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Guidelines for reading an optocoupler datasheet

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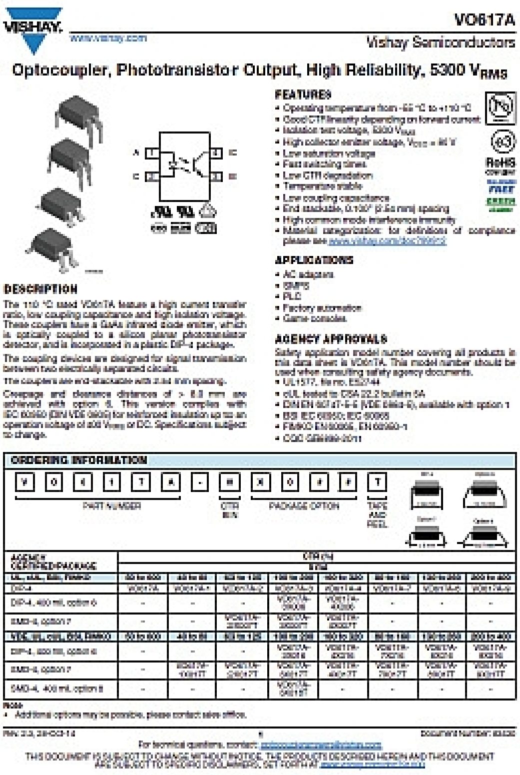
Introduction

Optocouplers, also known as opto-isolators, are components that transfer electrical signals between two isolated circuits by using infrared light. As an isolator, an optocoupler can prevent high voltages from affecting the side of the circuit receiving the signal. Transferring signals over a light barrier by using an infrared light-emitting diode and a light-sensitive product, such as a phototransistor, is the main structure of an optocoupler. On the first page, datasheets provide the main product description, its features, suggested areas of applications, ordering information, and agency approvals, as shown in Figure 1 for the VO617A optocoupler with phototransistor output. Following pages provide key technical specifications, operating conditions, and graphs showing the behavior of the product.



VO617A

Vishay Semiconductors

Optocoupler, Phototransistor Output, High Reliability, 5300 V_{RMS}

FEATURES

- Operating temperature from -55 °C to +110 °C
- Good CTR linearity depending on forward current
- Isolation test voltage, 5300 V_{RMS}
- Low saturation voltage
- Fast switching times
- Low CTR degradation
- Temperature stable
- Low coupling capacitance
- High common mode interference immunity

APPLICATIONS

- AC adapters
- SMPS
- PLC
- Factory automation
- Game consoles

AGENCY APPROVALS

Safety application model number covering all products in this data sheet is VO617A. This model number should be used when consulting safety agency documents.

DESCRIPTION

The 110 °C rated VO617A feature a high current transfer ratio, low coupling capacitance and high isolation voltage. These couplers have a GaAs infrared diode emitter, which is optically coupled to a silicon planar phototransistor detector, and is incorporated in a plastic DIP-4 package.

The coupling devices are designed for signal transmission between two electrically separated circuits.

ORDERING INFORMATION

AGENCY CERTIFIED/PACKAGE	CTR (%)							
	5 mA							
UL, cUL, BSI, FIMKO	50 to 600	40 to 80	63 to 125	100 to 200	160 to 320	80 to 160	130 to 260	200 to 400
DIP-4	VO617A	VO617A-1	VO617A-2	VO617A-3	VO617A-4	VO617A-7	VO617A-8	VO617A-9
DIP-4, 400 mil, option 6	-	-	-	VO617A-3X006	VO617A-4X006	-	-	-
SMD-4, option 7	-	-	VO617A-2X007T	VO617A-3X007T	VO617A-4X007T	-	-	-
VDE, UL, cUL, BSI, FIMKO	50 to 600	40 to 80	63 to 125	100 to 200	160 to 320	80 to 160	130 to 260	200 to 400
DIP-4, 400 mil, option 6	-	-	-	VO617A-3X016	VO617A-4X016	VO617A-7X016	VO617A-8X016	VO617A-9X016
SMD-4, option 7	-	VO617A-1X017T	VO617A-2X017T	VO617A-3X017T	VO617A-4X017T	VO617A-7X017T	VO617A-8X017T	VO617A-9X017T
SMD-4, 400 mil, option 8	-	-	-	VO617A-3X018T	-	-	-	-

Note
- Additional options may be possible, please contact sales office.

Figure 1: First page of VO617A datasheet

Datasheets generally begin with a header stating the product’s name, which is followed by a graphic representation of the package and symbol. Key features follow, with a list of the most popular applications and available safety agency approvals. An example has been given in Figure 1, which shows the introduction page for the VO617A. In general, all datasheets contain the following information:

- Description
- Features
- Applications
- Agency approvals
- Ordering information
- Absolute maximum ratings
- Electrical characteristics
- Current transfer ratio (CTR)
- Switching characteristics
- Safety and insulation ratings
- Typical static graphs
- Typical dynamic graphs
- Packaging dimensions, markings, and packaging

Description, features, applications, and agency approval information

The description will introduce the product, the main product category, the technology used, and its features. Special specifications such as high operating temperature, high current transfer ratio, and low coupling capacitance are identified to give an overview. The application section introduces the most common applications using the component. The agency approvals section provides an overview of the product's approvals to different standards and agencies. Above the description, a symbol and selection of package types are shown.

Optocouplers are available in many different packages and configurations. One typical symbol that can be found — an infrared diode and a phototransistor together in a 4-pin package — is shown in Figure 2. Figure 2 also highlights the different packages in which the VO617A is available. The first is the DIP 4 (dual in-line package), which is connected through the PCB. The others are SMD packages with different bending options to the pins. They are populated on the top of the PCB.

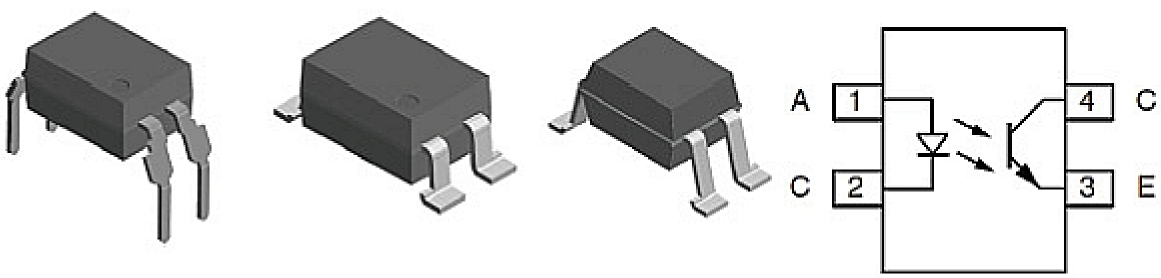
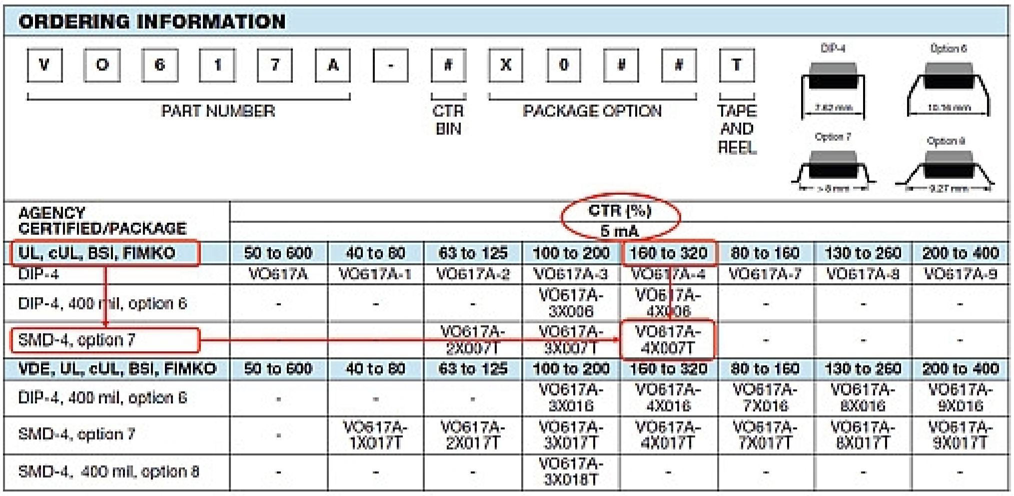


Figure 2: Typical packages and symbols

Ordering information

Intended to provide precise ordering information, the ordering information table indicates the basic part number and the nomenclature of available options that will complete a product part number. In Figure 3 the part numbering of the VOS617A is shown.



AGENCY CERTIFIED/PACKAGE	CTR (%) 5 mA							
UL, cUL, BSI, FIMKO	50 to 600	40 to 80	63 to 125	100 to 200	160 to 320	80 to 160	130 to 260	200 to 400
DIP-4	VO617A	VO617A-1	VO617A-2	VO617A-3	VO617A-4	VO617A-7	VO617A-8	VO617A-9
DIP-4, 400 mil, option 6	-	-	-	VO617A-3X006	VO617A-4X006	-	-	-
SMD-4, option 7			VO617A-2X007T	VO617A-3X007T	VO617A-4X007T	-	-	-
VDE, UL, cUL, BSI, FIMKO	50 to 600	40 to 80	63 to 125	100 to 200	160 to 320	80 to 160	130 to 260	200 to 400
DIP-4, 400 mil, option 6	-	-	-	VO617A-3X016	VO617A-4X016	VO617A-7X016	VO617A-8X016	VO617A-9X016
SMD-4, option 7	-	VO617A-1X017T	VO617A-2X017T	VO617A-3X017T	VO617A-4X017T	VO617A-7X017T	VO617A-8X017T	VO617A-9X017T
SMD-4, 400 mil, option 8	-	-	-	VO617A-3X018T	-	-	-	-

Figure 3: Product ordering information table

The complete part number is determined by the selection of several options. As an example, the table in Figure 3 shows the part VO617A-4X007T, which comprises the 160 % to 320 % CTR group (also referred to as a "bin," which is selected in numbered groups). CTR is one of the main parameters of the device and will be described in a later section. Also shown are the safety agency certification options, package types (e.g. DIP and SMD), and lead bending options that are available for this particular product. The type and number of available options vary according to the product group category and are thus specific to a device.

Absolute maximum ratings

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
INPUT				
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Surge forward current	$t_p \leq 10$ µs	I_{FSM}	2.5	A
Power dissipation	at 25 °C	P_{diss}	70	mW
OUTPUT				
Collector emitter voltage		V_{CEO}	80	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	50	mA
Collector peak current	$t_p/T = 0.5$, $t_p \leq 10$ ms	I_{CM}	100	mA
Output power dissipation	at 25 °C	P_{diss}	150	mW
COUPLER				
Isolation test voltage (RMS)	t = 1 min	V_{ISO}	5300	V_{RMS}
Total power dissipation		P_{tot}	200	mW
Operation temperature		T_{amb}	-55 to +110	°C
Storage temperature range		T_{stg}	-55 to +150	°C
Soldering temperature (1)	t = 10 s	T_{sld}	260	°C

Figure 4: Absolute maximum ratings

The maximum operating ratings represent parameters that must not be exceeded. The table in Figure 4 comprises key parameters for input (emitter side), output (phototransistor), and the combination of both (coupler). These maximum ratings values are used together with available graphs to apply the necessary corrections to an application’s foreseeable maximum ambient temperature (Tamb).

An application that needs to withstand an ambient temperature fluctuation, especially to the lowest and / or highest temperatures, requires a precise design that takes into consideration how the maximum ratings for all devices in a circuit will influence or affect one another within the entire application. On the input side, the infrared emitting diode has a maximum forward current (IF) rating and allowed reverse voltage (VR). Therefore, the emitter should be driven from a constant current source and the design-in for this product needs to make sure that negative VR bias is not exceeded.

Electrical characteristics

Electrical characteristics

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
INPUT						
Forward voltage	I_F = 50 mA	V_F		1.18	1.5	V
Reverse current	V_R = 6 V	I_R		0.01	10	µA
Capacitance	V_R = 0 V, f = 1 MHz	C_I		7.3		pF
OUTPUT						
Collector emitter leakage current	V_{CE} = 10 V	I_{CEO}		0.3	100	nA
Collector emitter breakdown voltage	I_C = 100 µA	BV_{CEO}	80			V
Emitter collector breakdown voltage	I_E = 10 µA	BV_{ECO}	7			V
Collector emitter capacitance	V_{CE} = 5 V, f = 1 MHz	C_{CE}		5		pF
COUPLER						
Collector emitter saturation voltage	I_F = 5 mA, I_C = 2.5 mA	V_{CEsat}		0.25	0.4	V
Cut-off frequency	I_F = 10 mA, V_{CC} = 5 V, R_L = 100 Ω	f_{ctr}		155		kHz

Figure 5: Electrical characteristics

The electrical characteristics table in Figure 5 provides information on key parameters for the input side, the output side, and the coupling itself. It provides the minimum, typical, and maximum values for a given parameter at a specific bias test condition and ambient temperature of 25 °C. The minimum and maximum values are tested during production. While the typical values served as distributed median values, they are provided by test engineering on the basis of product samples for characterization data.

Current transfer ratio

CURRENT TRANSFER RATIO (T_{amb} = 25 °C, unless otherwise specified)							
PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
I_C/I_F	I_F = 5 mA, V_{CE} = 5 V	VOS617A	CTR	50		600	%
		VOS617A-2	CTR	63		125	%
		VOS617A-3	CTR	100		200	%
		VOS617A-4	CTR	160		320	%
		VOS617A-7	CTR	80		160	%
		VOS617A-8	CTR	130		260	%
		VOS617A-9	CTR	200		400	%

Figure 6: Current transfer ratio

CTR is very much like a gain value for transistors. The CTR describes the ratio between the input current of the infrared diode (I_F) and the maximum possible current on the output transistor through the collector-emitter (I_{CE}). Figure 6 gives a detailed overview for the binning groups available, providing their minimum to maximum CTR range within a specific emitter current (IF) and collector-emitter voltage (VCE) at 25 °C ambient temperature. Each CTR group number, e.g. -2 to -9, is marked and placed adjacent to the device’s main product number.

Switching characteristics

SWITCHING CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
NON-SATURATED						
Rise and fall time	I_C = 2 mA, V_{CC} = 5 V, R_L = 100 Ω	t_r		3		µs
Fall time		t_f		3		µs
Turn-on time		t_{on}		6		µs
Turn-off time		t_{off}		4		µs
SATURATED						
Rise and fall time	I_F = 1.6 mA, V_{CC} = 5 V, R_L = 1.9 k Ω	T_r		3		µs
Fall time		T_f		12		µs
Turn-on time		T_{on}		4		µs
Turn-off time		T_{off}		18		µs

Figure 7: Switching characteristics

The switching characteristics table provides the typical signal switching times in the microsecond range. It provides these values at a specific bias for the emitter (IF) and the detector (VCC), as well as the load resistor (RL). It serves as a quick look-up table to compare switching times when the transistor is used in saturated or non-saturated configurations.

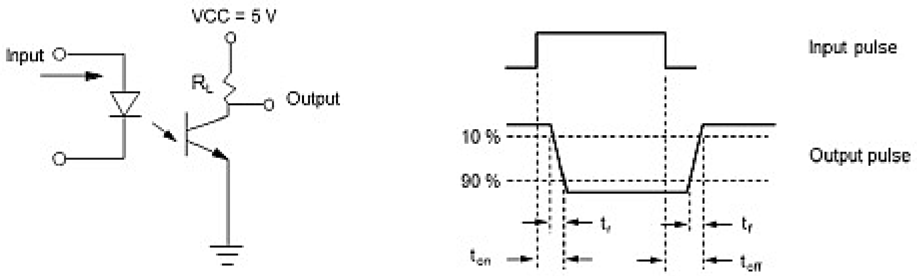


Figure 8: Test circuit and switching waveforms

When dynamic types of parameter values are given, and especially when they need to be compared, it is important for the test circuit to be known and, as Figure 8 shows, for the measurement points within the waveforms to be indicated properly. Notice that on an inverted output as shown in Figure 8, the "tr" is on the falling edge of the ton pulse and "tf" on the rise edge of the toff side of the pulse.

Safety and insulation ratings

SAFETY AND INSULATION RATINGS				
PARAMETER		SYMBOL	VALUE	UNIT
MAXIMUM SAFETY RATINGS				
Output safety power		P_{SO}	300	mW
Input safety current		I_{si}	200	mA
Safety temperature		Ts	150	°C
Comparative tracking index		CTI	175	
INSULATION RATED PARAMETERS				
Maximum withstanding isolation voltage	40 % to 60 % RH, AC test of 1 min	V_{ISO}	3750	V_{RMS}
Maximum transient isolation voltage		V_{IOTM}	6000	V_{peak}
Maximum repetitive peak isolation voltage		V_{IORM}	565	V_{peak}
Insulation resistance	T_{amb} = 25 °C, V_{DC} = 500 V	R_{IO}	$\geq 10^{12}$	Ω
Isolation resistance	T_{amb} = 100 °C, V_{DC} = 500 V	R_{IO}	$\geq 10^{11}$	Ω
Climatic classification (according to IEC 68 part 1)			55/110/21	
Environment (pollution degree in accordance to DIN VDE 0109)			2	
Creepage distance			≥ 5	mm
Clearance distance			≥ 5	mm
Insulation thickness		DTI	≥ 0.4	mm

Figure 9 - Safety and insulation ratings

Optocoupler devices are renowned for their high reliability in the areas of isolation and safety. The safety and insulation ratings table serves as a quick reference for all key parameters the device is qualified for. The number of safety agency approvals may vary from product to product, even according to available product options. All agency certificates are available on our website at the specific product page.

Typical agency approvals are:

- UL1577, file no. E52744
- DIN EN 60747-5-5 (VDE 0884-5)
- CQC GB4943.1-2011 & GB8898-2011
- FIMKO EN 60065, EN 60950-1
- cUL

The concise data in the Figure 9 table refers to specific safety norms and standards for which a separate document may be needed to fully understand the mandatory safety requirements for the intended application.

Typical static graphs

Typical static graphs

Certain characteristics are best shown graphically within a parameter range. These graphs provide a quick reference to estimate variables or trends for any specific condition.

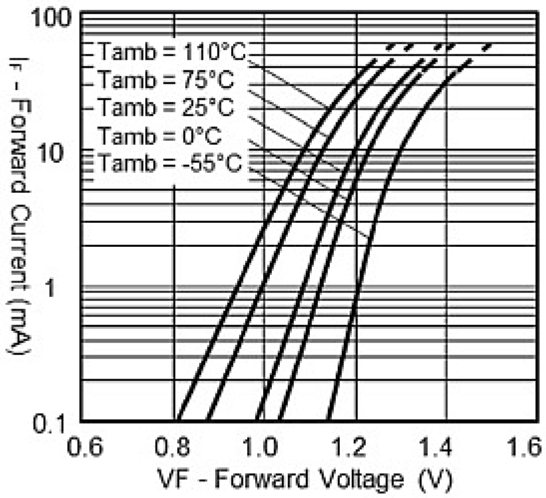


Figure 10: Emitter diode forward current vs. forward voltage

For the emitter side, the diagram in Figure 10 provides the most relevant curves for the infrared diode and shows its I-V characteristics as a function of forward voltage at different temperatures. Ideally, the emitter is driven with constant current to maintain a steady forward current across the rated ambient temperature.

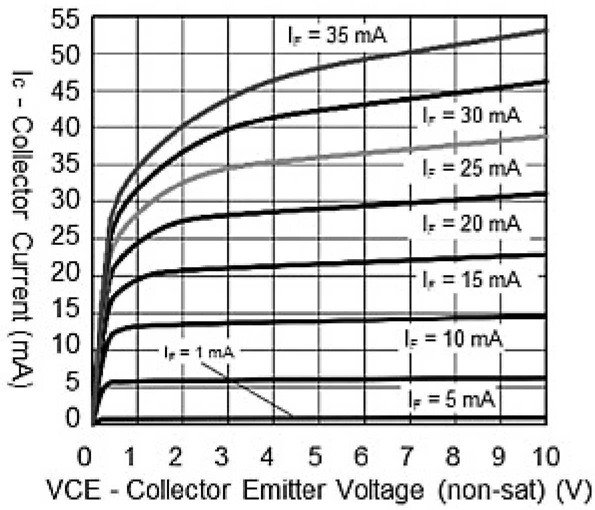


Figure 11: Collector current vs. collector-emitter voltage (non-saturated)

On the output side, Figure 11 shows a typical collector-emitter voltage (VCE) sweep, similar to a bipolar NPN or PNP transistor output curve. It consists of collector-emitter voltage (VCE) and collector current (IC) as a function of the base current (IBASE). With optocouplers, the emitter forward current (IF) is approximately equivalent to the transistor's base current (IBASE) and is plotted as forward current (IF) in various steps. The higher the forward current (IF), the higher are the base current (IBASE) and collector current (IC) for a given collector-emitter voltage (VCE).

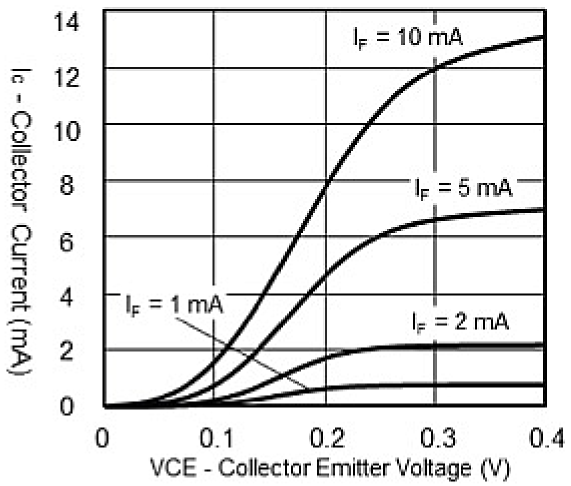


Figure 12: Collector current vs. collector-emitter voltage (saturated)

The phototransistor in full-saturated state, also known as full-switched, has a collector-emitter voltage (VCE) of 0.4 V or lower, as shown in Figure 12. Comparing to bipolar transistors, the different curves are defined with the forward current (I_F) of the emitting diode instead of the base current (I_B). With optocouplers, the phototransistor base is the photocurrent as the product of the forward current on the emitter side, and it is plotted in various steps.

Basically, there are two operating modes for phototransistor optocouplers: linear mode (non-saturated) and logic mode (saturated).

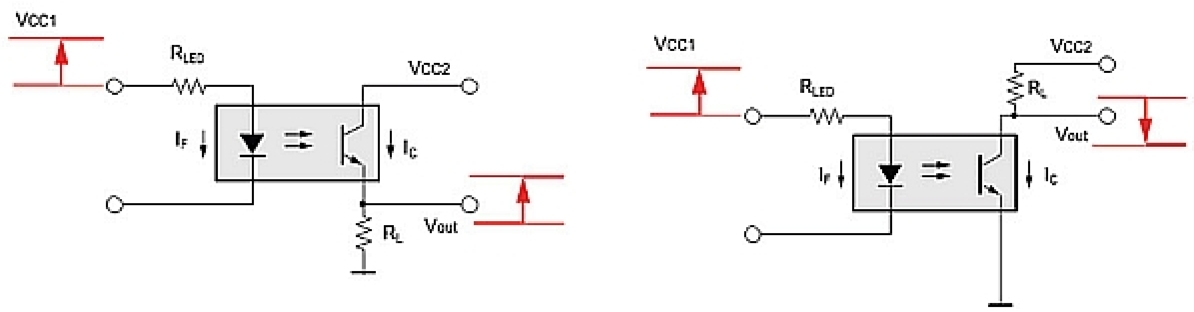


Figure 13: Optocoupler in common collector C-C (left) and common emitter C-E (right) configurations

In logic mode the output signal is either logic high (~VCC2) or logic low (~ground potential); logic high is the same voltage as the supply rail and logic low is the same voltage as the ground. In linear (non-saturated) mode the output voltage can be set to a fraction of VCC2. In addition to selecting if the phototransistor needs to be in saturated or non-saturated mode, its signal reproduction between input and output, the emitter (VCC1 with current limit resistor) and detector with RL, pull-up or pull-down, can be made inverting or non-inverting.

Figure 13 shows these two possible arrangements. For silicon-based phototransistors, the saturation voltage between the collector and emitter (C-E) would be 0.4 V or less. For applications where current drive is not the main criteria, but instead a low current drive with a small emitter forward current is desired, the non-saturated or linear mode is frequently the best approach where AC signal transmission performance is of importance. The collector current (IC) and the forward current (IF) are adjusted so that the transistor output in the active state would provide enough AC amplitude as needed at a specific DC bias point.

Optocouplers can be stacked in parallel so that a single controlled signal, driving the infrared emitter side, may provide two separated and isolated output types. When stacking multiple couplers, the current sharing needs some consideration. The emitter infrared diode has a negative temperature coefficient, thus even when the ambient temperature is equal for all emitters, any emitter with a slightly higher junction temperature will be drawing more current then the rest. When multiple optocouplers are required in a stacked configuration, a constant current source should be considered to provide a constant forward current.

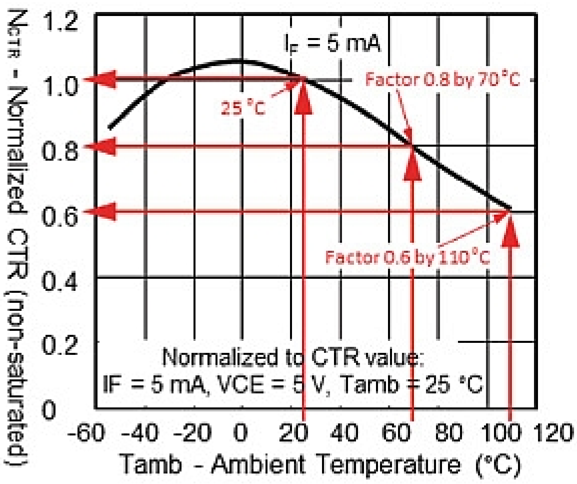


Figure 14: Normalized CTR (non-saturated) vs. ambient temperature

CTR is a ratio comparable to the gain (hFE) of a standard transistor, except that it is expressed as a ratio of the collector current (IC) divided by the forward current (IF) and multiplied by 100 %. Thus, CTR = IC/IF x 100 %. Furthermore, the CTR is affected by the forward current (IF), the collector-emitter voltage Vce, and the ambient temperature (Tamb).

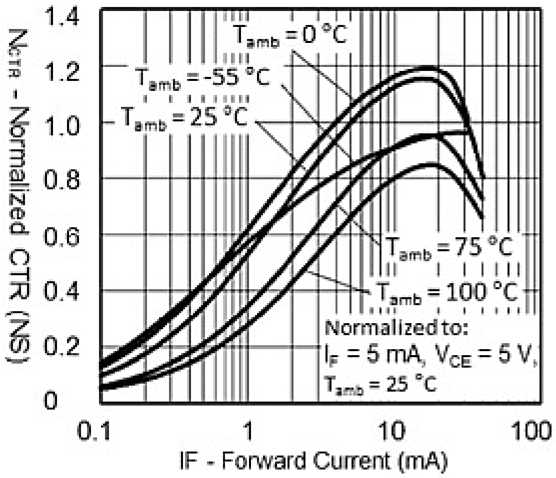


Figure 15: Normalized CTR (non-saturated) vs. forward current (IF)

The normalized form of the CTR graph in Figure 14 provides a reference for a quick estimation on the variation of the CTR at a given forward current (IF) and at ambient temperatures ranging from -50 °C to +100 °C.

Because optocouplers are provided in a large selection of CTR groups (binning), it is advantageous to have a method for establishing a factor that can provide a quick cross comparison between all available CTR groups. We use normalization scaling to accomplish just that. Normalization is the scaling of data to a nominal condition and it is mostly done at 25 °C and the coupler-specific forward current, as the graph in Figure 15 shows (NCTR at Tamb = 25 °C and IF = 5 mA is 1.0).

Typical dynamic graphs
Typical dynamic graphs

This group of graphs provides information on the AC characteristics of the phototransistor.

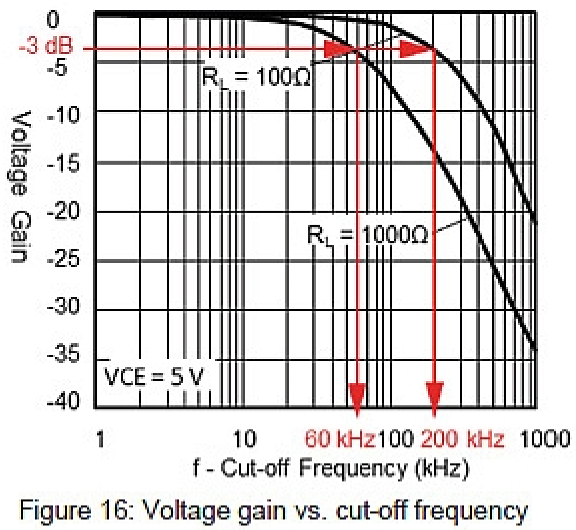


Figure 16: Voltage gain vs. cut-off frequency

The frequency cut-off graph of Figure 16 provides information regarding the highest effective frequency of a small AC signal that can be transmitted through the optocoupler. It is actually the frequency at which the output voltage reaches half the amplitude, which is defined at -3dB. The different curves show different load resistances.

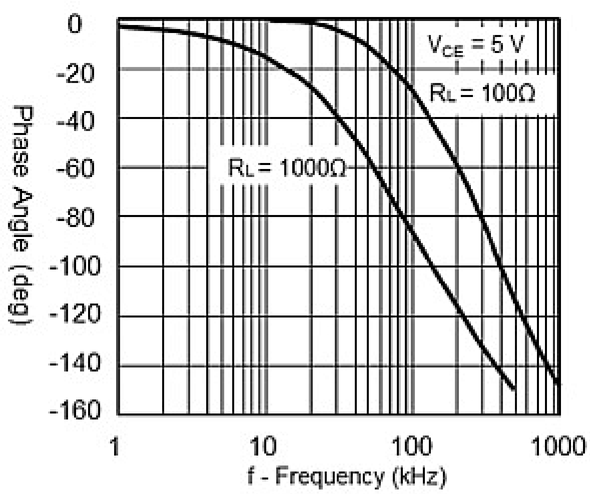


Figure 17: Phase angle vs. frequency

The phase-angle sweep across the operating frequency for a given collector-emitter voltage (VCE) and load resistance (RL) provides a quick phase-angle reference for popular optocoupler applications such as SMPS (switched mode power supply),which transfers power from a source switching between low-dissipation states and minimizes the wasted energy, where the optocoupler is generally used for the feedback loop.

The impedance of a capacitor is inversely proportional to the frequency and capacitance, and since the phototransistor Cout is very small, it is a high impedance at moderated low frequencies. However, as we design for higher frequencies the high impedance will drop, and thus the presence of parasitic capacitance has a significant effect on the voltage gain and phase. The phase shift as a function of frequency (Figure 17) at different load resistance (RL) can be estimated from the above graph.

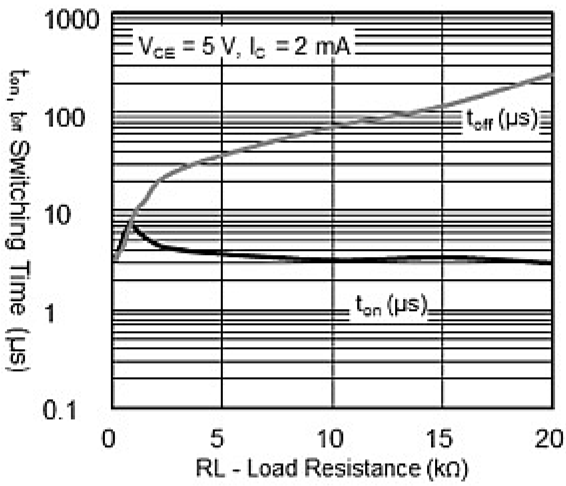


Figure 18: Switching time vs. load resistance

Datasheets also provide dynamic characteristic information, as is the case with phototransistor switching under specific conditions such as collector current (I_C) and collector-emitter voltage (V_{CE}), providing a sweep across load resistance (R_L). The graph in Figure 18 provides a quick reference for the tendencies of turn-on (t_{on}) and turn-off (t_{off}) switching time in microsecond units. This information, together with the data in the Figure 7 table, can provide a more accurate estimate on total switching times. If a base connection is available in the optocoupler, it can be used to adjust the switching time performance.

Packaging information

The packaging information consists of a detailed drawing of the packages that are available, with a recommended footprint. Further, marking is shown that is applied to every component for recognition.

As a second overview, there is information about the quantities in a tube, box, or tape-and-reel, together with a drawing of the delivered form.

Design-in considerations

When designing with optocouplers, there are some CTR dependencies worth considering. To build a robust application, all foreseeable factors that can influence performance must be considered.

There are four basic considerations summarized below:

1. *Saturated and non-saturated CTR*

   A datasheet provides detailed graphs for non-saturated as well as saturated curves for logic applications.
2. *Change in forward current*

   Based on datasheet graphs and depending on the device type, the IF needs to be adjusted.
3. *Adjustment for temperature deviation*

   The graphs from the datasheet cover the entire ambient temperature range, providing easy correlation for CTR estimates.
4. *Degradation factor / lifetime*

   For optocouplers, the lifetime is primarily affected by ambient temperature and forward current. The expected lifetime is generally defined to when a device has reached a 50 % CTR reduction from its original value.