APPLICATION NOTE

General Photo Coupler Used In Data Transmission

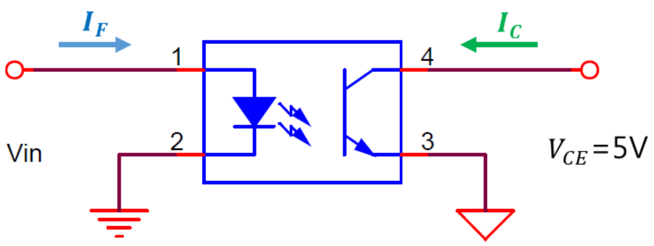
1. Function description

Optical couplers transmit signals by using light (including visible light, infrared light, etc.) as a medium. The main function of the coupler is to make the input and output circuits transmit electrical signals in an isolated manner. The photo coupler can transmit signals between two circuits that do not share the same ground. Even there is a high voltage difference between the two circuits, they will not affect each other, there by coupler is greatly improving its anti-interference ability, reliability and stability. It can be used for switching control or data transmission between two devices.

2. Signal characteristics

2.1 CTR (Current Transfer Ratio)

CTR is defined as the percentage of output current and input current ($\frac{I_C}{I_F} * 100\%$). Mainly used to evaluate the selection of load resistance. Fig.1 shows the measurement circuit of CTR.



CTR (Current Transfer Ratio)=$\frac{I_C}{I_F}$

Fig.1

2.2 Signal voltage level

In digital logic perspective, all signals can be represented by 0 or 1. V_{OH} and V_{OL} drive the voltage of the receiving terminals 1 and 0. The threshold voltages of V_{IH} and V_{IL} are used to judge input signal is logic 1 or 0, as show in Fig.2.

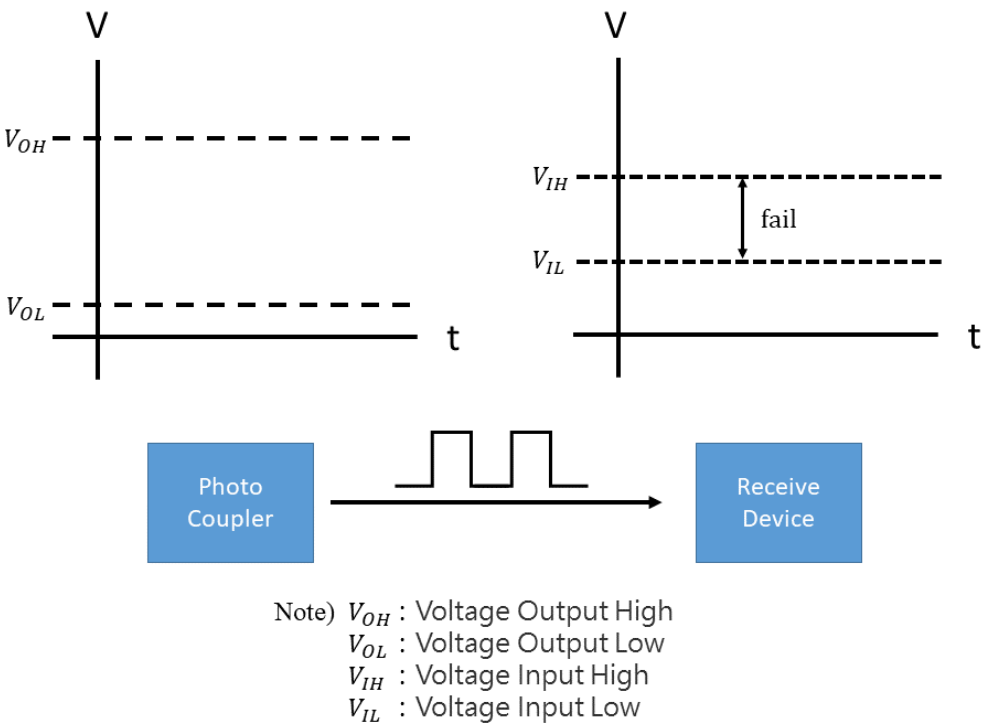


Fig.2

When the circuit is disturbed by noise, it may cause the voltage to rise or fall. Define this phenomenon as a range of noise margins, as shown in Fig.10.

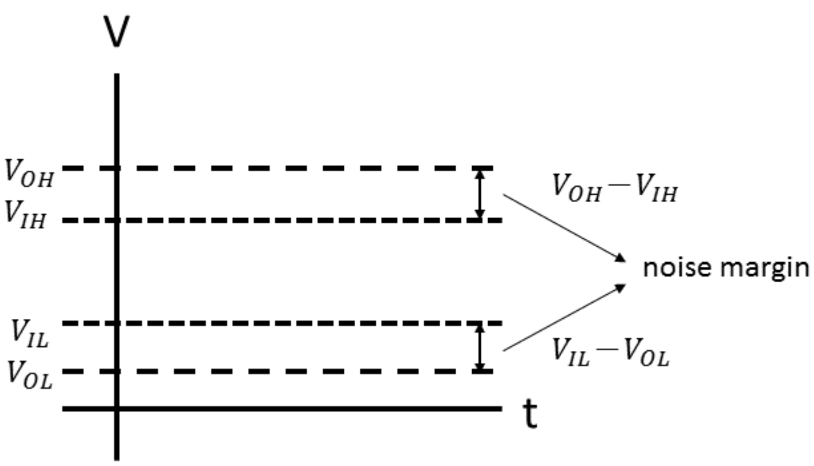


Fig.3

2.3 Holding time

In addition to the signal voltage level, also need to ensure the Holding time. Assuming that the high level and low level Holding time is greater than 22us, then the signal is valid. As shown in Fig.4, the low level is 25us and the high level is 20us, so the high level is not a valid signal. There are three ways to solve this problem:

- If you want to increase the Holding time of the high level, you need to reduce the switching (transmission) speed.
- Reducing load resistance R_L (Load resistance), but it is necessary to consider whether it can work in the saturation mode.
- Adjust the Holding time of the signal judgment, but it needs to be handled by software.

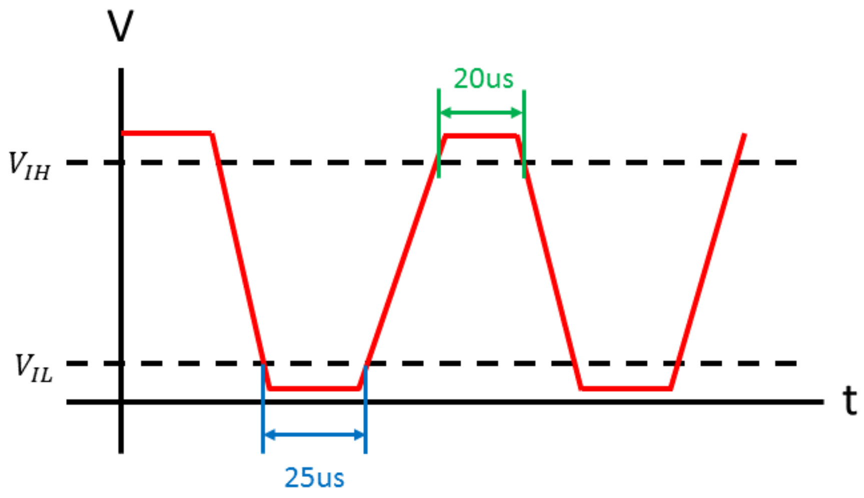


Fig.4

3. LED driving circuit

3.1 GPIO(General-Purpose Input/Output) control

As shown in Fig.5, the input power is connected in series with the IR LED via a resistor, and the I_F current value can be adjusted by changing the resistor value, and TXD is controlled by GPIO.

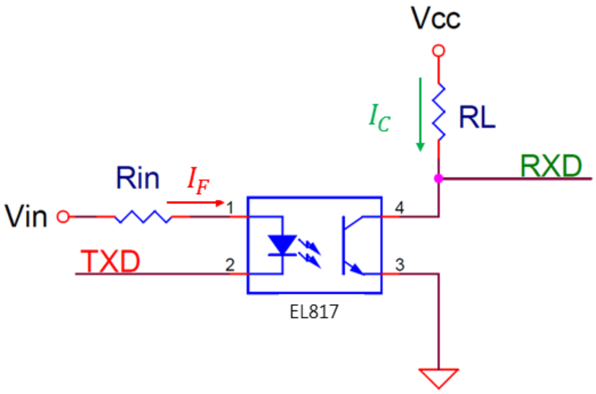


Fig.5

3.2 BJT(bipolar junction transistor) Driver

Fig.6 uses an NPN transistor as a switch for the LED, control pin provides control signals, I_F current is determined by V_{in} and R_{in}, which improves the I_F current insufficient problem. The following formula can be used to calculate the R_{in}.

$I_F = \frac{(V_{in} - V_F - V_{CE})}{R_{in}}$; $R_{in} = \frac{(V_{in} - V_F - V_{CE})}{I_F}$

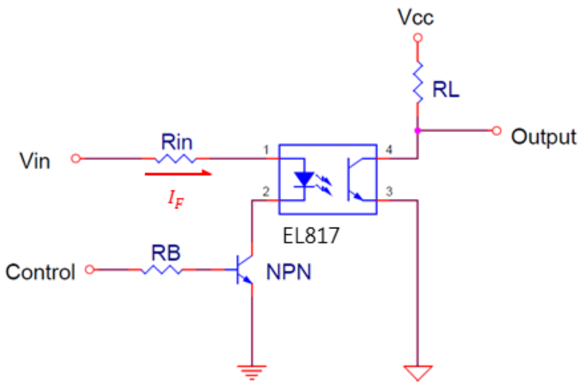


Fig.6

3.3 MOSFET(metal–oxide–semiconductor field-effect transistor) Driver

Fig.7 uses an N-MOSFET as a switch for the LED, control pin provides control signals, I_F current is determined by V_{in} and R_{in}, which improves the I_F current insufficient problem. The following formula can be used to calculate the R_{in}.

$I_F = \frac{(V_{in} - V_F - V_{DS})}{R_{in}}$; $R_{in} = \frac{(V_{in} - V_F - V_{DS})}{I_F}$

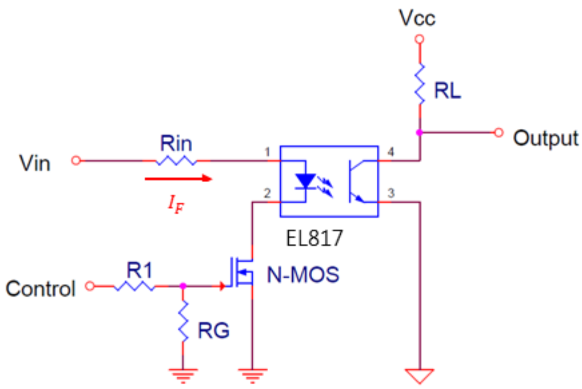


Fig.7

4. Application of circuit test

4.1 Output waveform comparison under different I_F conditions :

Taking Fig.8 for example, Using EL817 as the measured sample, the CTR% is 327% ($@I_F = 5mA$). CH1 is a Control (Input) signal, and CH2 is an output signal. Adjust the different I_F currents and observe the output waveform. As shown in Fig.9, At 5 mA, V_{OL} is still greater than 1V. Assuming $V_{IL} = 0.8V$ at the receiving end, so this low level signal is an invalid output signal. As shown in Fig.10~12, when $I_F = 10mA$ or more, V_{OL} is close to 0V. As shown in Fig.13, after the while input signal is turned off, comparison the output waveform of the different I_F, recover to the high level. You could find the lower I_F has a faster recovery time, but it is also more prone to the output low level being too high, causes the output fail to operate in saturation mode. When the I_F current is large, I_C can reach the upper limit current faster, but it also has a slower recovery time.

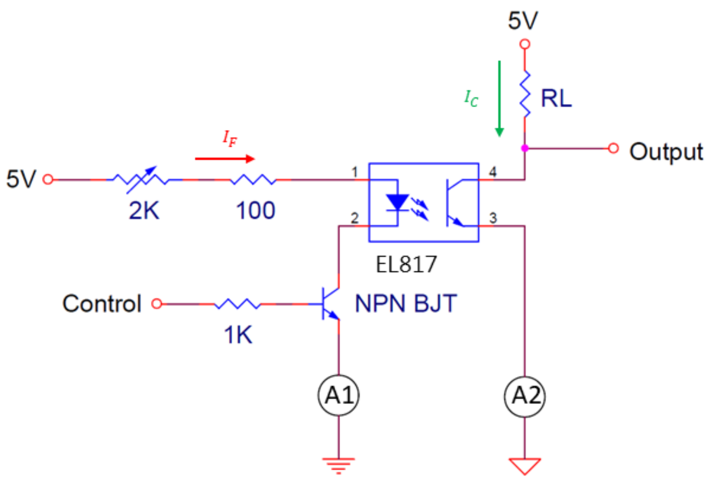


Fig.8

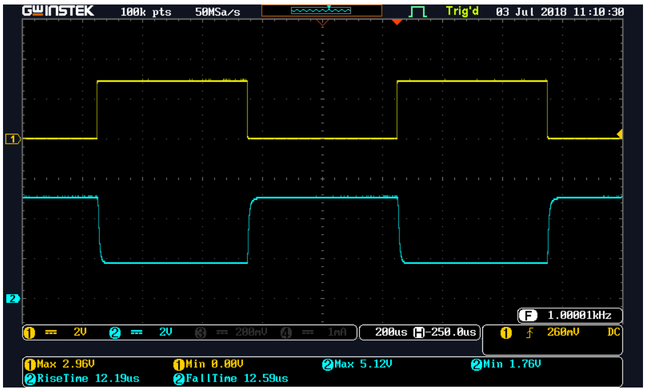


Fig.9 $I_F = 5\text{mA}$

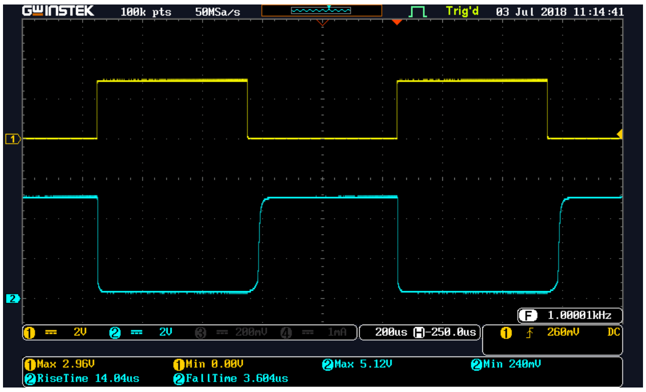


Fig.10 $I_F = 10\text{mA}$

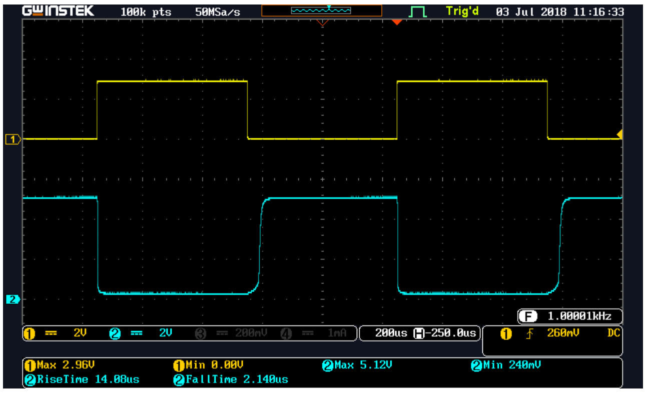


Fig.11 $I_F = 15\text{mA}$

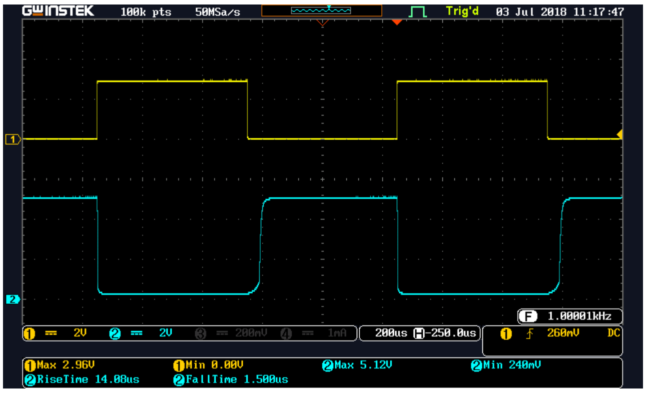


Fig.12 $I_F = 20\text{mA}$

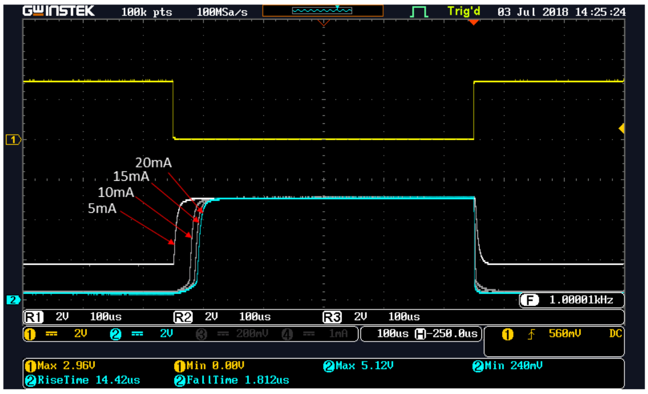


Fig.13

4.2 Output waveform comparison at different transmission speeds: :

Under the condition of $I_F = 10mA$ and $R_L = 1K\Omega$, the transmission speeds of 2400bps (1.2KHz), 4800bps (2.4KHz) and 9600bps (4.8KHz) are tested, and compare the difference between the Holding time of the high/ low levels, as shown in Fig.14~19.

2400bps (1.2KHz) :

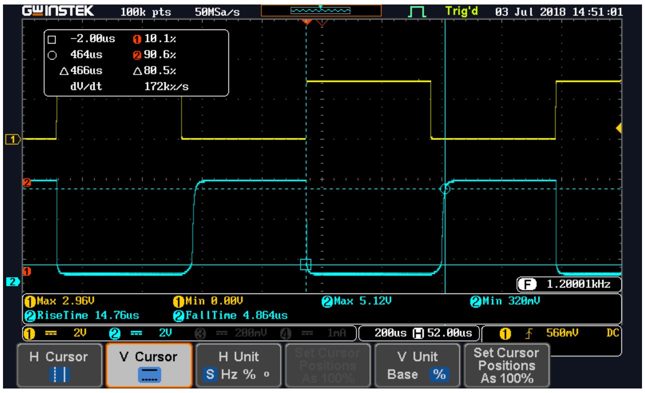


Fig.14 Low Level=466us

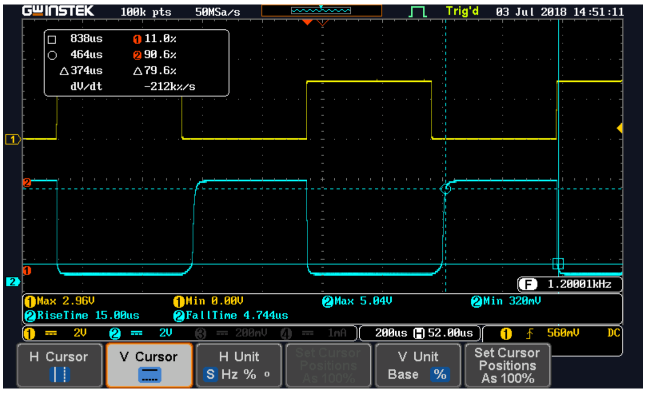


Fig.15 High Level=374us

4800bps (2.4KHz) :

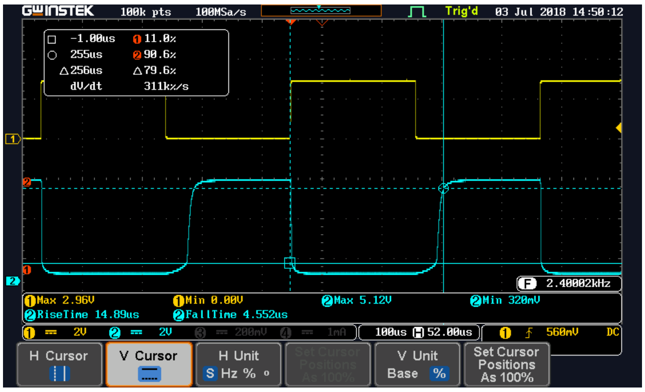


Fig.16 Low Level=256us

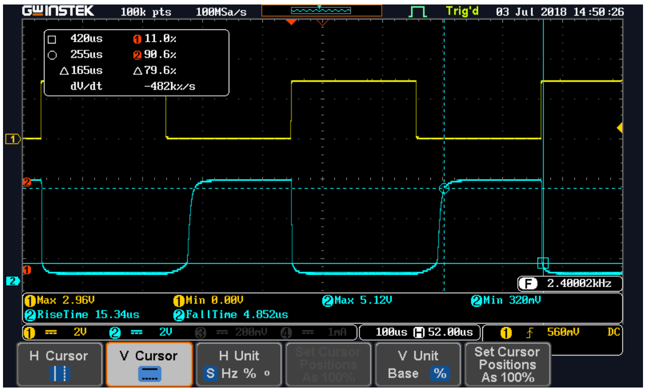


Fig.17 High Level=165us

9600bps (4.8KHz) :

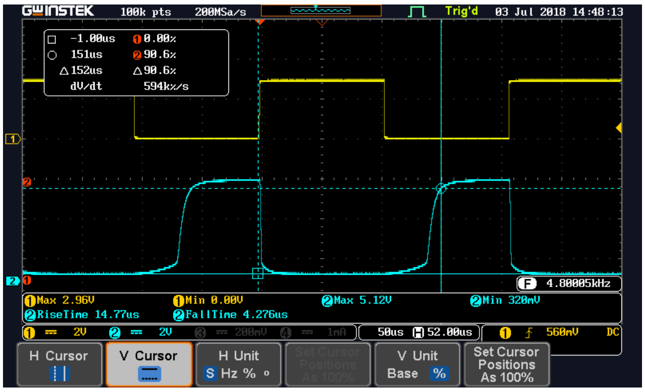


Fig.18 Low Level=152us

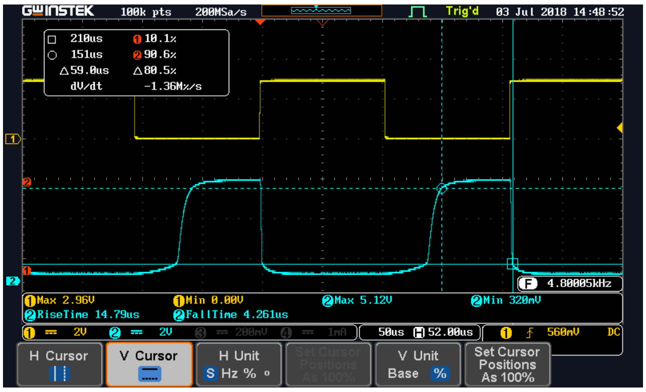


Fig.19 High Level=59us

Although the total time of the high and low levels are the same, however, after the input end is turned off, the output end takes a longer time to high level, causes the high level holding time become to shorter to accurate judge as logic high. This signal may be considered an invalid signal when the next device receive the high level signal. As shown in Table 1, the difference between the high/low levels holding time will not change with transmission speed, however, the faster the frequency, the shorter the high level duty cycle.

Transmission speed	Low level Holding time (us)	High level Holding time (us)	Time Difference (us)
2400bps(1.2KHz)	466	374	92
4800bps(2.4KHz)	256	165	91
9600bps(4.8KHz)	152	59	93

Table 1

4.3 Output waveform comparison under different R_L conditions：

An EL817 (CTR=327%), at 25°C, the driving conditions $I_F = 5\text{mA}$ 、$V_{CE} = 5\text{V}$, and R_L=100Ω. Output waveform as shown in Fig.20, when the input is turned on, $I_C = 16.35\text{mA}$, $V_{RL} = 16.35\text{mA} * 100 = 1.635\text{V}$, $V_{CE} = 5 - 1.635 = 3.265\text{V}$. Output voltage of low Level is about 3.265V. Increasing R_L can make V_{CE} enter the saturation zone. As shown in Fig.21, Increase R_L to 330Ω, V_{CE} has gradually decreased, As shown in Fig.22, Then R_L increases to 1KΩ, V_{CE} is close to 0V, As shown in Fig.23, is increased to 4.7K, but takes longer time to recover from low level to high level. Based on above test result, R_L = 1 K is the most suitable. As shown in Fig.24.

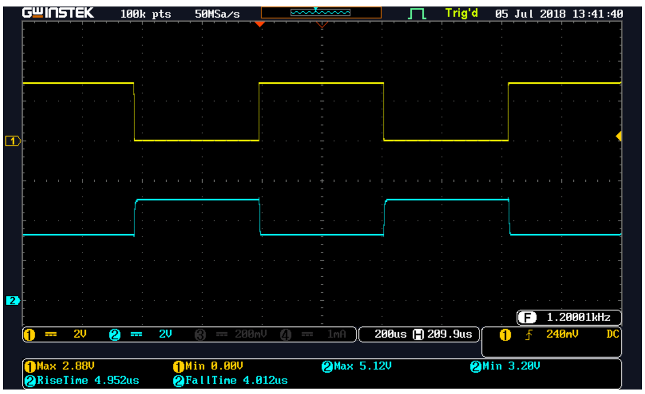


Fig.20 R_L=100Ω

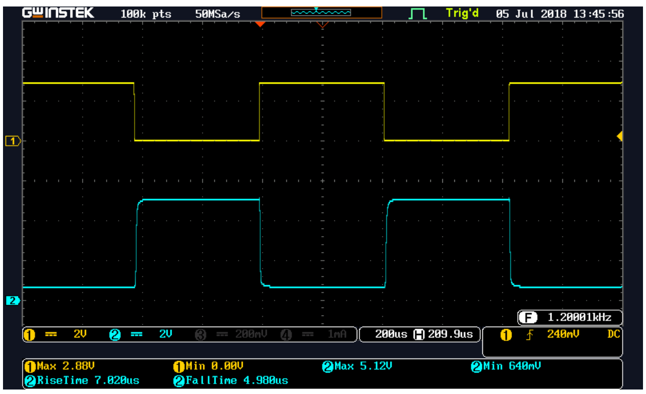


Fig.21 R_L=330Ω

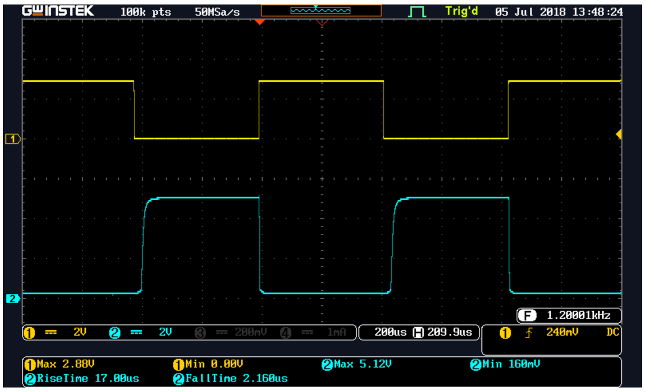


Fig.22 R_L=1KΩ

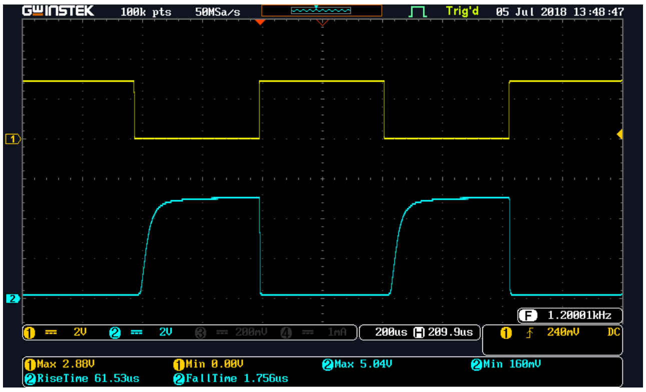


Fig.23 R_L=4.7KΩ

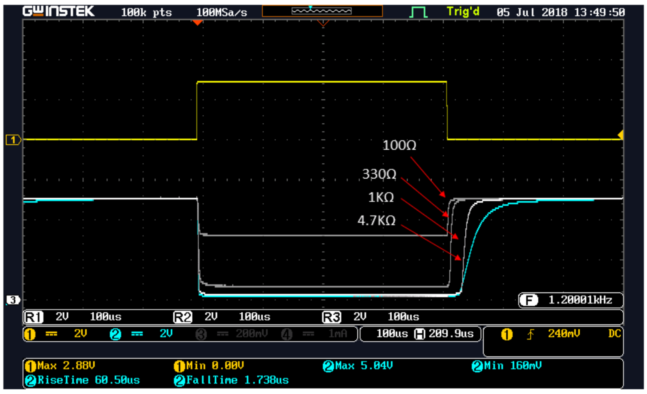


Fig.24

5. How to design the circuit effectively

Before designing, Designer need to know the relationship between input current (I_F), CTR range and load resistance (R_L) and the high/ low voltage levels of the final output signal processing. Fig.25 as a reference circuit for UART transmission.

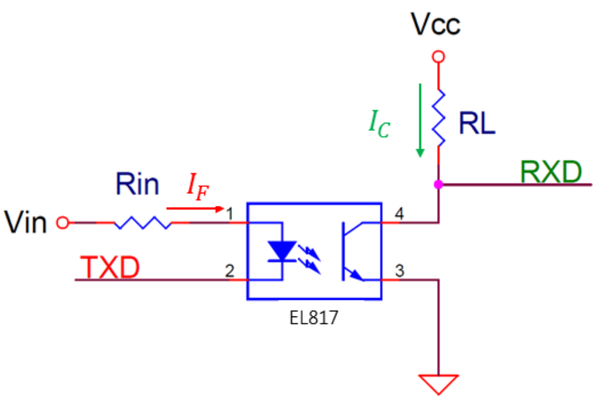


Fig.25

From the calculations, as you know the circuit behavior previously.

How to set I_F?

When TXD = 0 ， $I_{F(typ.)} = \frac{V_{in}-V_{F(typ.)}}{R_{in}}$; $R_{in} = \frac{V_{in}-V_{F(typ.)}}{I_{F(typ.)}}$

$V_{in} = 5\text{V}$ 、 $I_{F(typ.)} = 5\text{mA}$ 、 $V_{F(typ.)} = 1.2\text{V}$

then

$R_{in} = \frac{V_{in}-V_{F(typ.)}}{I_{F(typ.)}} = \frac{5-1.2}{5m}$=760Ω

In general, the lower CTR is more difficult to reach the state of the saturation, so it is calculated using the CTR minimum (taking into account the influence of the I_F current and the ambient temperature (T_A)).

$I_C = I_F * CTR(\text{min})$

When I_F=ON, RXD(Low Level)=V_{CE}=$V_{CC} - \text{Ic} * R_L$

When I_F=OFF, RXD(High Level)≒V_{CC}

The information in this application manual is only for customers' design reference. Please verify when actually use it. If have any other questions, please contact Everlight for further technical support.