cycle and thermal dissipation). To this end pins Clx (x:

L, M, H) on iC-NZ must be connected to the CI inputs of the relevant iC-HK and iC-NZ inputs LENx to iC-HK inputs EN1 and EN2 (Figure 16). Individual levels are set as described above in *Switching up to three laser power levels*.

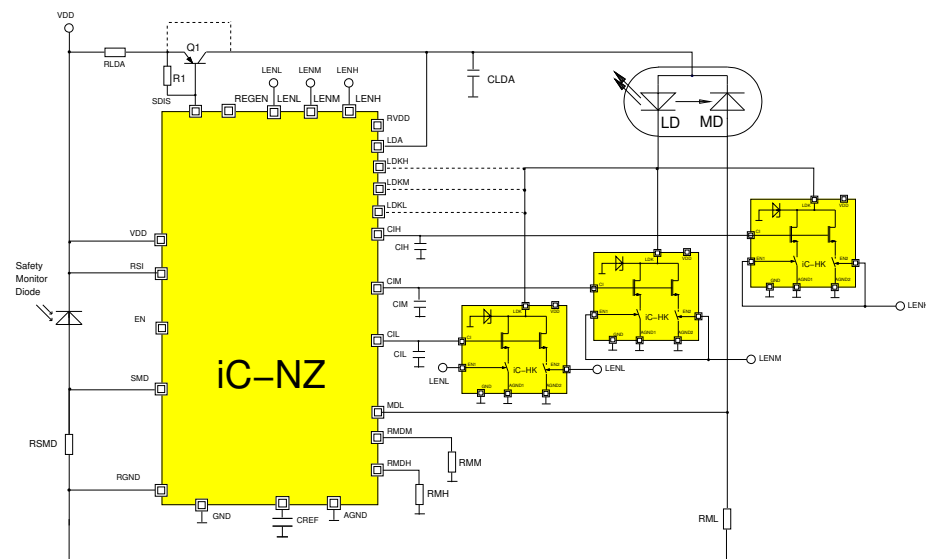


Figure 16: Extending the laser current

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### Driving blue laser diodes

It is also possible to drive blue laser diodes with iC-NZ. The laser diode is then directly powered by a second, higher voltage. The laser power is set as described above in *Switching up to three laser power lev-*

*els*. Figure 17 shows iC-NZ connected up to a blue laser diode. It is important to note that here the laser diode supply voltage should be as low as possible to keep iC power dissipation to a minimum.

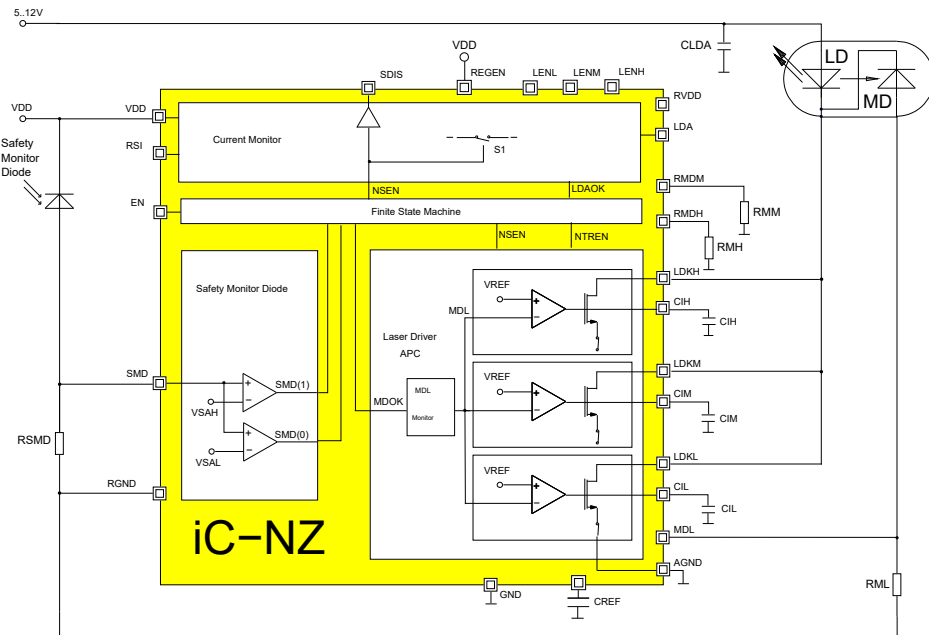


Figure 17: Driving blue laser diodes

### DEMO BOARD

The iC-NZ device is equipped with a Demo Board for test purposes. A description of the demo board is available as a separate document.

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### ORDERING INFORMATION

| Type             | Package           | Order Designation |
|------------------|-------------------|-------------------|
| iC-NZ            | QFN28 5 mm x 5 mm | iC-NZ QFN28       |
| Evaluation Board |                   | iC-NZ EVAL NZ1D   |