Understanding Isolation

True Galvanic Isolation • Reinforced Isolation
Excellent Signal Immunity • Low Leakage Current
Inherent capacitance (pF) = no Common Mode Noise Failure through leakage currents caused by Transients
No Inductance Very Low LC
Fast reaction times & endurance High performance
Broadcom — Industry Leader in High Performance Optocouplers

**Gate Drive Optocouplers**
- Very high CMR performance (signal isolation)
- More integrated features to protect IGBT, eg. Miller Clamp, etc.
- Smaller packages- space/cost saving on board
- Up to 20% cost saving on certain products

**Current & Voltage Sensing Optocouplers**
- High Accuracy
- Low Drift over Temperature
- Smaller footprint-space/cost saving on board
- Up to 40% cost saving vs. Hall effect sensor

**Low Power Digital Optocouplers**
- Low power consumption (more than 80% power saving)
- Extreme common-mode noise rejection
- Up to 20% cost saving on certain products

**Applications**
- Industrial Drives, Industrial Networking, Motor Control, PLC
- Input/Output Isolation, Power Distribution Systems, Robotics,
  Switching Power Supplies
Broadcom Optocouplers — Industry Leader in Isolation Performance

Value Proposition of Opto-Isolation:

• True Galvanic Isolation
• Reinforced = failsafe Isolation
• Excellent Signal Immunity
• Low impedance LED input (Ohm) = rejection of conducted & inducted EMI
• Very low inherent capacitance (pF) = no Common Mode Noise failure through leakage currents caused by Transients
• No Inductance
• Very Low Power Consumption (mWatt)
• Fast reaction times & endurance
• High performance LED technology (30 years field life)
MAKE SURE YOU UNDERSTAND

• The different isolation technologies and standards

• How safe and continuous working voltages are defined

• The different failure mechanisms and what they mean for optical and non-optical isolators

• Broadcom recommendations for different isolation requirements.

How to Keep your Customers SAFE!
Levels of Insulation

- **Electrical Safety**: Electrical insulation required to protect end users from electrical hazards.
- **Continuous Operating Stress Voltage**: Electrical stress conditions expected during nominal operation lifetime.
- **Transient Stress Voltage**: Commonly used to describe insulation suitable for providing electrical safety.
- **Reinforced Insulation**: Reinforced insulation compliance.
- **Minimum through Insulation Distance**: Double Insulation Layers Equivalent to 2x Basic Insulation.
- **Continuous Monitoring of High Voltage Aging Mechanism**: Reinforced insulation compliance.
What is the Difference Between Isolation and Insulation?

Although both terms are often used interchangeably, isolation refers to the separation between two systems or voltage levels, while insulation refers to the actual medium being used to do the separation. For example, an optocoupler is an isolation device with a silicon insulation barrier between the LED emitter and diode detector.

Broadcom Optocouplers
- DTI: 80 µm to 1000 µm
- Number of Layers: 3
- Insulation Material: Polyimide Tape + Silicone
- Electric Field Stress: Vbias / 80 µm

Typical Magnetic or Capacitive Isolators
- DTI: 8 µm to 17 µm
- Number of Layers: 1
- Insulation Material: SiO2 or Polyimide
- Electric Field Stress: Vbias / 8 µm
Safety Standards for Optocouplers and Isolators

IEC60664 — Insulation Coordinates for Low Voltage Equipment
3.3.2.2 Long term stresses and their effects
3.3.2.2.1 Partial discharges
3.3.2.3 Other stresses. Many other stresses can damage insulation and will have to be taken into account by technical committees

VDE0884 — Optocoupler Safety Standard
Use Partial discharge testing to provide 100% screen of HV lifetime

IEC60747-5-5 and IEC60747-5-2 — Optocoupler Component Safety Standard

Draft Standard VDE0884-10 Edition 1 Magnetic Isolator Standard
Uses only partial discharge testing to provide check of HV lifetime. Principle HV aging mechanism not checked

Draft Standard VDE0884-10 Edition 2
Uses partial discharge testing and type testing of principle aging mechanism to provide prediction of HV lifetime. Basic Insulation rating added.

IEC Version of Draft VDE0884-11
Committee formed

Formalized EN Version of IEC Standard
After voting and acceptance of IEC standard

Make Sure You Understand!!!
Talk to the right people at your customer. Standards and Quality departments are responsible for safety!
Defining a Safe Continuous Working Voltage

Safe Continuous Working Voltage is ... ... like walking along a cliff on a sunny day

- Determine the safe continuous voltage level that does not damage the isolator
  ... You can clearly see the edge of the cliff

- The safe continuous working voltage level should be far enough away from the transient variations in the nominal working voltage
  ... If you take a step left or right, you still won’t fall off

- The safe continuous voltage level should not change over time
  ... The edge is stable and not moving.
Relevant Aging Mechanisms for Isolators

• Optocouplers — Use of thick insulation materials protects against space charge aging. 
**Dominant failure mechanism is partial discharge.**

• Magnetic isolators using spin on polyimide coatings — Use of thin polymer spin coatings <25 µm, results in high dielectric stress which readily activates space charge degradation. 
**Dominant failure mechanism is space charge aging.**

• Capacitive/Magnetic isolators using thin film SIO2<10µm. High E field stress readily activates SIO2 specific time depended failure mechanism. 
**Dominant failure mechanism is SIO2 specific TDDB (time dependent dielectric breakdown).**

Make Sure You Understand!!!

Different isolation technologies have different failure mechanisms.
Working Voltage as Defined by IEC 60747-5-5

This is the maximum continuous voltage that the insulation barrier must survive over the lifetime of the device. The integrity of the insulation is guaranteed by a partial discharge test done on every production device.

In applications where there are significant potential differences, the most important safety parameter is the maximum working insulation voltage (Viorm) as defined by IEC/EN/DIN EN 60747-5-5. This standard uses partial discharge testing to determine the working voltage level that the optical insulation must survive over the lifetime of the device. The philosophy underlying the partial discharge testing is that insulation for safe electrical isolation needs to withstand not only a breakdown voltage, but also a voltage that prevents any degradation due to high electrical fields which may cause the insulation to break down over time or over repetitive cycles. In production, partial discharge test is performed for 1 second at 1.875x Viorm.

Make Sure You Understand!!!

Alternative isolating technologies are no longer IEC certified 60747-5-2. They are certified according to the latest VDE safety draft standard – VDE0844-10.
Testing Relevant Aging Mechanisms for Non-optical Isolators

In magnetic isolators using spin on polyimide coatings, there is a higher dielectric stress which activates space charge degradation. The dominant failure mechanism is space charge aging, which reduces the breakdown voltage over time. Currently it is not possible to test for space charge degradation in a finished product.

In capacitive or magnetic isolators using thin film SIO2, the dominant failure mechanism is specific to the SIO2 technology and is called time dependent dielectric breakdown (TDDB). The test method to determine TDDB is destructive and cannot be tested in production.
Why Can’t Partial Discharge Testing be Used on Non-optical Isolators?

Theoretically it can be done, however practically it is not valid as the dominant failure mechanism in these alternative technologies is different and cannot be detected by a partial discharge test. Alternative isolators, which passed partial discharge testing failed just hours later when subjected to a continuous voltage used in the partial discharge test (which optocouplers passed).
Using VDE0884-11 to Certify Working Voltage

- Uses type testing and statistical modeling to predict HV lifetime. No continuous monitoring of dominant HV aging mechanism.
  IEC60747-5-5 provides 100% continuous monitoring of dominant HV aging mechanism for optocouplers.
- Permits/Predicts failures to occur during lifetime — 1000ppm for Basic insulation and 1ppm for reinforced insulation.
  IEC60747-5-5 eliminates active HV aging mechanism in optocouplers — ensuring no failures over lifetime.
- Safety factor for reinforced insulation of just 1.25.
  IEC insulation coordinates system nominal requires a safety factor of 2. IEC60747-5-5 uses a safety factor of 1.85.

Make Sure You Understand!!!

The VDE0884-11 for reinforced isolation allows for 1 ppm for alternate isolators. There is no continuous production monitoring in the VDE standard. Make sure you understand the failure mechanisms in the different standards, as test results can be misleading and dangerous.
Withstand Voltage as Defined by UL1577

This is the maximum voltage the insulation barrier needs to hold up to for a duration of one minute.

The withstand voltage is a safety parameter defined by the dielectric voltage-withstand test according to UL1577. This is a one minute type test, where a voltage is applied between the input and output terminals of the isolator (destructive test). Typical withstand voltage ratings are 2500-5000 Vrms. This is the maximum voltage the insulation barrier needs to hold up to for one minute and is not related to high voltage over product lifetime. During manufacturing, each isolator is tested at 1.2x the rated dielectric insulation voltage for one second. UL1577 can be used to certify optocouplers as well as non-optical isolator technologies.

Make Sure You Understand!!!

Withstand voltage is not the same as working voltage. It defines the isolation voltage for a short term overvoltage condition, not over lifetime.
Safe Isolation with Robust LED Technology

The lifetime of the LED will inherently depend on its quality grade. The LED used in low cost consumer grade phototransistor optocouplers could potentially degrade faster than an LED used in industrial or automotive grade photo-IC optocouplers. Broadcom has done extensive testing and provides LED lifetime performance data for all of its industrial and automotive grade optocouplers. Worst case predictions show a degradation of less than 10% for over 30 years of lifetime in the field.

Make Sure You Understand!!!
Light output degradation depends on the quality of the LED being used. Comparative tests are often done using low performance phototransistors. Broadcom photo IC optocouplers use high performance, industrial grade LEDs.

<table>
<thead>
<tr>
<th>Power</th>
<th>Efficiency</th>
<th>Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Low VF Material</td>
<td>• High-brightness</td>
<td>• Epitaxial Growth</td>
</tr>
<tr>
<td>• Low IF Drive</td>
<td>• Material LED</td>
<td>• LED Fabrication</td>
</tr>
<tr>
<td>• Current-spreading Design</td>
<td>Light Extraction</td>
<td>• Assembling</td>
</tr>
<tr>
<td></td>
<td>• Lens/ Optics Design</td>
<td>• Handling</td>
</tr>
</tbody>
</table>
Introduction
Optocouplers are used extensively for high-voltage isolation and electrical noise rejection. They are ideal components for separating control signals from high-voltage electrical circuits, as they consist of a light-emitting diode (LED) that transmits light to a photodetector on the other side of an insulation barrier, such as a plastic or air gap.

The Current Transfer Ratio (CTR) is an electrical parameter usually specified for an optocoupler. CTR is defined as the ratio of the output current to the input drive current (IF). It is used to determine the performance of an optocoupler over time. The Average CTR (Ave) is the mean value of the CTR, and it is calculated as the average of the CTR values over a given period of time.

LED Reliability Stress Tests
Optocouplers are tested for reliability under various conditions to ensure they can withstand the stresses of continuous operation. One of the tests is the Temperature Operating Life (TOL) test, which is performed at a temperature range of 0°C to 125°C. This test is used to determine the reliability of the optocoupler over a specified period of time.

The manufacturer’s datasheets often include plots of CTR vs. field years for different LED types. These plots are used to calculate the LED lifetime performance based on the manufacturer’s performance data. The plots are constructed using the following equation:

CTR(t) = CTR(0) * (1 - t/τ)

where CTR(t) is the CTR at time t, CTR(0) is the initial CTR, and τ is the lifetime of the LED.

Figure 1 shows the CTR performance vs. field years for AlGaAs (Type 1) LED (operating IF = 16 mA, 50% duty cycle, TA = 80°C). Figure 2 shows the CTR performance vs. field years for AlGaAs (Type 2) LED (operating IF = 5 mA, 100% duty cycle, TA = 80°C). Figure 3 shows the CTR performance vs. field years for GaAs LED (operating IF = 16 mA, 50% duty cycle, TA = 80°C). Figure 4 shows the CTR performance vs. field years for AlGaAs (Type 2) LED at different IF (50% duty cycle, TA = 80°C).

Calculate Reliable LED Lifetime Performance
in Optocouplers

By understanding the performance characteristics of optocouplers, designers can select the most appropriate LED forward input current for their application.

Avago Technologies is an industry leader in optocouplers, using LED reliability stress data under accelerated conditions to project the expected LED lifetime performance based on Black Model (a generally accepted empirical model developed at General Electric in the 1960s, which assumes that the failure rate of a device increases exponentially with time).

Avago Technologies performs stress testing to determine LED reliability for periods of continuous operation up to 10,000 hours for the various LED types used in different models of their optocouplers. The analysis gives designers greater confidence and design flexibility so they can specify the most appropriate LED forward input current for their application.

www.broadcom.com
AV02-3401EN
Broadcom Isolation Products

Make Sure You Understand!!!

Broadcom has a full portfolio of optocouplers including non-optical isolators. Broadcom will recommend the type of isolator according to the type of isolation required — functional, basic, reinforced/safe.
# Broadcom Optocoupler Packages

## Photo IC

<table>
<thead>
<tr>
<th>Package</th>
<th>Creepage (mm)</th>
<th>Clearance (mm)</th>
<th>Internal Clearance (mm)</th>
<th>V_{iorm} (V peak)</th>
<th>V_{iso} (V rms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO8 (SSO-6)</td>
<td>5.0</td>
<td>5.0</td>
<td>0.08</td>
<td>567</td>
<td>3750</td>
</tr>
<tr>
<td>Stretched SO6 (SSO-6)</td>
<td>8.0</td>
<td>7.0</td>
<td>0.08</td>
<td>891</td>
<td>3750</td>
</tr>
<tr>
<td>ACPL-Hxxx</td>
<td>ACPL-Wxxx</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO8</td>
<td>4.5</td>
<td>4.9</td>
<td>0.08</td>
<td>567</td>
<td>2500/3750</td>
</tr>
<tr>
<td>Stretched SO8 (SSO-8)</td>
<td>8.0</td>
<td>7.0</td>
<td>0.08</td>
<td>891</td>
<td>3750</td>
</tr>
<tr>
<td>ACPL-Hxxx</td>
<td>ACPL-Kxxx</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stretched SO12 (SSO-12)</td>
<td>8.0</td>
<td>8.0</td>
<td>0.08</td>
<td>1140</td>
<td>5000</td>
</tr>
<tr>
<td>ACNL-Hxxx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wide Body</td>
<td>10.0</td>
<td>9.6</td>
<td>1.0</td>
<td>1441</td>
<td>5000</td>
</tr>
<tr>
<td>10-Pin</td>
<td>13.0</td>
<td>13.0</td>
<td>2.0</td>
<td>2262</td>
<td>7500</td>
</tr>
</tbody>
</table>

## IEC Working Voltage

- ACML
- ACNL
- ACNW

## UL Withstand Voltage

<table>
<thead>
<tr>
<th>Package</th>
<th>Creepage (mm)</th>
<th>Clearance (mm)</th>
<th>Internal Clearance (mm)</th>
<th>V_{iorm} (V peak)</th>
<th>V_{iso} (V rms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO8</td>
<td>4.0</td>
<td>4.0</td>
<td>-</td>
<td>-</td>
<td>2500</td>
</tr>
<tr>
<td>SO16</td>
<td>4.5</td>
<td>4.9</td>
<td>0.08</td>
<td>567</td>
<td>2500</td>
</tr>
<tr>
<td>8-Pin</td>
<td>7.4</td>
<td>7.1</td>
<td>0.08</td>
<td>630</td>
<td>3750</td>
</tr>
<tr>
<td>14.2mm SSO8</td>
<td>14.2</td>
<td>14.2</td>
<td>2.0</td>
<td>2262</td>
<td>7500</td>
</tr>
</tbody>
</table>

## Digital Isolator

<table>
<thead>
<tr>
<th>Package</th>
<th>Creepage (mm)</th>
<th>Clearance (mm)</th>
<th>Internal Clearance (mm)</th>
<th>V_{iorm} (V peak)</th>
<th>V_{iso} (V rms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO8</td>
<td>4.0</td>
<td>4.0</td>
<td>-</td>
<td>-</td>
<td>2500</td>
</tr>
<tr>
<td>SO16</td>
<td>8.1</td>
<td>8.1</td>
<td>-</td>
<td>-</td>
<td>2500</td>
</tr>
<tr>
<td>ACML</td>
<td>8.1</td>
<td>8.1</td>
<td>-</td>
<td>-</td>
<td>5600</td>
</tr>
</tbody>
</table>
## Our Recommendations for Isolation Technologies

<table>
<thead>
<tr>
<th></th>
<th>Functional Transient Voltage</th>
<th>Functional Continuous Voltage</th>
<th>Safety Transient Voltage</th>
<th>Safety Continuous Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optocoupler</strong>&lt;br&gt;Thick Polymer insulation</td>
<td>Internal insulation construction exceeds package external flashover voltage</td>
<td>Thick insulation prevents partial discharge and space charge aging</td>
<td>Internal insulation construction exceeds package external flashover voltage</td>
<td>Reinforced internal insulation construction&lt;br&gt;Dominant long term potential failure mode is partial discharge — 100% safety test available</td>
</tr>
<tr>
<td><strong>Magnetic Spin Coat Polyimide &lt;25 um</strong></td>
<td>ESD Hazard on exposed communication interfaces</td>
<td>E field stress readily activates space charge aging&lt;br&gt;Continuous high voltage exposure such as in motor inverter significantly ages insulation</td>
<td>Low energy ESD and repetitive overvoltage transients are capable of causing permanent damage to internal insulation</td>
<td>No reinforced internal insulation construction&lt;br&gt;Dominant long term failure mode is space charge aging not partial discharge — no appropriate safety test available.</td>
</tr>
<tr>
<td><strong>Capacitive SIO2</strong></td>
<td>ESD Hazard on exposed communication interfaces</td>
<td>E field stress readily activates SIO2 specific time dependent Breakdown&lt;br&gt;Continuous high voltage exposure such as in motor inverter significantly ages insulation</td>
<td>Low energy ESD and repetitive overvoltage transients are capable of causing permanent damage to internal insulation</td>
<td>No reinforced internal insulation construction&lt;br&gt;Dominant long term failure mode is SIO2 TBBD not partial discharge — no appropriate safety test available</td>
</tr>
<tr>
<td><strong>Reinforced Planar Transformer</strong>&lt;br&gt;Thick Polymer insulation</td>
<td>Internal insulation construction exceeds package external flashover voltage</td>
<td>Thick insulation prevents partial discharge and space charge aging</td>
<td>Internal insulation construction exceeds package external flashover voltage</td>
<td>Reinforced internal insulation construction&lt;br&gt;Dominant long term potential failure mode is partial discharge—100% safety test available</td>
</tr>
</tbody>
</table>

**Colors**
- **Green**: Go
- **Gold**: Be Careful
- **Red**: Stop