How to Use Optocoupler Normalized Curves

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INTRODUCTION

Optocouplers are used for signal transfer between a safe and a potentially hazardous or electrically noisy environment using galvanic isolation. The isolation voltage and noise rejection characteristics of the optocoupler are basically determined by the mechanical package design and isolating materials.

A phototransistor optocoupler has an infrared emitting diode, which is optically coupled to a silicon phototransistor detector. The infrared light of the LED irradiates the photosensitive base collector junction of the phototransistor which is amplified by the collector current of the transistor.

HOW TO USE THE NORMALIZED CURVES

The gain of the optocoupler is expressed as a current transfer ratio (CTR), which is the collector current (I_C) of the output divided by the forward current (I_F) of the input and multiplied by 100 %.

$$CTR = \frac{I_C}{I_F} \times 100\ \% \tag{1}$$

There are typically a number of CTR groups (binning) to choose from when selecting an optocoupler. CTR is not a static value. It is affected by the forward current (I_F), the collector-emitter voltage (V_{CE}), and the ambient temperature (T_{amb}). The datasheets include curves that show how each of these values can change based on ambient temperature. To be able to compare the performance of the optocoupler over temperature we normalize the curves. Normalization is the scaling of data to a nominal condition, typically at 25 °C and the coupler-specific forward current, as the graph in Fig. 1 shows (NCTR at T_{amb} = 25 °C and I_F = 5 mA is 1.0).

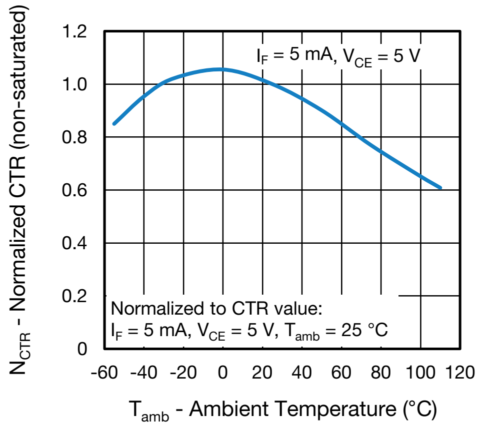

Fig. 1 - Normalized Current Transfer Ratio (non-saturated) vs. Ambient Temperature

Two separate CTRs are often needed to complete the interface design. One for the non-saturated or linear operation with a collector emitter voltage (V_{CE}) of 5.0 V and the second one for the saturated or switching operation with a collector emitter voltage (V_{CE}) of 0.4 V. The Fig. 1 illustrates the normalized CTR curves vs. forward current for different ambient temperatures for the non-saturated operation and Fig. 2 for the saturated operation.

APPLICATION NOTE

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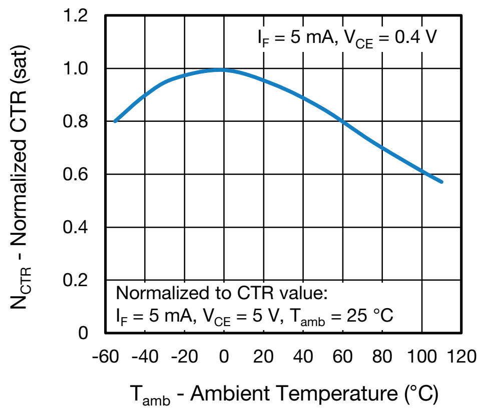

Fig. 2 - Normalized Current Transfer Ratio (saturated) vs. Ambient Temperature

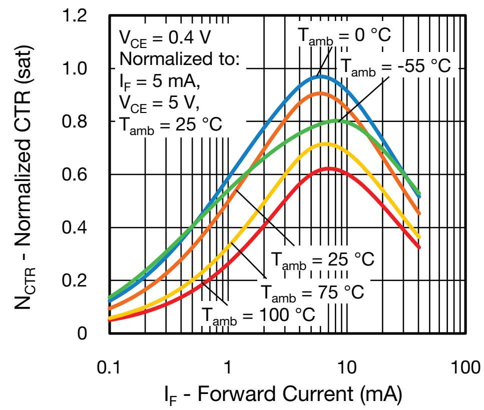

Fig. 4 - Normalized Current Transfer Ratio (saturated) vs. Forward Current

The normalized form of the CTR graph in Fig. 3 and Fig. 4 provides a reference for a quick estimation on the variation of the CTR at different forward currents and ambient temperatures ranging from -55 °C to +100 °C.

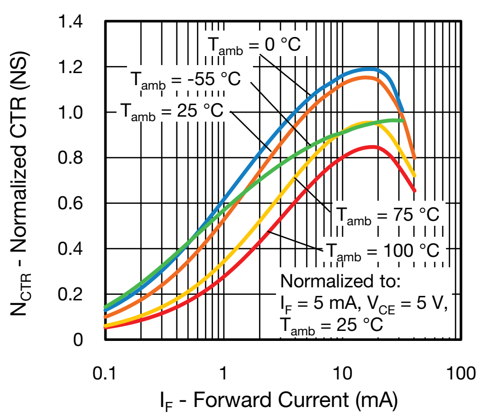

Fig. 3 - Normalized Current Transfer Ratio (non-saturated) vs. Forward Current

The following design example illustrates how the normalized curves can be used to calculate the appropriate load resistors.

Example 1

Using the VOL617A-3 optocoupler with a CTR range of 100 % to 200 % at a forward current of 5 mA in the non-saturated mode with following conditions: T_{amb} = 0 °C to +70 °C, I_F = 5 mA, V_{CC} = 5 V, V_{CE} = 0.4 V

SOLUTION

Step 1

Determine the saturated NCTR factor for the required temperature from 0 °C to +70 °C and a forward current of 5 mA by using Fig. 5.

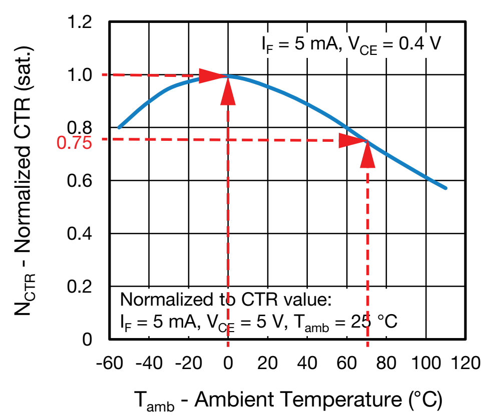

Fig. 5 - Normalized Current Transfer Ratio (saturated) vs. Ambient Temperature

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With the temperature range of 0 °C to +70 °C the CTR undergoes a change between 0 % and -25 % at a forward current of 5 mA.

The CTR_{sat} range over the required temperature will be about 100 x 0.75 = 75 % to 200 % x 0.75 = 150 % for a forward current of 5 mA.

Step 2

Select the load resistor using the following equation:

$$R_L \geq \frac{V_{CC} - V_{CE_{sat.}}}{I_F \times CTR_{sat.}} \geq \frac{5\ V - 0.4\ V}{5\ mA \times 0.75} \geq 1.22\ k\Omega \qquad (2)$$

Example 2:

Using an VOL617A-3 optocoupler in the circuit shown in Fig. 6, determine the worst-case load resistor under the following operation conditions:

T_{amb} = 75 °C, I_F = 7 mA, V_{CC} = 5 V, V_{CE} = 0.4 V, logic load = microcontroller I/O

VOL617A-3 characteristics:

$CTR_{non\text{-}sat.}$ = 100 % at I_F = 5 mA, V_{CE} = 5.0 V, and T_{amb} = 25 °C

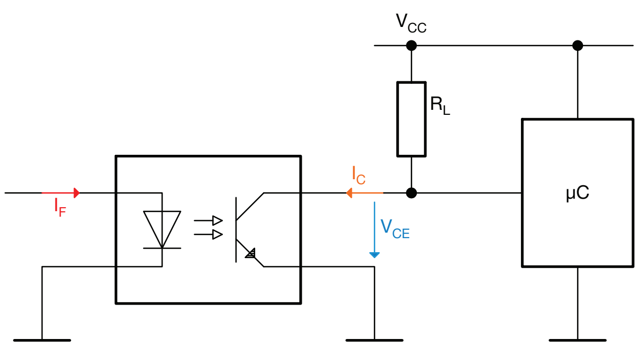

Fig. 6 - VOL617A-3 to Microcontroller Interface

SOLUTION

Step 1

Determine the saturated NCTR factor for the ambient temperature of 75 °C and a forward current of 7 mA, which can be found in Fig. 7.

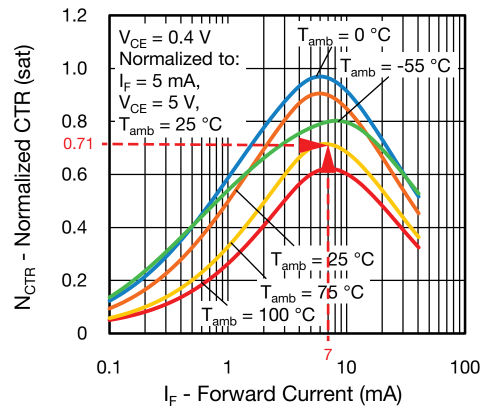

Fig. 7 - Normalized Current Transfer Ration (saturated) vs. Forward Current

The saturated NCTR factor is 0.71.

Assuming a ten year service life period of the interface circuit, allowance needs to be made for additional CTR reduction of approximately 20 % on account of degradation.

Making an additional tolerance allowance of approximately -25 % for the CTR will result in a safe minimum value of approximately 42.6 %.

$$CTR_{sat.} = CTR_{min.} \times NCTR \times aging \times tolerance \qquad (4)$$

$$CTR_{sat.} = 100\ \% \times 0.71 \times 0.8 \times 0.75 = 42.6\ \% \qquad (5)$$

Step 2

Select the minimum load resistor using the following equation:

$$R_{Lmin.} \geq \frac{V_{CC} - V_{CE_{sat.}}}{I_F \times CTR_{sat.}} \geq \frac{5\ V - 0.4\ V}{7\ mA \times 0.426} \geq 1.54\ k\Omega \qquad (6)$$