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Appendix 6.1: Regulatory Standards* Agency Addresses

1. IEC Central Office
   Customer Service Center
   3, rue de Varembe
   P.O. Box 131, 1211 Geneve 20
   Switzerland
   Telephone: +41 22 919 02 11
   Telefax: +41 22 919 03 00
   Internet: dn@iec.ch or
   ek@iec.ch

2. The Deutsche
   Elektrotechnische Kommission
   in the DIN and VDE (DKE)
   Berlin Office
   Burggrafenstr. 6, 1000
   Berlin 30.
   Germany

3. American National Standards
   Institute (ANSI)
   11 West 42nd Street,
   New York, New York
   10036-8002

4. American National Standards
   Institute (ANSI)
   105 - 111 South State Street,
   Hackensack, New Jersey 07601
   Telephone: 212 642 4900
   Fax: 212 302 1286

5. British Standards Institute
   (BSI)
   BSI Head Office
   British Standards House
   389 Chiswick High Road
   London W4 4AL
   Telephone: 0181 996 9000
   Fax: 0181 996 7400

6. Underwriters Laboratories Inc.
   333 Pingsten Road
   Northbrook, Illinois 60062-
   2096
   Telephone: 708 272 8800
   Fax: 708 272 8129

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* An increasing amount of safety standards related information is readily available on the Internet. A consolidated list of agencies and information is available at Product Safety International's web site at: http://www.safetylink.com

For further Optoisolator and Regulatory information, please visit our web site at:

http://www.hp.com/go/isolator

For any questions, comments, and further information regarding this guide, e-mail to:

isolator@hp.com

Visit the relevant web sites for further information regarding safety standards and agencies:

a) IEC: http://www.iec.ch/
b) VDE: http://www.vde.de/vde/html/e/more/more.htm
c) CSA: http://www.csa.ca/
d) BSI: http://www.bsi.org.uk/bsi/
e) UL: http://www.ul.com/
f) ANSI: http://www.ansi.org/home.html

Appendix 6.2: Bibliography

The following bibliography is limited to the safety standards consulted in the preparation of this “Regulatory Guide to Isolation Circuits”:

	Standard	Date	Title
1.	IEC 1010 - 1:	1990	Safety requirements for electrical equipment for measurement, control, and laboratory use.
2.	IEC 601 -1:	1988	Medical electrical equipment, general requirements for safety.
3.	IEC 65 :	1985	Safety requirements for mains operated electronic and related apparatus for household and similar general use.
4.	IEC 950:	1991	Safety of information technology equipment, including electrical business equipment.
5.	IEC 664 - 1:	1992	Insulation coordination for equipment within low-voltage systems.
6.	*DIN EN 50178: (VDE 0160)	1994	Safety requirements for electrical equipment for use in electrical power installations and their assembly into electrical power installations.
7.	UL 508:	1995	Standard for safety, industrial control equipment.
8.	UL 840:	1995	Standard for safety, insulation coordination, including clearances and creepage distances for electrical equipment.
9.	*DIN VDE 0884: (Draft)	1992	Optocouplers providing protective separation; Requirements; Tests.
10.	UL 1577:	1995	Standard for safety, optical isolators .
11.	*DIN VDE 0160:	1988	Electronic equipment for use in electrical power installations and their assembly into electrical power installations.
12.	*DIN VDE 0884:	1987	Optocouplers for protective separation against electric shock; Requirements; Tests.

* Relevant for use is always the current edition of each standard that is available at VDE-VERLAG, Bismarckstr. 33, D-10625 Berlin (Germany), fax# 49 (30) 341 70 93 and at Beuth Verlag, Burggrafenstr. 6, D-10787 Berlin (Germany), fax #49 (30) 26 01-12 60. English translations of DIN VDE 0884 (both standard and draft) and DIN VDE 0160 (standard) are available at VDE-VERLAG, Bismarckstr.33, D-10625 Berlin (Germany), fax# 49 (30) 341 70 93.

Appendix 6.3: Glossary of Terms and Definitions

Common Safety Terms and Definitions

Since safety terms and definitions may vary a little (based on context) from one safety standard to another, Agilent has compiled some common terms and referred to a specification (in parenthesis) from which the definition was taken. The purpose of this compilation is by no means to be exhaustive, but to give a sampling of common safety standards terms that may be of some use or interest to the general reader. The reader is encouraged to consult an appropriate safety standard listed for further details, elaboration, or information:

1. AIR CLEARANCE - Shortest path in air between conductive parts (IEC 601-1).

2. BASIC INSULATION - Insulation applied to live parts to provide basic protection against electric shock (IEC 664-1).

3. CLASS I EQUIPMENT - Equipment where protection against electric shock is achieved by:

a) using BASIC INSULATION, and also

b) providing means of connecting to the protective earthing conductor in the building wiring those conductive parts that are otherwise capable of assuming HAZARDOUS VOLTAGES if the BASIC INSULATION fails (IEC 950).

4. CLASS II EQUIPMENT - Equipment in which protection against electric shock does not rely on BASIC INSULATION only, but in which additional safety precautions, such as DOUBLE INSULATION or REINFORCED INSULATION, are provided, there being no provision for protective earthing or reliance upon installation conditions (IEC 950).

5. CLASS III EQUIPMENT - Equipment in which protection against electric shock relies upon SELV CIRCUITS and in which HAZARDOUS VOLTAGES are not generated (IEC 950).

6. CREEPAGE DISTANCE - Shortest path along the surface of insulating material between two conductive parts (IEC 601-1).

7. DOUBLE INSULATION - Insulation comprising both basic insulation and supplementary insulation (IEC 664-1).

8. EXTRA-LOW VOLTAGE (ELV) CIRCUIT - A SECONDARY CIRCUIT with voltages between conductors, and between any conductor and earth, not exceeding 42.4 V peak, or 60 V d.c., under normal operating conditions, which is separated from HAZARDOUS VOLTAGE by at least BASIC INSULATION, and which meets neither all of the requirements for a SELV CIRCUIT nor all of the requirements for a LIMITED CURRENT CIRCUIT (IEC 950).

9. FUNCTIONAL INSULATION - Insulation between conductive parts which is necessary only for the proper functioning of the equipment (IEC 664-1).

10. IMPULSE WITHSTAND VOLTAGE - The highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions (IEC 664-1).

11. INSTALLATION CATEGORY (OVERVOLTAGE CATEGORY) - Classification of parts of installation systems or circuits with standardized limits for transient overvoltages, dependent on the nominal line voltage to earth (IEC 1010-1).

12. MACRO-ENVIRONMENT - The environment of the room or other location in which the equipment is installed or used (IEC 664-1).

13. MAINS VOLTAGE - Voltage of SUPPLY MAINS between two line conductors of a polyphase system or voltage between the line conductor and the neutral conductor of a single-phase system (IEC 601-1).

14. MICRO-ENVIRONMENT - The immediate environment of the insulation which particularly influences the dimensioning of the creepage distances (IEC 664-1).

15. NORMAL CONDITION - Condition in which all means provided for protection against SAFETY HAZARD are intact (IEC 601-1).

16. OVERVOLTAGE CATEGORY 1 - Equipment of overvoltage category I is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level. Examples are protected electronic circuits (IEC 664-1).

17. OVERVOLTAGE CATEGORY II - Equipment of overvoltage category II is energy-consuming equipment to be supplied from the fixed installation. Examples of such equipment are appliances, portable tools and other household and similar loads (IEC 664-1).

18. OVERVOLTAGE CATEGORY III - Equipment of overvoltage category III is equipment in fixed installations and for cases where the reliability and the availability of the equipment are subject to special requirements. Examples of such equipment are switches in the fixed installation and equipment for industrial use with permanent connection to the fixed installation (IEC 664-1).

19. OVERVOLTAGE CATEGORY IV - Equipment of overvoltage category IV is for use at the origin of the installation. Examples of such equipment are electricity meters and primary overcurrent protection equipment.

20. PARTIAL DISCHARGE (PD) - Electric discharge that partially bridges the insulation (IEC 664-1).

21. PARTIAL DISCHARGE EXTINCTION VOLTAGE (Ue) - The lowest peak value of the test voltage at which the apparent charge becomes less than the specified discharge magnitude when the test voltage is reduced below a high level where such discharges have occurred (IEC 664-1).

22. PARTIAL DISCHARGE INCEPTION VOLTAGE (Ui) - The lowest peak value of the test voltage at which the apparent charge becomes greater than the specified discharge magnitude when the test voltage is increased above a low value for which no discharge occurs (IEC 664-1).

23. PARTIAL DISCHARGE TEST VOLTAGE (Ut) - The peak value of the test voltage at which the apparent charge has to be less than the specified discharge magnitude (IEC 664-1).

24. POLLUTION - Any addition of foreign matter, solid, liquid, or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation (IEC 664-1).

25. POLLUTION DEGREE - For the purposes of evaluating CREEPAGE DISTANCES and CLEARANCES the following four degrees of pollution in the microenvironment are established (IEC 664-1)

26. POLLUTION DEGREE 1 - No pollution or only dry, non-conductive pollution occurs. The pollution has no influence (IEC 664 -1)

27. POLLUTION DEGREE 2 - Only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected (IEC 664-1).

28. POLLUTION DEGREE 3 - Conductive pollution occurs or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected (IEC 664-1).

29. POLLUTION DEGREE 4 - The pollution generates persistent conductivity caused by conductive dust or by rain or snow (IEC 664-1).

30. PRIMARY CIRCUIT - An internal circuit which is directly connected to the external supply mains or other equivalent source (such as a motor-generator set) which supplies the electric power. It includes the primary windings of transformers, motors, other loading devices and the means of connection to the supply mains (IEC 950).

31. RATED VOLTAGE - The primary power voltages (for three-phase supply, the phase-to-phase voltage) as declared by the manufacturer (IEC 950).

32. REINFORCED INSULATION - A single insulation system applied to live parts, which provide a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant IEC standard (IEC 664-1).

33. ROUTINE TEST - A test of one or more samples of equipment (or parts of equipment) made to a particular design, to show that the design and construction meet one or more requirements of this standard (IEC 1010-1).

34. SAFETY EXTRA-LOW VOLTAGE (SELV) - Voltage which does not exceed a NOMINAL value of 25 V a.c. or 60 V d.c. at RATED supply voltage on the transformer or converter, between conductors in an earth-free circuit which is isolated from the SUPPLY MAINS by safety EXTRA-LOW VOLTAGE TRANSFORMER or by devices with an equivalent separation (IEC 601-1).

35. SECONDARY CIRCUIT - A circuit which has no direct connection to primary power and derives its power from a transformer, convertor or equivalent isolation device situated within the equipment (IEC 950).

36. SINGLE FAULT CONDITION - Condition in which a single means for protection against a SAFETY HAZARD in equipment is defective or a single external abnormal condition is present (IEC 601-1).

37. SUPPLEMENTARY INSULATION - Independent insulation applied in addition to basic insulation, in order to provide protection against electric shock in the event of a failure of basic insulation (IEC 664-1).

38. TRACKING - The progressive formation of conducting paths on the surface of a solid insulating material, due to the combined effects of electric stress and electrolytic contamination of this surface (IEC 950).

39. TRANSIENT OVERVOLTAGE - A short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped (IEC 664-1).

40. TYPE TEST - A test of one or more samples of equipment (or parts of equipment) made to a particular design, to show that the design and construction meet one or more requirements of this standard (IEC 1010-1).

41. WORKING VOLTAGE - The highest voltage to which the insulation under consideration is, or can be, subjected when the equipment is operating at its RATED VOLTAGE under conditions of normal use (IEC 950).

Appendix 6.4: About the IEC (International Electrotechnical Commission)

Since IEC is the truly international or global organization, manufacturers that are operating in the international arena must of necessity take cognizance of the safety standard requirements advised by this organization. The IEC standards are reviewed at maximum intervals of five years by the relevant Technical Committee, to determine whether they should be confirmed, revised, or withdrawn.

IEC is headquartered in Geneva, Switzerland. All of the IEC standards are listed in the "Catalogue of IEC Publications". Supplements updating the catalogue are published six times a year and are distributed with the IEC Bulletin.

The mission and objectives of the IEC are best captured in their own words, and we quote: "The International Electrotechnical Commission (IEC) is the authoritative worldwide body responsible for developing consensus of global standards in the electrotechnical field. It is dedicated to their global harmonization and voluntary adoption in the interests of society in general, supporting the transfer of electrotechnology, assisting certification, and promoting international trade.

The IEC has served the world's electrical industry since 1906, developing international standards to promote quality, safety, performance, reproducibility and environmental compatibility of materials, products and systems. For the past 40 years, it has also set standards for the electronics and telecommunications industries.

The IEC present membership of 51 countries includes most major trading nations. They represent at least 80 percent of the world's population and generate 95 percent of its electricity.

In each member country, a National Committee is expected to represent the full spectrum of electrotechnical interests in that country, including suppliers and users as well as government, trade, professional and scientific bodies. The officers of the IEC and the presidents of national committees govern the Commission, each national member having equal voting rights in all IEC bodies.

IEC work is carried out by technical committees, their sub-committees and working groups, each being responsible for developing standards for a well defined sector of technology. Some 200 such committees span virtually all electrotechnical sectors as well as associated disciplines such as terminology, symbols, safety and performance. Committee titles appear at the back of this catalogue.

IEC standards are widely adopted as the basis of national or regional electrotechnical standards, and are often quoted in manufacturers' specifications and by users when calling for tenders. For example, nearly 90 percent of the Electrotechnical European Standards (EN) harmonized by CENELEC and adopted in the countries of the European Union and the European Free Trade Area are either identical with or very closely based on the IEC international standards. Equivalent EN reference numbers are included with the appropriate IEC standards in the main list of publications in this catalogue.

This widespread adoption facilitates international trade in the electrical and electronic engineering sectors, already responsible for well over 30 percent of all manufactured goods traded world wide and making up the manufacturing sector with the highest growth rate.

IEC maintains working relationship with some 200 international governmental and non-governmental organizations. In particular, there is a close co-operation with the International Organization for Standards (ISO). Please refer to the ISO Catalogue for international standards in non-electrotechnical areas."

The IEC lists the following address:

> IEC Central Office Customer Service Center
> 3, rue de Varembe
> P.O. Box 131, 1211 Geneva 20
> Telephone: +41 22 919 02 11
> Telefax: +41 22 919 03 00
> Internet: dn@iec.ch or ek@iec.ch

In the United States, the IEC catalogue can be obtained from the American National Standards Institute (ANSI) located in New York. See Appendix 6.1 for their address.

Appendix 6.5: UL Organization Mission and Objectives

The mission and objective of Underwriters Laboratories Inc. is quoted here in full:

" Underwriters Laboratories Inc., founded in 1894, is chartered as a not-for-profit organization without capital stock, under the laws of the State of Delaware, to establish, maintain, and operate laboratories for the examination and testing of devices, systems and materials to determine their relation to hazards to life and property, and to as certain, define and publish standards, classifications and specifications of materials, devices, products, equipment, constructions, methods, and systems affecting such hazards.

UL Standards for safety are developed under a procedure which provides for participation and comment from the affected public as well as industry. The procedure takes into consideration a survey of known existing standards and the needs and opinions of a wide variety of interests concerned with the subject matter of the standard. Thus manufacturers, consumers, individuals associated with consumer-oriented organizations, academicians, government officials, industrial and commercial users, inspection authorities, insurance interests and others provide input to UL in the formulating of UL standards for Safety, to keep them consonant with social and technological advances."

Appendix 6.6: VDE Organization Mission and Objectives

The mission and objective of the VDE (Verband Deutscher Electrotechniker) is quoted here in full:

VDE – The Association of German Electrical Engineers

"The Association of German Electrical Engineers is a non-profit association for electrical science and technology. It was founded in 1893. More than 35,000 engineers, natural scientists and technicians are members of the VDE. In addition there are some 1,000 corporate members, including all important companies of the electrical and power industry as well as numerous federal authorities. On the regional level the VDE is represented by 34 local sections and 55 branch offices. The registered seat is Frankfurt am Main.

One of VDE's main tasks is the promotion of technical progress and the application of electrical engineering/electronics, information technology and associated tehnologies. VDE contributes through the organization of conferences to national and international transfer of technical know-how among experts. Another task of the VDE is to support in a competent and objective manner public discussions dealing with the assessment of consequences of technical development.

VDE in its capacity as a scientific organization

The technical and scientific work is mainly performed by five technical associations, namely the Information Technology Society and the Power Engineering Society within VDE jointly with the Verein Deutscher Ingenieure in the technical societies "Microelectronics", "Measurement and Automation Engineering" and "Microelectronics and Precision Engineering". Important work is done by the numerous committees, e.g. in the area of accident research or education policy. Every five years the VDE submits a study dealing with the topic of the demand for engineers in the field of electrical engineering.

German Electrotechnical Commission of DIN and VDE (DKE)

Standards covering the entire area of electrical engineering are drawn up by the German Electrotechnical Commission of DIN and VDE (DKE), the juridical responsibility for running the DKE being in the hands of the VDE whose registered seat is at the VDE Offices in Frankfurt. The DKE represents and safeguards German interests within the European Committee for Electrotechnical Standardization (CELELEC) and the International Electrotechnical Commission (IEC). The VDE Specifications (VDE Specifications Code) are issued in the form of DIN VDE Standards, the major part being European Standards. Some 4000 delegates are drawing up standards in approximately 150 committees, 270 sub-committees and 300 working groups.

VDE Testing and Certification Institute

According to the VDE Specifications or other generally acknowledged rules of engineering the VDE Testing and Certification Institute, being a neutral and independent body, carries out about 18,000 tests annually and issues test certificates. About 200,000 types of electrotechnical products, particularly household appliances, luminaires, medical electrical equipment, entertainment electronic equipment, installation material, etc., bear a VDE Certification Mark certifying compliance with all safety-relevant technical requirements.

Technology Center Information Technology

The VDI/VDE Technology Center Information Technology, Berlin, operated under the joint responsibility of VDE and VDI, is currently coordinating the establishment and enlargement of technology and foundation centers. The purpose of its activities is to facilitate the start of operations for young enterprises in particular.

International activities of the association

VDE's activities and reputation are not only confined to standardization and certification. It also organizes international and scientific meetings, is a member of EUREL, the Convention of National Societies and Electrical Engineers of Western Europe, and contributes, through the DKE committees' work, to the drawing-up of IEC and CENELEC Standards.

Publications in numerous areas of electrical science and technology

The "VDE-VERLAG GMBH" (Publishing House) with registered seats in Berlin and Offenbach undertakes the issue of publications in the field of electrical engineering and science among which particular stress is put on the VDE Standards Code, electrotechnical literature as well as national and European technical journals."

Further information regarding VDE can be found at VDE's web site at: http://www.vde.de/vde/html/e/more/more.htm

Appendix 6.7

Agilent Technologies

Optocoupler Input-Output Endurance Voltage

Application Note 1074

Introduction

A major concern of circuit designers is the reliability of an optocoupler when subjected to repeated and long-term, high-voltage stress between its input and output. Most of the technical data on optocouplers adequately address the capability of an optocoupler to withstand one-time high-voltage transients, but they do not adequately address the issues of:

a) how long one can apply a steady state ac or dc voltage between the input and output of the optocoupler before degrading the semiconductors or the insulation inside the optocoupler, and

b) how often one can apply high-voltage transients before degrading the optocoupler.

In attempting to answer these questions, a series of operating life tests were conducted on Agilent optocouplers. Several optocoupler lots were subjected to different input-output high-voltage stress tests to examine the failure rate and the time taken to fail. Upon completion of these tests, the test data was analyzed to create safe operating areas for long-term, input-output high-voltage stress. The boundary of the safe operating areas for the steady-state input-output high-voltage stress is referred to as Endurance Voltage.

Figure 1 describes the concept of Endurance Voltage for one family of Agilent optocouplers. As shown in this figure, the bottom region is the safe operating area for steady-state ac and dc input-output voltage stress meant for continuous application of a high-voltage stress. The middle region is the safe operating region for transient voltage stress. Operating outside both of these safe operating regions causes the optocoupler to wear-out either in functionality or in isolation capability, and is not recommended for use.

This application note discusses an Agilent input-output voltage stress study that was conducted on Agilent optocouplers. The results from these tests indicate that Agilent optocouplers are robust for long-term survival in applications where a continuous high-voltage stress is applied across the input-output. Agilent optocouplers can safely withstand a continuous voltage up to either 800 Vac, or 1000 Vdc. Before discussing the high-voltage stress test details, it is worthwhile to define some of the common high-voltage terminology and put that in context with Endurance Voltage.

High-Voltage Terminology

The basic purpose of an optocoupler is to send signals between two circuits or systems that need electrical insulation from one another. During signal transmission between the two circuits or systems the optocoupler must also have the capability to reject common mode voltages and transients and this capability is referred to as signal isolation. There are several terms used in the industry to define and quantify the signal isolation and electrical insulation capability of an optocoupler. Some of the common terms used in Agilent Technologies technical literature are described below.

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Signal Isolation
The isolation function of an optocoupler is defined by its ability to pass desired signals and reject unwanted signals or transients. Optocoupler isolation capability is largely determined by its input-output capacitance and the electrical design of the detector circuit. Most optocouplers use the common-mode rejection parameter to define and quantify the signal isolation capability.

Electrical Insulation
When an optocoupler acts as a coupling device between two circuits or systems that have a potential difference, then the insulation capability of the optocoupler is defined by its ability to prevent physical damage to the surrounding circuitry as well as to itself. Electrical insulation is often a safety issue which is regulated by many countries' safety agencies* at both the component level and at the equipment level. Safety standards are often set up to establish the requirements for the insulation barrier between safe and hazardous voltages within equipment. They also define test, material and dimensional requirements based on conditions which are expected to be encountered. Definitions of safe and hazardous voltage levels vary among countries and equipment. Components like optocouplers, which are often part of the insulation barrier, are sometimes addressed separately in order to simplify equipment level qualification. There are five major ways of defining and quantifying the insulation properties of an optocoupler.

Input-Output Resistance:
To measure the input-output resistance of an optocoupler, usually 500 Vdc is applied between the optocoupler input and output for a duration of one minute, and the leakage current is measured. With the leakage current value, one can calculate the input-output resistance. The input-output resistance is merely one type of short duration insulation test and it gives the circuit designer an indication of the amount of dc leakage current for a particular input-output voltage.

Input-Output Insulation Voltage or Dielectric Withstand Voltage:
This is usually defined by a one minute rating for the maximum voltage that can be applied between the input and output of an optocoupler. Either long duration or repeated application of high-voltage stress may cause permanent damage and functional failure of the optocoupler. The one-minute Dielectric Withstand Voltage does not indicate the capability of the optocoupler to withstand long-term application of high-voltage stress nor does it tell you how often and how many times one can apply these high-voltage pulses.

Internal Clearance: The shortest direct through-insulation distance between the input and output circuitry within the optocoupler.

External Clearance: The shortest air-gap distance between the input and output leads of the optocoupler.

External Creepage: The shortest external surface distance between the input and output leads of the optocoupler.

The Internal Clearance, External Clearance, and External Creepage specifications of optocouplers are useful for obtaining component and equipment regulatory insulation safety approvals in various countries, as well as for determining the Working Voltage of an optocoupler, which is defined below.

Working Voltage
The highest steady-state voltage that can be applied across the input-output insulation of an optocoupler as defined by equipment standards and Regulatory Agency guidelines is called the Working Voltage. Some of the considerations for determining the Working Voltage of an optocoupler are the type of equipment the optocoupler is designed into, the relevant safety issues in the use of the equipment, the mains voltage of the equipment, and the environment in which the equipment is used.

In situations where a Regulatory Agency is not involved, then the Working Voltage is defined by the equipment application. In such a case, the Working Voltage is the maximum input-output steady state voltage that the optocoupler encounters in the circuit application.

Endurance Voltage
The Endurance Voltage, a term defined by Agilent Technologies, is the maximum voltage that can be applied between the input and output terminals of an optocoupler for extended periods of time without damaging the optocoupler. Damage to an optocoupler can include loss of

* Examples of Safety Agencies are UL in USA, VDE in Germany, and CSA in Canada.

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operation or loss of insulation. Endurance Voltage is based on the inherent properties of the optocoupler and is not based on a Regulatory Agency guideline or the equipment application.

Some factors affecting insulation and operating life include input and output biases, applied input-output voltage, temperature, humidity, moisture, mechanical stress and exposure to a variety of chemical agents. For determining the use of an optocoupler in a particular equipment, a designer should consult the regulatory guidelines and the appropriate Working Voltage for that application. For proper use, the Endurance Voltage of an optocoupler must be equal to or greater than the Working Voltage.

Table 1. Stress Cell Matrix

	-40°C	Room Temp. (25°C)	85°C	100°C	125°C	150°C
1000 Vac		✓	✓•		✓	✓
1500 Vac	✓					
1800 Vac		✓				
2000 Vac	✓			✓	✓	✓
2500 Vac	✓	✓				
3000 Vac	✓				✓	✓
3800 Vac						✓
4000 Vac	✓	✓				
5000 Vac		✓				
2000 Vdc			✓•		✓•	✓•
2500 Vdc						✓•
3000 Vdc			✓•			
4000 Vdc					✓•	
5000 Vdc		✓				✓•

✓ Indicates that a high-voltage stress test was conducted for a group of optocouplers.
• Indicates cells with input and output operating biases.

Description of the Agilent-Internal Input-Output Voltage Stress Study

The objectives for the optocoupler input-output voltage stress tests conducted at Agilent included determining which temperature is the worst case temperature for partial discharge related wear-out, establishing data bases for demonstration data to extract ac and dc Endurance Voltages, and voltage and temperature acceleration factors. The following table shows the stress cells that were set up with combinations of temperatures and voltages to satisfy these objectives.

The cells at room temperature and 85°C were intended for the demonstration data base and the cells at 100°C and above were intended for determining the acceleration factors. The cells at 2000 Vac, -40°C were used to test whether room temperature or -40°C cell was the worst case and then to profile data at this temperature.

Only 8-pin P-DIP (7.62 mm wide), and SO-8 plastic optocouplers were used in the input-output high-voltage stress tests. The test units consisted of optocoupler and solid state relay samples from several product families. Refer to Figures 1, 2, and 3 for a full list of products that were subjected to these tests. In general, test units were conditioned prior to stress with a solder dip, 500 temperature cycles and 96 hours of pressure pot sequence. The SO-8 surface mount optocouplers were assembled on ceramic carriers and sent through an infra-red solder reflow process. The intent of the conditioning was to accelerate the aging of the optocoupler that would otherwise occur through its normal operating life.

Summary of Results of Input-Output High-Voltage Stress Tests

Input-Output Voltage-ac

The insulation failure rate of optocouplers caused by partial discharge related wear-out was worse at -40°C than at room and higher temperatures. The -40°C wear out is accelerated by at least a factor of three over room temperature tests at the high-voltages.

There was no evidence of systematic parametric drift due to ac input-output voltage found

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in the cells without operating bias. The failure rate with an operating bias is only slightly higher than for the test without the operating bias. The ac Endurance Voltage was set by the results of tests at -40°C as this condition defined the worst case. No failures occurred in all of the 1000 Vac stress cells for the full length of each test group. Some 1000 Vac stress tests were over 15,000 hours.

Input-Output Voltage-dc

The failure rate for dc input-output voltage stress is greater at high temperatures than at low temperatures. All the dc stress tests were conducted with an operating bias. No failures occurred in the 85°C, 2000 Vdc and 3000 Vdc cells for the entire test periods. Some of these cells were stressed over 5000 hours.

Recommended Operating Areas

Based on the high-voltage stress study conducted at Agilent, Endurance Voltage boundaries, and safe operating areas have been drawn up for different Agilent optocouplers. Figures 1, 2, and 3 show the recommended operating areas for input-output voltages that can be applied for three categories of Agilent optocouplers. Referring to Figures 1, 2, and 3, the safe operating region below 800 Vac is applicable for long-term continuous high-voltage stress. The safe operating region above 800 Vac is applicable only for transient voltages. The X-axis on these figures shows the maximum cumulative time that can be applied for the high-voltage stress. Exceeding this maximum cumulative time may cause either the optocoupler's insulation or its electrical functionality to fail. The safe operating region

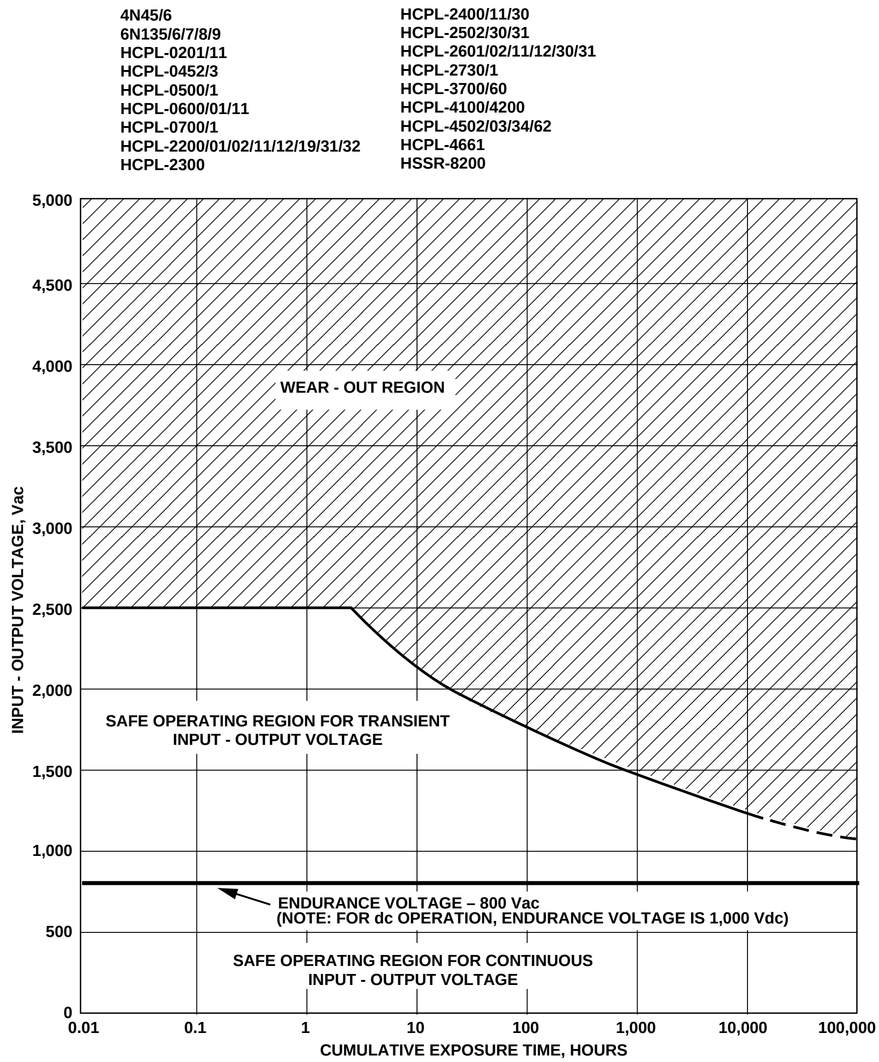

Figure 1. Recommended Safe Operating Area for Input-Output Voltage-Endurance Voltage for Category 1 Optocouplers.

guidelines are applicable when the optocoupler is used under normal conditions in a pollution free environment and within the maximum operating conditions. This includes operating the optocoupler within its specified ambient temperature range.

Although the Agilent time-to-failure tests were conducted at various temperature and voltage stress combinations after conditioning the test units to simulate end use with temperature cycling, solder processing and exposure to humidity, the test environment was relatively clean, where no condensation, precipitation or accumulation of corrosive or conductive material was expected. Consequently, the Endurance Voltage is primarily an indicator of internal characteristics. For the use of an optocoupler in specific equipment and environment, refer to the appropriate Safety Agencies such as UL and VDE for standards that determine the maximum allowable input-output voltages as defined by the Working Voltage. These standards generally consider attributes such as

Appendix 6.7

arc track resistance, corrosion resistance, and physical dimensions (creepage and clearance) for determining the Working Voltage and the maximum transient input-output voltages.

The Endurance Voltage defines a stable region for operation. Operation within this region for input-output voltage and within the other recommended operating parameters, allows the optocoupler to maintain the performance specified within its data sheet. Operation above the optocoupler Endurance Voltage region may result in damage leading to failure of the optocoupler either in insulation or in electrical functioning.

Temperature is another key factor for operating life. The insulating materials within Agilent plastic optocouplers are organic polymers and one would expect that an Arrhenius relationship exists between insulation life and temperature. However, the temperature characteristics are such that the life time of the optocoupler does not appear to be limited by the temperature induced insulation failures if the optocoupler is operated within the Endurance Voltage. This appears to be the case within the recommended operating region. But due to the construction of the optocoupler, a worst case condition exists at the coldest operating temperature that, in turn, defines the maximum acceptable ac Endurance Voltage.

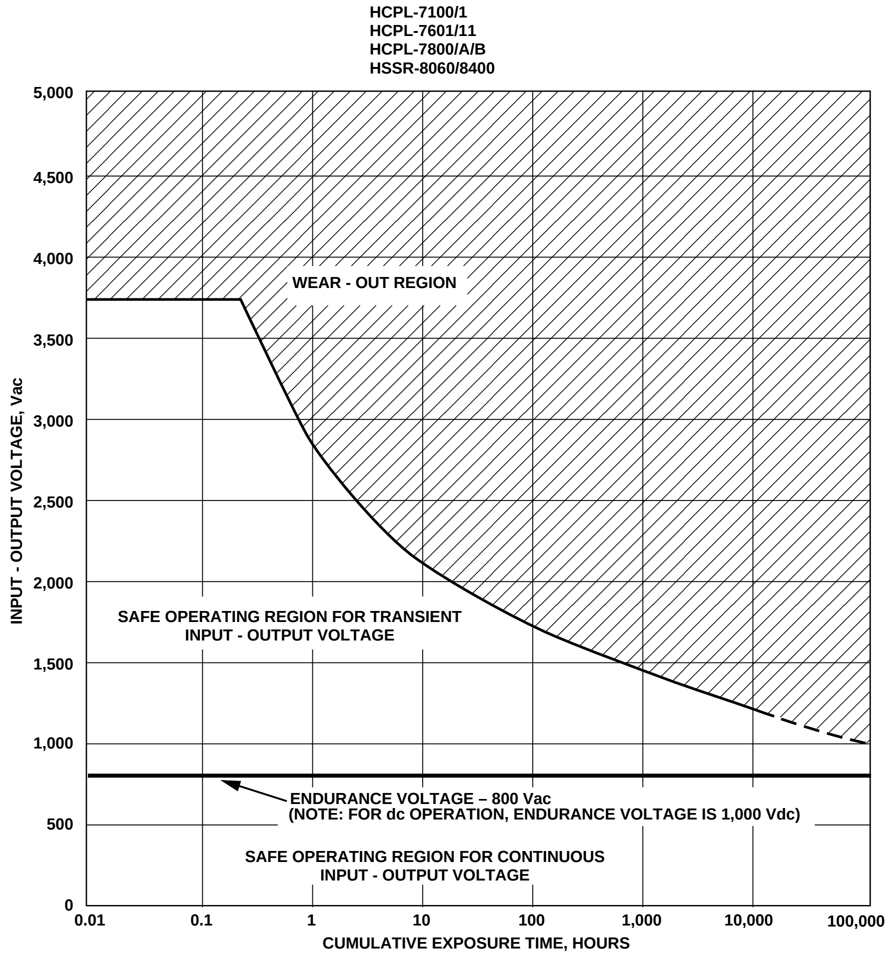

Figure 2. Recommended Safe Operating Area for Input-Output Voltage-Endurance Voltage for Category 2 Optocouplers.

Conclusion

Technical data specified on an Agilent optocoupler is valid at the time of shipment from Agilent's factory, or at the beginning of product life. Just like any semiconductor product, an optocoupler can potentially have some parameters degrade over the life of the product even though the optocoupler continues to be functional. The circuit designer who uses an optocoupler must consider any parameter that is likely to degrade over the product life, and must design sufficient margin so that the optocoupler still functions. This application note specifically addresses the insulation capability of an optocoupler as measured by a term called Endurance Voltage. The Endurance Voltage of an optocoupler is defined as the maximum voltage that can be applied between the input and output of an optocoupler for extended periods of time without causing functional failure of the optocoupler. By following the Endurance Voltage guidelines shown in Figures 1, 2, and 3, the optocoupler can be operated normally for its useful life without unduly increasing the risk of insulation or electrical failure.

Always take the Endurance Voltage guideline as having a lower precedence to the Safety Agency and equipment use standards such as Working Voltage. The Endurance Voltage guideline is applicable in a pollution free laboratory environment and is useful for determining the likelihood of failure of an optocoupler's insulation or electrical operation. The Agilent optocouplers tested in this study have been proved to withstand a continuous voltage of either 800 Vac, or 1000 Vdc, and this allows Agilent optocouplers to be safely used in a wide array of industrial applications.

WARNING: ***In all cases where regulatory compliance is required, Working Voltage sets the maximum allowable steady state input-output voltage. Working Voltage cannot be exceeded in a design that has to meet regulatory requirements.***

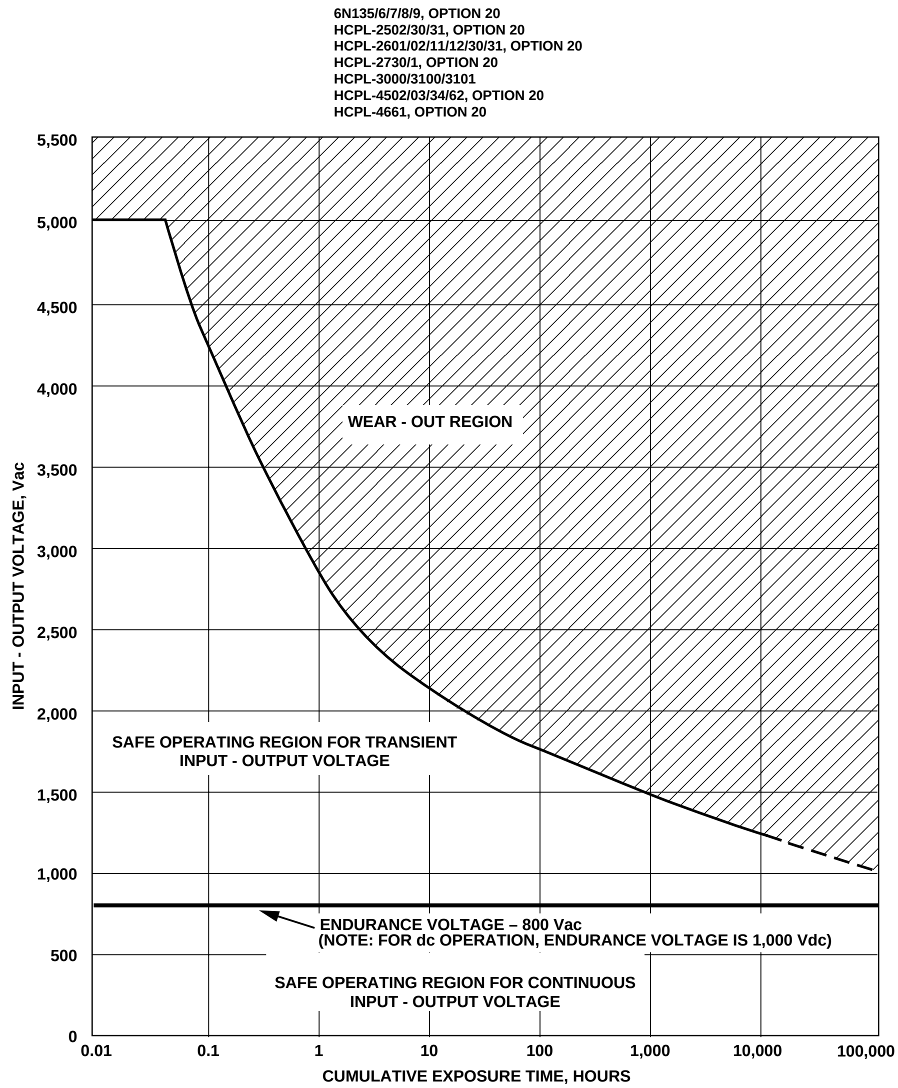

Figure 3. Recommended Safe Operating Area for Input-Output Voltage-Endurance Voltage for Category 3 Optocouplers.

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