Manufacturing and Reliability

THE IMPORTANCE OF OPTOCOUPLER RELIABILITY

Because of the widespread use of optocouplers as an interface device, optocoupler reliability has been of major importance to circuit designers and component engineers. Published studies of comparative tests have indicated a lack of manufacturing consistency with individual manufacturers, as well as from manufacturer to manufacturer. This has resulted in user uncertainty about designing with optocouplers; however, these devices often offer the better circuit solution.

This application note is intended to demonstrate Vishay’s concern, efforts, and results in addressing these manufacturing issues to assure users of the quality (out-going) and reliability (long-term) of our opto-isolated products. First, aspects of optocoupler characteristics are discussed along with the measures Vishay has taken to assure their quality and reliability. Second, the reliability tests used to approximate worst-case conditions and the latest results of these tests are described

OPTOCOUPLER OUTPUT

There are a variety of outputs available in optocouplers. A standard bipolar phototransistor is the most common. They are available with different ratings to fit most applications, including versions without access to the base of the transistor to reduce noise transmission. Darlington transistor outputs offer high gain with reduced input current requirements, but typically trade off speed. Logic optocouplers provide speed but trade off working voltage range. Logic couplers are normally only used in data transmission applications. Silicon controlled rectifier (SCR) devices allow control of much higher voltages and typically are applied to control AC loads. They are also offered in inverse-parallel (anti-parallel) SCR (TRIAC) configurations so that both cycles of an AC sinusoid can be switched. In Vishay’s manufacturing flow, all these devices are 100 % monitored at a high-temperature hot rail (see figure 1) to eliminate potential failures due to marginal die attaches and lead bends, resulting in a more reliable product. Vishay offers all the above types of products.

In optocouplers, especially the transistor, the slow change over several days in the electrical parameters when voltage is applied is termed the field effect. This process is extreme particularly at high temperatures (100 °C) and with a high DC voltage (1 kV). Changes in the electrical parameters of the silicon phototransistor can occur due to the release of charge carriers. In this way, a similar effect as takes place in a MOS transistor (inversion at the surface) is caused by the strong electrical field. This may result in changes in the gain, the reverse current, and the reverse voltage. In this case, the direction of the electrical field is a decisive factor.

In Vishay's optocouplers, the pn junctions of the silicon phototransistor are protected by a transparent ion screen from influences of the electrical field. In this way, changes of electrical parameters by the electrical field are limited to an extremely low value or do not occur at all.

OPTOCOUPLER INPUT

The area of greatest concern in optocoupler reliability has been the infrared LED. The decrease in LED light output power over current flow time has been the object of considerable attention in order to reduce its effects. (Circuit designs which have not included allowances for parametric changes with temperature, input current, phototransistor bias, etc. have been attributed to LED degradation. To insure reliable system operation over time, the variation of the circuit from data sheet conditions must be considered).

Vishay has focused on the infrared LED to improve CTR degradation and consequently achieved a significant improvement in coupler reliability. The improvements have included die geometry to improve coupling efficiency, metallization techniques to increase die shear strength and to increase yields while reducing user cost, and junction coating techniques to protect against mechanical stresses, thus stabilizing long-term output.

CURRENT TRANSFER RATIO

The current transfer ratio (CTR) is the amount of output current derived from the amount of input current. CTR is normally expressed as a percent. For example, if 10 mA of input current is applied to the input (LED) and 10 mA of collector current is obtained, then the CTR is 100, or 100 %. CTR is affected by a variety of influences, including LED output power, h_{FE} of the transistor, temperature, diode current, and device geometry. If all these factors remain constant, the principle cause of CTR degradation is the degradation of the input LED.

As mentioned earlier, Vishay has made tremendous progress in manufacturing techniques to reduce CTR degradation. Vishay's manufacturing techniques maximize coupling efficiency, which realizes high transfer ratios and low input current requirements. Additionally, this allows a large variety of standard CTR values, and the capability of special selection in production volumes.

ISOLATION BREAKDOWN VOLTAGE

Isolation voltage is the maximum voltage which may be applied across the input and output of the device without breaking down. This breakdown will not normally occur inside the package between the LED and the transistor, but rather on the boundary surfaces across which partial discharges can occur. Vishay uses a double mold manufacturing technique where the LED and transistor are encapsulated in an infrared transparent inner mold. The next step in the process is an epoxy over mold. The double-mold technique lengthens the leakage path for high-voltage discharges appreciably, allowing the device to achieve very high isolation voltages. All of Vishay's optocouplers are built using UL-approved processes. A standard line of VDE-approved optocouplers is also available in the Agency Table section.

COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE

Collector-emitter breakdown voltage (BV_{CEO}) can be thought of as a transistor's working voltage. When considering the application, the selection should be made to include a safety margin to insure the device is off when it is supposed to be off. Vishay transistor technology in wafer processing offers a variety of BV_{CEO} devices. Each is parametrically tested to insure proper operation (see figure 1).

BLOCKING VOLTAGE

Blocking voltage (V_{DRM}, expressed in peak value) is used when describing the working voltage for SCR or TRIAC type devices. Vishay offers products through 800 V of blocking capability.

DV/DT RATING

dV/dt, an important safety specification, describes a TRIAC type device's capability to withstand a rapidly rising voltage without turning on or false firing. Vishay's TRIAC type devices have the highest available dV/dt rating offered on the market. Vishay's manufacturing process yields a 10 000 V/μs dV/dt rating. This rating eliminates the need for snubber (RC) networks which negatively affect loads sensitive to leakage currents, while reducing component count for circuit implementation and cost. An example of such a load would be neon indicator lamps. Vishay's TRIAC type devices also carry a load current rating three times the industry standard. This 300 mA current capability allows the device to drive most AC loads without the need for a follow-on TRIAC or interposing an electromechanical relay. Vishay manufactures this device with or without zero-crossing detector logic.

TABLE 1 - RELIABILITY REQUIREMENTS FOR OPTOCOUPLER ENVIRONMENTAL TESTS

TEST	APPLICABLE REFERENCE	TEST CONDITIONS
Thermal climatic	IEC 60068	T_C = - 55 °C to + 150 °C, (see datasheet)
Solderability	J-STD-002B	245 °C/3 s SMD lead (Pb)-free

TABLE 2 - LIFE TESTS

TEST	TEST CONDITIONS			
	TEMP. (°C)	RH (%)	BIAS	TIME (h)
Electrical life test	T_j max.	< 60	Derated max. rating	1000
Temp/humidity life	85	85	0	1000
High temperature reverse bias	According data sheet	< 60	80 % of max. voltage rating	1000

QUALITY AND RELIABILITY TESTS

The tests in figure 1 were performed on Vishay optocouplers. The tests allow early detection of weak points and provide information regarding the reliability characteristics of the component.

From the life test information, assumptions of useful life expectancy can be obtained. All quality and reliability tests are performed in conditions that either exceed or are equivalent to the limits defined in our data sheets. International standards are also considered. Assuming that no additional failure mechanisms are created by the stress conditions, the results of the stress test will correlate to conditions in the field and can be used to estimate useful lifetime. The environmental stress tests ensure Vishay’s manufacturing capabilities will provide package integrity in the most rigorous conditions. The life test results highlight our ability in packaging and electrical performance to achieve MTTF hours which meet or exceed the highest industry standards for the semiconductor.

PACKAGE INTEGRITY

Although packaged in standard IC configurations, optocouplers have some unique package considerations. The use of two-chip and internal-light-transfer mediums require careful selection of materials to insure compatibility under a variety of operating conditions. In addition to the high isolation voltages achieved by Vishay optocouplers, our devices are tested to assure high levels of mechanical integrity and moisture resistance.

PACKAGE DENSITY

Board space has become increasingly important in the electronic industry. Vishay uses a plate molding technique to achieve reduction in cost, allowing us to offer a wide selection of packages. These consist of single-channel optocouplers in 4, 6, 8, and 16 pin packages, dual-channel devices in 8 pin DIP or SMD packages, and quad-channel devices in 16 pin DIP packages. The above devices are available in two surface mount lead configurations, as well as the standard through-hole lead. Vishay also has a standard single- and dual-channel optocoupler in an SOIC-8 package. The dual SOIC-8 package has the highest packaging density of any high-volume standard optocoupler available. All of these packages have been designed and tested to meet the highest quality and reliability expectations of the semiconductor industry.

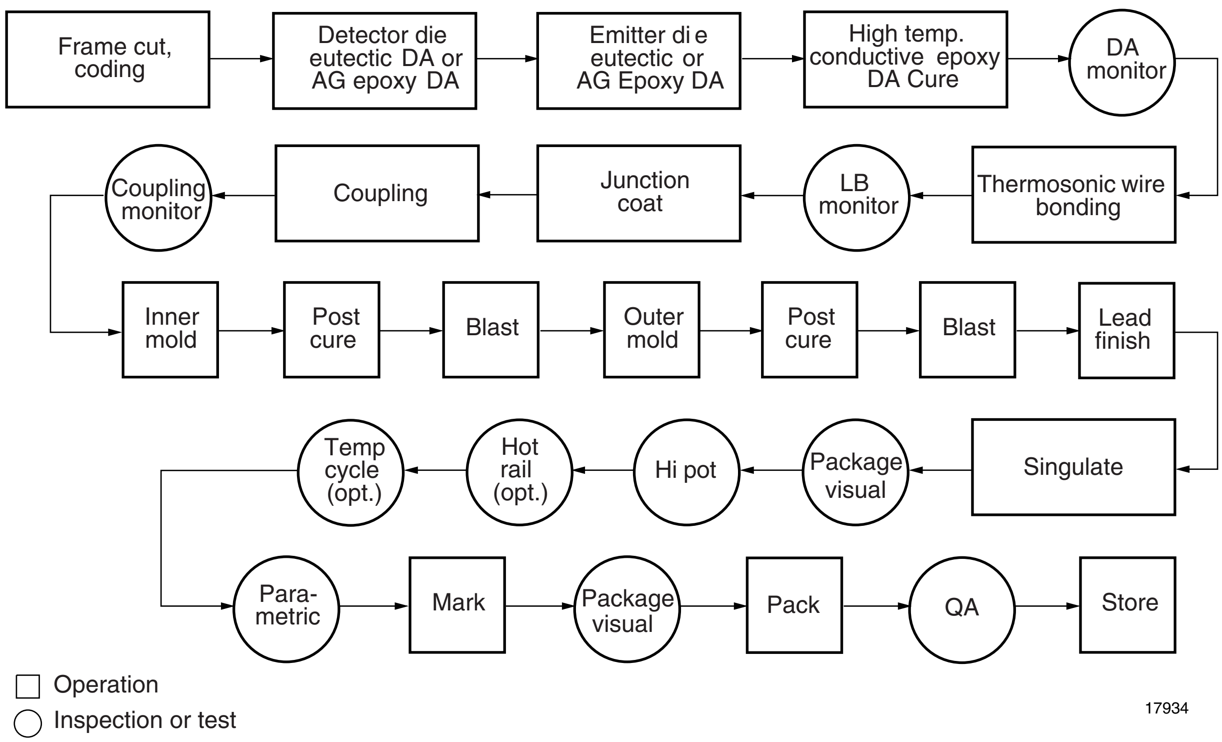

Fig. 1 - Coupler Process Flow and Inspections