

I'm not a robot



Opto isolator working principle

Optocouplers, also known as optoisolators or photocouplers, enable efficient transmission of DC signals and data between two circuit stages while maintaining excellent electrical isolation. They are particularly useful where extreme electrical isolation is required between stages. Optocouplers work by converting logic levels between circuits, blocking noise transfer, and eliminating ground loops. They can replace relays and transformers in digital circuit interfaces and offer unparalleled frequency response in analog circuits. Internally, an optocoupler consists of an infrared LED and a silicon photodetector device, such as a photo-transistor or photodiode, hermetically sealed in an opaque package. When the IR LED emits radiation at 900-940 nanometers, it activates the adjacent photodetector, creating continuity across its collector/emitter terminals. The device is molded in a light-proof epoxy resin and features a pinout diagram with neatly bent downward lead-frame pins. Two separate circuits utilize a solitary isolated internal infrared light signal. Pin three is either unconnected or open, rendering it irrelevant. It's feasible to convert the internal IR phototransistor into a photodiode by bridging and connecting pins six and four. This might not be accessible in a 4-pin optocoupler or multi-channel optocouplers due to varying specifications. Optocouplers exhibit a notable characteristic - their light coupling efficiency, denoted as the current transfer ratio (CTR). The CTR ratio is optimized when the IR LED signal spectrum harmoniously aligns with its adjacent phototransistor detection spectrum. It's calculated as the output current to input current ratio at a specific rated bias level for each optocoupler device:

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{\displaystyle CTR={I_{ced} \over I_{f}}\times 100\%.}

 A CTR of 100% indicates an output current transfer of one milliampere for every milliampere of IR LED current. The minimum CTR values can vary between 20 to 100 % across different optocouplers, influenced by input and output supply voltage and current specifications. Factors affecting the CTR include instantaneous voltage and current variations across the device's internal circuit stages. A graphical representation illustrates the relationship between phototransistor output current (ICB) and input current (IF) under a 10 V collector/base pin bias. Key optocoupler specification parameters include: Isolation voltage (Viso): the absolute maximum AC voltage that can exist across input and output circuit stages without causing harm, typically ranging from 500 V to 5 kV RMS. VCE: the maximum DC voltage applied across phototransistor pinouts, usually between 30 to 70 volts. If: the maximum continuous DC forward current flowing through the IR LED or IRED, standard values ranging from 40 to 100 mA. Rise/fall time: a measure of logical speed and bandwidth, typically within 2 to 5 microseconds for both rise and fall times. A basic optocoupler circuit is shown, where the amount of current passing through the phototransistor depends on the applied forward bias current of the IR LED or IRED, despite separation. When switch S1 is open, no current flows through the IRED, rendering the device inactive and resulting in zero voltage across output resistor R2. Upon closing S1, current flows through the IRED and R1, activating the IR LED and enabling it to switch ON, ultimately causing an output voltage to develop across R2. This basic circuit is specifically responsive to Optocouplers are versatile devices that can handle various types of input signals, including digital and analog inputs. They can also generate corresponding output signals in both formats. The phototransistor of an optocoupler may have different gain and working specifications, leading to diverse variants with unique combinations of IRED and output photodetectors. One variant features a bidirectional input, and phototransistor output, using gallium-arsenide IREDS for AC signal coupling and reverse polarity protection. Another type has a silicon-based photo-darlington amplifier, boosting its output current to 500% CTR at 30-35 volts. This, however, may compromise speed and bandwidth. Industry-standard photodarlington optocouplers include the 4N29 to 4N33, 6N138, and 6N139. A third variant features a MOSFET photosensor with bi-directional linear output, offering isolation up to 2500 volts RMS. Other types include SCR-based opto sensors, phototriac-output couplers, and Schmitt trigger IC-based devices. These latter devices convert sine wave or pulsed input signals into rectangular output voltages, making them suitable for multivibrator circuits. Given text here The IR LED of an optocoupler requires a resistor to regulate input current within safe limits. This resistor can be connected in two primary configurations: series with the anode (a) or cathode (b) terminal of the IRED. For AC inputs, AC optocouplers are recommended, but any standard optocoupler can also be configured with an AC input by adding an external diode to the IRED input pins. This setup ensures safety against accidental reverse input voltage conditions. To convert a digital or analog signal at the output of the optocoupler, a resistor can be added in series with the optotransistor collector pin or emitter pin. The output photo-transistor's base pin 6 can also be connected to ground, resulting in a drastic reduction in CTR value and an increased rise time. Optocouplers are suitable for digital signal interfacing, operating at various supply levels. They can interface with identical TTL, ECL, or CMOS family ICs, as well as personal computers or microcontrollers with mainframe computers or loads like motors, relays, solenoids, and lamps. A specific example is the interfacing diagram of an optocoupler with TTL circuits, where the IRED is connected across the +5V and TTL gate output instead of between the TTL output and ground. This connection allows optimal activation current for IRED whenever the TTL is low but also inverts the output response. Given article text here IC's can be easily interfaced with optocouplers IRED either in the sink mode or source mode. No matter the configuration chosen at the input side, R2 at the output must be large enough to enable full voltage swing between logic 0 and 1 states at the CMOS gate output. A microcontroller or Arduino output signal can be interfaced with an optocoupler through HJT stages. The IRED and phototransistor remain switched off when a HIGH +5V logic is applied from the Arduino, keeping Q1, Q2, and the load motor on. Once the Arduino output goes low, the optocoupler IRED activates, turning ON the phototransistor and switching OFF Q1, Q2, and the motor. An optocoupler can be used to interface analog signals across two circuit stages by determining a threshold current through the IRED and modulating it with the applied signal. This technique can be applied for coupling an analogue audio signal. The op amp IC2 is configured as a unity gain voltage follower circuit, with the IRED's negative feedback loop causing the voltage across R3 to precisely follow the applied voltage. The quiescent current or idle current draw for the IRED is attained at 1-2 mA via R3, while the phototransistor determines the output current on the other side of the optocoupler. This generates a voltage across potentiometer R4 whose value needs to be adjusted for optimal performance. The tracking modulated audio-output signal equivalent can be extracted across R4 and decoupled through C2 for further processing. Optocouplers are ideal for creating perfectly isolated coupling between low DC control circuits and high AC mains-based triac control circuits. It is recommended to keep the ground side of the DC input connected to a proper earthing line. The complete setup can be used for an isolated control of mains AC lamps, heaters, motors, and other similar loads. When switch S1 is closed, it instantly activates the IRED, which then turns on Q1. Q1 subsequently connects the 10V DC to the gate of the triac, switching it on and also turning on the connected load. The next circuit uses a silicon monolithic zero-voltage switch, the CA3059/CA3079. This circuit allows the triac to trigger only during the zero voltage crossing of the AC cycle waveform. When S1 is pressed, the opamp responds to it if the triac input AC cycle is near the zero crossing line. If the input trigger is made while the AC is not near the zero crossing line, then the opamp waits until the waveform reaches the zero crossing and only then triggers the triac via a positive logic from its pin4. This zero-crossing switching feature protects the connected load from sudden huge current surges and spikes, as the turn-on occurs at the zero crossing level and not when the AC is at its peaks. This also eliminates unnecessary RF noise and disturbances in the power line. The optocoupler triac-based zero-crossing switch can be effectively used for making SSR or solid-state relays. Optocouplers with photodetectors in the form of photoSCR and photo-Triac-output are generally rated with lower output current. However, unlike other optocoupler devices, optoTriac or optoSCR feature a rather high surge current handling capacity (pulsed) which may be much higher than their rated RMS values. The following images show a few application circuits using triac optocouplers. In the first diagram, the photoTriac can be seen configured to activate the lamp directly from the AC line. The bulb must be rated at less than 100 mA RMS and a peak inrush current ratio lower than 1.2 amps for safe working of the optocoupler. The second design shows how the photoTriac optocoupler can be configured for triggering a slave Triac, and subsequently activating a load as per any preferred power rating. This circuit is recommended to be used only with resistive loads such as incandescent lamps or heater elements. The third figure above illustrates how the upper two circuits could be modified for handling inductive loads like motors. The circuit consists of R2, C1, and R3 that generate a phase shifting on the gate drive network of the Triac. This allows the triac to go through a correct triggering action. Resistor R4 and C2 are introduced as a snubber network to suppress and control surge spikes due to inductive back EMFs. In all the above applications, R1 must be dimensioned such that the IRED is supplied with at least 20 mA forward current for proper triggering of the triac photodetector. The above figures explain a couple of unique customized optocouplers modules which could be used for speed counter or RPM measurement applications. The first concept shows a customized slotted coupler-interrupter, while the second design illustrates how the photoTriac optocoupler can be configured for triggering a slave Triac and subsequently activating a load. The third figure shows how the upper two circuits could be modified for handling inductive loads like motors. A specific optocoupler module features a discrete arrangement of an infrared emitter (IRED) and phototransistor, separated by an air gap slot. This setup enables IR signals to pass through the slot without obstruction when powered. However, when an opaque object is introduced, it can block the IR signal, leading to clock frequency variations at the phototransistor output terminals, which can be processed for measurement purposes. The module has a width of approximately 3 mm and uses a phototransistor with a minimum CTR of around 10% in its "open" condition. It is essentially an embedded optocoupler replica, differing from standard designs only in being discretely assembled within separate boxes. This type of optocoupler module can be used for measuring revolutions or as a revolution counter. Each time the wheel tab crosses the slot, the phototransistor switches OFF, generating a single count. The second design illustrates an optocoupler module designed to respond to reflected IR signals. The IRED and phototransistor are installed in separate compartments, allowing them to "see" each other only when objects move within a 5 mm focal point angle from the common optical axis. This enables the interrupter module to detect nearby moving objects that cannot be inserted into thin slots. This reflective opto module can be used for counting the passage of large objects over conveyor belts or down feed tubes. In this application, the module detects reflected IR signals between the IRED and phototransistor through mirror reflectors mounted on the opposite surface of a rotating disk. The separation between the optocoupler module and spinning disk is equal to the 5 mm focal length of the emitter detector pair. Reflective surfaces can be created using metallic paint or tape, or glass. These discrete optocouplers modules can also be effectively applied for engine shaft speed counting and RPM measurement, among other uses. The concept of photo interrupters and photoreflectors can be built using various opto detector devices, such as photodarlington, photoSCR, and photoTriac devices, depending on the output circuit configuration specifications. Furthermore, this optoisolator interrupter module can also function as a door or window intrusion alarm. This circuit is more effective and easier to install than traditional magnetic relay intrusion alarms. The air gap slot plays a crucial role in this application. optocouplers use an attachment to block the optoisolator, which can be integrated into the window or door Opening the door or window removes the blockage, allowing the IR LED to reach the phototransistors and activate the one-shot monostable IC 555 stage.The IC 555 instantly triggers the piezo buzzer, alerting to an intrusion.Figure 1 shows the typical pinouts for main optocoupler families in DIP6 packages, with output stages initially using photodiodes or phototransistors.Diversity emerged with output stages using Darlington, thyristor, and triac circuits.More recently, logic interfaces have been specifically designed, characterized by low input current and Schmitt trigger logic output stages.Figures 3h and 4c show these new optocouplers are compatible with TTL or CMOS logic circuits as inputs and outputs.Optotransistors represent most optocoupler production, using phototransistors for the output stage.Current passing through IRED irradiates the base-collector junction of a photosensitive transistor, converting light energy into current.This is amplified by the transistor's gain or hFE.The ratio between collector current and IRED bias current is generally 10% to 500%.Some models connect an output pin to the phototransistor's base (Figure 2b), mainly for dynamic behavior improvement and signal reduction.By using a resistance of around 100 kΩ to 300 kΩ, parasitic capacitances can be discharged, improving switching speed.The discharge of these capacitances improves turn-off duration, particularly reducing signal distortion.Optodarlington has a photodarlington output stage similar to the optotransistor, but with better transfer ratios up to 1,000%.Optothyristors have photosensitive thyristors as detectors, used for AC mains applications with safety isolation measures.These optocouplers have become popular for interfaces between logic circuits and AC mains applications.Figures 1e show two types of optotriacs, one triggering at zero crossing of sector voltage.Optotriacs offer a progressive growth feature to avoid current spikes and limit AC interference. Optocouplers have evolved to offer faster switching speeds and improved functionality. Initially, fast optocouplers were developed with rise and fall times under 4 ps, featuring integrated detectors with Schmitt triggers and stable power supplies ranging from 3 to 15 V. Their outputs are often open collector, requiring an external power supply and often including an "Enable" input for blocking the output. Later generations of optocouplers allowed switching speeds of around 10 Mbd, with the output stage being an integrated detector requiring an external +5 V power supply. The pinout of these new models varies among manufacturers, but some brands offer logic output optocouplers in DIP6 packages that can be used with DIP6 packages. Over time, many different types of optocouplers have been manufactured to meet various applications, including those with DIP4 or DIP8 packages and pinouts similar to popular DIP6 packages. Some models combine multiple optocouplers with independent inputs/outputs in the same package, while others feature a reversal of pinout between the emitter and collector of the phototransistor. Some variants include diodes in anti-parallel on the IRED of the input stage to protect against reverse voltage when the power source is alternating. Optocouplers also exist in Darlington or FET versions, offering various logical functions such as non-inverted and inverted connections. For example, a non-inverted logical connection can be achieved by blocking the photo-transistor in the absence of voltage on the input (E), while an inverted connection is obtained by placing the resistor RS between the collector of the photo-transistor and the power supply Valim. Using two optotransistors, logical functions AND, OR, NAND, NOR can be wired by placing the output stages in series. The RS circuit can only be activated when both photo-transistors are in an active state. This means that inputs E1 and E2 must be engaged simultaneously for current to flow (refer to figures 7c and 7e). The OR and NOR functions are implemented by connecting the output stages of two optocouplers in parallel, allowing at least one to activate the logical state of the output (see figures 7d and 7f). Additionally, inputs E1 and E2 can be isolated or share a common ground. By placing the load resistor at the output connected either to ground or the power supply positive, the inversion of OR and AND functions is achieved similarly as with "Follower" and "Inverter" connections. A brief pulse on input S is sufficient to switch output Q to its "high" state, while a reset pulse on input R returns it to its original state (refer to timing diagrams in Figure 6). One key aspect of this circuit is the use of optocouplers, particularly their optional connection that provides an additional output stage connected to the base of the phototransistor. This setup illustrates one utility of this optional connection. A monostable function can be achieved with the circuit shown in Figure 7 by applying a brief input pulse, resulting in a "stable high" state at the output whose duration is directly proportional to R x C (time constant). Although primarily designed for logic level transmission, optocouplers can also be used in audio applications, such as the one depicted in Figure 8. In this scenario, the phototransistor operates in linear mode, and it's essential to limit distortion of the audio signal by placing the DC bias current of the IRED at the center of a linear portion of the IRED characteristic. Typical application examples involving optocouplers are shown in Figure 5, where RE and RS correspond respectively to the input current calibration resistor and the output discharge resistor. These resistors should be systematically determined based on various applications. When using an optocoupler as a switch, resistance RE should be sufficiently low to ensure that the IRED receives sufficient current, approximately 5-10 mA in general use cases. The value of RE can be calculated based on the level of voltage applied to the optocoupler. For instance, with a +5 V source and an IF current of 10 mA, the calculation for RE is (5 - VF) / 0.01, where VF is the forward voltage drop across the IRED, approximately 1.1-1.5 V. Therefore, a resistance of 330 ohms would be suitable in this case. The load resistance RS should have a minimum value RS(min), dependent on the supply voltage and the current transfer ratio between the input and output for the phototransistor to be sufficiently saturated. Older documentation provided a curve indicating the collector current Ic as a function of IF (Figure 9 below), while more recent documentation provides the CTR ratio, the ratio between the output and input currents. The input current of an optocoupler and its operational modes play a crucial role in determining key performance ratios.The two primary ratios established by the operating mode are saturation CTR (Current Transfer Ratio) and linear CTR. These ratios, CTR(sat) and CTR(linear), depend on whether the optocoupler is functioning in saturation or linear mode. In saturation mode, when the collector-emitter voltage (VCE) is 0.4 V, these ratios can sometimes decrease below their optimal values. In contrast, during linear operation, which typically occurs at a VCE of +5 or +10 V (as specified by the manufacturer), these ratios remain relatively stable.To calculate the minimum resistance required for an optocoupler circuit, the expression RS(min) = (Vsupply - 0.4)/(CTR x IF - IL) can be used. For instance, if we're dealing with a transfer ratio of 12%, an input current (IF) of 10 mA, and a +5 V power supply, along with an HCMOS logic that draws an IL of 50 pA, the calculation becomes RS(min) = 4.6/(0.12 x 0.01 - 50 x 10^-6). This results in a value for RS(min) of approximately 4.0 kΩ.It's essential to note that the minimum resistance should be at least four times greater than the collector current (Ic).Therefore, using a resistance of around 4.7 kΩ will not only meet this requirement but also enhance the speed of optocoupler switching by reducing the RS resistance.