

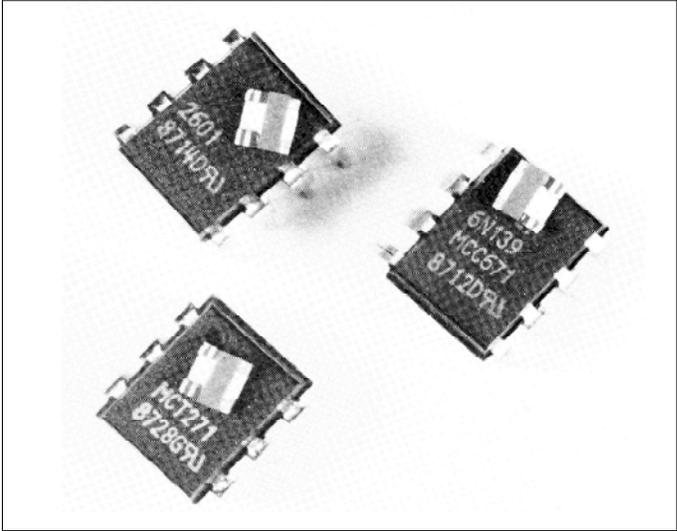


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Optocouplers for the Hybrid Industry

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Hybrid optocouplers compared to their dual in-line plastic package counterparts. Hybrid optocouplers are smaller and made for hybrid mounting.

The use of optocouplers in the hybrid industry has generally lagged behind their appearance in nonhybrid fields. While most hybrid applications for optocouplers are limited to simple phototransistors, nonhybrid designers are producing circuits with state-of-the-art high-performance optocouplers in dual in-line packages. These optocouplers offer design benefits and flexibility, including high speed, very low input current operation, high common mode rejection, high input to output insulation, logic compatible inputs and outputs, integrated line receiving functions, AC/DC to logic interfacing, and current loop and output and highrel/military applications. Unfortunately, these readily available optocouplers are not always obtainable in hybrid-compatible form. Engineers themselves must design hybrid optocouplers from basic components each time designs require optocoupling.

First, hybrid optocoupler designers must understand the need for optocoupling in the circuit. What circuit portion requires isolation? What voltage? How much input current is available and how much output current is necessary? What data rate or switching speed is required? What about common mode rejection? Engineers must choose the correct emitters and detectors for these design restrictions. Often, high-performance emitters and detectors are not readily available, especially in small quantities for prototype designs and pilot pro-

ductions. In this case, the layout and package must be produced and the emitter and detector assembled, coupled, and characterized.

Employing optocouplers in circuit designs is hampered because these optocouplers must be created with wide performance margins since the entire hybrid circuit cannot be tested until the emitter and detector are coupled with a lightpipe. Rework of a faulty hybrid assembly would be difficult at best and often inadvisable or impossible. However, due to higher levels of integration in future hybrid designs and especially in telecommunications, power controlling and monitoring, and electromechanical interfacing, more optocoupling and optoisolation will be the trend.

Optocoupler Basics and Construction

Every optocoupler has three basic elements - a light emitter, light detector, and coupling medium which are critically linked

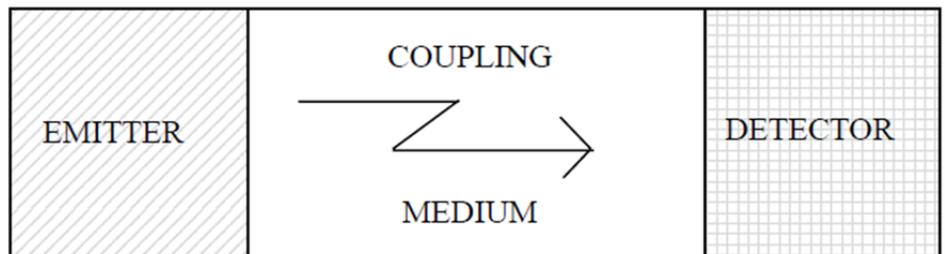


Figure 1, the basic elements of an optocoupler.

to each other. One element without the other two will not function as an optocoupler, as seen in figure 1.

The emitter is usually a light emitting diode (LED). When a forward current is passed through the LED, photons are generated. The amount of light emitted by the LED is directly proportional to the amount of current entering it. Depending on the optocoupler's function and application, the wavelength of the light emitted from the LED can be selected from red to near infrared (650 to 950 nm). LED construction can be as simple as a liquid phase epitaxy (LPE) gallium arsenide (GaAs), to vapor phase epitaxy (VPE) gallium arsenide phosphide (GaAsP), to more exotic, state-of-the-art LEDs of single and double heterojunction gallium aluminum arsenide (GaAlAs).

LED selection is the most critical element of an optocoupler design because LED characteristics determine optimum detector and packaging design. For slower applications, GaAs LED at 940 nm emission wavelength usually is used due to its easy

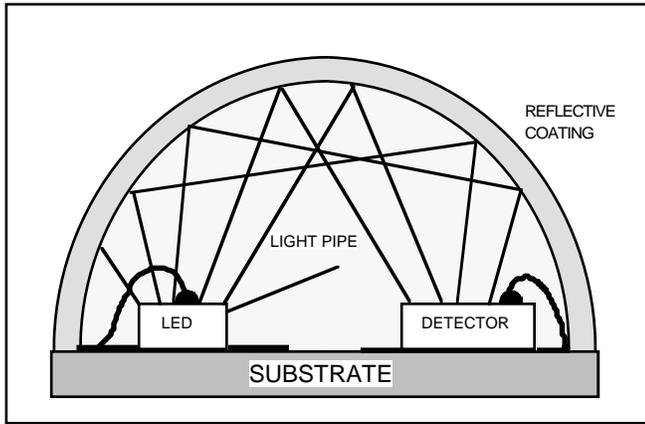


Figure 2a, side-by-side reflective coupling.

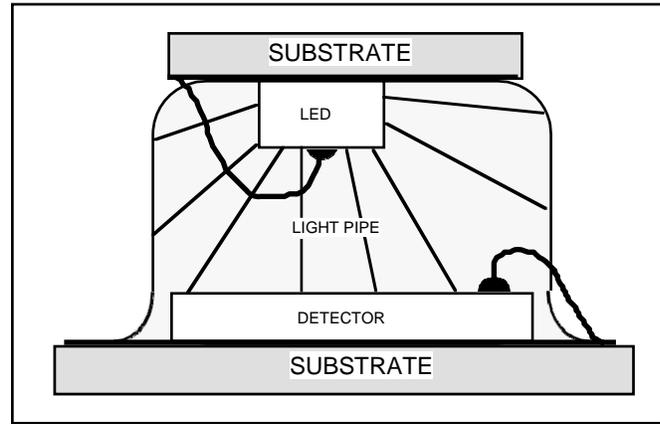


Figure 2b, over-under direct coupling.

availability, relatively high power output, and low cost. Infrared GaAlAs LEDs also are employed for this application and have two to three times better radiated output power (ROP) than GaAs LEDs and their approximately 880 nm emitted wavelength matches the responsivity of silicon detectors better than GaAs for higher coupling efficiency. For high speed optocouplers, LEDs in the red or near infrared wavelength range are used. These LEDs usually boast less than 40 ns light output response times and the emitted wavelength is optimized for use with high speed photodiodes.

The basic detector is a photodiode that detects light and converts photons to electrons. For simple phototransistors, the photodiode is usually the transistor's collector/base junction. The area of the base is increased to many times that of a standard transistor to maximize light collection; then the transistor amplifies the photocurrent generated by the collector/base junction.

For high-speed detectors, the photodiode is a separate photodiode integrated with other elements in an integrated circuit. This design reduces the capacitance effect of the large collector/base junction employed in phototransistors. Photodiode junction depth also can be optimized for responsivity at a near infrared wavelength. With the integrated detector approach, many circuit designs can be produced for various optocoupling functions. For photovoltaic optocouplers, the detector is an integrated array of dielectrically isolated photodiodes connected in series to generate a voltage when light is detected. The

resulting isolated floating voltage and current are used to drive the gate of MOS transistors.

The coupling medium optimizes light emitted by the LED and couples the light to the photodetector. This material must be optically transparent to the emitted wavelength. The index of refraction should be as high as possible to better match the LED and silicon material's indexes of refraction

- common materials for this purpose are silicones and epoxies. A reflective coating sometimes is placed over this lightpiping medium to optimize coupling efficiency. Coupling and reflective coatings must be chosen carefully so as not to place excessive thermomechanic stress on the LED and connecting wires.

Since optocouplers isolate the circuits on the input side of the optocoupler from the output side and vice versa and prevent unwanted high voltages, the coupling material's dielectric performance and LED and detector layout are very important. LED and detector positioning is a compromise between the need to optimize the light coupling from the LED to the detector and space them apart for high insulation performance between the two.

The most common layouts are side-by-side reflective coupling or overunder direct coupling, as shown in figure 2. In the side-by-side reflective construction, the LED and detector are placed on the same plane. Light coupling is accomplished by placing lightpiping material connecting the light emitting area of the LED and the photosensitive portion of the detector, laying a white reflective coating over the transparent material to improve light coupling

and reduce light leakage to the outside. In the over-under direct coupling method, the LED faces the detector and a lightpipe material is placed between the two to couple the light and act as a dielectric.

The side-by-side reflective method is simple and easy to assemble compared to the over-under direct coupling technique. However, its coupling efficiency is not as favorable as that of over-under direct coupling. For some high performance optocouplers, over-under coupling must be employed due to the low light output of some high-speed emitters. No matter which construction is used, the optocoupler's functionality cannot be fully tested or characterized until coupling is complete.

Optocoupler Parameters

Some important optocoupler characteristics are forward coupling efficiency, input current requirements, input to output insulation voltage, switching speed, and temperature performance, as illustrated in table 1.

Forward coupling efficiency can be quantified as current transfer ratio (CTR) for transistor products. CTR is the ratio of output current to input current. A CTR of 100 percent means a 10 mA input to the LED will result in a 10 mA output collector current. For logic output optocouplers, coupling efficiency can be quantified as the input current to the LED that would cause a change of logic state to the optocoupler's output. The better the LED power output and coupling, the higher the CTR for the same transistor gain. For logic

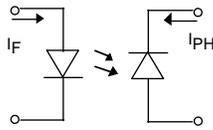
TABLE 1 - COMMON OPTOCOUPLER CONFIGURATIONS

Types/Part number

Schematic

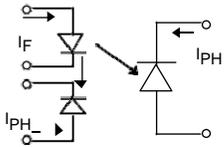
Characteristics

High Voltage Photodiode



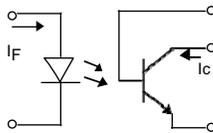
High voltage photodiode > 1000 V
signal level ~10 to 100 A

Photodiode Feedback
OLS 700



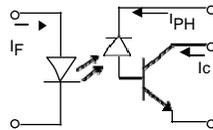
Excellent linear output vs. input Feedback photodiode regulates forward photodiode transfer linearity.

Phototransistor
OLI 100



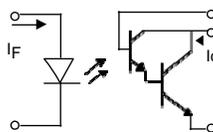
General purpose.
Good output signal level,
~1 to 20 mA
Slow switching speed, ~ 10 to 50 S
SIMILAR TO 4N2X/3X

Photodiode/Transistor OLI
300



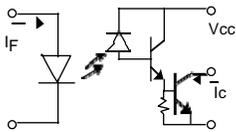
General purpose.
Good CTR.
High switching speed, ~0.2 to 2.0 S
SIMILAR TO 6N135/136

Photodarlington
OLI 200



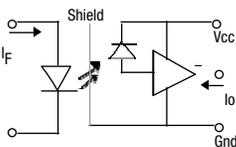
High output at low input current
Limited operating temperature.
Very slow switching speed,
~100 to 1000 S
High Vsat, ~1V

Photodiode/Darlington
OLI 400



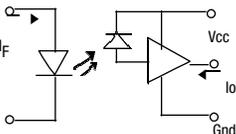
High output current at very low input current, as low as 250 A
Wider operating range than Photodarlingtons. Fair switching speed, ~10 to 100 S.
Low Vsat, ~0.2V SIMILAR TO 6N138/139

High-speed Logic Gate
High common mode
OLI 500



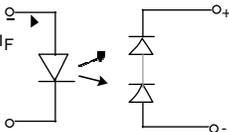
Logic compatible output.
Very High switching speed, ~50 to 100nS.
SIMILAR TO 6N137

High-speed Logic Gate
OLI 600



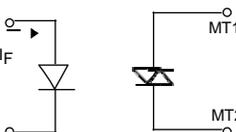
Vcc and Vout 18v., Logic compatible output.
Very high switching speed, ~200 to 300nS.

Photovoltaic
OLI 900



Floating voltage generator for driving power MOS gates.
Dielectrically isolated photodiode array.

Phototriac
and Custom optocoupler
CALL FACTORY



AC power control.
High breakdown voltage, >500 Vrms. →
Can be used to drive power triac gates.

optocouplers, lower LED current would be required to change the output logic state. The present trend is for optocouplers with reduced input power. New hybrid optocouplers are now available to operate with as little as 0.25 mA LED current, which is important for direct CMOS drive compatibility. Low input current places more constraints on hybrid optocoupler designers for choice of LED and coupling optimization. Most simple hybrid phototransistor optocouplers require at least 5 mA of LED current for usable output current.

Most optocoupler hybrid applications call for a minimum of 500 V DC of insulation between optocoupler input and output. With proper layout, packaging, and LED and detector selection, insulation voltage up to 2500 V AC is achievable without significantly compromising coupling efficiency.

For simple phototransistors, switching speed is in the tens of microseconds range. Usually, if the LED is brighter than usual, the transistor will turn on faster since more photocurrent is generated to charge the circuit capacitance faster. If transistor gain is made higher than normal for higher CTR, turn-off time will be longer due to more charge storage and slower rise time. If higher switching speeds are required, an

integrated photodiode-transistor detector is needed.

This method separates the optocoupler light-gathering function from the amplification function. The transistor now can be of small geometry to optimize switching characteristics. Switching speed for this type of hybrid optocoupler is from approximately 0.2 s to 1.5 s. To achieve even higher switching speeds, logic optocouplers are available with Schottky-clamped output transistors with switching speeds of 50 ns to 100 ns, approximately 10 MHz.

Some hybrid circuits are expected to operate over a wide temperature range and optocouplers used in these hybrids also must function within that temperature range. LED light output decreases with increasing temperature, which reduces the amount of light detected by the photodiode and lowers the output current at high ambient temperatures. Detector gain also varies with temperature change. At high temperatures the current transfer ratio tends to decrease while leakage current tends to increase. Switching time also is affected by ambient temperature and should be fully characterized to provide hybrid circuit designers information needed to guarantee total hybrid performance over the required temperature range. LED light outputs

degrade with operating time. Usually, the degradation range is higher with higher temperatures and higher current entering into the LED. LED degradation parameters must be characterized empirically with accelerated high-temperature operating life tests. Present LED emitters usually have excellent light degradation characteristics with less than a 5 percent average decrease in light output in 1000 hours of continuous operation. With careful circuit design and component choice, LED light degradation effect on the optocoupler's operating life performance can be managed.

Conclusion

Use of optocouplers in hybrid design is increasing. By understanding the characteristics and performances of various optocouplers, hybrid designers can benefit from greater design flexibility, higher levels of integration in designs, and new opportunities.

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