

# Control integrated Power System (CIPOS™)

IKCS22F60F2A

IKCS22F60F2C

<http://www.infineon.com/cipos>

Power Management & Drives



N e v e r   s t o p   t h i n k i n g .

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Previous Version: 2

| Page | Subjects (major changes since last revision) |
|------|----------------------------------------------|
| 4    | Added UL certification                       |
| 10   | Change $V_{IT,HYS}$                          |
| 11   | Revised energy units                         |
|      |                                              |

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# CIPOS™ Control integrated Power System

*Single In-Line Intelligent Power Module*

*3Φ-bridge 600V / 22A @ 25°C*

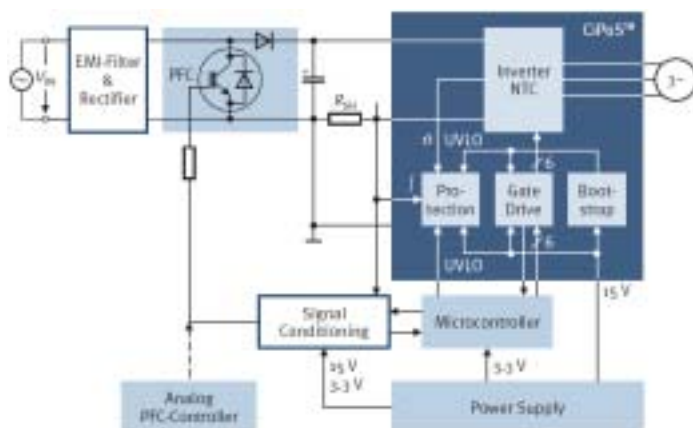


## Features

- DCB isolated Single In-Line molded module
- FAULT signal
- TrenchStop® IGBTs with lowest  $V_{CE(sat)}$
- Optimal adapted antiparallel diode for low EMI
- Integrated bootstrap diode and capacitor
- Rugged SOI gate driver technology with stability against transient and negative voltage
- Fully compliant to 3.3V and 5V microcontrollers
- Temperature sense
- Undervoltage lockout at all channels
- Matched propagation delay for all channels
- Low side emitter pins accessible for all phase current monitoring (open emitter)
- Cross-conduction prevention
- Lead-free terminal plating; RoHS compliant
- Qualified according to JEDEC<sup>1</sup> (high temperature stress tests for 1000h) for target applications

## Target Applications

- Washing machines
- Consumer Fans and Consumer Compressors



## Description

The CIPOS™ module family offers the chance for integrating various power and control components to increase reliability, optimize PCB size and system costs.

This SIL-IPM is designed to control AC motors in variable speed drives for applications like air conditioning, compressors and washing machines. The package concept is specially adapted to power applications, which need extremely good thermal conduction and electrical isolation, but also EMI-save control and overload protection. The features of Infineon TrenchStop® IGBTs and antiparallel diodes are combined with a new optimized Infineon SOI gate driver for excellent electrical performance. The product provides a FAULT signal, which is significantly simplifying the system.

## System Configuration

- 3 halfbridges with TrenchStop® IGBT & FW-diodes
- 3Φ SOI gate driver
- Bootstrap diodes for high side supply
- Integrated 100nF bootstrap capacitance
- Temperature sensor, passive components for adaptations
- Isolated heatsink
- Creepage distance typ. 3.2mm

## Certification

UL 1577 (UL file E314539)

<sup>1</sup> J-STD-020 and JESD-022

## Internal Electrical Schematic

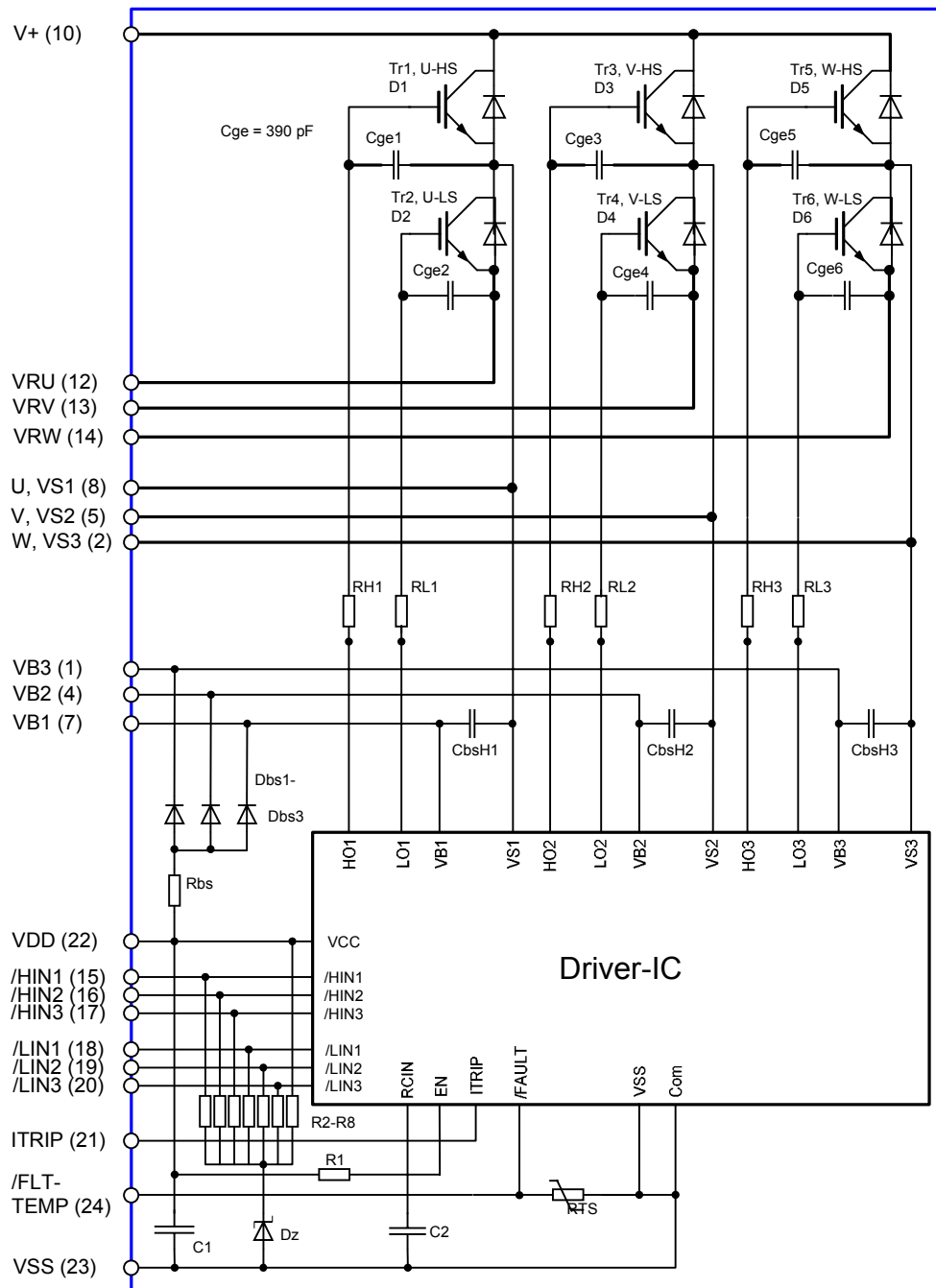


Figure 1: Internal Schematic

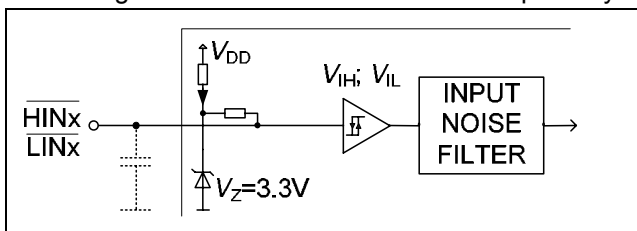
## Pin Assignment

| Pin Number | Pin Name  | Pin Description                                             |
|------------|-----------|-------------------------------------------------------------|
| 1          | VB3       | high side floating IC supply voltage                        |
| 2          | W,VS3     | motor output W, high side floating IC supply offset voltage |
| 3          | n.a.      | None                                                        |
| 4          | VB2       | high side floating IC supply voltage                        |
| 5          | V,VS2     | motor output V, high side floating IC supply offset voltage |
| 6          | n.a.      | None                                                        |
| 7          | VB1       | high side floating IC supply voltage                        |
| 8          | U,VS1     | motor output U, high side floating IC supply offset voltage |
| 9          | n.a.      | None                                                        |
| 10         | V+        | positive bus input voltage                                  |
| 11         | n.a.      | None                                                        |
| 12         | VRU       | low side emitter                                            |
| 13         | VRV       | low side emitter                                            |
| 14         | VRW       | low side emitter                                            |
| 15         | /HIN1     | input gate driver high side 1/U                             |
| 16         | /HIN2     | input gate driver high side 2/V                             |
| 17         | /HIN3     | input gate driver high side 3/W                             |
| 18         | /LIN1     | input gate driver low side 1/U                              |
| 19         | /LIN2     | input gate driver low side 2/V                              |
| 20         | /LIN3     | input gate driver low side 3/W                              |
| 21         | ITRIP     | input overcurrent shutdown                                  |
| 22         | VDD       | module control supply                                       |
| 23         | VSS       | module negative supply                                      |
| 24         | /FLT-TEMP | Fault indication and temperature monitoring                 |

## Pin Description

### /HIN1,2,3 and /LIN1,2,3 (Low side and high side control pins, Pin 15 - 20)

These pins are active low and they are responsible for the control of the integrated IGBT. The Schmitt-trigger input threshold of them are such to guarantee LSTTL and CMOS compatibility



**Figure 2: Input pin structure**

down to 3.3V controller outputs. The maximum voltage at these pins is 6V and therefore fully compliant to 3.3V-microcontrollers. Pull-up resistor of about 75 kΩ is internally provided to pre-bias inputs during supply start-up and a zener clamp is provided for pin protection purposes. Input schmitt-trigger and noise filter provide beneficial noise rejection to short input pulses.

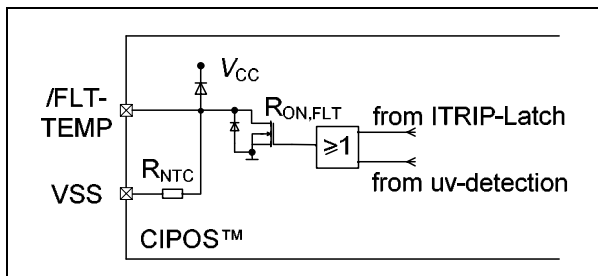
It is recommended for proper work of CIPOS™ not to provide an input pulse-width and PWM deadtimes lower than 1μs.

The integrated gate drive provides additionally a shoot through prevention capability which avoids the simultaneous on-state of two gate drivers of the same leg (i.e. HO1 and LO1, HO2 and LO2, HO3 and LO3).

A minimum dead time insertion of typ 380ns is also provided, in order to reduce cross-conduction of the external power switches.

#### /FLT-TEMP (temperature NTC, Pin 24)

The TEMP terminal provides direct access to the NTC, which is referenced to VSS. An external pull-up resistor connected to +5V ensures, that the resulting voltage can be directly connected to the microcontroller.



**Figure 3: Internal Circuit at pin TEMP**

The same pin indicates a module failure in case of under voltage at pin VDD or in case of triggered over current detection at ITRIP. A pull-up resistor is externally required to bias the NTC. No temperature information is available during fault.

#### ITRIP (Over-current detection function, Pin 21)

CIPOS™ provides an over-current detection function by connecting the ITRIP input with the motor current feedback. The ITRIP comparator threshold (typ 0.46V) is referenced to VSS ground. A input noise filter (typ:  $t_{TRIPMIN} = 220ns$ ) prevents the driver to detect false over-current events.

Over-current detection generates a hard shut down of all outputs of the gate driver after the shutdown propagation delay of typically 900ns.

The fault-clear time is set to typically to 4.7ms.

#### VDD, VSS (control side supply and reference, Pin 22, 23)

VDD is the low side supply and it provides power both to input logic and to low side output power stage. Input logic is referenced to VSS ground as well as the under-voltage detection circuit.

The under-voltage circuit enables the device to operate at power on when a supply voltage of at least a typical voltage of  $V_{DDUV+} = 12.1 V$  is at least present.

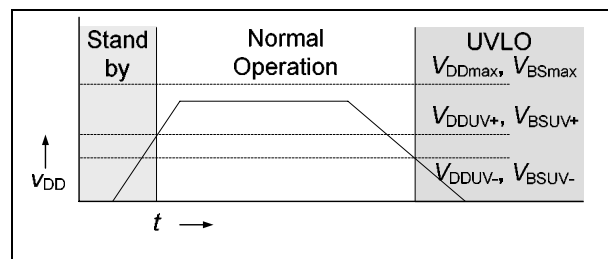
The IC shuts down all the gate drivers power outputs, when the VCC supply voltage is below

$V_{DDUV-} = 10.4 V$ . This prevents the external power switches from critically low gate voltage levels during on-state and therefore from excessive power dissipation.

#### VB1,2,3 and VS1,2,3 (High side supplies, Pin 1, 2, 4, 5, 7, 8)

VB to VS is the high side supply voltage. The high side circuit can float with respect to VSS following the external high side power device emitter/source voltage.

Due to the low power consumption, the floating driver stage is supplied by an integrated bootstrap circuit connected to VDD. This includes also integrated bootstrap capacitors of 100 nF at each floating supply, which are located very close to the



**Figure 4: Input filter timing diagram**

gate drive circuit.

The under-voltage detection operates with a rising supply threshold of typical  $V_{BSUV+} = 12.1 V$  and a falling threshold of  $V_{DDUV-} = 10.4 V$  according to Figure 4.

VS1,2,3 provide a high robustness against negative voltage in respect of VSS of -50 V. This ensures very stable designs even under rough conditions.

#### VRU, VRV, VRW (low side emitter, Pin 12, 13, 14)

The low side emitters are available for current measurements of each phase leg. It is recommended to keep the connection to pin VSS as short as possible in order to avoid unnecessary inductive voltage drops.

#### V+ (positive bus input voltage, Pin 10)

The high side IGBT are connected to the bus voltage. It is recommended, that the bus voltage does not exceed 500 V.

## Absolute Maximum Ratings

( $T_c = 25^\circ\text{C}$ , if not stated otherwise)

### Module Section

| Description                                    | Condition                                                | Symbol              | Value |     | Unit              |
|------------------------------------------------|----------------------------------------------------------|---------------------|-------|-----|-------------------|
|                                                |                                                          |                     | Min   | max |                   |
| Storage temperature range                      |                                                          | $T_{\text{stg}}$    | -40   | 125 | $^\circ\text{C}$  |
| Operating temperature control PCB <sup>1</sup> |                                                          | $T_{\text{PCB}}$    | -     | 125 | $^\circ\text{C}$  |
| Solder temperature                             | Wave soldering,<br>1.6mm (0.063in.)<br>from case for 10s | $T_{\text{sol}}$    | -     | 260 | $^\circ\text{C}$  |
| Insulation test voltage                        | RMS, $f=50\text{Hz}$ , $t=1\text{min}$                   | $V_{\text{ISOL}}$   | 2500  | -   | V                 |
| Mounting torque                                | M3 screw and washer                                      | $M_S$               | -     | 0.6 | Nm                |
| Mounting pressure on surface                   | Package flat on<br>mounting surface                      | $N_{\text{MC}}$     | -     | 150 | N/mm <sup>2</sup> |
| Creepage distance                              |                                                          | $d_S$               | 3.1   | -   | mm                |
| Max. peak power of bootstrap<br>resistor       | $t_p = 100\mu\text{s}$<br>$T_c = 100^\circ\text{C}$      | $P_{\text{BRpeak}}$ |       | 90  | W                 |

### IGBT and Diode Section

| Description                               | Condition                                                                                                                  | Symbol           | Value      |          | Unit             |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|------------------|------------|----------|------------------|
|                                           |                                                                                                                            |                  | min        | max      |                  |
| Max. Blocking Voltage                     |                                                                                                                            | $V_{\text{CES}}$ | 600        | -        | V                |
| DC output current                         | $T_c = 25^\circ\text{C}, T_{\text{vj}} < 150^\circ\text{C}$<br>$T_c = 80^\circ\text{C}, T_{\text{vj}} < 150^\circ\text{C}$ | $I_u, I_v, I_w$  | -22<br>-14 | 22<br>14 | A                |
| Repetitive peak collector current         | $T_p$ limited by $T_{\text{vjmax}}$                                                                                        | $I_u, I_v, I_w$  | -45        | 45       | A                |
| Short circuit withstand time <sup>2</sup> | $V_{\text{DD}}=15\text{V}$ , $V_{\text{DC}}=400\text{V}$ ,<br>$T_{\text{vj}} = 150^\circ\text{C}$                          | $t_{\text{sc}}$  | -          | 5        | $\mu\text{s}$    |
| Power dissipation per IGBT                | $T_c = 25^\circ\text{C}$                                                                                                   | $P_{\text{tot}}$ | -          | 59       | W                |
| Operating junction temperature range      | IGBT                                                                                                                       | $T_{\text{vjI}}$ | -40        | 150      | $^\circ\text{C}$ |
|                                           | Diode                                                                                                                      | $T_{\text{vjD}}$ | -40        | 150      | $^\circ\text{C}$ |

<sup>1</sup> Monitored by pin 24

<sup>2</sup> Allowed number of short circuits: <1000; time between short circuits: >1s.

| Description                                    | Condition | Symbol      | Value |     |     | Unit |
|------------------------------------------------|-----------|-------------|-------|-----|-----|------|
|                                                |           |             | min   | typ | max |      |
| Single IGBT thermal resistance, junction-case  |           | $R_{thJC}$  | -     | -   | 2.1 | K/W  |
| Single diode thermal resistance, junction-case |           | $R_{thJCD}$ | -     | -   | 2.7 |      |

### Control Section

| Description                                   | Condition               | Symbol         | Value                   |     | Unit |
|-----------------------------------------------|-------------------------|----------------|-------------------------|-----|------|
|                                               |                         |                | min                     | max |      |
| Module supply voltage                         |                         | $V_{DD}$       | -1                      | 20  | V    |
| High side floating supply voltage (VB vs. VS) |                         | $V_{BS}$       | -1                      | 20  |      |
| High side floating IC supply offset voltage   | $t_p < 500ns$           | $V_{S1,2,3}$   | VDD-VBS-6<br>VDD-VBS-50 | 600 |      |
| ITRIP input voltage                           |                         | $V_{IN,ITRIP}$ | -1                      | 10  |      |
| /FLT-TEMP Input voltage                       |                         | $V_{IN,FLT}$   | -1                      | 20  |      |
| /HIN, /LIN Input voltage                      | $V_{IN} = \text{float}$ | $V_{IN}$       | -                       | 5.5 |      |
| /FLT-TEMP Input current                       |                         | $I_{IN,FLT}$   | -                       | 5   | mA   |
| Operating junction temperature <sup>1</sup>   |                         | $T_{J,IC}$     | -                       | 125 | °C   |
| Max. switching frequency                      |                         | $f_{PWM}$      | -                       | 20  | kHz  |

### Recommended Operation Conditions

All voltages are absolute voltages referenced to  $V_{SS}$  -Potential unless otherwise specified.

| Description                                           | Symbol   | Value |      | Unit |
|-------------------------------------------------------|----------|-------|------|------|
|                                                       |          | min   | max  |      |
| High side floating supply offset voltage              | $V_S$    | -3    | 500  | V    |
| High side floating supply voltage ( $V_B$ vs. $V_S$ ) | $V_{BS}$ | 12.5  | 17.5 |      |
| Low side power supply                                 | $V_{DD}$ | 12.5  | 17.5 |      |
| Logic input voltages LIN, HIN, ITRIP                  | $V_{IN}$ | 0     | 5    |      |

<sup>1</sup> Monitored by pin 24

## Static Parameters

( $T_c = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{V}$ , if not stated otherwise)

| Description                                                        | Condition                                                                                                        | Symbol                       | Value  |             |            | Unit          |
|--------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|------------------------------|--------|-------------|------------|---------------|
|                                                                    |                                                                                                                  |                              | min    | typ         | max        |               |
| Collector-Emitter breakdown voltage                                | $V_{IN} = 5\text{V}$ , $I_C = 0.25\text{mA}$                                                                     | $V_{(BR)CES}$                | 600    |             |            | V             |
| Collector-Emitter saturation voltage                               | $I_{out} = \pm 15\text{A}$<br>$T_{vj} = 25^\circ\text{C}$<br>$T_{vj} = 150^\circ\text{C}$                        | $V_{CE(sat)}$                | -<br>- | 1.65<br>1.9 | 2.1        | V             |
| Diode forward voltage                                              | $V_{IN} = 5\text{V}$ , $I_{out} = \pm 15\text{A}$<br>$T_{vj} = 25^\circ\text{C}$<br>$T_{vj} = 150^\circ\text{C}$ | $V_F$                        | -<br>- | 1.7<br>1.6  | 2.05       | V             |
| Zero gate voltage collector current of IGBT                        | $V_{CE} = 600\text{V}$ , $V_{IN} = 5\text{V}$<br>$T_{vj} = 25^\circ\text{C}$<br>$T_{vj} = 150^\circ\text{C}$     | $I_{CES}$                    | -<br>- | -<br>-      | 40<br>1000 | $\mu\text{A}$ |
| Short circuit collector current <sup>1</sup>                       | $t_{SC} \leq 5\mu\text{s}$<br>$V_{CC} = 400\text{V}$ , $T_{vj} = 150^\circ\text{C}$                              | $I_{C(SC)}^2$                | -      | 95          | -          | A             |
| Logic "0" input voltage (LIN,HIN)                                  |                                                                                                                  | $V_{IH}$                     | 1.7    | 2.1         | 2.4        | V             |
| Logic "1" input voltage (LIN,HIN)                                  |                                                                                                                  | $V_{IL}$                     | 0.7    | 0.9         | 1.1        | V             |
| ITRIP positive going threshold                                     |                                                                                                                  | $V_{IT,TH+}$                 | 360    | 460         | 540        | mV            |
| ITRIP input hysteresis                                             |                                                                                                                  | $V_{IT,HYS}$                 | 45     | 75          | -          | mV            |
| $V_{DD}$ and $V_{BS}$ supply undervoltage positive going threshold |                                                                                                                  | $V_{DDUV+}^2$<br>$V_{BSUV+}$ | 11.0   | 12.1        | 12.8       | V             |
| $V_{DD}$ and $V_{BS}$ supply undervoltage negative going threshold |                                                                                                                  | $V_{DDUV-}^2$<br>$V_{BSUV-}$ | 9.5    | 10.4        | 11.0       | V             |
| $V_{CC}$ and $V_{BS}$ supply undervoltage lockout hysteresis       |                                                                                                                  | $V_{DDUVH}^2$<br>$V_{BSUVH}$ | 1.2    | 1.7         | -          | V             |
| Input clamp voltage (/HIN, /LIN)                                   | $I_{IN} = 4\text{mA}$                                                                                            | $V_{INCLAMP}$                | 9.0    | 10.4        | 13.0       | V             |
| Input clamp voltage (ITRIP)                                        | $I_{IN} = 4\text{mA}$                                                                                            | $V_{INCLAMP2}$               | 9.0    | 10.6        | 13.0       | V             |
| Quiescent $V_{Bx}$ supply current ( $V_{Bx}$ only)                 | $V_{HIN} = \text{low}$                                                                                           | $I_{QB}$                     | -      | 300         | 550        | $\mu\text{A}$ |
| Quiescent VDD supply current (VDD only)                            | $V_{IN} = \text{float}$                                                                                          | $I_{QDD}$                    | -      | 2.4         | 3.4        | mA            |
| Input bias current                                                 | $V_{IN} = 5\text{V}$                                                                                             | $I_{IN+}$                    | -      | 55          | 100        | $\mu\text{A}$ |
| Input bias current                                                 | $V_{IN} = 0\text{V}$                                                                                             | $I_{IN-}$                    | -      | 220         | 400        | $\mu\text{A}$ |
| ITRIP Input bias current                                           | $V_{ITRIP} = 5\text{V}$                                                                                          | $I_{ITRIP+}$                 | -      | 75          | 120        | $\mu\text{A}$ |
| Leakage current of high side                                       | $T_{j,IC} = 125^\circ\text{C}$                                                                                   | $I_{LVS}^2$                  | -      | 30          | -          | $\mu\text{A}$ |
| FAULT low on resistance of the pull down transistors               | $V_{FLT} = 0.5\text{V}$ , $V_{ITRIP} = 1\text{V}$                                                                | $R_{on,FLT}$                 | -      | 56          | -          | $\Omega$      |

<sup>1</sup> Allowed number of short circuits: <1000; time between short circuits: >1s.

<sup>2</sup> Test is not subject of product test, verified by characterisation

## Dynamic Parameters

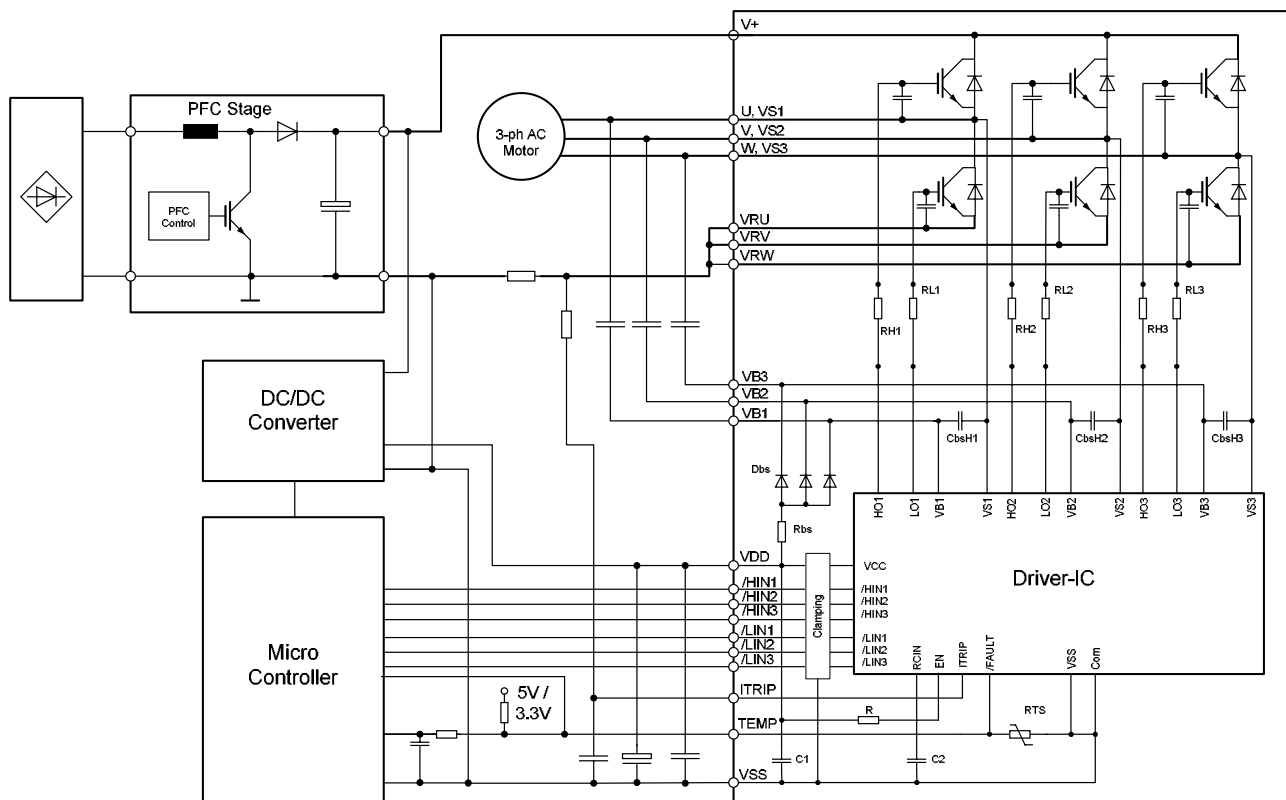
( $T_c = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{V}$ , if not stated otherwise)

| Description                                                                                      | Condition                                                                                                      | Symbol         | Value |      |     | Unit          |
|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------|-------|------|-----|---------------|
|                                                                                                  |                                                                                                                |                | min   | typ  | max |               |
| Turn-on propagation delay<br>High side or low side                                               | $V_{LIN,HIN} = 0\text{V}$ ; $I_{out} = 15\text{A}$ ,<br>$V_{DC} = 300\text{V}$                                 | $t_{d(on)}$    | -     | 718  | -   | ns            |
| Turn-on rise time<br>High side or low side                                                       | $V_{LIN,HIN} = 5\text{V}$ , $I_{out} = 15\text{A}$ ,<br>$V_{DC} = 300\text{V}$                                 | $t_r$          | -     | 61   | -   |               |
| Turn-off propagation delay<br>High side or low side                                              | $V_{LIN,HIN} = 5\text{V}$ ; $I_{out} = 15\text{A}$ ,<br>$V_{DC} = 300\text{V}$                                 | $t_{d(off)}$   | -     | 937  | -   |               |
| Turn-off fall time<br>High side or low side                                                      | $V_{LIN,HIN} = 0\text{V}$ , $I_{out} = 15\text{A}$ ,<br>$V_{DC} = 300\text{V}$                                 | $t_f$          | -     | 74   | -   |               |
| Shutdown propagation delay ITRIP                                                                 | $V_{ITRIP} = 1\text{V}$ , $I_u$ , $I_v$ , $I_w = 15\text{A}$                                                   | $t_{ITRIP}$    | -     | 1100 | -   |               |
| Input filter time ITRIP                                                                          | $V_{ITRIP} = 1\text{V}$                                                                                        | $t_{ITRIPmin}$ | 155   | 210  | 380 |               |
| Propagation delay ITRIP to FAULT                                                                 | $V_{ITRIP} = 1\text{V}$                                                                                        | $t_{FLT}$      |       | 370  |     |               |
| Input filter time at LIN for turn on<br>and off and input filter time at HIN<br>for turn on only | $V_{LIN,HIN} = 0\text{V} \& 5\text{V}$                                                                         | $t_{FILIN}$    | 120   | 270  | -   |               |
| Input filter time at HIN for turn off                                                            | $V_{HIN} = 5\text{V}$                                                                                          | $t_{FILIN1}$   | -     | 220  | -   |               |
| Input filter time at HIN for turn off                                                            | $V_{HIN} = 5\text{V}$                                                                                          | $t_{FILIN2}$   | -     | 400  | -   |               |
| Fault clear time after ITRIP-fault                                                               | $V_{LIN,HIN} = 0\text{V} \& 5\text{V}$<br>$V_{ITRIP} = 0\text{V}$                                              | $t_{FLTCLR}$   | -     | 4.7  | -   | ms            |
| Min. deadtime between low side<br>and high side                                                  |                                                                                                                | $DT_{PWM}$     | -     | 1.5  | -   | $\mu\text{s}$ |
| Deadtime of gate drive circuit                                                                   |                                                                                                                | $DT_{IC}$      | -     | 380  | -   | ns            |
| IGBT Turn-on Energy (includes<br>reverse recovery of diode)                                      | $I_{out} = 15\text{A}$ , $V_{DC} = 300\text{V}$<br>$T_{vj} = 25^\circ\text{C}$<br>$T_{vj} = 150^\circ\text{C}$ | $E_{on}$       | -     | 0.69 | -   | mJ            |
|                                                                                                  |                                                                                                                |                | -     | 0.93 | -   |               |
| IGBT Turn-off Energy                                                                             | $I_{out} = 15\text{A}$ , $V_{DC} = 300\text{V}$<br>$T_{vj} = 25^\circ\text{C}$<br>$T_{vj} = 150^\circ\text{C}$ | $E_{off}$      | -     | 0.27 | -   |               |
|                                                                                                  |                                                                                                                |                | -     | 0.37 | -   |               |
| Diode recovery Energy                                                                            | $I_{out} = 15\text{A}$ , $V_{DC} = 300\text{V}$<br>$T_{vj} = 25^\circ\text{C}$<br>$T_{vj} = 150^\circ\text{C}$ | $E_{rec}$      | -     | 0.07 | -   |               |
|                                                                                                  |                                                                                                                |                | -     | 0.17 | -   |               |

## Integrated Components

| Description                                          | Condition                      | Symbol <sup>1</sup> | Value |      |      | Unit |
|------------------------------------------------------|--------------------------------|---------------------|-------|------|------|------|
|                                                      |                                |                     | min   | typ  | max  |      |
| Resistor                                             |                                | Rbs                 | -     | 10   | -    | Ω    |
| Resistor                                             | $T_{NTC} = 25^{\circ}\text{C}$ | RTS                 | -     | 100  | -    | kΩ   |
| B-Constant of NTC (Negative Temperature Coefficient) | $T_{NTC} = 25^{\circ}\text{C}$ | B25                 | -     | 4250 | -    | K    |
| Bootstrap diode forward voltage                      | $I_{FDbS} = 100\text{mA}$      | $V_{FDbS}$          | -     | 1.9  | 2.05 | V    |
| Capacitor                                            |                                | C1                  | -     | 100  | -    | nF   |
| Capacitor                                            |                                | Cgex                | -     | 0.39 | -    |      |
| Bootstrap Capacitor                                  |                                | CbsH <sub>x</sub>   | -     | 100  | -    |      |

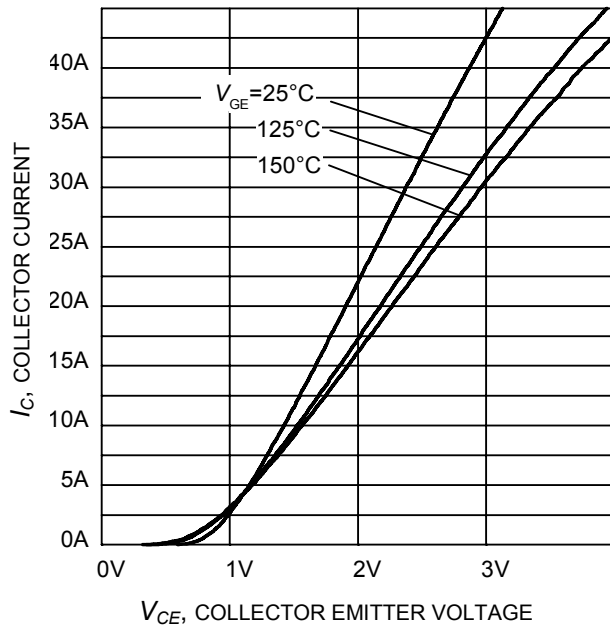
## Typical Application



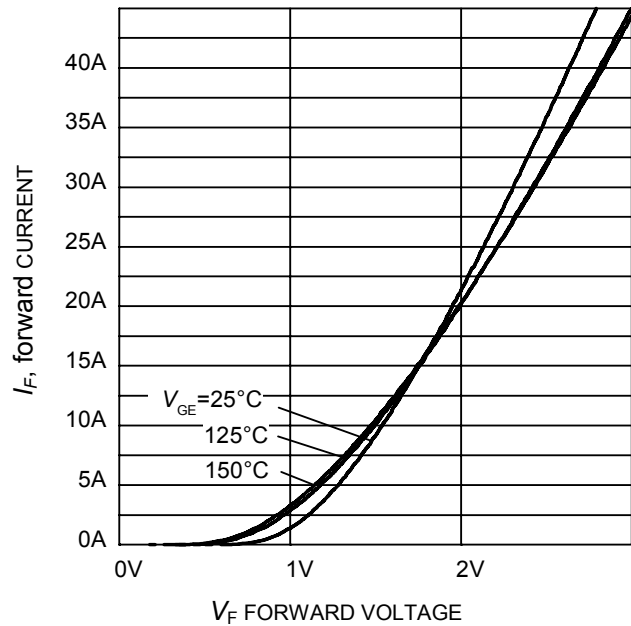
<sup>1</sup> Symbols according to Figure 1

## Characteristics

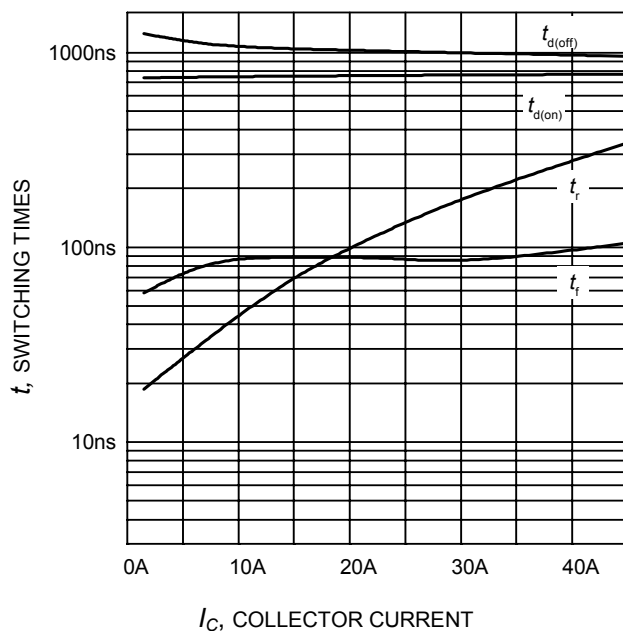
( $T_C = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{V}$ , if not stated otherwise)



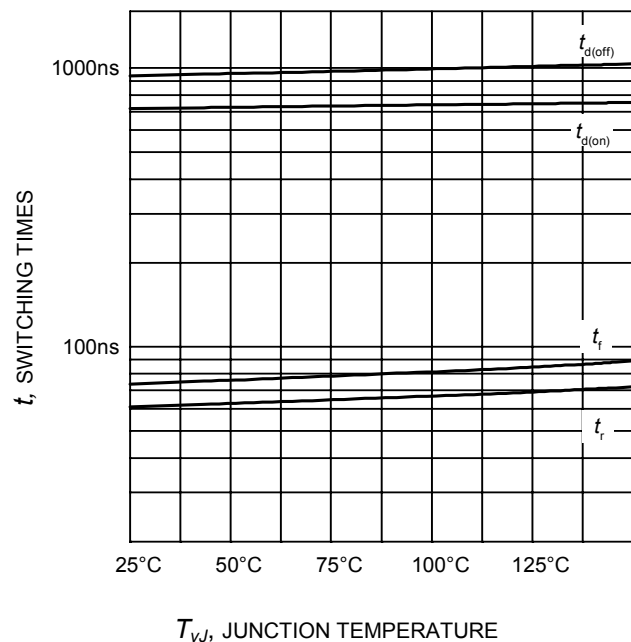
**Figure 5. Typical IGBT output characteristic**



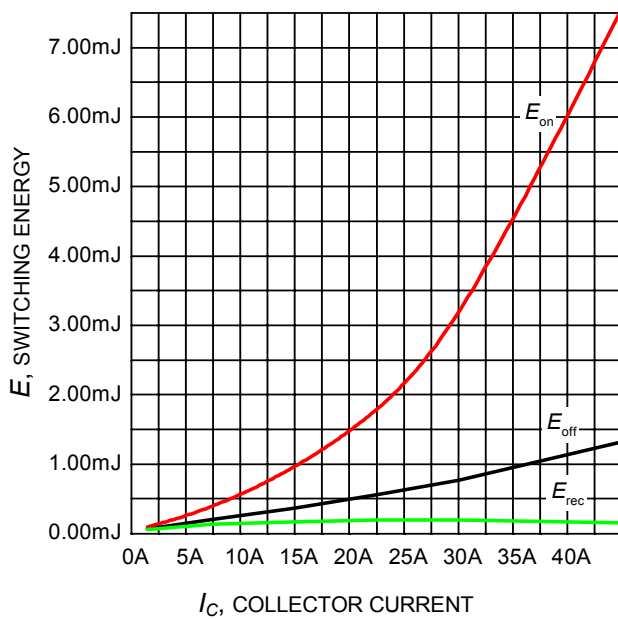
**Figure 6. Typical diode forward current as a function of forward voltage**



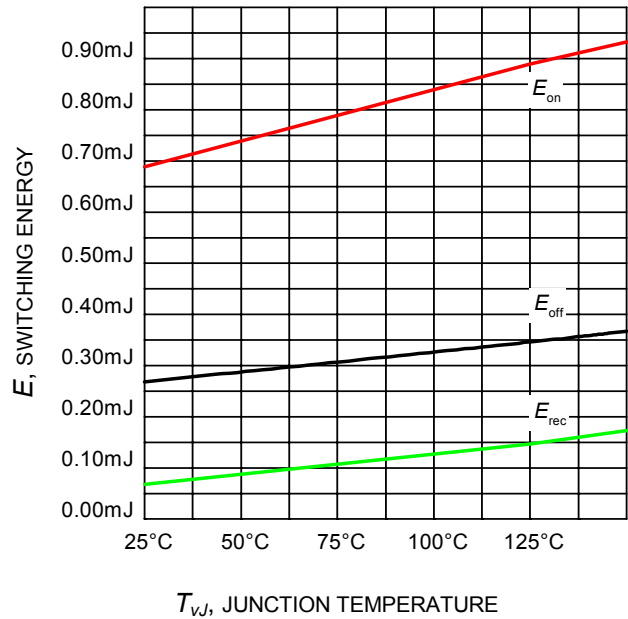
**Figure 7. Typical switching times as a function of collector current**  
(inductive load,  $T_J = 150^\circ\text{C}$ ,  
 $V_{CE} = 300\text{V}$   
Dynamic test circuit in Figure A)



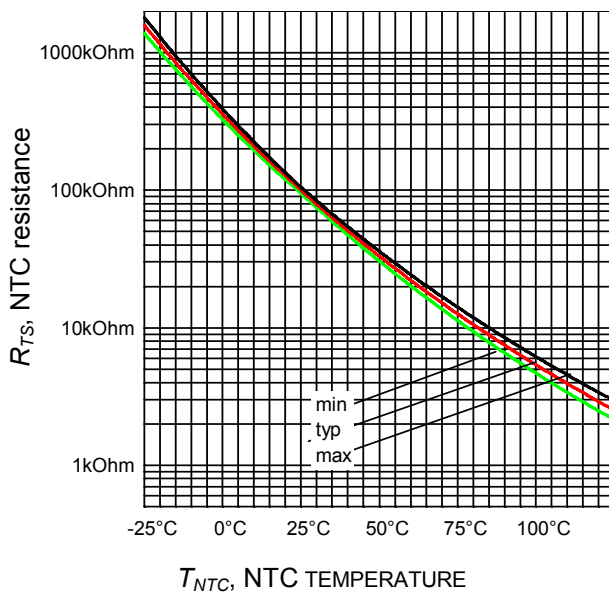
**Figure 8. Typical switching times as a function of junction temperature**  
(inductive load,  $V_{CE} = 300\text{V}$ ,  $I_C = 15\text{A}$   
Dynamic test circuit in Figure A)



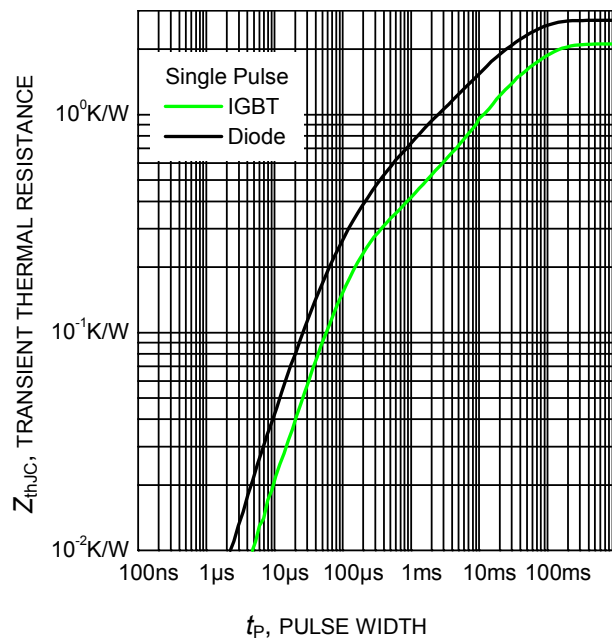
**Figure 9. Typical switching energy losses as a function of collector current**  
 (inductive load,  $T_J = 150^\circ\text{C}$ ,  $V_{CE} = 300\text{V}$   
 Dynamic test circuit in Figure A)



**Figure 10. Typical switching energy losses as a function of junction temperature**  
 (inductive load,  $V_{CE} = 300\text{V}$ ,  $I_C = 15\text{A}$   
 Dynamic test circuit in Figure A)

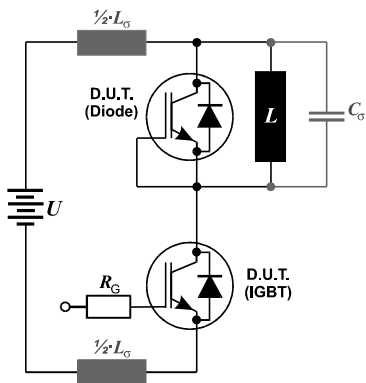


**Figure 11. Characteristic of NTC as a function of NTC temperature**

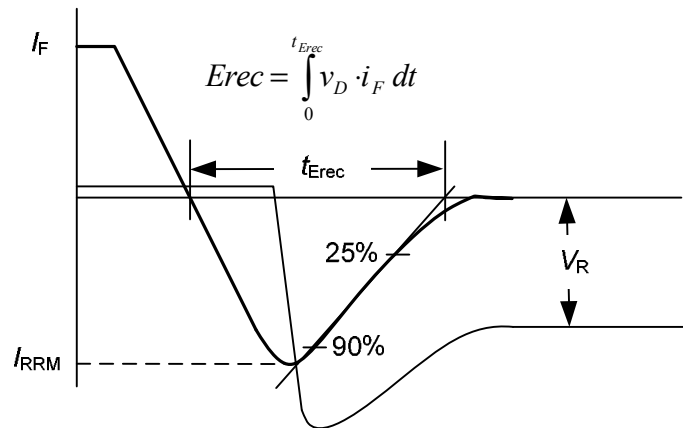


**Figure 12. Transient thermal impedance as a function of pulse width**  
 ( $D = t_p / T$ )

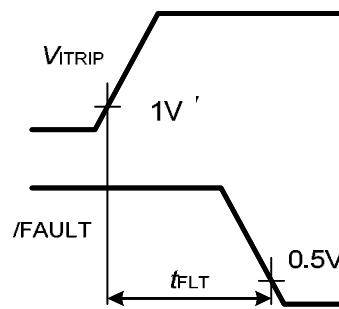
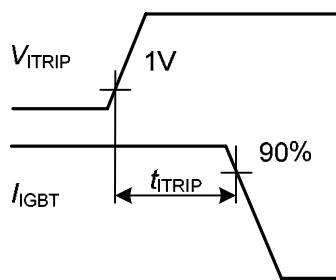
## Test Circuits and Parameter Definition



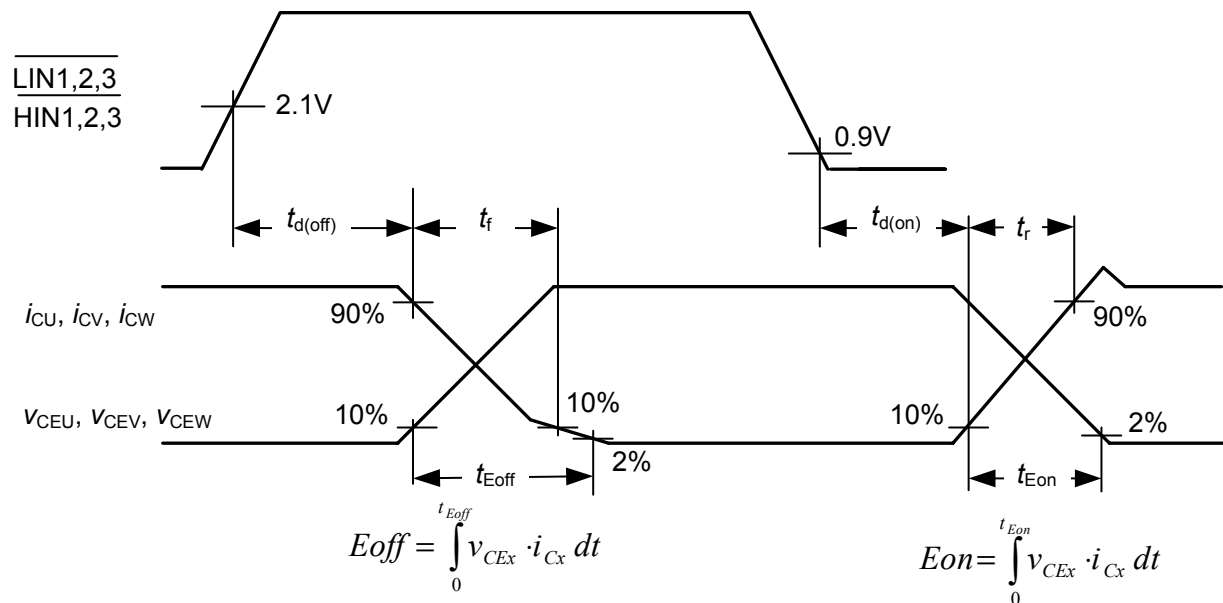
**Figure A: Dynamic test circuit**  
Leakage inductance  $L_{\sigma} = 180\text{nH}$   
Stray capacitance  $C_{\sigma} = 39\text{pF}$



**Figure B: Definition of diodes switching characteristics**



**Figure C: Definition of ITIRP propagation delay**



**Figure D: Switching times definition and switching energy definition**

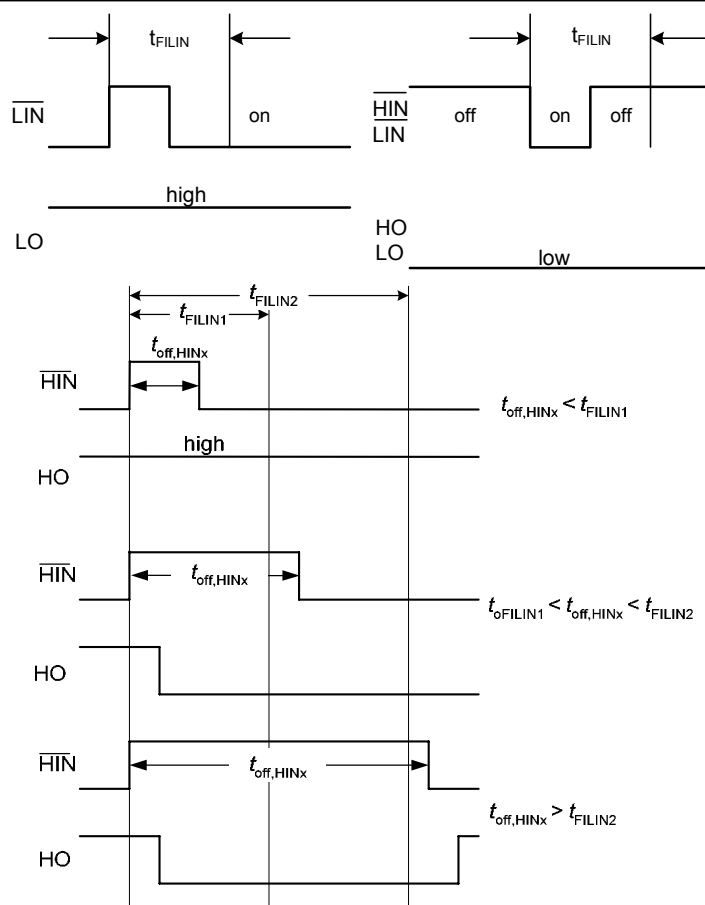
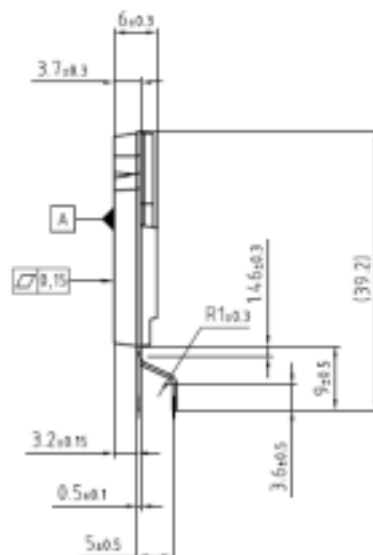


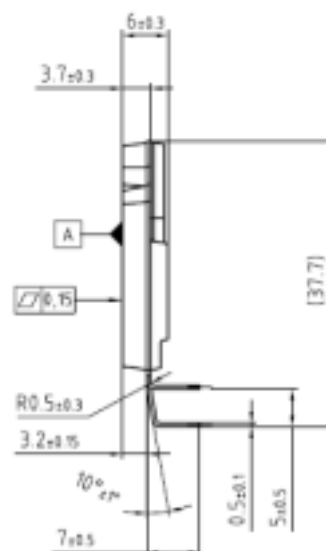
Figure E: Short Pulse suppression



|                                                                 |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
|-----------------------------------------------------------------|--|----------------------------------------------------------------------------------------------------|--|--------------------------------------------------------------------------------------|--|------------|--|--------------------------|--|
| Proprietary data<br>Company confidential<br>All rights reserved |  | Drawing according to<br>ISO 9673<br>General dimensions<br>at 20 °C                                 |  |  |  | Scale: 1:1 |  |                          |  |
| 01. 0104/2008 KARG 2T wT                                        |  |  <b>Inficon</b> |  | PACKAGE OUTLINE<br>PG-MSIP-20-1                                                      |  |            |  | Form<br>A3<br>Page<br>00 |  |
| 02. 0107/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 03. 0108/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 04. 0109/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 05. 0110/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 06. 0111/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 07. 0112/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 08. 0113/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 09. 0114/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 10. 0115/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 11. 0116/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 12. 0117/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 13. 0118/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 14. 0119/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
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| 18. 0123/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 19. 0124/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
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| 99. 0204/2001 KARG 2T wT                                        |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 100. 0205/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
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| 104. 0209/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
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| 108. 0213/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 109. 0214/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 110. 0215/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
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| 118. 0223/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 119. 0224/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 120. 0225/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 121. 0226/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 122. 0227/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 123. 0228/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 124. 0229/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 125. 0230/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 126. 0231/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 127. 0232/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 128. 0233/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 129. 0234/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 130. 0235/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 131. 0236/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 132. 0237/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 133. 0238/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 134. 0239/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 135. 0240/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 136. 0241/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 137. 0242/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 138. 0243/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 139. 0244/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 140. 0245/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 141. 0246/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 142. 0247/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 143. 0248/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 144. 0249/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 145. 0250/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 146. 0251/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 147. 0252/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 148. 0253/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 149. 0254/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 150. 0255/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 151. 0256/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 152. 0257/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 153. 0258/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 154. 0259/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 155. 0260/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 156. 0261/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 157. 0262/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 158. 0263/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 159. 0264/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 160. 0265/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 161. 0266/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 162. 0267/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 163. 0268/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 164. 0269/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 165. 0270/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 166. 0271/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 167. 0272/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 168. 0273/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 169. 0274/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 170. 0275/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 171. 0276/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 172. 0277/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 173. 0278/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 174. 0279/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 175. 0280/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 176. 0281/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 177. 0282/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 178. 0283/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 179. 0284/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 180. 0285/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 181. 0286/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 182. 0287/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 183. 0288/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 184. 0289/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 185. 0290/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 186. 0291/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 187. 0292/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 188. 0293/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 189. 0294/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 190. 0295/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 191. 0296/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 192. 0297/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 193. 0298/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 194. 0299/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 195. 0300/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 196. 0301/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 197. 0302/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 198. 0303/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 199. 0304/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 200. 0305/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 201. 0306/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 202. 0307/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 203. 0308/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 204. 0309/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 205. 0310/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 206. 0311/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 207. 0312/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 208. 0313/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 209. 0314/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 210. 0315/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 211. 0316/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 212. 0317/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 213. 0318/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 214. 0319/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 215. 0320/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 216. 0321/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 217. 0322/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 218. 0323/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 219. 0324/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 220. 0325/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 221. 0326/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 222. 0327/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 223. 0328/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 224. 0329/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 225. 0330/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 226. 0331/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 227. 0332/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 228. 0333/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |
| 229. 0334/2001 KARG 2T wT                                       |  |                                                                                                    |  |                                                                                      |  |            |  |                          |  |

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Technical drawing of a component showing a dimension of  $50.4 \pm 0.3$  and a feature labeled 'B'.

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