AN 3004

How to simulate Current Transfer Ratios (CTR) and long-term CTR degradation in transistor optocouplers

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Introduction

There are a variety of analog and digital optocouplers available today. The most common is the bipolar phototransistor. These devices feature a GaAs LED as a light source, and an NPN bipolar phototransistor as a receiver.

A key parameter in measuring transistor optocoupler performance is Current Transfer Ratio or CTR. CTR is the ratio of the output, or collector current of the device \((I_c)\), to the input current \((I_f)\) applied to the LED:

\[
CTR = \frac{I_c}{I_f}
\]

CTR is normally expressed as a percentage. If 5mA of current is applied to the optocoupler’s LED and 5mA of collector current is received, the device has a CTR of 100%. CTR is influenced by a number of factors: the LED’s output power \((P_c)\) and forward current \((I_f)\), the current gain \((hfe)\) of the phototransistor, and the ambient temperature. The CTR of devices within a given product family can vary considerably.

This application note will present a method for simulating the effects of various CTRs in a circuit. By evaluating how CTR variation influences the behavior of a circuit in the design phase, the engineer can select the appropriate rank device for the application.

Methodology

This application note will use NEC’s popular PS2501-1 as an example. The PS2501-1 is a single channel, optically-coupled isolator that uses a GaAs LED as a light source and a bipolar NPN phototransistor as a receiver. Its CTR can range from 80% to 600%.

*Figure 1* shows a block diagram of the PS2501-1.

By assuming the following:

- \(I_c = 10\, \text{mA}\)
- \(I_f = 5\, \text{mA}\)
- \(V_{CC} = 5.0\, \text{V}\)
- \(R_1 = 100\, \Omega\)

the CTR is easy to calculate:

\[
\frac{10\, \text{mA}}{5\, \text{mA}} = 2 \text{ or a CTR of 200%}
\]

To simulate the circuit at a different CTR, simply change the value of the resistance \(R_1\). The new value, \(R_{NEW}\), is easily calculated using this formula:

\[
\frac{CTR_{(NEW)}}{CTR\, (Original)} = X \text{ and } R_{(NEW)} = X \times R_1
\]

If \(R_1 = 100\, \Omega\), the original CTR is 200%, and you wish to simulate a CTR of 600%, \(R_{NEW}\) would be:

\[
\frac{600}{200} = 3 \text{ and } R_{(NEW)} = 300\, \Omega = 3 \times 100\, \Omega
\]

To calculate \(R_{NEW}\) for a simulated CTR of 80%:

\[
\frac{80}{200} = 0.4 \text{ and } R_{(NEW)} = 40\, \Omega = 0.4 \times 100\, \Omega
\]

Simulating CTR Degradation

By using the same methodology, one can also simulate the long term CTR degradation of transistor optocouplers.

Using the PS2501-1 again as an example, the data sheet provides a *Long Term CTR Degradation* table:

(Figure 2, over)
As shown in the table in Figure 2, after 100,000 (10^5) hours at T_A = 60°C, the CTR of the device will degrade to 0.8 (80%) of its original value.

To simulate this condition, the load resistance in the optocoupler circuit (R_1) can be modified. Figure the new resistance (R_{\text{NEW}}) using the same formula:

\[
\frac{\text{CTR (NEW)}}{\text{CTR (Original)}} = X \quad \text{and} \quad R_{\text{NEW}} = X \times R_1
\]

If \( R_1 = 100\,\Omega \), to determine the new resistance \( R_{\text{NEW}} \):

\[
\frac{80}{100} = 0.8 \quad \text{and} \quad R_{\text{NEW}} = 80\,\Omega = 0.8 \times 100\,\Omega
\]

By changing the load resistance to 80\,\Omega, the effect on circuit behavior of a degradation of the CTR to 80% can be simulated.

**Avoid Saturation Mode**

In calculating the new load resistance, \( R_{\text{NEW}} \), make sure that it meets the following criteria:

\[
I_C \times R_{\text{NEW}} < V_{CC} - 0.3\,V
\]

If \( I_C \) times \( R_{\text{NEW}} \) exceeds \( V_{CC} \) less 0.3V, the device could operate in saturation mode, a condition for which it may not have been originally intended.

**Conclusion**

By changing the load resistance in the circuit, one can easily simulate CTR variation and evaluate its influence on the behavior of the circuit. This makes it easy to select the appropriate device rank for the application under development.

In addition, this same methodology can also be used to evaluate the effect of long term degradation of the optocoupler’s CTR on the application under development.