

## EiceDRIVER™ 1ED38x0Mc12M Enhanced

### Datasheet

Single-channel 5.7 kV (rms) isolated gate driver IC with I2C configurability for DESAT, Soft-off, UVLO, Miller clamp and optional two-level turn-off

### Features

- 650 V, 1200 V, 1700 V, 2300 V IGBTs, SiC, and Si MOSFETs
- 40 V absolute maximum output supply voltage
- $\pm 3$  A,  $\pm 6$  A, and  $\pm 9$  A typical sinking and sourcing peak output current
- Separate source and sink outputs for hard switching or optional two-level turn-off and with active Miller clamp
- I2C bus for parameter configuration and status register readout
- Precise, adjustable, and temperature compensated  $V_{CEsat}$  detection (DESAT) with fault output
- Adjustable IGBT soft turn-off after desaturation detection
- Operation at high ambient temperature up to 125 °C with over-temperature shut down at 160 °C ( $\pm 10$  °C)
- Tight IC-to-IC propagation delay matching ( $t_{PDD,max} = 30$  ns)
- Undervoltage lockout protection with hysteresis for input and output side with active shut-down
- Configurable feedback or fault-off behavior for comparator result of integrated ADC
- High common-mode transient immunity CMTI = 200 kV/ $\mu$ s
- Small space-saving DSO-16 fine-pitch package with large creepage distance (>8 mm)
- Safety certification
  - UL 1577 recognized (File E311313) with  $V_{ISO,test} = 6840$  V (rms) for 1 s,  $V_{ISO} = 5700$  V (rms) for 60 s
  - VDE 0884-11 approval (Certificate no. 40053980) with  $V_{IORM} = 1767$  V (peak, reinforced)
- Additional [reference manual](#) available for detailed functional description

### Potential applications

- Industrial motor drives - compact, standard, premium, servo drives
- Solar inverters
- UPS systems
- Welding
- Commercial and agricultural vehicles (CAV)
- Commercial air-conditioning (CAC)
- High-voltage isolated DC-DC converters
- Isolated switch mode power supplies (SMPS)



PG-DSO-16

### Product validation

Qualified for industrial applications according to the relevant tests of JEDEC47/20/22.

## Device information

| Product type | Output current | Isolation class | Marking  | OPN                               |
|--------------|----------------|-----------------|----------|-----------------------------------|
| 1ED3830MC12M | 3 A (typ)      | reinforced      | 3830MC12 | <a href="#">1ED3830MC12MXUMA1</a> |
| 1ED3860MC12M | 6 A (typ)      | reinforced      | 3860MC12 | <a href="#">1ED3860MC12MXUMA1</a> |
| 1ED3890MC12M | 9 A (typ)      | reinforced      | 3890MC12 | <a href="#">1ED3890MC12MXUMA1</a> |
| 1ED3830MU12M | 3 A (typ)      | UL 1577         | 3830MU12 | <a href="#">1ED3830MU12MXUMA1</a> |
| 1ED3860MU12M | 6 A (typ)      | UL 1577         | 3860MU12 | <a href="#">1ED3860MU12MXUMA1</a> |
| 1ED3890MU12M | 9 A (typ)      | UL 1577         | 3890MU12 | <a href="#">1ED3890MU12MXUMA1</a> |

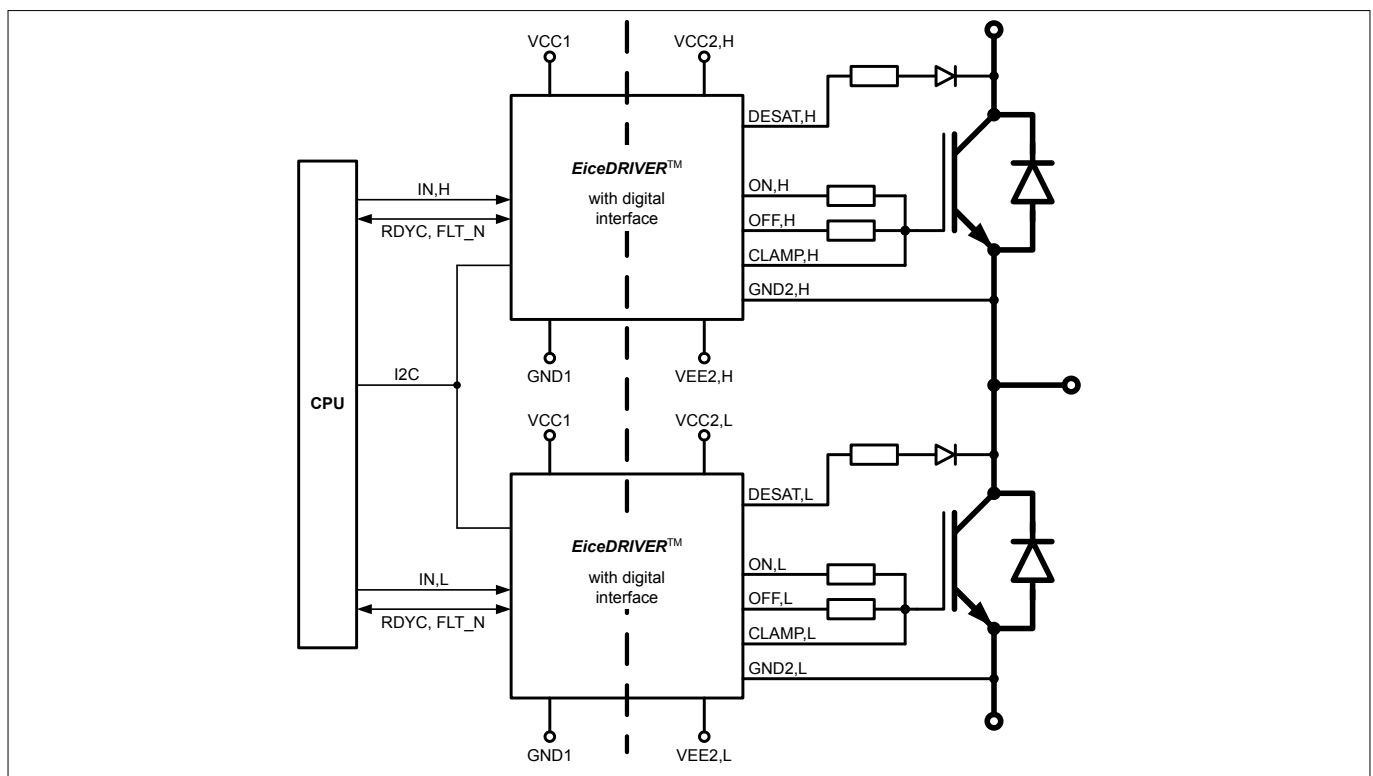
## Description

The 1ED38x0Mc12M family (X3 Digital) consists of galvanically isolated single channel gate driver ICs in a small PG-DSO-16 package with a large creepage and clearance of 8 mm. The gate driver ICs provide a typical peak output current of 3 A, 6 A, and 9 A.

Adjustable control and protection functions are included to simplify the design of highly reliable systems. All parameter adjustments are done from the input side via the I2C interface (pin SDA and SCL).

All logic I/O pins are supply voltage dependent 3.3 V or 5 V CMOS compatible and can be directly connected to a microcontroller.

The data transfer across the galvanic isolation is realized by the integrated coreless transformer technology.



**Figure 1** Typical application

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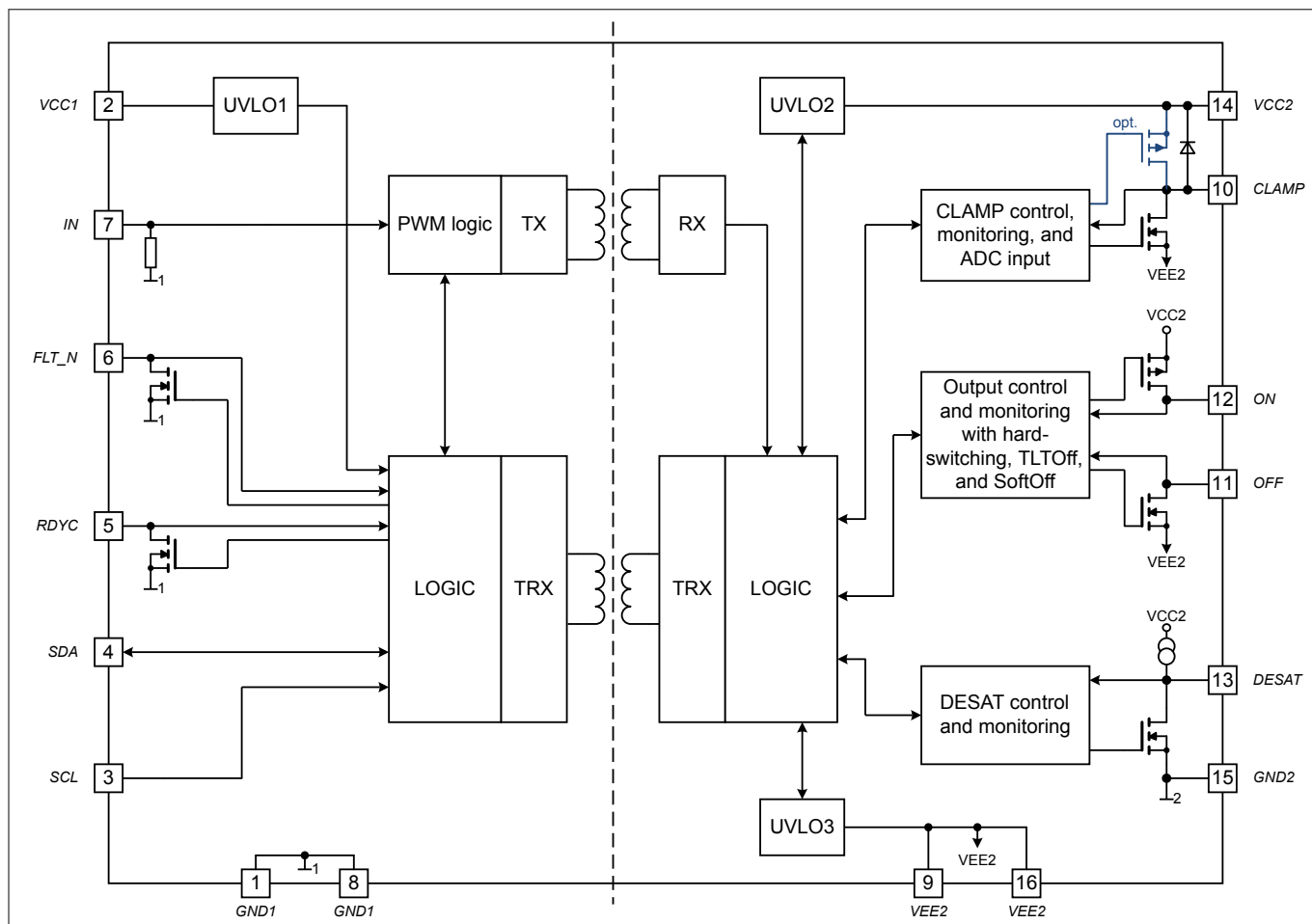
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**1 Block diagram**

**1 Block diagram**



**Figure 2 Block diagram**

## 2 Related products

## 2 Related products

*Note: Please consider the gate driver IC power dissipation and insulation requirements for the selected power switch and operating condition.*

| Product group                | Product name                      | Description                                                               |
|------------------------------|-----------------------------------|---------------------------------------------------------------------------|
| TRENCHSTOP™ IGBT Discrete    | <a href="#">IKQ75N120CS6</a>      | High Speed 1200 V, 75 A IGBT with anti-parallel diode in TO247-3          |
|                              | <a href="#">IKW15N120BH6</a>      | High Speed 1200 V, 15 A IGBT with anti-parallel diode in TO247            |
|                              | <a href="#">IHW40N120R5</a>       | Reverse conducting 1200 V, 40 A IH IGBT with integrated diode in TO247    |
| CoolSiC™ SiC MOSFET Discrete | <a href="#">IMBF170R650M1</a>     | 1700 V, 650 mΩ SiC MOSFET in TO263-7 package                              |
|                              | <a href="#">IMBG120R045M1H</a>    | 1200 V, 45 mΩ SiC MOSFET in TO263-7 package                               |
|                              | <a href="#">IMZ120R350M1H</a>     | 1200 V, 350 mΩ SiC MOSFET in TO247-4 package                              |
| CoolSiC™ SiC MOSFET Module   | <a href="#">FS45MR12W1M1_B11</a>  | EasyPACK™ 1B 1200 V / 45 mΩ sixpack module                                |
|                              | <a href="#">FF23MR12W1M1_B11</a>  | EasyDUAL™ 1B 1200 V, 23 mΩ half-bridge module                             |
|                              | <a href="#">FF6MR12W2M1_B11</a>   | EasyDUAL™ 2B 1200 V, 6 mΩ half-bridge module                              |
|                              | <a href="#">F3L11MR12W2M1_B74</a> | EasyPACK™ 2B 1200 V, 11 mΩ 3-Level module in Advanced NPC (ANPC) topology |
|                              | <a href="#">F4-23MR12W1M1_B11</a> | EasyPACK™ 1B 1200 V, 23 mΩ fourpack module                                |
| TRENCHSTOP™ IGBT Modules     | <a href="#">F4-100R17N3E4</a>     | EconoPACK™ 3 1700 V, 100 A fourpack IGBT module                           |
|                              | <a href="#">F4-200R17N3E4</a>     | EconoPACK™ 3 1700 V, 200 A fourpack IGBT module                           |
|                              | <a href="#">FS150R17N3E4</a>      | EconoPACK™ 3 1700 V, 150 A sixpack IGBT module                            |
|                              | <a href="#">FF650R17IE4</a>       | PrimePACK™ 3 1700 V, 650 A half-bridge dual IGBT module                   |
|                              | <a href="#">FF1000R17IE4</a>      | PrimePACK™ 3 1700 V, 1000 A half-bridge dual IGBT module                  |
|                              | <a href="#">FF1200R17IP5</a>      | PrimePACK™ 3+ 1700 V, 1200 A dual IGBT module                             |
|                              | <a href="#">FF1500R17IP5</a>      | PrimePACK™ 3+ 1700 V, 1500 A dual IGBT module                             |
|                              | <a href="#">FF1500R17IP5R</a>     | PrimePACK™ 3 1700 V, 1500 A dual IGBT module                              |
|                              | <a href="#">FF1800R17IP5</a>      | PrimePACK™ 3+ 1700 V, 1800 A dual IGBT module                             |
|                              | <a href="#">FP10R12W1T7_B11</a>   | EasyPIM™ 1B 1200 V, 10 A three phase input rectifier PIM IGBT module      |
|                              | <a href="#">FS100R12W2T7_B11</a>  | EasyPACK™ 2B 1200 V, 100 A sixpack IGBT module                            |
|                              | <a href="#">FP150R12KT4_B11</a>   | EconoPIM™ 3 1200V three-phase PIM IGBT module                             |
|                              | <a href="#">FS200R12KT4R_B11</a>  | EconoPACK™ 3 1200 V, 200 A sixpack IGBT module                            |

### 3 Pin configuration and functionality

## 3 Pin configuration and functionality

The pin assignment at the gate driver IC generally differentiates between the input side and the output side.

**Table 1 General pin assignment**

| Pins    | Designation                                              |
|---------|----------------------------------------------------------|
| 1 to 8  | input side, input logic signal side, or low voltage side |
| 9 to 16 | output side, driver power side, or high voltage side     |

For simplicity reasons the driver is described as an IGBT driver. For use with MOSFETs and other power switches simply replace any mentioning of collector and emitter with their corresponding pin names.

### 3.1 Pin configuration

**Table 2 Pin configuration table abbreviations**

| Abbreviation   | Description                                               |
|----------------|-----------------------------------------------------------|
| Pin type       |                                                           |
| <b>PWR</b>     | Power supply and gate current output pins                 |
| <b>I/O</b>     | Digital input and output pin                              |
| <b>I</b>       | Digital input pin                                         |
| <b>GND</b>     | Ground reference pin                                      |
| <b>AI</b>      | Analog input pin                                          |
| Buffer type    |                                                           |
| <b>OD</b>      | Open drain output                                         |
| <b>CMOS</b>    | CMOS compatible input threshold levels                    |
| <b>PP</b>      | Push/pull output buffer                                   |
| <b>analog</b>  | Analog input buffer                                       |
| <b>special</b> | Special output/input function, see individual description |
| Pull device    |                                                           |
| <b>PD</b>      | Pull-down resistor                                        |
| <b>CS</b>      | Current source                                            |

**Table 3 Pin configuration**

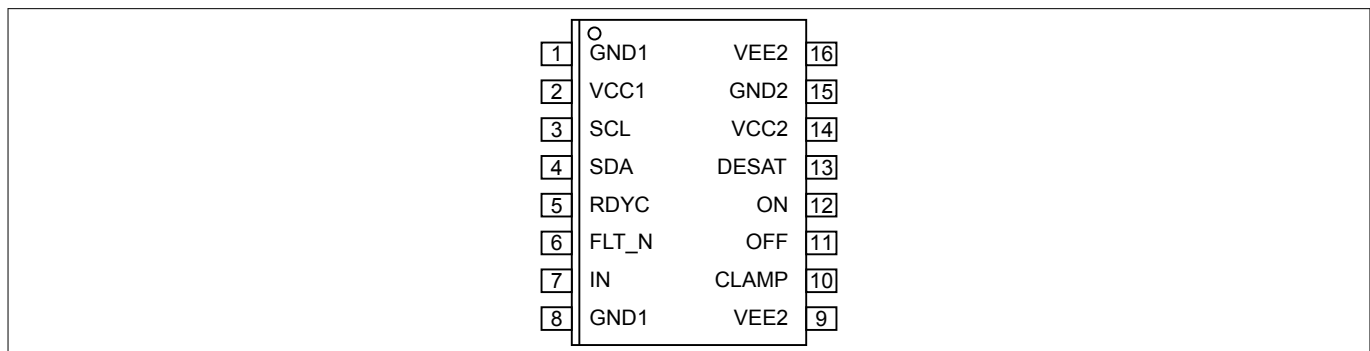
| Pin no. | Pin name     | Pin type | Buffer type | Pull device | Function                                                                                |
|---------|--------------|----------|-------------|-------------|-----------------------------------------------------------------------------------------|
| 1       | <i>GND1</i>  | GND      | –           | –           | Ground input side                                                                       |
| 2       | <i>VCC1</i>  | PWR      | –           | –           | Positive power supply input side                                                        |
| 3       | <i>SCL</i>   | I        | CMOS        | –           | Clock input of serial I2C bus                                                           |
| 4       | <i>SDA</i>   | I/O      | OD, CMOS    | –           | Data I/O of serial I2C bus                                                              |
| 5       | <i>RDYC</i>  | I/O      | OD, CMOS    | –           | Combined ready output, high active and fault clear input and soft-off input, low active |
| 6       | <i>FLT_N</i> | I/O      | OD, CMOS    | –           | Fault output, low active and soft-off input, low active                                 |

(table continues...)

### 3 Pin configuration and functionality

**Table 3** (continued) Pin configuration

| Pin no. | Pin name | Pin type | Buffer type    | Pull device | Function                                                                                       |
|---------|----------|----------|----------------|-------------|------------------------------------------------------------------------------------------------|
| 7       | IN       | I        | CMOS           | PD, 40 kΩ   | Non inverted driver input                                                                      |
| 8       | GND1     | GND      | –              | –           | Ground input side                                                                              |
| 9       | VEE2     | GND      | –              | –           | Negative power supply output side                                                              |
| 10      | CLAMP    | PWR, AI  | OD, PP, analog | –           | Active Miller clamping with open drain to VEE2, clamp driver for external MOSFET, or ADC input |
| 11      | OFF      | PWR, AI  | OD             | –           | Driver sink output                                                                             |
| 12      | ON       | PWR, AI  | OD             | –           | Driver source output                                                                           |
| 13      | DESAT    | AI       | special        | CS, 500 μA  | Enhanced desaturation protection                                                               |
| 14      | VCC2     | PWR      | –              | –           | Positive power supply output side                                                              |
| 15      | GND2     | AI       | –              | –           | Signal ground output side                                                                      |
| 16      | VEE2     | GND      | –              | –           | Negative power supply output side                                                              |



**Figure 3** PG-DSO-16 (top view)

### 3.2 Pin functionality

#### **GND1**

Reference ground of the input side. Connect direct to input signal ground.

#### **VCC1**

Positive power supply terminal of the input side, connect to 5 V or 3.3 V for proper operation. Place a decoupling capacitor close to this pin and *GND1*.

#### **SCL and SDA serial bus connection**

Serial data I/O and clock input pin of the I2C bus. Connect to a microcontroller with 5 V or 3.3 V I/O and add a pull-up resistor to positive supply voltage *VCC1*. Signals *SCL* and *SDA* are referenced to *GND1*.

#### **RDYC ready status output, fault-off input and fault-clear input**

Open-drain output reports the correct operation of the device, ready output is high active. Fault-clear input and fault-off input clears a gate driver fault or switch the gate driver output to off with fault-off function, input is low active. Connect to a microcontroller with 5 V or 3.3 V I/O with an external pull-up resistor to *VCC1*. A typical value for this resistor is 2.2 kΩ. The *RDCY* signal is referenced to *GND1*.

### 3 Pin configuration and functionality

#### ***FLT\_N* fault output and fault-off input**

Open-drain output reports the failures related to operating of the inverter system to the microcontroller, fault output is active low. Fault-off input switch the gate driver output to off with fault-off function, input is low active. Connect to a microcontroller with 5 V or 3.3 V I/O with an external pull-up resistor to *VCC1*. A typical value for this resistor is 2.2 kΩ. The *FLT\_N* signal is referenced to *GND1*.

#### ***IN* non inverting gate driver input**

*IN* input controls the output of the gate driver IC, the IGBT is turned on if *IN* is set to high. Connect to a PWM output of the microcontroller with 5 V or 3.3 V IO. An internal pull-down resistor ensures IGBT off-state if not connected.

#### ***VEE2***

Negative power supply terminal of the output side. Connect to a voltage of 0 V to -25 V referenced to *GND2* for proper operation. Place a decoupling capacitor close to the following pins:

- *VCC2* and *VEE2*
- *GND2* and *VEE2*

If no negative supply voltage is used, all *VEE2* pins have to be connected to *GND2*.

#### ***CLAMP* Miller clamp output, Miller clamp pre-driver output, ADC input**

The function and operating mode of this pin is depending on the register configuration.

High-current clamp output to hold the gate voltage low during collector-emitter-voltage rise. Connect directly to the gate of the IGBT.

Clamp pre-driver output for the use of an external clamp switch. Connect directly to the gate of a n-channel MOSFET.

Sensing input for 8-bit ADC. Connect the external signal source between *CLAMP* and *VEE2*.

#### ***OFF* driver output**

High-current driver sink output to discharge the gate of the external IGBT and the optional two-level turn-off control output. The gate driver IC also sinks the Soft-off current at this pin. The pin is used as sense input for the gate high-level indicator **PINSTAT**.OFF\_PIN and TLTOFF comparator **PINSTAT**.TLTO\_LVL. Connect to the gate of the IGBT via a chosen turn-off gate resistor.

#### ***ON* driver output**

High-current driver source output to charge the gate of the external IGBT and turn it on and sense input for the CLAMP function. It is also the sense input for the gate low-level indicator **PINSTAT**.ON\_PIN. Connect to the gate of the IGBT via a chosen turn-on gate resistor.

#### ***DESAT* enhanced desaturation detection input**

Desaturation detection input to monitor the IGBT collector-emitter voltage ( $V_{CE}$ ) to detect desaturation caused by short circuit events. Connect to the collector of the driven IGBT via a series connection of a protection resistor and a high-voltage diode. The *DESAT* signal is referenced to *GND2*.

#### ***VCC2***

Positive power supply terminal of the output side. Connect to sufficient supply voltage referenced to *GND2* for proper operation. Place a decoupling capacitor close to the following pins:

- *VCC2* and *VEE2*
- *VCC2* and *GND2*

### 3 Pin configuration and functionality

#### GND2 reference ground

Reference ground of the output side. Connect to common voltage of a bipolar supply and the emitter of the IGBT. Place a decoupling capacitor close to the following pins:

- VCC2 and GND2
- GND2 and VEE2

### 3.3 Configurable parameters via I2C

The following parameters are fully configurable via the I2C interface. The default behavior describes the gate driver configuration if only the address configuration has been set before writing **CFGOK.USER\_OK** to 1<sub>B</sub>.

**Table 4**                      **Configurability via I2C**

|                   | Adjustable parameter                                   | Default behavior/value                                                                           |
|-------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| UVLO              | VCC2-GND2 turn-on UVLO (max)                           | 12.6 V                                                                                           |
|                   | VEE2-GND2 UVLO (n.a./-3.5/-6/-12.0 V)                  | Not active                                                                                       |
| Output drive      | CLAMP pin mode (3 A, pre-driver, or ADC)               | 3 A sink only                                                                                    |
|                   | Filter time for CLAMP and pin status monitoring        | 235 ns                                                                                           |
|                   | CLAMP and switch on filter type                        | Up-reset                                                                                         |
|                   | Two-level turn-off                                     | Hard switch-off<br>A = 30 V/ns; 9.0 V; 2.0 μs; B = hard switch-off                               |
|                   | Soft-off current (set as default fault-off method)     | <b>CSSOFFCFG.CSSOFF_I</b> =9 <sub>D</sub> , 1ED3830M: 146 mA, 1ED3860M: 291 mA, 1ED3890M: 437 mA |
|                   | Driver input filter length                             | 103 ns                                                                                           |
| DESAT             | DESAT1 threshold voltage                               | 9.18 V                                                                                           |
|                   | Leading edge blanking time                             | 400 ns                                                                                           |
|                   | DESAT1 filter time                                     | 225 ns                                                                                           |
|                   | DESAT1 filter type                                     | Up-reset                                                                                         |
|                   | DESAT2 threshold, filter, and action configuration     | Disabled                                                                                         |
| Fault/fault clear | Fault clear source (RDYC or self clear time)           | RDYC                                                                                             |
|                   | Self clear time (not active, 400 μs, 1600 μs)          | Not active                                                                                       |
|                   | Fault-off mode (hard switch-off, soft-off, TLTOff)     | Hard switch-off                                                                                  |
|                   | Over-temperature warning action (warning or fault off) | Warning                                                                                          |
|                   | Over-temperature warning level                         | 140°C                                                                                            |

## 4 Functional description

### 4 Functional description

The 1ED38x0Mc12M family (X3 Digital) consists of galvanically isolated single channel gate driver ICs with an extensive digital adjustable feature parameter set. All adjustments are done from low voltage input side during start up via I2C bus. The configuration is stored into registers.

To start-up the gate driver IC for normal operation both input and output sides of the gate driver IC need to be powered.

The 1ED38x0Mc12M family (X3 Digital) is designed to support various supply configurations on the input and output side. On the output side unipolar and bipolar supply is possible.

The output stage is realized as rail-to-rail. There the gate driver voltage follows the supply voltage without an additional voltage drop. In addition it provides an easy clamping of the gate voltage during short circuit of an external IGBT.

The *RDYC* status output reports correct operation of the gate driver IC like sufficient voltage supply. The *FLT\_N* status output reports failures in the application like desaturation detection.

To ensure safe operation the gate driver IC is equipped with an input and output side under-voltage lockout circuit. The UVLO levels are optimized for IGBTs and MOSFETs, and are adjustable.

The desaturation detection circuit protects the external IGBT from destruction at a short circuit. The gate driver IC reacts on a DESAT fault by turning off the IGBT with one of the following configurable turn-off methods:

- two-level turn-off
- adjustable soft-off
- hard switch-off

The two-level turn-off (TLTOff) is a voltage controlled turn-off function.

The soft turn-off function is used to switch-off the external IGBT in overcurrent conditions in a soft-controlled manner to protect the IGBT against collector emitter over-voltages.

An adjustable active Miller clamp function protects the IGBT from parasitic turn-on in fast switching applications.

The 1ED38x0 family also offers several measurement and monitoring functions. The monitoring functions can be divided into:

- hardware based functions and
- ADC measurement based functions.

*Note:* Please refer to the reference manual of this product for a detailed functional description. This chapter does not provide all the information required to fully operate the product.

#### 4.1 Start-up and fault clearing

For normal operation both input and output sides of the gate driver IC need to be powered. A low level at the *FLT\_N* pin always indicates a fault condition. In this case the IC starts internal mechanisms for fault clearing.

##### Input side start-up

1. Voltage at *VCC1* reaches the input UVLO threshold: input side of gate driver IC starts operating
2. *FLT\_N* follows input supply voltage
3. Input side is ready to communicate across I2C bus, awaiting user gate driver parameter configuration
4. Records parameters received across the I2C bus
5. Waits until output side is powered
6. Initiates internal start-up: Transfers configured values to output side
7. Performs internal self-test

The complete start-up time  $t_{\text{START1}}$  depends on the duration of the user parameter configuration.

## 4 Functional description

### Output side start-up

1. Voltage at  $VCC2$  reaches the output UVLO threshold: output side of gate driver IC starts operating
2. Activates OFF gate driver output: connected gate stays discharged
3. Waits until input side is powered
4. Initiates internal start-up: Receives configured values from input side
5. Performs internal self-test

The complete start-up time  $t_{START2}$  depends on the duration of the user parameter configuration.

The gate driver IC releases  $RDYC$  to high to signal a successful start-up and its readiness to operate. The gate driver IC will follow the status of the  $IN$  signal.

### Clearing a fault with $RDYC$ to low cycle

1. Set  $IN$  to low
2. Set  $RDYC$  to low for a duration longer than the fault clear time  $t_{CLRMIN}$
3. Release  $RDYC$  to high
  - a. If the source of the fault is no longer present,  $FLT\_N$  is released to high
  - b. If another fault source is active,  $FLT\_N$  stays low and the cycle needs to be repeated
4. Continue PWM operation

### Clearing a fault by self clear timer

1. Set  $IN$  to low
2. Self clear timer starts counting
3. Self clear timer reaches self clear time
  - a. If the source of the fault is no longer present,  $FLT\_N$  is released to high
  - b. If another fault source is active,  $FLT\_N$  stays low and the timer restarts
4. Continue PWM operation

## 4.2 Supply

The 1ED38x0Mc12M family (X3 Digital) is designed to support various supply configurations. The input side can be used with a 3.3 V or 5 V supply.

The output side requires either an unipolar supply ( $VEE2 = GND2$ ) or a bipolar supply.

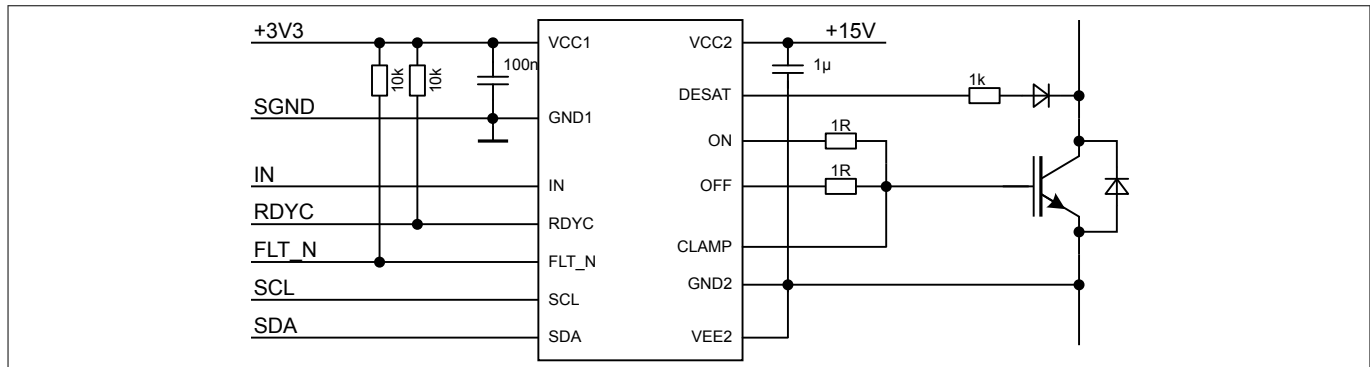
- Individual supply voltages between  $VCC2$  and  $GND2$  or  $GND2$  and  $VEE2$  shall not exceed 25 V.
- The total supply voltage between  $VCC2$  and  $VEE2$  shall not exceed 35 V.

To ensure safe operation of the gate driver IC, it is equipped with an input and output side undervoltage lockout circuit.

### Unipolar supply

In unipolar supply configuration the gate driver IC is typically supplied with a positive voltage of 15 V at  $VCC2$ .  $GND2$  and  $VEE2$  are connected together and this common potential is connected to the IGBT emitter.

## 4 Functional description

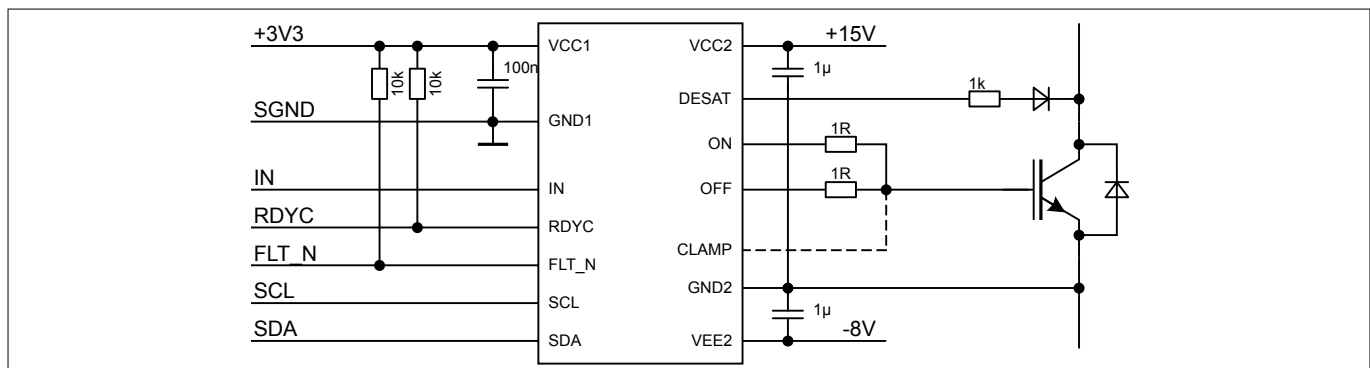


**Figure 4** Application example with unipolar supply

### Bipolar supply

For bipolar supply the gate driver IC is typically supplied with a positive voltage of 15 V at VCC2 and a negative voltage of -8 V or -15 V at VEE2 relative to GND2.

Between VCC2 and VEE2 the maximum potential difference is 35 V.



**Figure 5** Application example with bipolar supply

Negative supply prevents a parasitic turn-on due to the additional voltage margin to the gate turn-on threshold.

### VEE2 over GND2 supply connection check

The gate driver IC has a built-in connection check for VEE2. A loss of VEE2 connection will be detected and signaled via RDYC.

## 4.3 Input side logic

The input threshold levels are always CMOS compliant. The threshold levels are 30% of VCC1 for low level and 70% of VCC1 for high level.

The pins IN and SCL are for input only, and the pins SDA, FLT\_N, and RDYC are input/output pins.

## 4.4 I2C bus

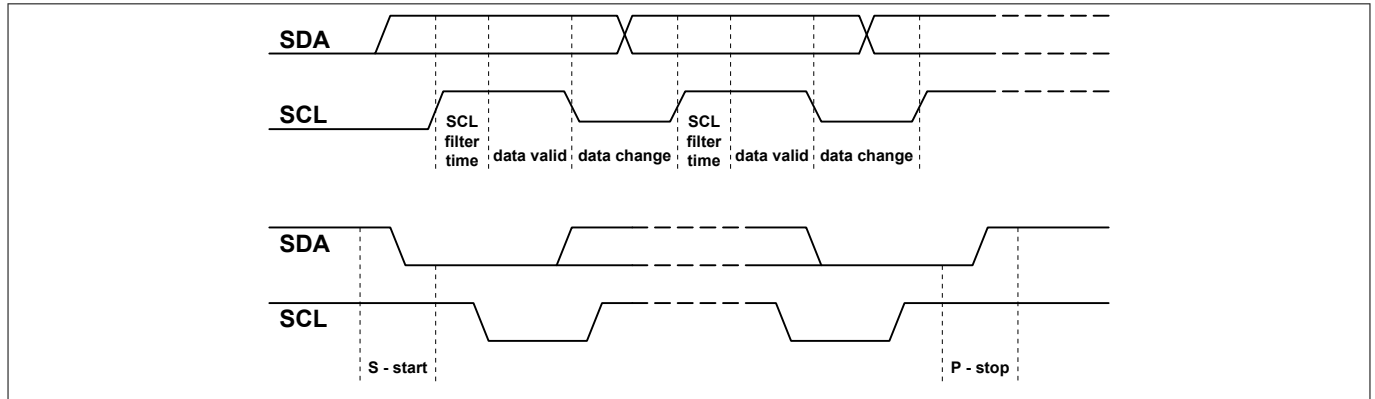
The 1ED38x0 family is equipped with a standard I2C bus interface to configure various parameters of the gate driver IC and read out measurement and monitoring registers.

Key I2C features include:

- I2C bus slave device implementing all mandatory slave bus protocols for the specification [UM10204 rev. 6](#)
- 7 bit device addresses for individual and group addressing
- Initial I2C device address: 1A<sub>H</sub> (MSB aligned, bits 7:1)

#### 4 Functional description

- Signal voltage level compatible to 3.3 V and 5 V
- Supported bus speeds at gate driver data pin (SDA) and clock pin (SCL):
  - standard-mode (Sm), with bit rates up to 100 kbit/s
  - fast-mode (Fm), with bit rates up to 400 kbit/s
  - fast-mode plus (FM+), with bit rates up to 1 Mbit/s



**Figure 6 Start, stop and data conditions**

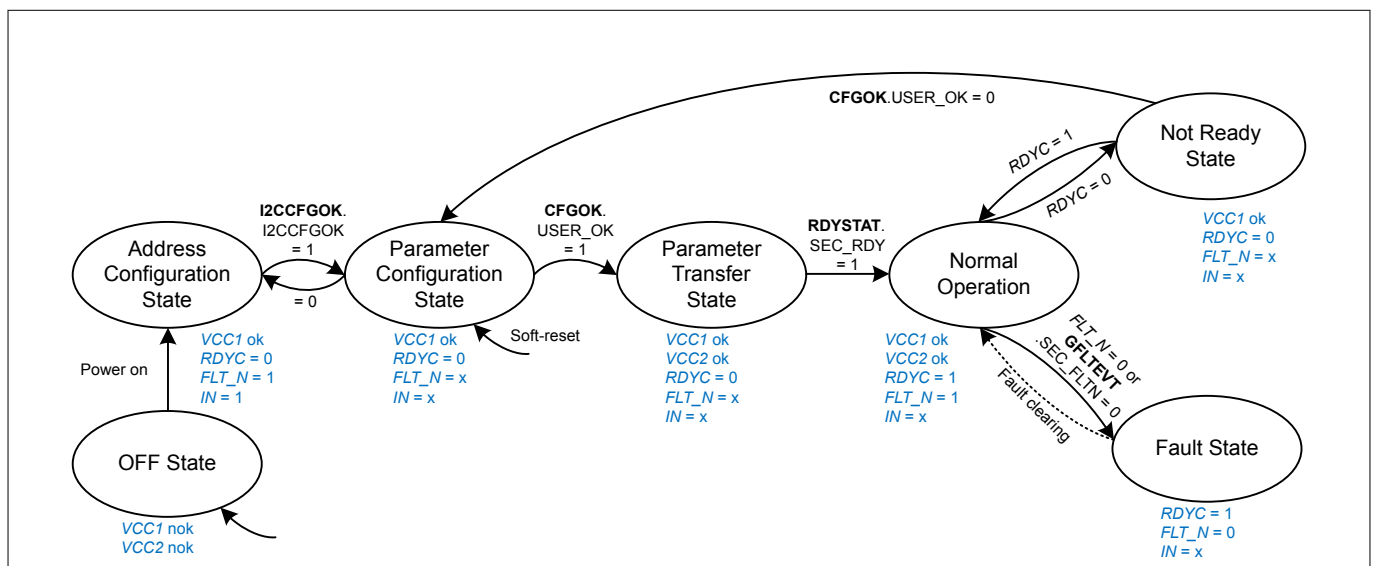
All I2C bus commands start with a start condition and stops with a stop condition. The data at the SDA pin gets valid if SCL level is above the CMOS level threshold and the filter time has elapsed.

## 4 Functional description

### 4.5 Operating states

The 1ED38x0 family of gate driver ICs can take the following states:

- OFF state, device not powered
- Address configuration state, the I2C addresses can be set, gate driver IC is not active
- Parameter configuration state, the gate driver parameters can be set and changed, gate driver IC is not active
- Parameter transfer state, the gate driver IC is transferring the parameters from input side to output side, gate driver IC is not active
- Normal operation, gate driver IC is active, ON and OFF outputs are following the IN signal, registers are read only
- Not ready state, gate driver IC is switched off according to fault off settings, status signaled by a low at *RDYC* pin
- Fault state, gate driver IC is switched off according to fault off settings, status signaled by a low at *FLT\_N* pin
- See later section for additional sub states on fault clear, soft-reset, recover, and restore of parameter configuration after power loss



**Figure 7 Operating state diagram**

- Pin names in uppercase italic letters, supply pin status listed as either okay (ok) or not okay (nok) and for logic pins with low (0), high (1), or either (x)
- Register names in uppercase bold letters followed by the register bit name and value
- States in bubbles with transitions marked by arrows with conditions attached

### 4.6 Measurement

The 1ED38x0 family offers several measurement functions and uses a free running successive-approximation-register analog-to-digital converter (SAR-ADC). The SAR-ADC has a 8 bit resolution and the results are digitally filtered with a three-point-two pass moving average filter.

Following internal and external parameter measurements are available:

- **ADCMVCC2** Measurement *VCC2* to *VEE2*
- **ADCMVDIF** Measurement and calculation *VCC2* to *GND2*
- **ADCMGND2** Measurement *GND2* to *VEE2*

## 4 Functional description

- **ADCMTEMP** Measurement junction temperature  $T_J$
- **ADCMVEXT** Measurement external voltages, e.g. NTC

Measurement result registers will be updated sequentially depending on selected sample sources. The update rate is typically below 100  $\mu$ s.

The SAR-ADC configuration register **ADCCFG** is used to activate measurement channels and external voltage compare behavior. Measurement of internal junction temperature is always active. Activated SAR-ADC measurements also enable monitoring functions.

### 4.7 Monitoring

The 1ED38x0 family offers many monitoring functions. The monitoring functions can be divided into:

- Hardware based functions

The hardware based monitoring functions use dedicated hardware, e.g. fast UVLO.

- ADC-based functions

The ADC-based functions gather measured values of different parameters and compare them with limit values. Enable ADC measurement to use related ADC-based monitoring functions.

Both groups contain non-configurable and configurable functions.

Non-configurable hardware monitoring:

- **VEE2** over **GND2**, e.g. **VEE2** connection failure
- Turn-off monitoring,  $V_{ON} > VEE2 + 2\text{ V}$  (**FLTEVT.VOUT\_ST** = 1<sub>B</sub>)
- Gate voltage monitoring below  $VEE2 + 2\text{ V}$  (**PINSTAT.ON\_PIN** = 1<sub>B</sub>)
- Gate voltage monitoring above  $VCC2 - 2\text{ V}$  (**PINSTAT.OFF\_PIN** = 1<sub>B</sub>)
- Gate voltage monitoring above  $V_{TLTOFF}$  (**PINSTAT.TLTO\_LVL** = 1<sub>B</sub>)
- Pin status monitoring of **IN** pin high (**PINSTAT.PWM\_IN** = 1<sub>B</sub>)
- Pin status monitoring of **RDYC** pin high (**PINSTAT.RDYC** = 1<sub>B</sub>)
- Pin status monitoring of **FLT\_N** pin high (**PINSTAT.FLT\_N** = 1<sub>B</sub>)
- **VCC1** supply voltage UVLO spike detection (**UV1FCNT**)
- **VCC2** supply voltage UVLO spike detection (**UV2FCNT**)

Configurable hardware monitoring:

- Normal **VCC2** supply UVLO event (**SECUEVT.UV\_VCC2**)
- Normal **VEE2** supply UVLO event (**SECUEVT.UV\_VEE2**)
- Switch-off timeout,  $V_{ON} > VEE2 + 2\text{ V}$  and maximal switch-off timeout time elapsed (**FLTEVT.SOTO\_EVT**)

Non-configurable ADC-based monitoring:

- Over temperature protection event (**FLTEVT.OTP\_EVT**)

Configurable ADC-based monitoring:

- **VCC2** supply soft UVLO event (**SECUEVT.UVSVCC2**)
- **VEE2** supply soft UVLO event (**SECUEVT.UVSVEE2**)
- External voltage compare event (**FLTEVT.VEXTFLT**)
- Over temperature warning event (**FLTEVT.OTW\_EVT**)

#### Gate driver reaction to **VEE2** over **GND2** detected

A **VEE2** over **GND2** event triggers the following sequence:

1. IC detects **VEE2** over **GND2**
2. IC initiates an output side reset, including
  - Activation of active shutdown as a safety measure

#### **4 Functional description**

- Resetting all configuration registers to their reset values
  - Ignoring all PWM signals and reporting a not ready state
- 3.** IC listens to its previously configured I2C address
- If **RECOVER.RESTORE** = 1<sub>B</sub>, the gate driver IC will restore the output side configuration from the input side
  - If **RECOVER.RESTORE** = 0<sub>B</sub>, the gate driver IC performs a soft-reset and waits for a re-configuration via I2C bus
- 4.** After the configuration of the output side is valid again, the IC continues operation

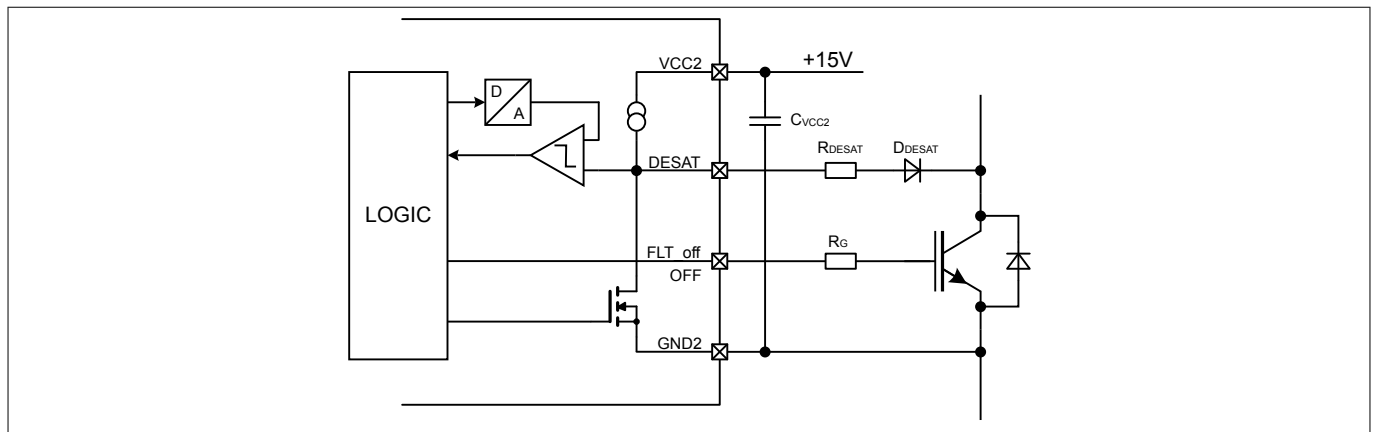
*Note: To avoid unintended VEE2 over GND2 detection, take extra care in power supply design, routing, and capacitive blocking at these pins.*

## 4 Functional description

### 4.8 Desaturation protection

The desaturation detection circuit protects the external IGBT from destruction at a short circuit. The desaturation protection follows the given sequence:

1. Voltage at *DESAT* pin reaches DESAT threshold level, e.g. 9.18 V, for a period of time exceeding the filter time
2. Gate driver IC output switches the external IGBT off, using the defined fault off method
3. Gate driver IC switches *FLT\_N* pin to low to indicate the fault to a connected microcontroller
4. Short circuit situation is resolved
  - after the voltage at the *ON* pin has dropped below the  $V_{EE2}+2\text{ V}$  threshold,
  - no other fault condition is present,
  - the input has been turned off and
  - the fault has been cleared using the defined fault clear method



**Figure 8** DESAT circuit (only relevant pins shown)

The high-precision internal current source results in a minimum impact on the DESAT detection variation.

#### 4.8.1 DESAT behavior

The DESAT function offers a leading edge blanking time and filters to optimize the DESAT detection for application usage.

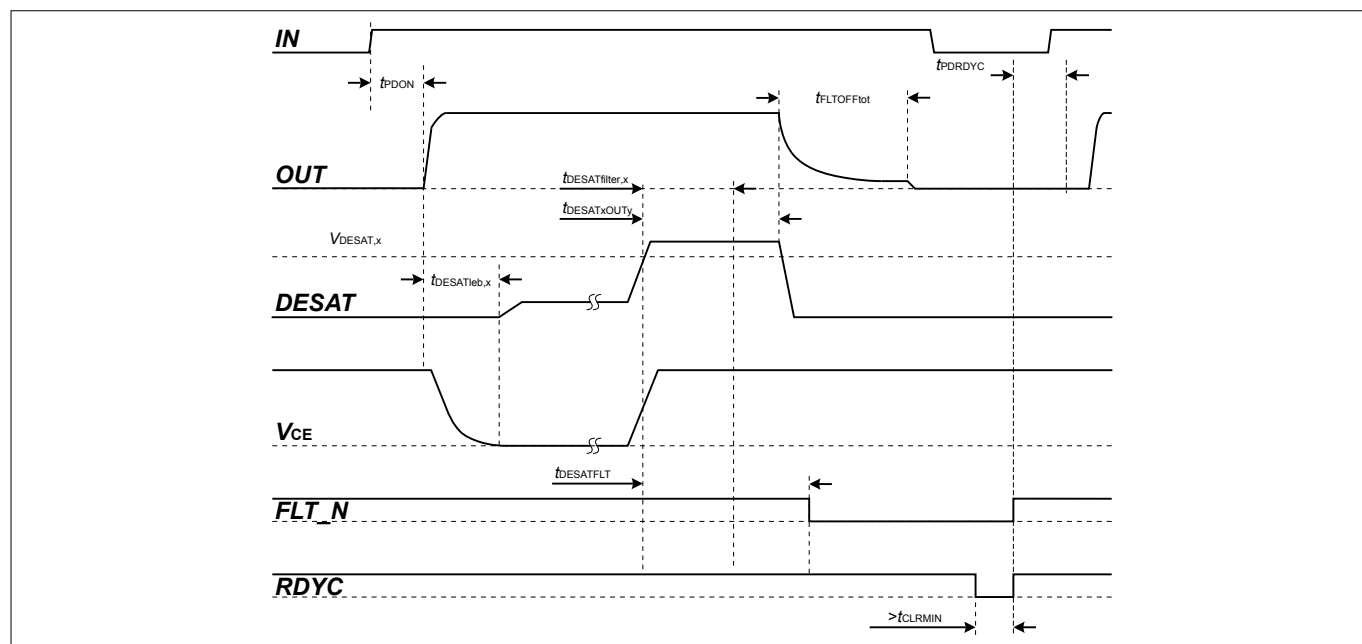
The leading edge blanking inhibits threshold detection during an IGBT turn on phase. The typical IGBT turn on behavior starts with charging of the gate, commutation of the application load current and finally  $V_{CE}$  voltage decrease to  $V_{CEsat}$  voltage levels. To prevent the gate driver IC from detecting a false DESAT event, leading edge blanking pauses the DESAT circuit until the time  $t_{DESATleb}$  has elapsed.

Following the leading edge blanking time, the gate driver IC forces the DESAT current into the external DESAT circuit. The current typically flows through a protection resistor, a fast high voltage diode and the collector-emitter path of the IGBT. The resulting voltage at the *DESAT* pin is the sum of the voltage drop across this path.

During a short circuit condition, the  $V_{CE}$  voltage increases, resulting in a reverse polarity condition of the DESAT diode. The remaining DESAT current also increases the voltage level at the *DESAT* pin and triggers the DESAT threshold. If the pin voltage level stays above the threshold for the duration of the DESAT filter time  $t_{DESATfilter}$ , the gate driver IC registers the DESAT event and acts accordingly.

The internal processing time after DESAT threshold crossing, filtering and beginning of fault-off is defined as  $t_{DESATOUT}$ . The duration of the gate discharge during fault-off is defined as  $t_{FLTOFFtot}$  and is depending on the defined fault off function and the gate load.

#### 4 Functional description



**Figure 9** DESAT timing with leading edge blanking, filter and reaction times

## 4 Functional description

### 4.9 Gate driver output

The gate driver output side uses MOSFETs to provide a rail-to-rail output. Therefore, the gate drive voltage follows the supply voltage closely.

Due to the low internal voltage drop, the switching behavior of the IGBT is predominantly governed by the external gate resistor. The gate driver IC offers separate sink and source outputs to adapt the gate resistor for turn-on and turn-off separately without additional bypass components.

The cell value x in the following table is placeholder for high or low and indicates that this pin does not influence the resulting gate driver output state. The arrow (→) in cells indicate the transition initiated by the pin of the logic input and gate driver supply pins resulting in a transition to the gate driver output state as listed.

**Table 5 Driver output state including transition behavior**

| Logic input and gate driver supply                         |            |            |            |            | Gate driver output |                  |
|------------------------------------------------------------|------------|------------|------------|------------|--------------------|------------------|
| IN                                                         | RDYC       | FLT_N      | VCC1       | VCC2       | ON                 | OFF              |
| Static gate driver output state: on and off                |            |            |            |            |                    |                  |
| high                                                       | high       | high       | high       | high       | high               | tri-state        |
| low                                                        | high       | high       | high       | high       | tri-state          | low              |
| Transition to not ready and static not ready state         |            |            |            |            |                    |                  |
| x                                                          | high → low | high       | high       | high       | → tri-state        | → fault off      |
| x                                                          | low        | high       | high       | high       | tri-state          | low              |
| Transition to fault and static fault state                 |            |            |            |            |                    |                  |
| x                                                          | high       | high → low | high       | high       | → tri-state        | → fault off      |
| x                                                          | high       | low        | high       | high       | tri-state          | low              |
| Transition with VCC1 power loss and unsupplied input side  |            |            |            |            |                    |                  |
| x                                                          | x          | x          | high → low | high       | → tri-state        | → fault off      |
| x                                                          | x          | x          | low        | high       | tri-state          | low              |
| Transition with VCC2 power loss and unsupplied output side |            |            |            |            |                    |                  |
| x                                                          | x          | x          | x          | high → low | → tri-state        | → fault off      |
| x                                                          | x          | x          | x          | low        | tri-state          | active shut down |

## 4 Functional description

### 4.9.1 Turn-on behavior

The 1ED38x0Mc12M family (X3 Digital) is optimized for hard switching turn-on. A turn-on command switches the *ON* pin internally to *VCC2*.

### 4.9.2 Turn-off and fault turn-off behavior

The gate driver IC supports different turn-off sequences to adapt to different applications and IGBT currents during normal switching operation and in the case of a fault.

**Table 6** Turn-off sequences

| Turn-off reason | Turn-off sequence |                    |               | Remark     |
|-----------------|-------------------|--------------------|---------------|------------|
|                 | Hard switching    | Two-level turn-off | Soft turn-off |            |
| normal off      | X                 | X                  |               | adjustable |
| fault turn-off  | X                 | X                  | X             | adjustable |

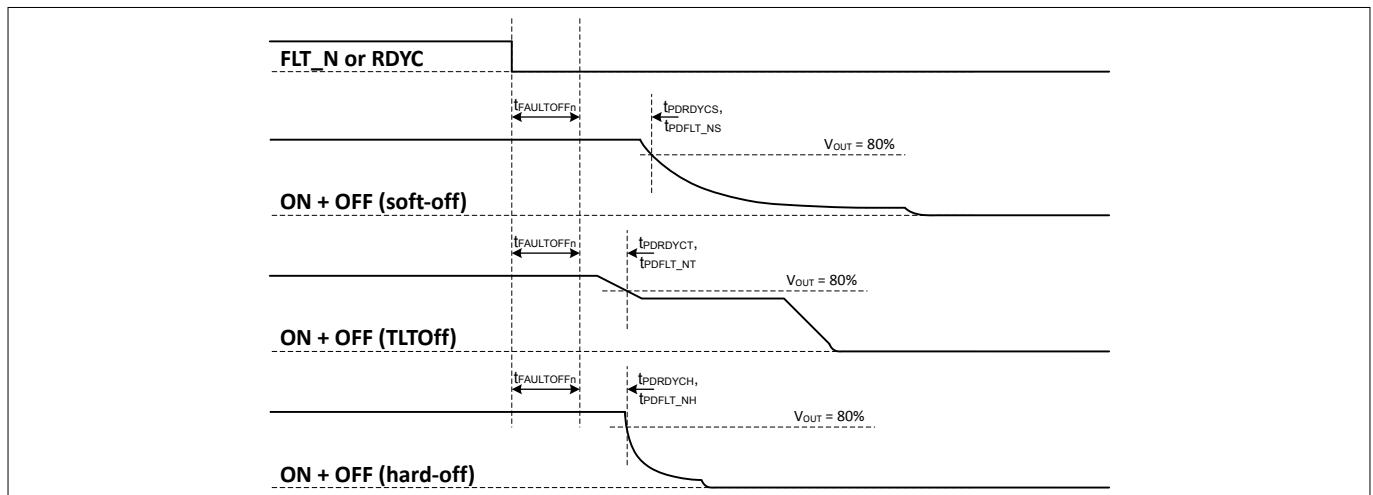
The gate driver turn-off behavior can be configured in register **DRVCFG.STD\_OFF**.

The gate driver fault turn-off behavior can be configured in register **DRVFOFF.DRV\_FOFF**.

In some topologies the fault turn-off needs to be delayed for individual switch positions. The fault turn-off delay time  $t_{\text{FAULTOFFn}}$  is adjustable in the register **F2ODLY.F2O\_DLY**.

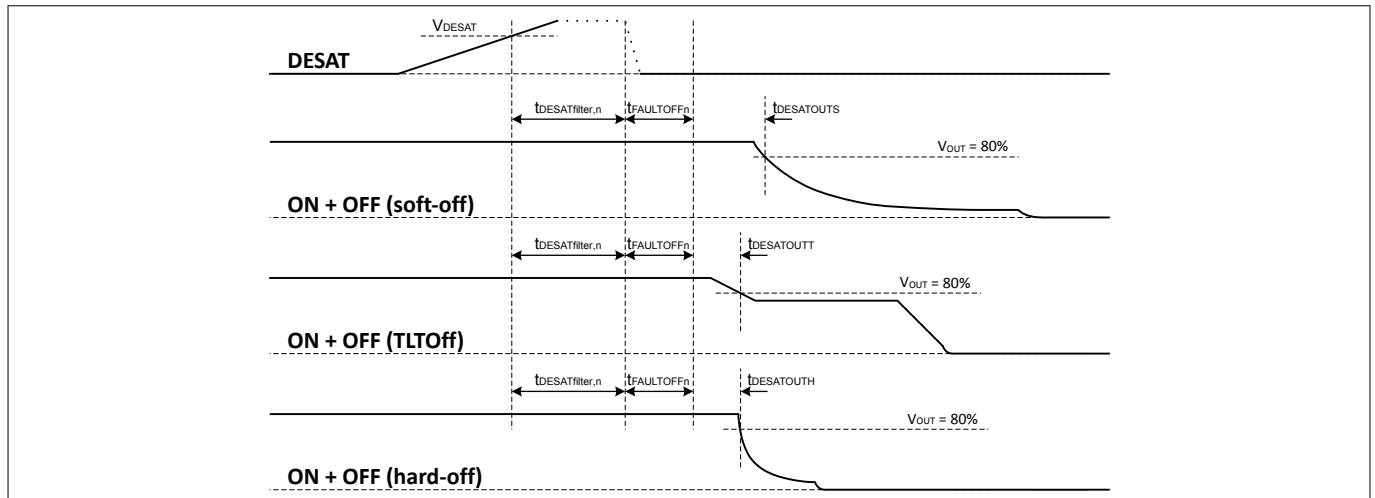
The gate driver monitors the gate voltage and sets the register bit **FLTEVT.VOUT\_ST** to 1<sub>B</sub> as long as the voltage at the *ON* pin is above  $VEE2 + 2 \text{ V}$ .

Once started, the fault turn-off sequence cannot be interrupted by an *IN* = low turn-off signal.



**Figure 10** Fault turn-off sequence initiated by *FLT\_N* or *RDYC*

## 4 Functional description



**Figure 11** Fault turn-off sequence initiated by DESAT event

### 4.9.2.1 Hard switching turn-off

Hard switching turn-off supports fast switching applications and applications with emitter-follower booster stages. The switching behavior of the IGBT is controlled by adjusting the external gate resistance between the *OFF* pin and the IGBT gate.

### 4.9.2.2 Two-level turn-off

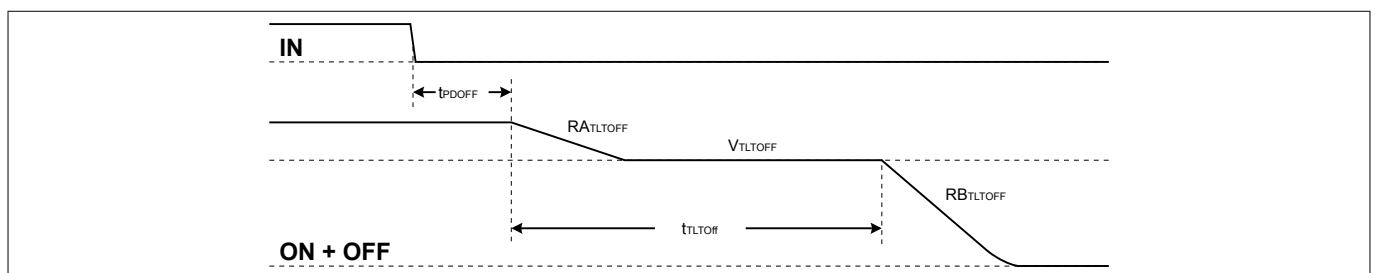
The two-level turn-off (TLTOFF) is a voltage controlled turn-off function.

Two-level turn-off supports secure IGBT turn-off even under overload conditions with low  $V_{CE}$  overshoot. It also operates in applications with emitter-follower booster stages, typical for high power applications with larger  $di/dt$ . With two-level turn-off the switching behavior of the IGBT is controlled by the plateau voltage and the ramp speed.

The gate driver IC is switching the IGBT gate off by discharging from positive supply to an intermediate voltage level plateau to reduce a collector over current and continued turn-off thereafter. In detail this includes:

1. Discharge gate from  $V_{CC2}$  voltage level to intermediate voltage level with the controlled voltage ramp A.
2. At the intermediate gate voltage level the IGBT collector current is being limited at overload application conditions.
3. The configured duration of ramp A and intermediate voltage level depends on individual application requirements.
4. Finally the gate voltage is further reduced by the controlled voltage ramp B until the IGBT is completely switched off and the gate voltage reaches  $V_{EE2}$ .

The gate driver two-level turn-off function can be activated in register **DRVCFG.STD\_OFF**. The behavior can be adjusted with four parameters in the registers **TLTOC1** and **TLTOC2**.



**Figure 12** Two-level turn-off timing and ramp-down behavior

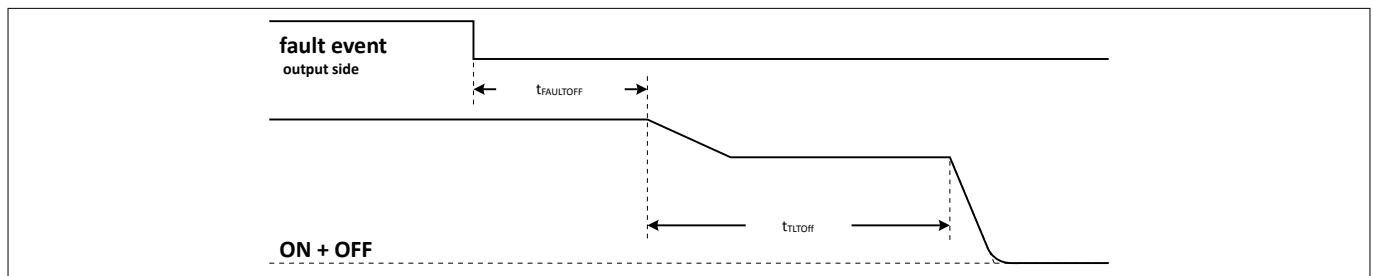
## 4 Functional description

In the two-level turn-off mode, the turn-on propagation delay is a function of the plateau time and the gate driver propagation delay without TLTOff function  $t_{PDOn}$ . This means the gate driver propagation delay will be enlarged by the plateau time for turn-on to ensure a constant on-time of the switch. The two-level turn-off does not change the on-time of an *IN* pulse. The TLTOff voltage will be controlled in a closed loop at the *OFF* output pin of the gate driver IC.

For switch-off initiated by:

- the *IN* signal, the gate driver IC is starting the TLTOff sequence after the propagation delay
- the DESAT function, the gate driver switch-off is delayed by desaturation sense to OFF delay and an optional fault-off delay
- a non-DESAT fault event or a not ready event on output side, the gate driver switch-off occurs immediately or after an optional fault-off delay

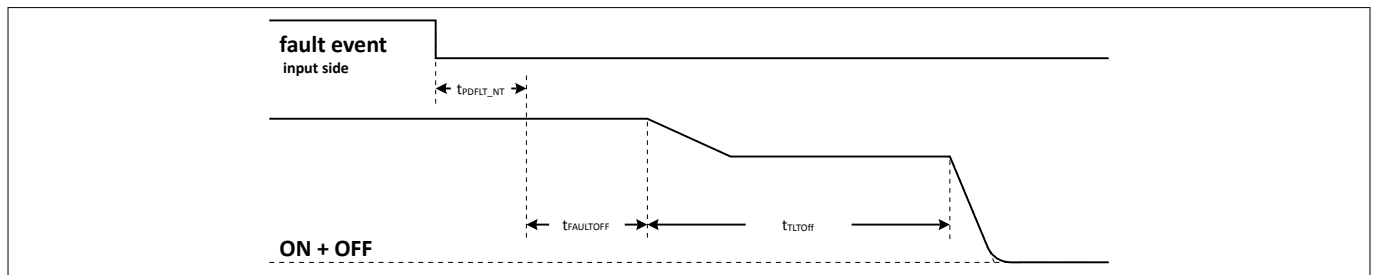
After the elapsed plateau time the gate driver IC switches from the plateau voltage down to *VEE2* voltage.



**Figure 13 Two-level turn-off after fault event (output side)**

For switch-off initiated by:

- FLT\_N* or *RDYC* signal or an internal fault event from input side, the output is switched off after the propagation delay with an optional fault off delay using the defined fault off function



**Figure 14 Two-level turn-off after fault event (input side)**

### 4.9.2.3 Soft turn-off

The soft turn-off function protects the IGBT against collector-emitter overvoltage during turn off in an overcurrent condition. It turns-off the IGBT with a reduced gate current to reduce the  $di/dt$  induced overvoltage..

The IGBT gate is connected via *OFF* to an internal current sink circuit. The discharge current is typically lower than the hard switch-off current used for normal operation. Since soft turn-off is a single event after a failure, the gate driver IC can handle the additional power dissipation internally.

The soft turn-off function is implemented as a current source which can be adjusted with a 4 bit value in the register **CSSOFCFG**.

The adjustable range depends on the current strength of the gate driver IC:

- 1ED3830M: 15 mA - 233 mA
- 1ED3860M: 29 mA - 466 mA
- 1ED3890M: 44 mA - 699 mA

## 4 Functional description

### 4.9.3 Active shut-down

The active shut-down feature ensures a safe IGBT off-state, if the output chip is not supplied. It protects the IGBT against a floating gate. The IGBT gate is always clamped via *OFF* to *VEE2*.

### 4.9.4 Active Miller clamp

The 1ED38x0Mc12M family (X3 Digital) is equipped with a configurable active Miller clamp function to protect the IGBT from parasitic turn-on in fast switching applications.

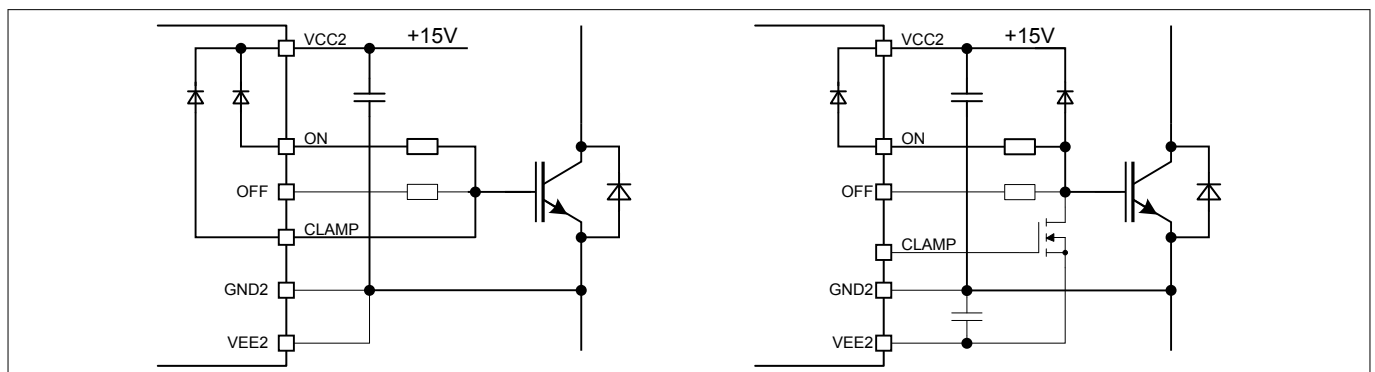
After a turn-off command the gate driver IC follows the implemented sequence:

1. Discharge of the IGBT gate while monitoring the voltage level at the *ON* pin
2. Detection of a voltage at the *ON* pin less than a level of  $VEE2 + 2.0\text{ V}$
3. Filtering of the detection to avoid false CLAMP activation and not to influence regular turn-off behavior
4. Activating clamp function to keep IGBT gate at *VEE2* level

### 4.10 Short circuit clamping

The integrated short circuit clamping diode limits the IGBT gate over voltage during a short circuit. The over voltage is typically triggered by the capacitive feedback of the Miller capacitance.

The internal diodes from *ON* and *CLAMP* to *VCC2* limit the gate driver voltage to a value slightly higher than the supply voltage. These diode paths are rated for a maximum current of 0.75 A and the duration of 6  $\mu\text{s}$ . Add an external Schottky diode if higher currents are expected or a tighter clamping is desired. Also use an external diode if the active Miller clamping circuit uses the pre-driver output configuration.



**Figure 15** Short circuit clamping circuitry

## 5 Electrical parameters

## 5 Electrical parameters

### 5.1 Absolute maximum ratings

*Note:* Absolute maximum ratings are defined as ratings, which when being exceeded may lead to destruction of the integrated circuit. Unless otherwise noted all voltages are given with respect to their respective GND (GND1 for pins 1 to 8, GND2 for pins 9 to 16).

**Table 7 Absolute maximum ratings**

| Parameter                                                                             | Symbol                | Values                  |                         | Unit          | Note / Test Condition                                                                                                                 |
|---------------------------------------------------------------------------------------|-----------------------|-------------------------|-------------------------|---------------|---------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                       |                       | Min.                    | Max.                    |               |                                                                                                                                       |
| Input to output offset voltage                                                        | $V_{\text{OFFSET}}$   | –                       | 2300                    | V             | $V_{\text{VEE2,max}} - V_{\text{VEE2,min}}$ with $V_{\text{VEE2,max}} \geq V_{\text{GND1}} \geq V_{\text{VEE2,min}}$ <sup>1) 2)</sup> |
| Supply voltage input side                                                             | $V_{\text{VCC1}}$     | -0.3                    | 6.5                     | V             | –                                                                                                                                     |
| Logic input voltage (IN)                                                              | $V_{\text{LogicIN}}$  | -0.3                    | 6.5                     | V             | –                                                                                                                                     |
| Logic input voltage (RDYC, FLT_N)                                                     | $V_{\text{LogicRF}}$  | -0.3                    | 6.5                     | V             | –                                                                                                                                     |
| I2C logic input voltage (SDA, SCL)                                                    | $V_{\text{LogicI2C}}$ | -0.3                    | 6.5                     | V             | –                                                                                                                                     |
| Open drain logic output current (RDYC, FLT_N)                                         | $I_{\text{LogicOC}}$  | –                       | 10                      | mA            | –                                                                                                                                     |
| I2C logic output current (SDA)                                                        | $I_{\text{SDA}}$      | –                       | 50                      | mA            | –                                                                                                                                     |
| Positive supply voltage output side                                                   | $V_{\text{VCC2}}$     | -0.3                    | 40                      | V             | –                                                                                                                                     |
| Negative supply voltage output side                                                   | $V_{\text{VEE2}}$     | -40                     | 0.3                     | V             | –                                                                                                                                     |
| Maximum supply voltage difference output side ( $V_{\text{VCC2}} - V_{\text{VEE2}}$ ) | $V_{\text{max2}}$     | –                       | 40                      | V             | –                                                                                                                                     |
| DESAT input voltage                                                                   | $V_{\text{DESAT}}$    | -0.3                    | $V_{\text{VCC2}} + 0.3$ | V             | –                                                                                                                                     |
| CLAMP input voltage                                                                   | $V_{\text{CLAMP}}$    | $V_{\text{VEE2}} - 0.3$ | $V_{\text{VCC2}} + 0.3$ | V             | <sup>3)</sup>                                                                                                                         |
| Maximum CLAMP output current                                                          | $I_{\text{CLAMP}}$    | –                       | 2.4                     | A             | $t < 5 \mu\text{s}$                                                                                                                   |
| Gate driver output voltage (ON, OFF)                                                  | $V_{\text{OUT}}$      | $V_{\text{VEE2}} - 0.3$ | $V_{\text{max2}} + 0.3$ | V             | –                                                                                                                                     |
| Maximum CLAMP to VCC2 diode IGBT short circuit clamping time                          | $t_{\text{CLP}}$      | –                       | 6                       | $\mu\text{s}$ | $I_{\text{CLAMP/OUT}} = 0.75 \text{ A}$                                                                                               |
| Junction temperature                                                                  | $T_{\text{J}}$        | -40                     | 150                     | °C            | –                                                                                                                                     |
| Storage temperature                                                                   | $T_{\text{Stg}}$      | -55                     | 150                     | °C            | –                                                                                                                                     |
| Power dissipation, input side                                                         | $P_{\text{D,IN}}$     | –                       | 100                     | mW            | @ $T_{\text{A}} = 25 \text{ °C}$                                                                                                      |
| Power dissipation, output side                                                        | $P_{\text{D,OUT}}$    | –                       | 700                     | mW            | @ $T_{\text{A}} = 25 \text{ °C}$ <sup>4)</sup>                                                                                        |
| ESD capability: Human body model                                                      | $V_{\text{ESDHBM}}$   | –                       | 2                       | kV            | <sup>5)</sup>                                                                                                                         |
| ESD capability: Charged device model                                                  | $V_{\text{ESDCDM}}$   | –                       | 500                     | V             | <sup>6)</sup>                                                                                                                         |

1) for functional operation only

2) See also [Chapter 6](#) on page 43

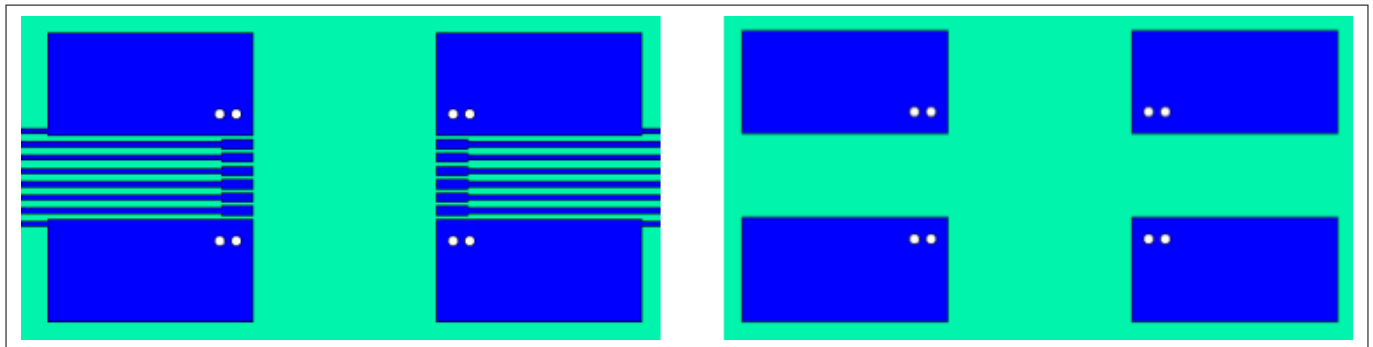
3) May be exceeded during short circuit clamping.

## 5 Electrical parameters

- 4) Derating the power above 65°C with 8 mW/°C
- 5) According to ANSI/ESDA/JEDEC-JS-001-2017 (discharging a 100 pF capacitor through a 1.5 kΩ series resistor).
- 6) According to ANSI/ESDA/JEDEC-JS-002-2014 (TC = test condition in volt)

### 5.2 Thermal parameters

Thermal performance may change significantly with layout and heat dissipation of components in close proximity.



**Figure 16** Reference layout for thermal data (Two layer PCB; copper thickness 35 μm; left: top layer; right: bottom layer)

The PCB layout represents the reference layout used for the thermal characterization. Pins 1 and 8 (*GND1*) and pins 9 and 16 (*VEE2*) require ground plane connections for achieving maximum power dissipation. The 1ED38x0Mc12M family (X3 Digital) is conceived to dissipate most of the heat generated through these pins.

**Table 8** Thermal parameters

| Parameter                                                     | Symbol         | Value | Unit | Note / Test Condition                                                                                                    |
|---------------------------------------------------------------|----------------|-------|------|--------------------------------------------------------------------------------------------------------------------------|
| Thermal resistance junction to ambient                        | $R_{THJA,OUT}$ | 122   | K/W  | @ $T_A = 65^\circ\text{C}$ , $P_{D,OUT} = 400\text{ mW}$ ,<br>$P_{D,IN} = 50\text{ mW}$ , 4 layer test PCB,<br>PG-DSO-16 |
| Characterization parameter junction to package top input side | $\Psi_{Jtop}$  | 8     | K/W  |                                                                                                                          |

### 5.3 Operating parameters

*Note:* Within the operating range the IC operates as described in the functional description. Unless otherwise noted all voltages are given with respect to their respective GND (*GND1* for pins 1 to 8, *GND2* for pins 9 to 16).

**Table 9** Operating parameters

| Parameter <sup>1)</sup>                                                                   | Symbol        | Values |      | Unit | Note / Test Condition |
|-------------------------------------------------------------------------------------------|---------------|--------|------|------|-----------------------|
|                                                                                           |               | Min.   | Max. |      |                       |
| Supply voltage input side                                                                 | $V_{VCC1}$    | 3.0    | 5.5  | V    | –                     |
| Logic input voltages ( <i>IN</i> , <i>RDYC</i> , <i>FLT_N</i> , <i>SDA</i> , <i>SCL</i> ) | $V_{LogicIN}$ | -0.3   | 5.5  | V    | –                     |
| Positive supply voltage output side                                                       | $V_{VCC2}$    | 13     | 25   | V    | –                     |

(table continues...)

**5 Electrical parameters**

**Table 9 (continued) Operating parameters**

| Parameter <sup>1)</sup>                                            | Symbol     | Values |      | Unit | Note / Test Condition              |
|--------------------------------------------------------------------|------------|--------|------|------|------------------------------------|
|                                                                    |            | Min.   | Max. |      |                                    |
| Negative supply voltage output side                                | $V_{VEE2}$ | -25    | 0    | V    | –                                  |
| Supply voltage difference output side<br>( $V_{VCC2} - V_{VEE2}$ ) | $V_{max2}$ | 13     | 35   | V    | –                                  |
| Ambient temperature                                                | $T_A$      | -40    | 125  | °C   | <sup>2)</sup>                      |
| Switching frequency                                                | $f_{SW}$   | 0      | 250  | kHz  | max $P_D$ applies                  |
| Common mode transient immunity                                     | $ CMTI $   | 0      | 200  | V/ns | $V_{OFFSET, test} = 1500\text{ V}$ |

1) Parameter is not subject to production test - verified by design/characterization

2)  $T_J$  has to be below over temperature protection temperature  $T_{OTPOFF}$

## 5 Electrical parameters

### 5.4 Electrical characteristics

*Note:* The electrical characteristics include the spread of values in supply voltages, load, and junction temperatures within the operating parameters and default parameter settings unless specified otherwise. Typical values represent the median values at  $T_A = 25^\circ\text{C}$ . Unless otherwise noted all voltages are given with respect to their respective GND (GND1 for pins 1 to 8, GND2 for pins 9 to 16).

#### 5.4.1 Voltage supply

**Table 10** Voltage supply

| Parameter                                              | Symbol         | Values |      |      | Unit | Note or Test Condition                                                                                                         |
|--------------------------------------------------------|----------------|--------|------|------|------|--------------------------------------------------------------------------------------------------------------------------------|
|                                                        |                | Min.   | Typ. | Max. |      |                                                                                                                                |
| VCC1 UVLO threshold                                    | $V_{UVLO1H}$   | –      | 2.95 | 3.05 | V    | –                                                                                                                              |
|                                                        | $V_{UVLO1L}$   | 2.6    | 2.8  | –    | V    | –                                                                                                                              |
| VCC1 UVLO hysteresis ( $V_{UVLO1H} - V_{UVLO1L}$ )     | $V_{HYS1}$     | 0.1    | 0.14 | –    | V    | –                                                                                                                              |
| VCC1 quiescent current                                 | $I_{Q1}$       | –      | 2.4  | 4.0  | mA   | $V_{VCC1} = 3.3\text{ V}$ , $IN = \text{High}$ , $RDYC = \text{High}$ , $FLT\_N = \text{High}$                                 |
| VCC1 operating current                                 | $I_{O1}$       | –      | 2.4  | 4.0  | mA   | $V_{VCC1} = 3.3\text{ V}$ , $IN = 16\text{ kHz}$ , $50\%$ , $RDYC = \text{High}$ , $FLT\_N = \text{High}$ , $SCL = \text{Low}$ |
| VCC2 UVLO threshold                                    | $V_{UVLO2H,0}$ | –      | 12.0 | 12.6 | V    | <b>UVTLVL.UVVCC2TL</b> = $0_H$                                                                                                 |
|                                                        | $V_{UVLO2L,0}$ | 10.4   | 11.0 | –    | V    |                                                                                                                                |
| VCC2 UVLO hysteresis ( $V_{UVLO2H,0} - V_{UVLO2L,0}$ ) | $V_{HYS2,0}$   | 0.75   | 1.0  | –    | V    |                                                                                                                                |
| VCC2 UVLO threshold                                    | $V_{UVLO2H,1}$ | –      | 9.4  | 10.0 | V    | <b>UVTLVL.UVVCC2TL</b> = $1_H$                                                                                                 |
|                                                        | $V_{UVLO2L,1}$ | 8.0    | 8.7  | –    | V    |                                                                                                                                |
| VCC2 UVLO hysteresis ( $V_{UVLO2H,1} - V_{UVLO2L,1}$ ) | $V_{HYS2,1}$   | 0.6    | 0.7  | –    | V    |                                                                                                                                |
| Soft VCC2 UVLO voltage level                           | $V_{UV2S,0}$   | –      | 9.5  | –    | V    | <sup>1)</sup><br><b>UVSVCC2C.UVSVCC2L</b>                                                                                      |
|                                                        | $V_{UV2S,1}$   | –      | 10.0 | –    | V    |                                                                                                                                |
|                                                        |                |        | ...  |      |      |                                                                                                                                |
|                                                        | $V_{UV2S,E}$   | –      | 16.5 | –    | V    |                                                                                                                                |
|                                                        | $V_{UV2S,F}$   | –      | 17.0 | –    | V    |                                                                                                                                |
| VEE2 not connected detection threshold                 | $V_{VEE2,NC}$  | –      | 0.5  | –    | V    | $V_{VEE2} - V_{GND2}$                                                                                                          |
| VEE2 UVLO threshold                                    | $V_{UVLO3H,1}$ | -3.6   | -3.5 | –    | V    | <b>UVTLVL.UVVEE2TL</b> = $1_H$                                                                                                 |
|                                                        | $V_{UVLO3L,1}$ | –      | -3.0 | -2.9 | V    |                                                                                                                                |

(table continues...)

**5 Electrical parameters**

**Table 10 (continued) Voltage supply**

| Parameter                                              | Symbol         | Values |       |       | Unit | Note or Test Condition                                                                                                                                                                                                            |
|--------------------------------------------------------|----------------|--------|-------|-------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                        |                | Min.   | Typ.  | Max.  |      |                                                                                                                                                                                                                                   |
| VEE2 UVLO hysteresis ( $V_{UVLO3L,1} - V_{UVLO3H,1}$ ) | $V_{HYS3,1}$   | 0.4    | 0.5   | –     | V    |                                                                                                                                                                                                                                   |
| VEE2 UVLO threshold                                    | $V_{UVLO3H,2}$ | -6.15  | -6    | –     | V    | <b>UVTLVL.UVVEE2TL</b> = 2 <sub>H</sub>                                                                                                                                                                                           |
|                                                        | $V_{UVLO3L,2}$ | –      | -5.5  | -5.35 | V    |                                                                                                                                                                                                                                   |
| VEE2 UVLO hysteresis ( $V_{UVLO3L,2} - V_{UVLO3H,2}$ ) | $V_{HYS3,2}$   | 0.4    | 0.5   | –     | V    |                                                                                                                                                                                                                                   |
| VEE2 UVLO threshold                                    | $V_{UVLO3H,3}$ | -12.3  | -12.0 | –     | V    | <b>UVTLVL.UVVEE2TL</b> = 3 <sub>H</sub>                                                                                                                                                                                           |
|                                                        | $V_{UVLO3L,3}$ | –      | -11.0 | -10.7 | V    |                                                                                                                                                                                                                                   |
| VEE2 UVLO hysteresis ( $V_{UVLO3L,3} - V_{UVLO3H,3}$ ) | $V_{HYS3,3}$   | 0.8    | 1.0   | –     | V    |                                                                                                                                                                                                                                   |
| Soft VEE2 UVLO voltage level                           | $V_{UV3S,0}$   | –      | -2.0  | –     | V    | 1)<br><b>UVSVEE2C.UVSVCC2</b><br>E                                                                                                                                                                                                |
|                                                        | $V_{UV3S,1}$   | –      | -3.0  | –     | V    |                                                                                                                                                                                                                                   |
|                                                        |                |        | ...   |       |      |                                                                                                                                                                                                                                   |
|                                                        | $V_{UV3S,E}$   | –      | -16.0 | –     | V    |                                                                                                                                                                                                                                   |
|                                                        | $V_{UV3S,F}$   | –      | -17.0 | –     | V    |                                                                                                                                                                                                                                   |
| VCC2 quiescent current                                 | $I_{Q2}$       | –      | 3.9   | 5     | mA   | $V_{VCC2} = 15\text{ V}$ , $V_{VEE2} = -8\text{ V}$ , $OUT = \text{High}$ , $DESAT = \text{Low}$ , <b>DRVCFG.STD_OFF</b> = 0 <sub>H</sub> , <b>DRVFOFF</b> = 00 <sub>H</sub> /01 <sub>H</sub>                                     |
| VCC2 operating current                                 | $I_{O2}$       | –      | 3.9   | 5     | mA   | $V_{VCC2} = 15\text{ V}$ , $V_{VEE2} = -8\text{ V}$ , $OUT = 16\text{ kHz}$ , 50%, $DESAT = \text{Low}$ , $C_{LOAD} = 100\text{ pF}$ , <b>DRVCFG.STD_OFF</b> = 0 <sub>H</sub> , <b>DRVFOFF</b> = 00 <sub>H</sub> /01 <sub>H</sub> |

1) Parameter is not subject to production test - verified by design/characterization

## 5 Electrical parameters

### 5.4.2 Logic input and output

**Table 11** Logic input and output

| Parameter                                                                                     | Symbol                                        | Values |      |      | Unit          | Note or Test Condition                                               |
|-----------------------------------------------------------------------------------------------|-----------------------------------------------|--------|------|------|---------------|----------------------------------------------------------------------|
|                                                                                               |                                               | Min.   | Typ. | Max. |               |                                                                      |
| Logic low input voltage ( <i>IN</i> , <i>RDYC</i> , <i>FLT_N</i> , <i>SDA</i> , <i>SCL</i> )  | $V_{\text{LogicINL}}$                         | –      | –    | 30   | %             | of $V_{\text{CC1}}$                                                  |
| Logic high input voltage ( <i>IN</i> , <i>RDYC</i> , <i>FLT_N</i> , <i>SDA</i> , <i>SCL</i> ) | $V_{\text{LogicINH}}$                         | 70     | –    | –    | %             | of $V_{\text{CC1}}$                                                  |
| Logic low output voltage ( <i>RDYC</i> , <i>FLT_N</i> )                                       | $V_{\text{RDYC5}}$ ,<br>$V_{\text{FLT_N5}}$   | –      | –    | 300  | mV            | $I_{\text{SINK}} = 5 \text{ mA}$                                     |
| Logic low output voltage <i>SDA</i>                                                           | $V_{\text{SDA20}}$                            | –      | –    | 400  | mV            | $I_{\text{SINK}} = 20 \text{ mA}$                                    |
| Logic input pull down resistor ( <i>IN</i> )                                                  | $R_{\text{INPD}}$                             | 33     | 40   | 47   | k $\Omega$    | –                                                                    |
| Logic input pull down resistor ( <i>RDYC</i> , <i>FLT_N</i> )                                 | $R_{\text{RDYCPD}}$ ,<br>$R_{\text{FLT_NPD}}$ | 0.8    | 1.0  | 1.2  | M $\Omega$    | –                                                                    |
| Logic input current ( <i>SDA</i> , <i>SCL</i> )                                               | $I_{\text{SDA}}$ , $I_{\text{SCL}}$           | -10    | 0    | +10  | $\mu\text{A}$ | $0.1 \cdot V_{\text{CC1}} < V_{\text{I}} < 0.9 \cdot V_{\text{CC1}}$ |
| Logic input pull down resistor ( <i>SDA</i> , <i>SCL</i> )                                    | $R_{\text{SDAPD}}$ ,<br>$R_{\text{SCLPD}}$    | 0.8    | 1.0  | 1.2  | M $\Omega$    | –                                                                    |
| Logic pin input capacitance ( <i>SDA</i> , <i>SCL</i> )                                       | $C_{\text{SDA}}$ , $C_{\text{SCL}}$           | –      | –    | 10   | pF            | 1)                                                                   |

1) Parameter is not subject to production test - verified by design/characterization

## 5 Electrical parameters

### 5.4.3 Gate driver

*Note: High and low level output currents are absolute values without an information of current direction.*

**Table 12 Gate driver**

| Parameter                                | Symbol           | Values |                   |                   | Unit     | Note or Test Condition                    |
|------------------------------------------|------------------|--------|-------------------|-------------------|----------|-------------------------------------------|
|                                          |                  | Min.   | Typ.              | Max.              |          |                                           |
| High level output voltage                | $V_{ON0}$        | –      | $V_{VCC2} + 0.87$ | $V_{VCC2} + 1.01$ | V        | $I_{ON} = 500 \text{ mA}^{1)}$            |
| High level output peak current 1ED3830M  | $I_{ON}$         | 2.6    | 3.8               | –                 | A        | $^{2) 3)} C_{LOAD} = 33 \text{ nF}$       |
| High level output on resistance 1ED3830M | $R_{DS(on),H}$   | 0.51   | 1.12              | 2.24              | $\Omega$ | $I_{ON} = 67 \text{ mA}^{3)}$             |
| Low level output peak current 1ED3830M   | $I_{OFF}$        | 2.0    | 2.5               | –                 | A        | $^{2) 4)} C_{LOAD} = 33 \text{ nF}$       |
| Low level output on resistance 1ED3830M  | $R_{DS(on),L}$   | 0.31   | 0.82              | 1.64              | $\Omega$ | $I_{OFF} = 67 \text{ mA}^{4)}$            |
| High level output peak current 1ED3860M  | $I_{ON}$         | 5.2    | 7.5               | –                 | A        | $^{2) 3)} C_{LOAD} = 68 \text{ nF}$       |
| High level output on resistance 1ED3860M | $R_{DS(on),H}$   | 0.26   | 0.56              | 1.13              | $\Omega$ | $I_{ON} = 133 \text{ mA}^{3)}$            |
| Low level output peak current 1ED3860M   | $I_{OFF}$        | 4.0    | 5.0               | –                 | A        | $^{2) 4)} C_{LOAD} = 68 \text{ nF}$       |
| Low level output on resistance 1ED3860M  | $R_{DS(on),L}$   | 0.16   | 0.41              | 0.83              | $\Omega$ | $I_{OFF} = 133 \text{ mA}^{4)}$           |
| High Level output peak current 1ED3890M  | $I_{ON}$         | 7.9    | 11                | –                 | A        | $^{2) 3)} C_{LOAD} = 100 \text{ nF}$      |
| High level output on resistance 1ED3890M | $R_{DS(on),H}$   | 0.17   | 0.38              | 0.75              | $\Omega$ | $I_{ON} = 200 \text{ mA}^{3)}$            |
| Low Level output peak current 1ED3890M   | $I_{OFF}$        | 6.0    | 7.5               | –                 | A        | $^{2) 4)} C_{LOAD} = 100 \text{ nF}$      |
| Low level output on resistance 1ED3890M  | $R_{DS(on),L}$   | 0.11   | 0.28              | 0.55              | $\Omega$ | $I_{OFF} = 200 \text{ mA}^{4)}$           |
| Active Shut Down Voltage OFF 1ED3830M    | $V_{ACTSD}^{5)}$ | –      | –                 | $V_{VEE2} + 2.4$  | V        | $I_{OUT} = 67 \text{ mA}, V_{VCC2}$ open  |
| Active Shut Down Voltage OFF 1ED3860M    | $V_{ACTSD}^{5)}$ | –      | –                 | $V_{VEE2} + 2.4$  | V        | $I_{OUT} = 133 \text{ mA}, V_{VCC2}$ open |
| Active Shut Down Voltage OFF 1ED3890M    | $V_{ACTSD}^{5)}$ | –      | –                 | $V_{VEE2} + 2.4$  | V        | $I_{OUT} = 200 \text{ mA}, V_{VCC2}$ open |

1) Integrated diode ON vs. VCC2 clamping test

2) Parameter is not subject to production test - verified by design/characterization

3)  $I_N = \text{High}$ ,  $O_N = \text{High}$ ;  $V_{CC2-ON} = 15 \text{ V}$ ;  $R_G = 0.1 \Omega$ ;  $V_{CC2} = 15 \text{ V}$ ;  $V_{EE2} = -8 \text{ V}$

4)  $I_N = \text{Low}$ ,  $O_F = \text{Low}$ ;  $O_F-V_{EE2} = 15 \text{ V}$ ;  $R_G = 0.1 \Omega$ ;  $V_{CC2} = 15 \text{ V}$ ;  $V_{EE2} = -8 \text{ V}$

## 5 Electrical parameters

5) With reference to  $V_{EE2}$

### 5.4.4 Active Miller clamp

**Table 13** Active Miller clamp

| Parameter                                         | Symbol              | Values                 |                        |                        | Unit          | Note or Test Condition                                                                                                                                 |
|---------------------------------------------------|---------------------|------------------------|------------------------|------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   |                     | Min.                   | Typ.                   | Max.                   |               |                                                                                                                                                        |
| High level clamp voltage                          | $V_{CLAMPH0}$       | –                      | $V_{VCC2} + 1.5$       | $V_{VCC2} + 1.63$      | V             | $I_{CLAMP} = 500 \text{ mA}^{1) 2)}$                                                                                                                   |
|                                                   | $V_{CLAMPH1}$       | –                      | $V_{VCC2} + 0.9$       | $V_{VCC2} + 1.1$       | V             | $I_{CLAMP} = 50 \text{ mA}^{1) 2)}$                                                                                                                    |
| Clamp-driver high level output voltage            | $V_{CLAMPDH1}$      | $V_{VEE2} + 7.5$       | $V_{VEE2} + 9.5$       | $V_{VEE2} + 11.5$      | V             | $I_{CLAMP} = 5 \text{ mA}^{3)}$                                                                                                                        |
|                                                   | $V_{CLAMPDH2}$      | $V_{VEE2} + 4.5$       | $V_{VEE2} + 6.7$       | –                      | V             | $I_{CLAMP} = 50 \text{ mA}^{3)}$                                                                                                                       |
| Clamp-driver high level output peak current       | $I_{CLAMP}$         | 0.20                   | 0.27                   | –                      | A             | <sup>4)</sup> $V_{CC2} = 15 \text{ V}$ ; $V_{EE2} = 0 \text{ V}$ ; $C_{CLAMP} = 100 \text{ nF}$ ; $R_{CLAMP} = 1 \Omega$                               |
| Clamp/Clamp-driver output low level current       | $I_{CLAMPL,2}$      | 1.1                    | 1.8                    | –                      | A             | <sup>4)</sup> $V_{CC2} = 15 \text{ V}$ ; $V_{EE2} = 0 \text{ V}$ ; $V_{CLAMP} = 2 \text{ V}$ ; $C_{CLAMP} = 100 \text{ nF}$ ; $R_{CLAMP} = 0.1 \Omega$ |
| Clamp/Clamp-driver output low level current       | $I_{CLAMPL,5}$      | 2.2                    | 3.5                    | –                      | A             | <sup>4)</sup> $V_{CC2} = 15 \text{ V}$ ; $V_{EE2} = 0 \text{ V}$ ; $V_{CLAMP} = 5 \text{ V}$ ; $C_{CLAMP} = 100 \text{ nF}$ ; $R_{CLAMP} = 0.1 \Omega$ |
| Clamp/Clamp-driver output low level ON resistance | $R_{DS(on),CLP}$    | 0.50                   | 0.85                   | 1.35                   | $\Omega$      | $I_{CLAMPL} = 200 \text{ mA}$                                                                                                                          |
| Clamp threshold voltage                           | $V_{ON\_CLAMP}$     | 1.5                    | 2.0                    | 2.5                    | V             | Related to $V_{EE2}$                                                                                                                                   |
| Filter time for CLAMP and pin status monitoring   | $t_{CLAMPfilter,1}$ | 90                     | 105                    | 120                    | ns            | <b>CLCFG.CLFLT_T</b>                                                                                                                                   |
|                                                   | $t_{CLAMPfilter,2}$ | 123                    | 145                    | 167                    | ns            |                                                                                                                                                        |
|                                                   | $t_{CLAMPfilter,3}$ | 159                    | 190                    | 221                    | ns            |                                                                                                                                                        |
|                                                   | $t_{CLAMPfilter,4}$ | 195                    | 235                    | 275                    | ns            |                                                                                                                                                        |
|                                                   | $t_{CLAMPfilter,5}$ | 225                    | 275                    | 325                    | ns            |                                                                                                                                                        |
|                                                   | $t_{CLAMPfilter,6}$ | 263                    | 325                    | 387                    | ns            |                                                                                                                                                        |
|                                                   | $t_{CLAMPfilter,7}$ | 296                    | 370                    | 444                    | ns            |                                                                                                                                                        |
| CLAMP reaction time in CLAMP mode                 | $t_{CLAMP\_ON}$     | $16 + t_{CLAMPfilter}$ | $23 + t_{CLAMPfilter}$ | $35 + t_{CLAMPfilter}$ | ns            | <sup>4) 5)</sup> $C_{LOAD} = 100 \text{ pF}$                                                                                                           |
| CLAMP reaction time in CLAMP driver mode          | $t_{CLAMPD\_ON}$    | $24 + t_{CLAMPfilter}$ | $35 + t_{CLAMPfilter}$ | $53 + t_{CLAMPfilter}$ | ns            | <sup>4) 6)</sup> $C_{LOAD} = 100 \text{ pF}$                                                                                                           |
| Switch-off time-out time                          | $t_{CTT,0}$         | –                      | 0.2                    | –                      | $\mu\text{s}$ | <sup>4)</sup> <b>SOTOUT.SOTOUT_T</b>                                                                                                                   |
|                                                   | $t_{CTT,1}$         | –                      | 0.4                    | –                      | $\mu\text{s}$ |                                                                                                                                                        |
|                                                   | $t_{CTT,2}$         | –                      | 0.6                    | –                      | $\mu\text{s}$ |                                                                                                                                                        |

(table continues...)

## 5 Electrical parameters

**Table 13 (continued) Active Miller clamp**

| Parameter                                   | Symbol       | Values |      |      | Unit | Note or Test Condition                                  |
|---------------------------------------------|--------------|--------|------|------|------|---------------------------------------------------------|
|                                             |              | Min.   | Typ. | Max. |      |                                                         |
|                                             | $t_{CTT,3}$  | –      | 0.8  | –    | μs   |                                                         |
|                                             | $t_{CTT,4}$  | –      | 1.2  | –    | μs   |                                                         |
|                                             | $t_{CTT,5}$  | –      | 1.6  | –    | μs   |                                                         |
|                                             | $t_{CTT,6}$  | –      | 2.4  | –    | μs   |                                                         |
|                                             | $t_{CTT,7}$  | –      | 3.2  | –    | μs   |                                                         |
| Switch-off time-out<br>soft-off offset time | $t_{CTSOOS}$ | –      | 2.4  | –    | μs   | <sup>4)</sup> additional time-out delay during soft-off |

- 1) Integrated diode *CLAMP* vs. *VCC2* clamping test
- 2) only valid for direct clamping: *IN* = High, *OUT* = High
- 3) only valid for clamp pre-driver output: *IN* = Low, *OUT* = Low
- 4) Parameter is not subject to production test - verified by design/characterization
- 5) CLAMP mode reaction time specified with 3.3 kΩ pull-up from *CLAMP* to 3.3 V, from CLAMP threshold until reaching 0.8 V (falling) at *CLAMP* pin
- 6) CLAMP driver mode reaction time specified from CLAMP threshold until reaching 0.8 V (rising) at *CLAMP(DRV)* pin

### 5.4.5 Dynamic characteristics

Dynamic characteristics are measured with  $V_{VCC1} = 5\text{ V}$ ,  $V_{VCC2} = 15\text{ V}$  and  $V_{VEE2} = -8\text{ V}$ , short filter time (**PSUPR**), hard switch off (**DRVCFG**), and CLAMP function activated unless specified otherwise.

**Table 14 Dynamic characteristics**

| Parameter                                                               | Symbol                                 | Values |      |      | Unit | Note or Test Condition                                                                       |
|-------------------------------------------------------------------------|----------------------------------------|--------|------|------|------|----------------------------------------------------------------------------------------------|
|                                                                         |                                        | Min.   | Typ. | Max. |      |                                                                                              |
| Input pulse suppression time <i>IN</i>                                  | $t_{INMIN,0}$                          | 98     | 103  | 108  | ns   | <b>PSUPR.IN_SUPR</b>                                                                         |
|                                                                         | $t_{INMIN,1}$                          | 174    | 183  | 192  | ns   |                                                                                              |
| Input pulse suppression time <i>RDYC/FLT_N</i> for enable / fault off   | $t_{RDYCMIN,0}$                        | 85     | 100  | 115  | ns   | <b>PSUPR.IN_SUPR</b>                                                                         |
|                                                                         | $t_{RDYCMIN,1}$ ,<br>$t_{FLT\_NMIN,1}$ | 153    | 180  | 207  | ns   |                                                                                              |
| Input pulse width <i>RDYC</i> for <i>FLT_N</i> reset (Fault clear time) | $t_{CLRMIN}$                           | –      | 1.0  | 1.2  | μs   | <b>FCLR.FCLR_CFG</b> = 0                                                                     |
| Fault self clear time for <i>FLT_N</i> reset                            | $t_{FSCLR,0}$                          | –      | 400  | 440  | μs   | <b>FCLR.FCLR_CFG</b> = 1,<br><b>FCLR.FSCLR_T</b>                                             |
|                                                                         | $t_{FSCLR,1}$                          | –      | 1600 | 1760 | μs   |                                                                                              |
| Input pulse suppression for I2C ( <i>SDA</i> , <i>SCL</i> )             | $t_{I2CMIN,0}$                         | 41     | 50   | 59   | ns   | <b>PSUPR.IN_SUPR</b>                                                                         |
|                                                                         | $t_{I2CMIN,1}$                         | 74     | 90   | 106  | ns   |                                                                                              |
| Output fall time for I2C ( <i>SDA</i> )                                 | $t_{I2CFALL}$                          | 20     | –    | 120  | ns   | <sup>1)</sup> $V_{CC1} = 5\text{ V}$ ; $V_{LogicIN} = V_{VCC1} * 70\% \dots V_{VCC1} * 30\%$ |

(table continues...)

**5 Electrical parameters**

**Table 14 (continued) Dynamic characteristics**

| Parameter                                                                                                                            | Symbol                             | Values |      |      | Unit | Note or Test Condition                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|--------|------|------|------|--------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                      |                                    | Min.   | Typ. | Max. |      |                                                                                                                                |
| Input <i>I/N</i> to output propagation delay <i>ON</i>                                                                               | $t_{PDON}$                         | 226    | 244  | 270  | ns   | $C_{LOAD} = 100 \text{ pF}$ , $V_{IN} = 70\%$ , $V_{OUT} = 20\%$ , with $t_{INMIN,0}$                                          |
| Input <i>I/N</i> to output propagation delay <i>OFF</i>                                                                              | $t_{PDOFF}$                        | 218    | 236  | 262  | ns   | $C_{LOAD} = 100 \text{ pF}$ , $V_{IN} = 30\%$ , $V_{OUT} = 80\%$ , with $t_{INMIN,0}$                                          |
| Input to output propagation delay distortion ( $t_{PDOFF} - t_{PDON}$ )                                                              | $t_{PDISTO}$                       | -23    | -8   | 7    | ns   | $C_{LOAD} = 100 \text{ pF}$                                                                                                    |
| Input <i>I/N</i> to output propagation delay distortion between any devices ( $t_{PDON} - t_{PDON}$ ) or ( $t_{PDOFF} - t_{PDOFF}$ ) | $t_{PDD}$                          | –      | –    | 30   | ns   | <sup>1)</sup> same conditions ( $V_{IN}$ , $V_{VCC1}$ , $V_{VCC2}$ and $V_{VEE2}$ , $C_{LOAD}$ , $T_A$ , $t_{INMIN,0}$ )       |
| State synchronization time between input and output                                                                                  | $t_{SSIO}$                         | –      | –    | 13   | μs   | <sup>1)</sup>                                                                                                                  |
| Input <i>RDYC</i> to output on propagation delay                                                                                     | $t_{PDRDYC}$                       | 447    | 523  | 600  | ns   | $C_{LOAD} = 100 \text{ pF}$ ; <i>I/N</i> high; $V_{RDYC} = 70\%$ , $V_{OUT} = 20\%$ , with $t_{INMIN,0}$                       |
| Input <i>RDYC</i> or <i>FLT_N</i> to Soft-off output propagation delay                                                               | $t_{PDRDYCS}$ ,<br>$t_{PDFLT\_NS}$ | 323    | 361  | 407  | ns   | $C_{LOAD} = 100 \text{ pF}$ , $V_{Signal} = 30\%$ , $V_{OUT} = 80\%$ , with $t_{MINRDYC,0}$ , Soft-off function $I_{CSOFF,15}$ |
| Input <i>RDYC</i> or <i>FLT_N</i> to hard switch-off output propagation delay                                                        | $t_{PDRDYCH}$ ,<br>$t_{PDFLT\_NH}$ | 303    | 342  | 384  | ns   | $C_{LOAD} = 100 \text{ pF}$ , $V_{Signal} = 30\%$ , $V_{OUT} = 80\%$ , with $t_{MINRDYC,0}$ , OFF function                     |
| Input <i>RDYC</i> or <i>FLT_N</i> to TLTOff output propagation delay 1ED3830M                                                        | $t_{PDRDYCT}$ ,<br>$t_{PDFLT\_NT}$ | 330    | 387  | 452  | ns   | $C_{LOAD} = 100 \text{ pF}$ , $V_{Signal} = 30\%$ , $V_{OUT} = 80\%$ , with $t_{MINRDYC,0}$ , TLTOff function,                 |
| Input <i>RDYC</i> or <i>FLT_N</i> to TLTOff output propagation delay 1ED3860M                                                        | $t_{PDRDYCT}$ ,<br>$t_{PDFLT\_NT}$ | 360    | 417  | 482  | ns   | <b>TLTOC1</b> .TLTO_RA = 3 <sub>H</sub> ; .TLTO_V = 13 <sub>H</sub> ; <b>DRVCFG</b> .TLTO_GCH = 3 <sub>H</sub>                 |
| Input <i>RDYC</i> or <i>FLT_N</i> to TLTOff output propagation delay 1ED3890M                                                        | $t_{PDRDYCT}$ ,<br>$t_{PDFLT\_NT}$ | 390    | 447  | 512  | ns   |                                                                                                                                |
|                                                                                                                                      | $t_{FAULTOFF,00}$                  | –      | 0    | –    | μs   |                                                                                                                                |

**(table continues...)**

## 5 Electrical parameters

**Table 14 (continued) Dynamic characteristics**

| Parameter                               | Symbol                   | Values |       |      | Unit | Note or Test Condition                                                        |
|-----------------------------------------|--------------------------|--------|-------|------|------|-------------------------------------------------------------------------------|
|                                         |                          | Min.   | Typ.  | Max. |      |                                                                               |
| Fault off event to fault off delay time | $t_{\text{FAULTOFF},01}$ | -5%    | 0.263 | +5%  | μs   | <b>F20DLY.F2O_DLY</b><br>Step size 0.25 μs,<br>initial step is 12.5 ns longer |
|                                         | $t_{\text{FAULTOFF},02}$ | -5%    | 0.513 | +5%  | μs   |                                                                               |
|                                         |                          |        | ...   |      |      |                                                                               |
|                                         | $t_{\text{FAULTOFF},1E}$ | -5%    | 7.513 | +5%  | μs   |                                                                               |
|                                         | $t_{\text{FAULTOFF},1F}$ | -5%    | 7.763 | +5%  | μs   |                                                                               |
| Rise time 1ED3830M                      | $t_{\text{RISE}}$        | –      | 15    | 30   | ns   | $C_{\text{LOAD}} = 1 \text{ nF}$ , $V_{\text{OUT}}$ : 20% to 80%              |
| Fall time 1ED3830M                      | $t_{\text{FALL}}$        | –      | 15    | 30   | ns   | $C_{\text{LOAD}} = 1 \text{ nF}$ , $V_{\text{OUT}}$ : 80% to 20%              |
| Rise time 1ED3860M                      | $t_{\text{RISE}}$        | –      | 15    | 30   | ns   | $C_{\text{LOAD}} = 2.2 \text{ nF}$ , $V_{\text{OUT}}$ : 20% to 80%            |
| Fall Time 1ED3860M                      | $t_{\text{FALL}}$        | –      | 15    | 30   | ns   | $C_{\text{LOAD}} = 2.2 \text{ nF}$ , $V_{\text{OUT}}$ : 80% to 20%            |
| Rise Time 1ED3890M                      | $t_{\text{RISE}}$        | –      | 15    | 30   | ns   | $C_{\text{LOAD}} = 3.3 \text{ nF}$ , $V_{\text{OUT}}$ : 20% to 80%            |
| Fall Time 1ED3890M                      | $t_{\text{FALL}}$        | –      | 15    | 30   | ns   | $C_{\text{LOAD}} = 3.3 \text{ nF}$ , $V_{\text{OUT}}$ : 80% to 20%            |

1) Parameter is not subject to production test - verified by design/characterization

### 5.4.6 Desaturation protection

All parameters valid for  $V_{\text{CC1}} = 5 \text{ V}$ ,  $V_{\text{CC2}} = 15 \text{ V}$ , and  $V_{\text{EE2}} = 0 \text{ V}$  unless specified otherwise.

**Table 15 Desaturation protection**

| Parameter                               | Symbol                | Values |       |      | Unit | Note or Test Condition                           |
|-----------------------------------------|-----------------------|--------|-------|------|------|--------------------------------------------------|
|                                         |                       | Min.   | Typ.  | Max. |      |                                                  |
| DESAT charge current                    | $I_{\text{DESATC}}$   | 470    | 500   | 525  | μA   | $V_{\text{DESAT}} = 0 \text{ V}$                 |
| DESAT voltage divider resistance        | $R_{\text{DVD}}$      | 259    | 312.5 | 366  | kΩ   | between <i>DESAT</i> and <i>GND2</i> pins        |
| DESAT clamp and discharge ON resistance | $R_{\text{DSON},D}$   | –      | 7.7   | 25.0 | Ω    | $I_{\text{DESATD}} = 200 \text{ mA}$             |
| DESAT threshold level                   | $V_{\text{DESAT},1F}$ | 8.88   | 9.18  | 9.48 | V    | <b>D1LVL.D1_V_LVL</b> ,<br><b>D2LVL.D2_V_LVL</b> |
|                                         | $V_{\text{DESAT},1E}$ | 8.50   | 8.89  | 8.99 | V    |                                                  |
|                                         | $V_{\text{DESAT},1D}$ | 8.23   | 8.61  | 8.70 | V    |                                                  |
|                                         | $V_{\text{DESAT},1C}$ | 7.96   | 8.33  | 8.70 | V    |                                                  |
|                                         | $V_{\text{DESAT},1B}$ | 7.68   | 8.05  | 8.42 | V    |                                                  |

(table continues...)

**5 Electrical parameters**

**Table 15 (continued) Desaturation protection**

| Parameter                        | Symbol                   | Values |      |      | Unit | Note or Test Condition                                                                                                                                                                                 |
|----------------------------------|--------------------------|--------|------|------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                  |                          | Min.   | Typ. | Max. |      |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},1A}$    | 7.41   | 7.77 | 8.13 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},19}$    | 7.14   | 7.49 | 7.84 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},18}$    | 6.86   | 7.20 | 7.54 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},17}$    | 6.63   | 6.96 | 7.29 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},16}$    | 6.36   | 6.68 | 7.00 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},15}$    | 6.08   | 6.40 | 6.72 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},14}$    | 5.81   | 6.12 | 6.43 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},13}$    | 5.54   | 5.84 | 6.14 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},12}$    | 5.26   | 5.55 | 5.84 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},11}$    | 4.99   | 5.27 | 5.55 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},10}$    | 4.72   | 4.99 | 5.26 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},0F}$    | 4.52   | 4.79 | 5.06 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},0E}$    | 4.33   | 4.59 | 4.85 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},0D}$    | 4.13   | 4.39 | 4.65 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},0C}$    | 3.94   | 4.19 | 4.44 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},0B}$    | 3.73   | 3.98 | 4.23 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},0A}$    | 3.54   | 3.78 | 4.02 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},09}$    | 3.35   | 3.58 | 3.81 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},08}$    | 3.16   | 3.38 | 3.60 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},07}$    | 2.96   | 3.18 | 3.40 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},06}$    | 2.77   | 2.98 | 3.19 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},05}$    | 2.57   | 2.78 | 2.99 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},04}$    | 2.38   | 2.58 | 2.78 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},03}$    | 2.17   | 2.37 | 2.57 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},02}$    | 2.02   | 2.21 | 2.40 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},01}$    | 1.83   | 2.01 | 2.19 | V    |                                                                                                                                                                                                        |
|                                  | $V_{\text{DESAT},00}$    | 1.67   | 1.85 | 2.03 | V    |                                                                                                                                                                                                        |
| DESAT leading edge blanking time | $t_{\text{DESATleb},00}$ | 65     | 100  | 134  | ns   | <b>DLEBT.D_LEB_T</b> , $V_{\text{ON}}$<br>20% rising to $V_{\text{DESAT}}$<br>$= 1\text{ V}$ , $C_{\text{LOAD}} =$<br>$100\text{ pF}$ , $C_{\text{DESAT}} = 2\text{ pF}$ ,<br>$t_{\text{FAULTOFF},00}$ |
|                                  | $t_{\text{DESATleb},01}$ | 163    | 200  | 237  | ns   |                                                                                                                                                                                                        |
|                                  | $t_{\text{DESATleb},02}$ | 211    | 250  | 288  | ns   |                                                                                                                                                                                                        |
|                                  |                          |        | ...  |      |      |                                                                                                                                                                                                        |
|                                  | $t_{\text{DESATleb},3E}$ | 3094   | 3250 | 3406 | ns   |                                                                                                                                                                                                        |
|                                  | $t_{\text{DESATleb},3F}$ | 3142   | 3300 | 3458 | ns   |                                                                                                                                                                                                        |

**(table continues...)**

**5 Electrical parameters**

**Table 15 (continued) Desaturation protection**

| Parameter                                         | Symbol                      | Values                         |                                |                                | Unit | Note or Test Condition                                                                                                                                                                                     |
|---------------------------------------------------|-----------------------------|--------------------------------|--------------------------------|--------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   |                             | Min.                           | Typ.                           | Max.                           |      |                                                                                                                                                                                                            |
| DESAT filter time                                 | $t_{\text{DESATfilter},00}$ | –                              | –                              | –                              | ns   | <b>D1FILT.D1FILT_T</b> ,<br><b>D2FILT.D2FILT_T</b>                                                                                                                                                         |
|                                                   | $t_{\text{DESATfilter},01}$ | 48                             | 75                             | 105                            | ns   |                                                                                                                                                                                                            |
|                                                   |                             | –                              | ...                            | –                              | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},06}$ | 286                            | 325                            | 368                            | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},07}$ | 333                            | 375                            | 421                            | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},08}$ | 429                            | 475                            | 526                            | ns   |                                                                                                                                                                                                            |
|                                                   |                             |                                | ...                            |                                |      |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},0E}$ | 1000                           | 1075                           | 1158                           | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},0F}$ | 1095                           | 1175                           | 1263                           | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},10}$ | 1286                           | 1375                           | 1474                           | ns   |                                                                                                                                                                                                            |
|                                                   |                             |                                | ...                            |                                |      |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},16}$ | 2429                           | 2575                           | 2737                           | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},17}$ | 2619                           | 2775                           | 2947                           | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},18}$ | 3000                           | 3175                           | 3368                           | ns   |                                                                                                                                                                                                            |
|                                                   |                             |                                | ...                            |                                |      |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},1E}$ | 5286                           | 5575                           | 5895                           | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESATfilter},1F}$ | 5667                           | 5975                           | 6316                           | ns   |                                                                                                                                                                                                            |
| DESAT1 sense to $FLT\_N$ low delay                | $t_{\text{DESAT1FLT}}$      | 623                            | 743                            | 883                            | ns   | $V_{\text{FLT\_N}} = 30\%$ , $I_{\text{FLT\_N}} = 5 \text{ mA}$ , $t_{\text{DESATfilter},04}$ ,<br>$C_{\text{FLT\_N}} = 100 \text{ pF}$                                                                    |
| DESAT2 sense to $FLT\_N$ low delay                | $t_{\text{DESAT2FLT}}$      | 673                            | 793                            | 933                            | ns   |                                                                                                                                                                                                            |
| DESAT1 sense to $OFF$ low delay, Soft-off         | $t_{\text{DESAT1OUTS}}$     | $287 + t_{\text{DESATfilter}}$ | $333 + t_{\text{DESATfilter}}$ | $382 + t_{\text{DESATfilter}}$ | ns   | $V_{\text{OUT}} = 80\%$ , $C_{\text{LOAD}} = 100 \text{ pF}$ , $t_{\text{FAULTOFF},n} = 0 \mu\text{s}$ , $I_{\text{CSOFF},15}$                                                                             |
| DESAT2 sense to $OFF$ low delay, Soft-off         | $t_{\text{DESAT2OUTS}}$     | $337 + t_{\text{DESATfilter}}$ | $383 + t_{\text{DESATfilter}}$ | $432 + t_{\text{DESATfilter}}$ | ns   |                                                                                                                                                                                                            |
| DESAT1 sense to $OFF$ low delay, TLTOff, 1ED3830M | $t_{\text{DESAT1OUTT3}}$    | $294 + t_{\text{DESATfilter}}$ | $359 + t_{\text{DESATfilter}}$ | $427 + t_{\text{DESATfilter}}$ | ns   | $V_{\text{OUT}} = 80\%$ , $C_{\text{LOAD}} = 100 \text{ pF}$ , $t_{\text{FAULTOFF},n} = 0 \mu\text{s}$ , <b>TLTOC1.TLTO_RA</b> = $3_H$ , <b>TLTOC1.TLTO_V</b> = $13_H$ ,<br><b>DRVCFG.TLTO_GCH</b> = $3_H$ |
| DESAT1 sense to $OFF$ low delay, TLTOff, 1ED3860M | $t_{\text{DESAT1OUTT6}}$    | $324 + t_{\text{DESATfilter}}$ | $389 + t_{\text{DESATfilter}}$ | $457 + t_{\text{DESATfilter}}$ | ns   |                                                                                                                                                                                                            |
| DESAT1 sense to $OFF$ low delay, TLTOff, 1ED3890M | $t_{\text{DESAT1OUTT9}}$    | $354 + t_{\text{DESATfilter}}$ | $419 + t_{\text{DESATfilter}}$ | $487 + t_{\text{DESATfilter}}$ | ns   |                                                                                                                                                                                                            |
|                                                   | $t_{\text{DESAT2OUTT3}}$    | $344 + t_{\text{DESATfilter}}$ | $409 + t_{\text{DESATfilter}}$ | $477 + t_{\text{DESATfilter}}$ | ns   |                                                                                                                                                                                                            |

(table continues...)

**5 Electrical parameters**

**Table 15 (continued) Desaturation protection**

| Parameter                                                    | Symbol                   | Values                            |                                   |                                   | Unit | Note or Test Condition                                                                                 |
|--------------------------------------------------------------|--------------------------|-----------------------------------|-----------------------------------|-----------------------------------|------|--------------------------------------------------------------------------------------------------------|
|                                                              |                          | Min.                              | Typ.                              | Max.                              |      |                                                                                                        |
| DESAT2 sense to <i>OFF</i><br>low delay, TLTOff,<br>1ED3830M |                          |                                   |                                   |                                   |      |                                                                                                        |
| DESAT2 sense to <i>OFF</i><br>low delay, TLTOff,<br>1ED3860M | $t_{\text{DESAT2OUTT6}}$ | 374 +<br>$t_{\text{DESATfilter}}$ | 439 +<br>$t_{\text{DESATfilter}}$ | 507 +<br>$t_{\text{DESATfilter}}$ | ns   |                                                                                                        |
| DESAT2 sense to <i>OFF</i><br>low delay, TLTOff,<br>1ED3890M | $t_{\text{DESAT2OUTT9}}$ | 404 +<br>$t_{\text{DESATfilter}}$ | 469 +<br>$t_{\text{DESATfilter}}$ | 537 +<br>$t_{\text{DESATfilter}}$ | ns   |                                                                                                        |
| DESAT1 sense to <i>OFF</i><br>low delay, hard switch-<br>off | $t_{\text{DESAT1OUTH}}$  | 267 +<br>$t_{\text{DESATfilter}}$ | 314 +<br>$t_{\text{DESATfilter}}$ | 359 +<br>$t_{\text{DESATfilter}}$ | ns   | $V_{\text{OUT}} = 80\%$ , $C_{\text{LOAD}} = 100 \text{ pF}$ , $t_{\text{FAULTOFF},n} = 0 \mu\text{s}$ |
| DESAT2 sense to <i>OFF</i><br>low delay, hard switch-<br>off | $t_{\text{DESAT2OUTH}}$  | 317 +<br>$t_{\text{DESATfilter}}$ | 364 +<br>$t_{\text{DESATfilter}}$ | 409 +<br>$t_{\text{DESATfilter}}$ | ns   |                                                                                                        |

**5 Electrical parameters**

**5.4.7 Two-level turn-off**

**Table 16 Two-level turn-off**

| Parameter <sup>1)</sup>               | Symbol          | Values |       |      | Unit      | Note or Test Condition                                                                                                                                                                                                  |
|---------------------------------------|-----------------|--------|-------|------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                       |                 | Min.   | Typ.  | Max. |           |                                                                                                                                                                                                                         |
| Two-level turn-off time <sup>2)</sup> | $t_{TLTOff,00}$ | –      | 0     | –    | $\mu s$   | <b>TLTOC2.TLTO_T</b> ;<br>$C_{LOAD} = 100 \text{ pF}$ ;<br>$t_{MININ,0}$ ; $V_{VCC2} = 15 \text{ V}$ ;<br>$V_{VEE2} = -8 \text{ V}$ ; $V_{VCC1} = 5 \text{ V}$ ; $RA_{TLTOff,3}$ ;<br>$RB_{TLTOff,0}$ ; $V_{TLTOff,13}$ |
|                                       | $t_{TLTOff,01}$ | -5%    | 0.25  | +5%  | $\mu s$   |                                                                                                                                                                                                                         |
|                                       |                 | –      | ...   | –    |           |                                                                                                                                                                                                                         |
|                                       | $t_{TLTOff,1E}$ | -5%    | 7.50  | +5%  | $\mu s$   |                                                                                                                                                                                                                         |
|                                       | $t_{TLTOff,1F}$ | -5%    | 7.75  | +5%  | $\mu s$   |                                                                                                                                                                                                                         |
| Two-level turn-off ramp A             | $RA_{TLTOff,0}$ | –      | 7.5   | –    | $V/\mu s$ | <b>TLTOC1.TLTO_RA</b>                                                                                                                                                                                                   |
|                                       | $RA_{TLTOff,1}$ | –      | 15    | –    | $V/\mu s$ |                                                                                                                                                                                                                         |
|                                       | $RA_{TLTOff,2}$ | –      | 30    | –    | $V/\mu s$ |                                                                                                                                                                                                                         |
|                                       | $RA_{TLTOff,3}$ | –      | 60    | –    | $V/\mu s$ |                                                                                                                                                                                                                         |
| Two-level turn-off ramp B             | $RB_{TLTOff,4}$ | –      | 7.5   | –    | $V/\mu s$ | <b>TLTOC2.TLTO_RB</b>                                                                                                                                                                                                   |
|                                       | $RB_{TLTOff,5}$ | –      | 15    | –    | $V/\mu s$ |                                                                                                                                                                                                                         |
|                                       | $RB_{TLTOff,6}$ | –      | 30    | –    | $V/\mu s$ |                                                                                                                                                                                                                         |
|                                       | $RB_{TLTOff,7}$ | –      | 60    | –    | $V/\mu s$ |                                                                                                                                                                                                                         |
|                                       | $RB_{TLTOff,0}$ | –      | max   | –    | $V/\mu s$ | hard switch-off, not controlled, compare to driver fall time                                                                                                                                                            |
| Two-level turn-off plateau voltage    | $V_{TLTOff,00}$ | –      | 4.25  | –    | V         | <b>TLTOC1.TLTO_V</b>                                                                                                                                                                                                    |
|                                       | $V_{TLTOff,01}$ | –      | 4.5   | –    | V         |                                                                                                                                                                                                                         |
|                                       |                 |        | ...   |      |           |                                                                                                                                                                                                                         |
|                                       | $V_{TLTOff,1E}$ | –      | 11.75 | –    | V         |                                                                                                                                                                                                                         |
|                                       | $V_{TLTOff,1F}$ | –      | 12.0  | –    | V         |                                                                                                                                                                                                                         |

1) Parameter is not subject to production test - verified by design/characterization

2) Two-level turn-off time defined as: Time from turn-off threshold ( $V_{IN}=30\%$ ) to output off detection threshold ( $V_{OFF}=V_{VEE2}+2 \text{ V}$ ) minus turn-off propagation delay  $t_{PDOFF}$

## 5 Electrical parameters

### 5.4.8 Soft-off current source

Soft-off current source values specified at *OFF* pin at  $V_{OFF} = 3\text{ V}$  with unipolar supply of  $V_{CC2} = 15\text{ V}$ .

**Table 17** Current source turn-off

| Parameter                                | Symbol         | Values |      |      | Unit | Note or Test Condition |
|------------------------------------------|----------------|--------|------|------|------|------------------------|
|                                          |                | Min.   | Typ. | Max. |      |                        |
| Soft-off current source current 1ED3830M | $I_{CSOFF,0}$  | 10     | 15   | 19   | mA   | CSSOFCFG.CSSOFF_I      |
|                                          | $I_{CSOFF,1}$  | 24     | 29   | 36   | mA   |                        |
|                                          | $I_{CSOFF,2}$  | 35     | 44   | 52   | mA   |                        |
|                                          | $I_{CSOFF,3}$  | 47     | 58   | 70   | mA   |                        |
|                                          | $I_{CSOFF,4}$  | 58     | 73   | 87   | mA   |                        |
|                                          | $I_{CSOFF,5}$  | 70     | 87   | 105  | mA   |                        |
|                                          | $I_{CSOFF,6}$  | 82     | 102  | 122  | mA   |                        |
|                                          | $I_{CSOFF,7}$  | 93     | 116  | 140  | mA   |                        |
|                                          | $I_{CSOFF,8}$  | 105    | 131  | 157  | mA   |                        |
|                                          | $I_{CSOFF,9}$  | 116    | 146  | 175  | mA   |                        |
|                                          | $I_{CSOFF,10}$ | 128    | 160  | 192  | mA   |                        |
|                                          | $I_{CSOFF,11}$ | 140    | 175  | 210  | mA   |                        |
|                                          | $I_{CSOFF,12}$ | 151    | 189  | 227  | mA   |                        |
|                                          | $I_{CSOFF,13}$ | 163    | 204  | 245  | mA   |                        |
|                                          | $I_{CSOFF,14}$ | 175    | 218  | 262  | mA   |                        |
|                                          | $I_{CSOFF,15}$ | 186    | 233  | 280  | mA   |                        |
| Soft-off current source current 1ED3860M | $I_{CSOFF,0}$  | 22     | 29   | 36   | mA   | CSSOFCFG.CSSOFF_I      |
|                                          | $I_{CSOFF,1}$  | 45     | 58   | 72   | mA   |                        |
|                                          | $I_{CSOFF,2}$  | 70     | 87   | 105  | mA   |                        |
|                                          | $I_{CSOFF,3}$  | 93     | 116  | 140  | mA   |                        |
|                                          | $I_{CSOFF,4}$  | 116    | 146  | 175  | mA   |                        |
|                                          | $I_{CSOFF,5}$  | 140    | 175  | 210  | mA   |                        |
|                                          | $I_{CSOFF,6}$  | 163    | 204  | 245  | mA   |                        |
|                                          | $I_{CSOFF,7}$  | 186    | 233  | 280  | mA   |                        |
|                                          | $I_{CSOFF,8}$  | 210    | 262  | 314  | mA   |                        |
|                                          | $I_{CSOFF,9}$  | 233    | 291  | 349  | mA   |                        |
|                                          | $I_{CSOFF,10}$ | 256    | 320  | 384  | mA   |                        |
|                                          | $I_{CSOFF,11}$ | 280    | 349  | 419  | mA   |                        |
|                                          | $I_{CSOFF,12}$ | 303    | 379  | 454  | mA   |                        |
|                                          | $I_{CSOFF,13}$ | 326    | 408  | 489  | mA   |                        |
|                                          | $I_{CSOFF,14}$ | 349    | 437  | 524  | mA   |                        |

(table continues...)

**5 Electrical parameters**

**Table 17 (continued) Current source turn-off**

| Parameter                                | Symbol                | Values |      |      | Unit | Note or Test Condition   |
|------------------------------------------|-----------------------|--------|------|------|------|--------------------------|
|                                          |                       | Min.   | Typ. | Max. |      |                          |
|                                          | $I_{\text{CSOFF},15}$ | 373    | 466  | 559  | mA   |                          |
| Soft-off current source current 1ED3890M | $I_{\text{CSOFF},0}$  | 34     | 44   | 54   | mA   | <b>CSSOFCFG.CSSOFF_I</b> |
|                                          | $I_{\text{CSOFF},1}$  | 70     | 87   | 105  | mA   |                          |
|                                          | $I_{\text{CSOFF},2}$  | 105    | 131  | 157  | mA   |                          |
|                                          | $I_{\text{CSOFF},3}$  | 140    | 175  | 210  | mA   |                          |
|                                          | $I_{\text{CSOFF},4}$  | 175    | 218  | 262  | mA   |                          |
|                                          | $I_{\text{CSOFF},5}$  | 210    | 262  | 314  | mA   |                          |
|                                          | $I_{\text{CSOFF},6}$  | 245    | 306  | 367  | mA   |                          |
|                                          | $I_{\text{CSOFF},7}$  | 280    | 349  | 419  | mA   |                          |
|                                          | $I_{\text{CSOFF},8}$  | 314    | 393  | 472  | mA   |                          |
|                                          | $I_{\text{CSOFF},9}$  | 349    | 437  | 524  | mA   |                          |
|                                          | $I_{\text{CSOFF},10}$ | 384    | 480  | 577  | mA   |                          |
|                                          | $I_{\text{CSOFF},11}$ | 419    | 524  | 629  | mA   |                          |
|                                          | $I_{\text{CSOFF},12}$ | 454    | 568  | 681  | mA   |                          |
|                                          | $I_{\text{CSOFF},13}$ | 489    | 612  | 734  | mA   |                          |
|                                          | $I_{\text{CSOFF},14}$ | 524    | 655  | 786  | mA   |                          |
|                                          | $I_{\text{CSOFF},15}$ | 559    | 699  | 839  | mA   |                          |

### 5.4.9 Over-temperature protection

**Table 18 Over-temperature protection and over-temperature warning**

| Parameter <sup>1)</sup>           | Symbol              | Values |      |      | Unit | Note or Test Condition |
|-----------------------------------|---------------------|--------|------|------|------|------------------------|
|                                   |                     | Min.   | Typ. | Max. |      |                        |
| Over-temperature protection level | $T_{\text{OTPOFF}}$ | 150    | 160  | 170  | °C   |                        |
| Over-temperature warning level    | $T_{\text{OTW},7}$  | –      | 95   | –    | °C   | <b>OTWCFG.OTW_LVL</b>  |
|                                   | $T_{\text{OTW},6}$  | –      | 101  | –    | °C   |                        |
|                                   | $T_{\text{OTW},5}$  | –      | 108  | –    | °C   |                        |
|                                   | $T_{\text{OTW},4}$  | –      | 114  | –    | °C   |                        |
|                                   | $T_{\text{OTW},3}$  | –      | 120  | –    | °C   |                        |
|                                   | $T_{\text{OTW},2}$  | –      | 127  | –    | °C   |                        |
|                                   | $T_{\text{OTW},1}$  | –      | 134  | –    | °C   |                        |
|                                   | $T_{\text{OTW},0}$  | –      | 140  | –    | °C   |                        |

## 5 Electrical parameters

1) Parameter is not subject to production test - verified by design/characterization

### 5.4.10 ADC measurement

**Table 19** ADC voltage and temperature measurement

| Parameter <sup>1)</sup>             | Symbol           | Values |       |      | Unit | Note or Test Condition                                                   |
|-------------------------------------|------------------|--------|-------|------|------|--------------------------------------------------------------------------|
|                                     |                  | Min.   | Typ.  | Max. |      |                                                                          |
| Internal ADC voltage max            | $V_{ADCINTmax}$  | –      | 38.67 | –    | V    | <b>ADCMVCC2/</b><br><b>ADCMGND2/</b><br><b>ADCMVDIF = FF<sub>H</sub></b> |
| Internal ADC voltage resolution     | $V_{ADCINTres}$  | –      | 151.5 | –    | mV   |                                                                          |
| External ADC voltage max            | $V_{ADCEXTmax}$  | –      | 2.86  | –    | V    | <b>ADCMVEXT = FF<sub>H</sub></b>                                         |
| External ADC voltage resolution     | $V_{ADCEXTres}$  | –      | 11.2  | –    | mV   |                                                                          |
| Internal temperature ADC max        | $T_{ADCTEMPmax}$ | 140    | 150   | 160  | °C   | <b>ADCMTEMP = 84<sub>H</sub></b>                                         |
| Internal temperature ADC min        | $T_{ADCTEMPmin}$ | –      | -40   | –    | °C   | <b>ADCMTEMP = 49<sub>H</sub></b>                                         |
| Internal temperature ADC resolution | $T_{ADCTEMPres}$ | –      | 3.21  | –    | °C   |                                                                          |

1) Parameter is not subject to production test - verified by design/characterization

## 6 Insulation characteristics

### 6 Insulation characteristics

The following isolation classes are available for the 1ED38x0Mc12M family (X3 Digital).

**Table 20 Product isolation classes**

| Product name | Marking  | Insulation characteristics   | Values specified in | UL values |
|--------------|----------|------------------------------|---------------------|-----------|
| 1ED38x0MU12M | 38x0MU12 | UL 1577 certified insulation | -                   | Table 23  |
| 1ED38x0MC12M | 38x0MC12 | Reinforced insulation        | Table 22            | Table 23  |

**Table 21 Safety limiting values**

This coupler is suitable for rated insulation only within the given safety ratings. Compliance with the safety ratings shall be ensured by means of suitable protective circuits.

| Description                                                            | Symbol    | Characteristic | Unit |
|------------------------------------------------------------------------|-----------|----------------|------|
| Maximum ambient safety temperature                                     | $T_S$     | 150            | °C   |
| Maximum input-side power dissipation at $T_A = 25^\circ\text{C}$       | $P_{SI}$  | 100            | mW   |
| Maximum output-side power dissipation at $T_A = 25^\circ\text{C}^{1)}$ | $P_{SO}$  | 1000           | mW   |
| Maximum driver output current (ON, OFF) <sup>2)</sup>                  | $I_{OUT}$ |                | A    |
| 1ED3830MC                                                              |           | 2.4            |      |
| 1ED3860MC                                                              |           | 4.8            |      |
| 1ED3890MC                                                              |           | 7.2            |      |

1) IC output-side power dissipation is derated linearly at 8 mW/°C above 65 °C

2) Maximum pulse length of  $t = 5 \mu\text{s}$

#### 6.1 Certified according to VDE 0884-11 reinforced insulation (Certificate no. 40053980)

Valid for parts with part name 1ED38x0MC12M, x indicate different variants.

This coupler is suitable for safe electrical insulation only within the safety ratings. Compliance with the safety ratings shall be ensured by means of suitable protective circuits.

**Table 22 Reinforced insulation according to VDE 0884-11**

| Description                                                                                                                                                                                                                                                                  | Symbol | Characteristic                | Unit |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------------------------------|------|
| Installation classification per EN 60664-1, Table 1<br>for rated mains voltage $\leq 150 \text{ V (rms)}$<br>for rated mains voltage $\leq 300 \text{ V (rms)}$<br>for rated mains voltage $\leq 600 \text{ V (rms)}$<br>for rated mains voltage $\leq 1000 \text{ V (rms)}$ |        | I-IV<br>I-IV<br>I-III<br>I-II | –    |
| Climatic classification                                                                                                                                                                                                                                                      |        | 40/125/21                     | –    |
| Pollution degree (EN 60664-1)                                                                                                                                                                                                                                                |        | 2                             | –    |
| Minimum external clearance                                                                                                                                                                                                                                                   | CLR    | >8                            | mm   |
| Minimum external creepage                                                                                                                                                                                                                                                    | CPG    | >8                            | mm   |
| Minimum comparative tracking index                                                                                                                                                                                                                                           | CTI    | 400                           | –    |

(table continues...)

## 6 Insulation characteristics

**Table 22 (continued) Reinforced insulation according to VDE 0884-11**

| Description                                                                                                                        | Symbol      | Characteristic | Unit     |
|------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------|----------|
| Apparent charge, method a<br>$V_{pd(ini),a} = V_{IOTM}$ , $V_{pd(m)} = 1.6 \times V_{IORM}$ , $t_{ini} = 1 \text{ min}$            | $q_C$       | <5             | pC       |
| Apparent charge, method b<br>$V_{pd(ini),b} = V_{IOTM} \times 1.2$ , $V_{pd(m)} = 1.875 \times V_{IORM}$ , $t_{ini} = 1 \text{ s}$ | $q_C$       | <5             | pC       |
| Isolation resistance at $T_{A,max}$                                                                                                | $R_{IO}$    | $> 10^{11}$    | $\Omega$ |
| Isolation resistance at $T_S$                                                                                                      | $R_{IO\_S}$ | $> 10^9$       | $\Omega$ |
| Maximum rated transient isolation voltage                                                                                          | $V_{IOTM}$  | 8000           | V (peak) |
| Maximum repetitive insulation voltage                                                                                              | $V_{IORM}$  | 1767           | V (peak) |
| Maximum surge isolation voltage for reinforced isolation<br>$V_{TEST} = V_{IOSM} \times 1.6$                                       | $V_{IOSM}$  | 6875           | V (peak) |
| Insulation capacitance                                                                                                             | $C_{IO}$    | 1.7            | pF       |

## 6.2 Recognized under UL 1577 (File E311313)

**Table 23 Recognized under UL 1577**

| Description                        | Symbol          | Characteristic | Unit    |
|------------------------------------|-----------------|----------------|---------|
| Insulation withstand voltage/1 min | $V_{ISO}$       | 5700           | V (rms) |
| Insulation test voltage/1 s        | $V_{ISO, TEST}$ | 6840           | V (rms) |

## 7 Package information

### 7 Package information

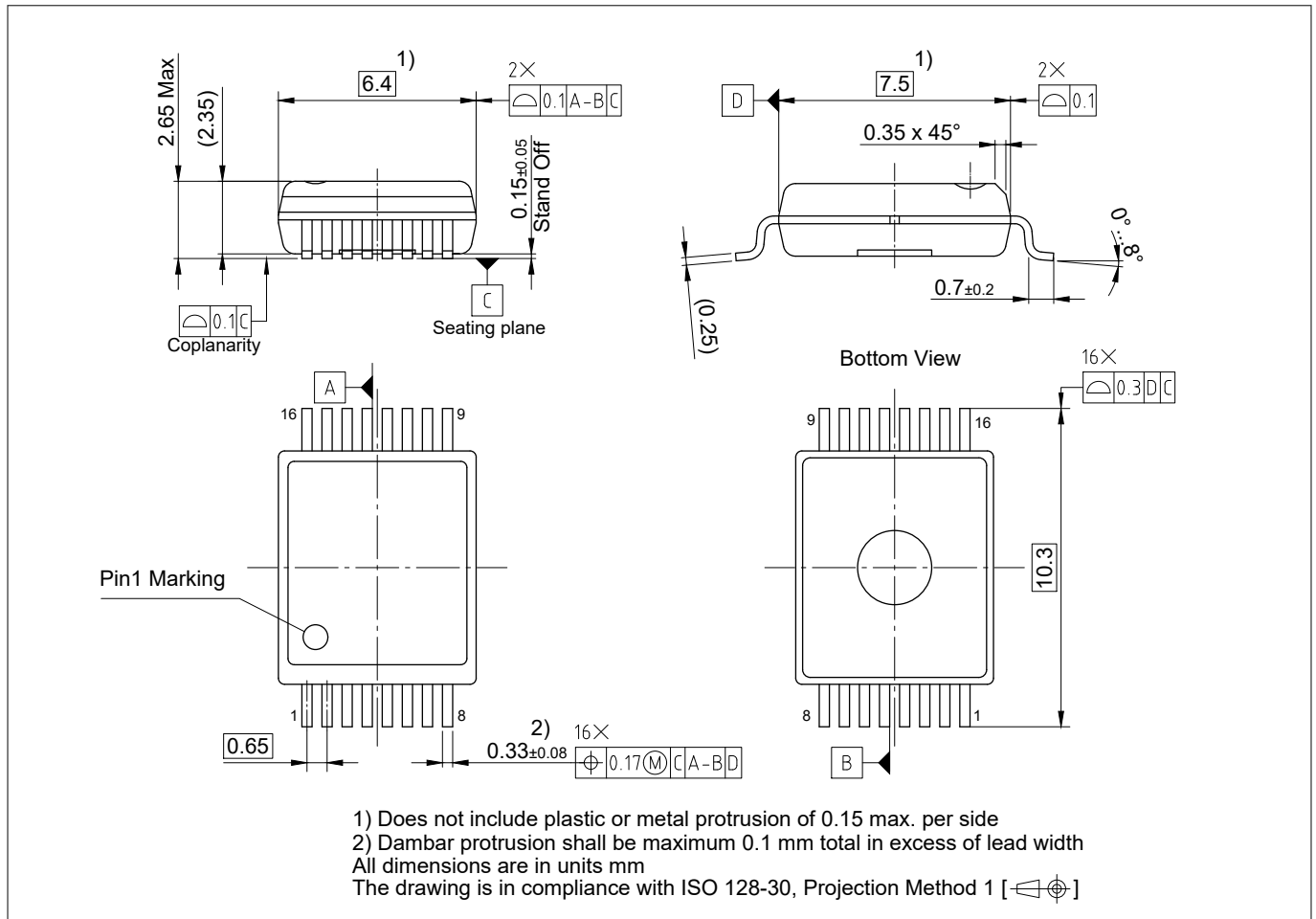


Figure 17 PG-DSO-16-28/33 - 300 mil 16-pin fine pitch plastic green dual small outline package

## Revision history

### Revision History

| Reference            | Description                                                                                                                                                                                                                |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| v2.1<br>(2021-02-15) | <ul style="list-style-type: none"> <li>Change footnotes to tablenotes, added parameter <math>V_{\text{OFFSET}}</math></li> <li>Product links and certification information update</li> </ul>                               |
| (2021-09-01)         | New version number schema: Target/Preliminary datasheet: 0.XY; Final datasheet: 1.XY                                                                                                                                       |
| 1.10<br>(2021-10-08) | <ul style="list-style-type: none"> <li>Certification information update (VDE certification)</li> <li>Fix unit and conditions in certification table according to standards</li> <li>Related product list update</li> </ul> |

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