Optocouplers in Switching Power Supplies

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Introduction

This report should give the designer a full understanding on how to use optocouplers which provide protection against electric shock for designs.

Safety standards for optocouplers are intended to prevent injury or damage due to electric shock

Two levels of electrical interface are normally used:

Reinforced, or safe insulation is required in an optocoupler interface between a hazardous voltage circuit (like an AC line) and a touchable **S**afety **E**xtra **L**ow **V**oltage (SELV) circuit.

Basic insulation is required in an optocoupler interface between a hazardous voltage circuit and a non-touchable **E**xtra **L**ow **V**oltage (ELV) circuit.

The most widely used insulation for optocouplers in switch-mode power supply is reinforced insulation (class II). The following information enables the designer to understand the safety aspects, the basic concept of the VDE 0884 and the design requirements for applications.

VDE 0884 – Facts and Information

Optocouplers for line-voltage separation must have several national standards. The most accepted standards are:

- UL/ CSA for America
- BSI for Great Britain
- SETI, SEMKO, NEMKO, DEMKO for Nordic countries (Europe)
- VDE for Germany

Today, most manufacturers operate on a global scale. It is therefore mandatory to perform all approvals.

The VDE 0884 is now becoming a major safety standard in the world, partly due to German experts having a long record of experience in this field. It is therefore worthwhile understanding some requirements and methods of the VDE 0884.

At the moment there are two drafts which are being circulated to set the VDE 0884 to an international IEC standard.

The IEC 47 (CO) 1042 describes the terms and definitions – IEC 47 (CO) 1175 the test procedure, while the test method itself is already incorporated in IEC 747-5.

If design engineers work with TEMIC optocouplers**,** they will find some terms and definitions in the data sheets which relate to VDE 0884. These will now be explained:

Rated isolation voltages: V_{IO} is the voltage between the input terminals and the output terminals.

Note: All voltages are peak voltages!

- V_{IOWM} is a maximum rms. voltage value of the optocouplers assigned by TEMIC. This characterizes the long-term withstand capability of its insulation.
- V_{IORM} is a maximum recurring peak (repetitive) voltage value of the optocoupler assigned by TEMIC. This characterizes the long-term withstand capability against recurring peak voltages.
- V_{IOTM} is an impulse voltage value of the optocoupler assigned by TEMIC. This characterizes the long-term withstand capability against transient over voltages.

Isolation test voltage for routine tests is at factor 1.875 higher than the specified V_{IOWM}/ V_{IORM} (peak).

A partial discharge test is a different test method to the normal isolation voltage test. This method is more sensitive and will not damage the isolation behavior of the optocoupler like other test methods probably do.

The VDE 0884 therefore does not require a minimum thickness through insulation. The philosophy is that a mechanical distance only does not give you an indication of the safety reliability of the coupler. It is more recommendable to check the total construction together with the assembling performance. The **partial discharge test method** can monitor this more reliably.

The following tests must be done to guarantee this safety requirement.

100% test (piece by piece) for one second at a voltage level of specified V_{IOWM}/V_{IORM} (peak) multiplied by 1.875 - test criteria is partial discharge less than 5 pico coulomb.

A lotwise test at V_{IOTM} for 10 seconds and at a voltage level of specified V_{IOWM}/ V_{IORM} (peak) multiplied by 1.5 for 1 minute – test criteria is partial discharge less than 5 pico coulomb.

Design example:

The line AC voltage is 380 V rms. Your application class is III (DIN/VDE 0110 Part 1/1.89). According to table 1, you must calculate with a maximum line voltage of 600 V and a transient over voltage of 6000 V.

Table 1. Recommended transient overvoltages related to AC/ DC line voltage (peak values)

V_{IOWM}/V_{IORM} up to	Appl. Class I	Appl. Class II	Appl. Class III	Appl. Class IV
50 V	350 V	500 V	800 V	1500 V
100 V	500.V	800.V	1500.V	2500.V
150 V	800 V	1500 V	2500 V	4000 V
300 V	1500 V	2500 V	400 V	600 V
600.V	2500 V	4000 V	6000 V	800 V
1000 V	4000 V	6000 V	8000 V	1200 V

Now select the CNY75 from our TEMIC coupler program. The next voltage step of 380 V is 600 V (V_{IOWM}).The test voltages are 1600 V for the CNY75 for the routine test and 6000 V/ 1300 V for the sample test.

The VDE 0884 together with the isolation test voltages also require very high isolation resistance, tested at an ambient temperature of 100°C.

Apart from these tests for the running production, the VDE Testing and Approvals Institute also investigates the total construction of the optocoupler. The VDE0884 requires life tests in a very special sequence; 5 lots for 5 different subgroups are tested.

The sequence for the main group is as follows:

- Cycle test
- Vibration
- Shock
- Dry heat
- Accelerated damp heat
- Low temperature storage (normally -55°C)
- Damp heat steady state
- Final measurements.

Finally there is another chapter concerning the safety ratings. This is described in VDE 0884.

The maximum safety ratings are the electrical, thermal and mechanical conditions that exceed the absolute maximum ratings for normal operations. The philosophy is that optocouplers must withstand a certain exceeding of the input current, output power dissipation, and temperature for at least a weekend. The test time is actually 72 hours. This is a simulated space of time where failures may occur.

It is the designer's task to create his design inside of the maximum safety ratings.

Optocouplers – approved to the VDE 0884 – must consequently pass all tests undertaken. This then enables you to go ahead and start your design.

Layout Design Rules

The previous chapter described the important safety requirements for the optocoupler itself; but the knowledge of the creepage distance and clearance path is also important for the design engineer if the coupler is to be mounted onto the circuit board. Although several different creepage distances referring to different safety standards, like the IEC 65 for TV or the IEC 950 for office equipment, computer, data equipment etc. are requested, there is one distance which meanwhile dominates switching power supplies: This is the 8-mm spacing requirement between the two circuits: The hazardous input voltage (AC 240 power-line voltage) and the safety low voltage.

This 8-mm spacing is related to the 250-V power line and defines the shortest distance between the conductive parts (either from the input to the output leads) along the case of the optocoupler, or across the surface of the print board between the solder eyes of the optocoupler input/ output leads, as shown in figure 1. The normal distance input to output leads of an optocoupler is 0.3 ″. This is too tight for the 8-mm requirement. The designer now has two options: He can provide a slit in the board, but then the airgap is still lower; or he can use the „G“

optocoupler from TEMIC. „G“ stands for a wide-spaced lead form of 0.4″ and obtains the-8 mm creepage, clearance distance. The type designation for this type of „G“ coupler is, for example: CNY75G.

The spacing requirements of the 8 mm must also be taken into consideration for the layout of the board.

Figures 2 and 3 provide examples for your layout.

The creepage distance is also related to the resistance of the tracking creepage current stability. The plastic material of the optocoupler itself and the material of the board must provide a specified creeping-current resistance. The behavior of this resistance is tested with special test methods described in the IEC 112. The term is "CTI" (**C**omparative **T**racking **I**ndex).

The VDE 0884 requires a minimum of a CTI of 175. All TEMIC optocouplers have a CTI of 275.

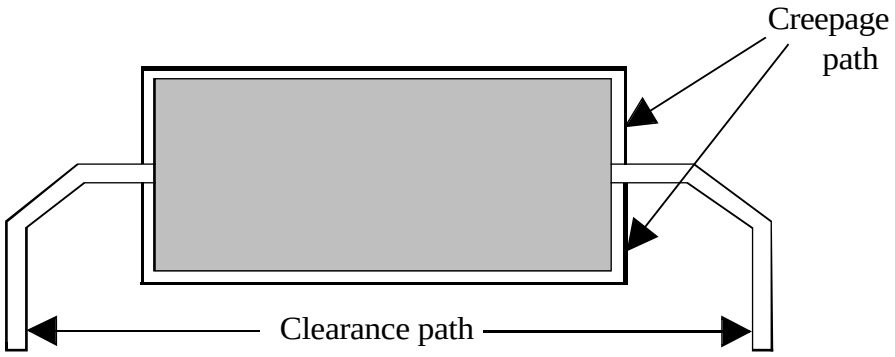

Figure 1. Isolation creepage/ clearance path

(The creepage path is the shortest distance between conductive parts along the surface of the isolation material. The clearance path is the shortest distance between conductive parts.)

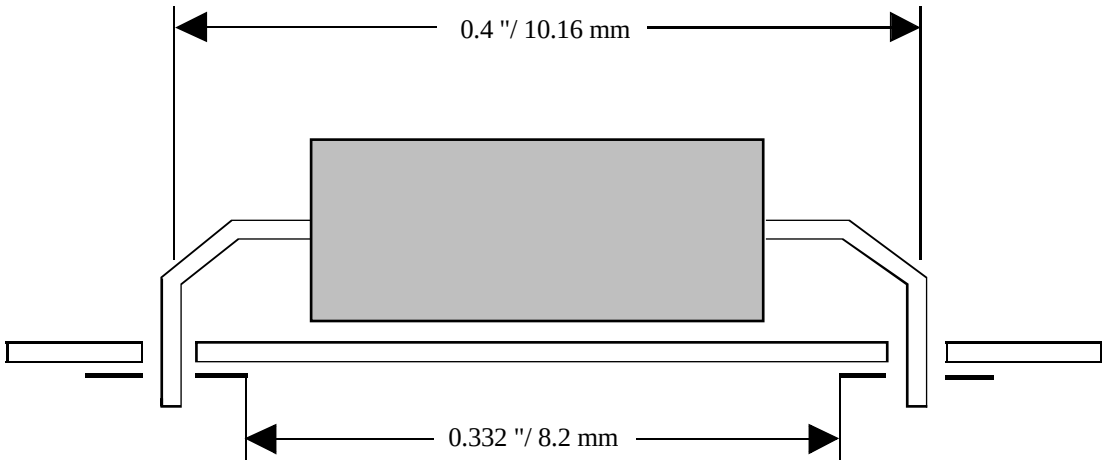

Figure 2. Optocoupler mounting on a board (side view)

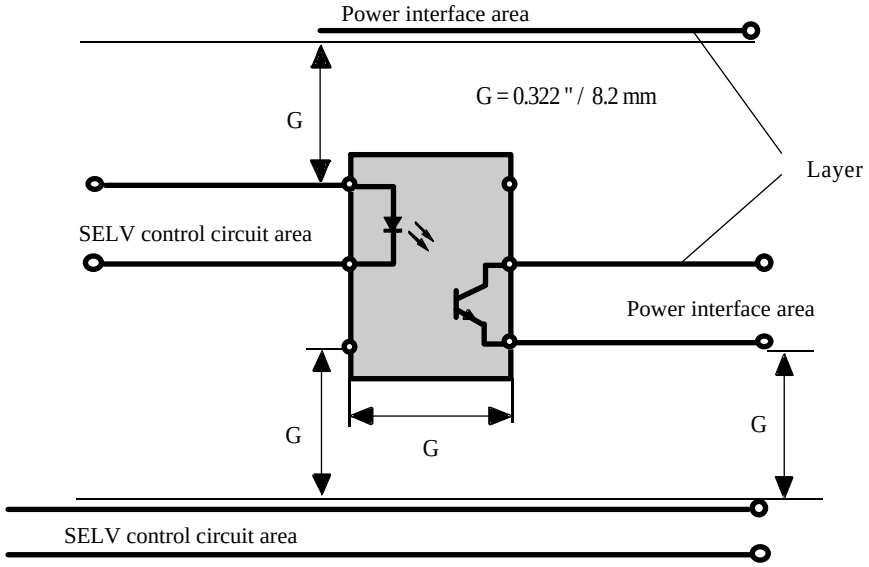

Figure 3. Top view of optocoupler mounting on a board
(clearance on PC board: 0.322 ″/ 8.2 mm, creepage path on PC board is 0.322 ″/ 8.2 mm)
Not only the solder eyes of the coupler itself on the board must have the 8-mm distance, but also all layers located between the SELV areas and the power interface areas.

TEMIC Optocoupler Program

Construction

An optocoupler is comparable with a transformer or a mechanical relay; but its advantages are smaller dimensions, shorter switching time, no contact bounces, no interference caused by arcs and the possibility of adapting a signal already in the coupler for the following stage of the circuit.

This combination together with the safety aspects provides outstanding advantages for use in power supplies. Safety factors in particular depend on the design, construction and selected materials. TEMIC optocouplers are designed with a coplanar lead frame, where the die are mounted side by side. A semi-ellipsoid with even better reflection capabilities is fitted over each dice. The entire system is then casted in a plastic material impermeable to the infrared range and of high di-electric strength. The whole system is now molded with a special mold compound to ensure that no external influences such as light or dust etc. interfere with the functioning of the coupler (see figure 4). This design has several advantages: The "thicknessthrough insula-tion", the clearance (internally) between the input and the output side is fixed at 0.75 mm and is thus mecha-nically stable even under thermal overloads, i.e. the possibility of a short circuit caused by material defor-mation is excluded. Deviations of this distance during the production process are also excluded. These two features are the specific reasons why TEMICopto-couplers are well-accepted by manufacturers of power supplies.

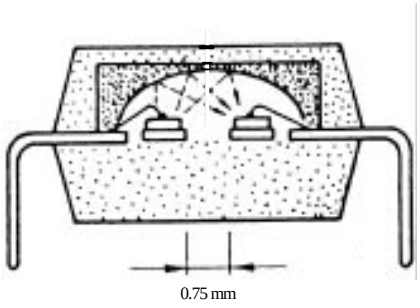

Figure 4. Cut through of a TEMIC optocoupler (thickness through insulation)

Overview

The information given in this brochure enables the designer to select the right optocoupler for his application. The previous chapters focused only on safety aspects. Apart from this there are other characteristics for the optocoupler. Table 2 enables the designer to select the optocoupler to suit his own needs. This selection should be done using the most important characteristics like CTR (**C**urrent **T**ransfer **R**atio) and devices with or without base connection. The designer may ask for our data sheets for detailed information.

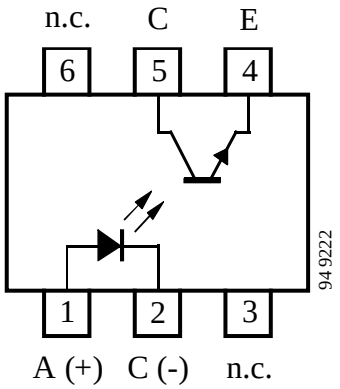

Figure 5. Without base connection

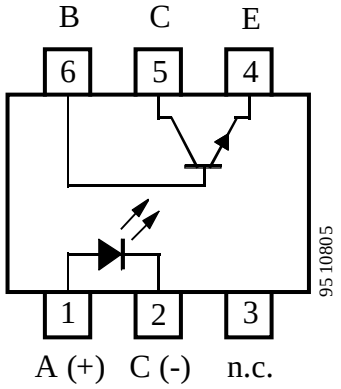

Figure 6. With base connection

6-PIN STD Isolators

Table 2. Devices offering (VDE 0884-tested)

CTR IC/ IF	V_{CE} > 32 V Ungrouped CTR		V_{CE} > 32 V Grouped CTR		V_{CE} > 90 V Grouped CTR	
Base Connection	With	Without	With	Without	With	Without
> 20%	4N25(G)V					
> 50%			CQY80N(G)	TCDT1100(G)		TCDT1120(G)
> 100%	4N35(G)V	TCDT1110(G)				
40 - 80%			CNY17(G)-1	TCDT1101(G)		
63 - 125%			CNY17(G)-2	TCDT1102(G)	CNY75(G)A	TCDT1122(G)
100 - 200%			CNY17(G)-3	TCDT1103(G)	CNY75(G)B	TCDT1123(G)
160 - 320%					CNY75(G)C	TCDT1124(G)

G = wide space 0.4″ lead form, for 8-mm PC board spacing requirements

Appendix

Approvals List

As mentioned before, as long there is no equivalent IEC-standard to the VDE 0884, optocouplers must still fulfill all other national safety standards. The enclosed copies of documents present all certificates the designer needs for worldwide acceptance of his power supply. All the approvals below are most important. If the designer needs any others, he must be aware that there are many agreements between national institutes, e.g., UL for USA is also accepted by CSA/Canada.

TEMIC divides optocouplers into "coupling systems". Each coupling system represents the same technology, materials etc. The coupling systems are indicated with capital letters and each coupler is marked with this coupling system indicator letter. The certificates at least also refer to the systems and list all subtypes to the related coupling system. The user is able to track his selected coupler on the certificate.

Certified Optocouplers for Switchmode Power Supplies

	Coupling System G, H, I, K	Coupling System A, C, S
German Standard VDE 0884 File No: System S: 70753 System A: 68301 System G: 70902 System H: 70977 System J: 70977 System K: 70977	CNY64 CNY65 CNY66 CNY21N	CQY80N, CQY80NG CNY17(G)1-3 CNY75(G)A-C TCDT1101(G)A-C TCDT1101(G)-1103(G) TCDT1110(G) TCDT1120-1124(G)
American (USA) Test Institute UL 1577 File No: E76222	CNY64 CNY65 CNY66 CNY21N	4N25(G)V 4N35(G)V
Nordic Approvals (SETI)	CNY64 CNY65 CNY21N	K3010P(G)-K3012P(G) K3020P(G)-K3023P(G)
British Std BS415 BS7002	CNY65	
Internal Structure		
Case		

Certifications

Note: The certificates have been left out because of resolution problems. If you need the original application note, please contact TEMIC.