Impact of the Current Transfer Ratio on Switching Times in Optocouplers With Transistor Output

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INTRODUCTION

Optocouplers with transistor outputs are widely used in applications requiring electrical isolation and signal transmission. These devices typically consist of an infrared emitting diode (IRED), which is optically coupled to a silicon phototransistor detector, facilitating the transfer of signals across an isolation barrier. A key performance parameter in optocouplers is the **current transfer ratio (CTR)**, defined as the ratio of the output current (I_{CE}) to the forward current (I_F):

$$\text{CTR (\%)} = \left(\frac{I_{CE}}{I_F}\right) \times 100$$

CTR can vary significantly across devices and directly impacts the switching characteristics, particularly turn-on time (t_{on}) and turn-off time (t_{off}). For critical timing applications (e.g., data communication, digital interfacing, or pulse-width modulation control), where precise control of switching times is essential, the variation in CTR must be carefully considered. This application note explores how CTR influences switching times and provides guidelines for selecting optocouplers in timing-sensitive applications.

EFFECTS OF CTR RANGE AND VARIABILITY

Optocouplers like the VO617A are typically categorized into groups based on their CTR, which can range from 50 % to 600 %, or have a narrow CTR range, as shown in the Table 1 below:

TABLE 1 - VO617A CTR RANGES

PART	SYMBOL	MIN.	MAX.	UNIT
VO617A	CTR	50	600	%
VO617A-1	CTR	40	80	%
VO617A-2	CTR	63	125	%
VO617A-3	CTR	100	200	%
VO617A-4	CTR	160	320	%
VO617A-7	CTR	80	160	%
VO617A-8	CTR	130	260	%
VO617A-9	CTR	200	400	%

Note

(1) See the VO617A - Fig. 16 - Switching Time vs. Load Resistance

HOW CTR AFFECTS SWITCHING TIMES

The switching times of an optocoupler are the time intervals required for the output transistor to transition between its “on” and “off” states. These transitions are affected by the value of the required load resistor (1) and the CTR of the device, with higher or lower values leading to differences in the turn-on and turn-off time. But even within the CTR groups, switching times may vary due to different internal chip combinations.

Turn-On Time (t_{on})

The turn-on time is the time it takes for the output transistor to switch from the off state to the on state after the LED is forward biased. CTR plays a key role in determining how quickly the transistor saturates:

Higher CTR → Faster Turn-On: optocouplers with higher CTR generally exhibit faster turn-on times. A higher CTR means that for a given forward current (I_F), more photocurrent is generated, enabling the output transistor to reach saturation more quickly, as shown in Fig. 1.

Lower CTR → Slower Turn-On: conversely, in optocouplers with lower CTR, the output transistor takes longer to saturate because less photocurrent is available. This results in slightly slower turn-on times compared to higher CTR devices, as shown in Fig. 1.

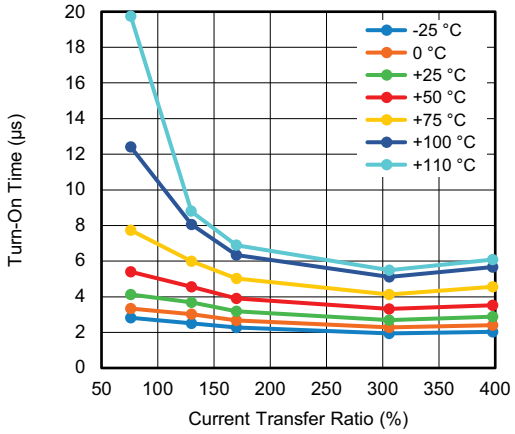

Fig. 1 - Turn-On Time vs. Current Transfer Ratio

APPLICATION NOTE

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Turn-Off Time (t_{off})

The turn-off time is the interval between turning off the LED input and the output transistor fully turning off (leaving saturation). The relationship between CTR and turn-off time behaves differently from turn-on:

Higher CTR → Slower Turn-Off: while higher CTR devices can turn on more quickly, they generally have slower turn-off times. This is due to the increased charge stored in the base-collector junction of the transistor when it is saturated; more charge must be removed before the transistor can switch off, leading to a longer turn-off time, as shown in Fig. 2.

Lower CTR → Faster Turn-Off: optocouplers with lower CTR tend to have less stored charge in the output transistor, resulting in faster turn-off times, as shown in Fig. 2. This makes low CTR devices more suitable for applications where fast turn-off is critical.

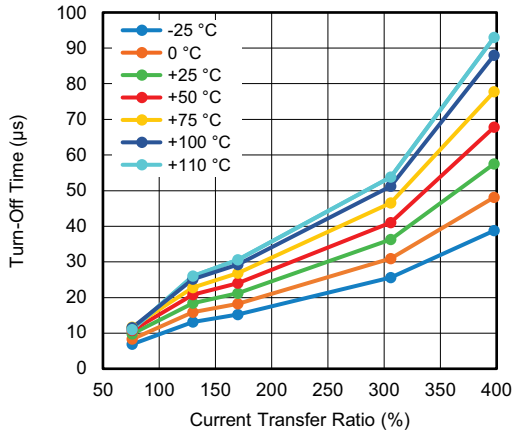

Fig. 2 - Turn-Off Time vs. Current Transfer Ratio

As shown in Fig. 1 and Fig. 2, temperature has an additional effect on the switching times - while the turn-on time increases slightly with rising temperature, the turn-off time increases significantly.

RECOMMENDATIONS FOR CRITICAL TIMING APPLICATIONS

In applications where precise timing and fast switching are required, selecting the appropriate optocoupler is important. The following guidelines can help optimize performance:

Chose Lower CTR Devices for Balanced Performance: although lower CTR devices have slower turn-on times, they offer faster turn-off times, which can be beneficial when consistent and quick switching behavior is needed for both transitions. For example, in data communication interfaces, the quicker turn-off time reduces signal distortion and timing errors, ensuring more reliable data transmission.

Higher CTR Devices for Faster Turn-on: for applications in which the turn-on speed is more critical than the turn-off, devices with higher CTR may be preferable; however, ensure that the slower turn-off time does not interfere with the system's performance requirements. For example, in fault indicators a fast response to an active signal is important, while the slower turn-off time is acceptable.

Narrow CTR Range for Consistent Timing: choosing devices with a narrow CTR range (e.g., 40 % to 80 %) minimizes the variation in switching times across devices and operating conditions. This is especially important for applications requiring precise timing control.

CONCLUSION

CTR plays a significant role in the switching characteristics of optocouplers with transistor outputs, particularly influencing the turn-on and turn-off times. While higher CTR devices offer faster turn-on times, they typically have slower turn-off times, making them less suitable for applications requiring fast switching in both transitions. On the other hand, lower CTR devices provide quicker turn-off times but may have slightly slower turn-on times.

For time-critical applications, selecting an optocoupler with a lower CTR and a narrow CTR range can help achieve more consistent switching behavior. However, it is important to note that even with these selections, precise switching times are not guaranteed due to the inherent variation in CTR and environmental factors.

In cases where guaranteed switching performance is required, particularly for highly critical timing applications, we recommend switching to high speed optocouplers. These specialized devices are designed with guaranteed switching times that are clearly specified in the datasheets, ensuring reliable performance in environments where timing precision is crucial.

Our measurements confirm that devices with higher CTR exhibit faster turn-on times but slower turn-off times, while lower CTR devices offer the opposite behavior. These results underscore the importance of selecting optocouplers based on specific timing requirements in critical applications.

APPLICATION NOTE