

Basic Characteristics and Application Circuit Design of Transistor Output Photocouplers

Description

This document outlines the basic characteristics and application design of general-purpose transistor output photocouplers (optical isolators).

Toshiba Electronic Devices & Storage Corporation

This is for reference only. Do not design the final equipment in this document.

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Photocouplers optically links, via transparent isolating material, a light emitter and a photodetector. Used as an interface between circuits with different ground potentials, photocouplers replace isolation transformers and electromagnetic relays. Traditionally, relays or transformers have been used for isolation interfaces between logic circuits and power line load circuits. Photocouplers not only replace these devices but also have merits such as elimination of impedance mismatching, improvement in isolation capability between input and output, and ease of noise cutoff. Moreover, while circuits nowadays consist of many more LSIs and microcomputers than before, additional merits of photocouplers include reduction in the area occupied on the printed circuit board, and maintenance-free operation due to improvement in reliability. This section outlines the basic characteristics and application design of general-purpose transistor output photocouplers (optical isolators).

1. Basic Characteristics

1.1. Current Transfer Ratio (CTR)

Figure 1.1 shows the pin configuration of general transistor output photocouplers. CTR is defined as the ratio I_C/I_F (expressed as a percentage) of the output-side transistor collector current I_C to the current I_F flowing in the input-side LED. Figure 1.2 shows the CTR distribution. CTR varies with I_F . At standard conditions of $I_F = 5 \text{ mA}$ and $V_{CE} = 5 \text{ V}$, CTR is designed to be between 50% to 600%.

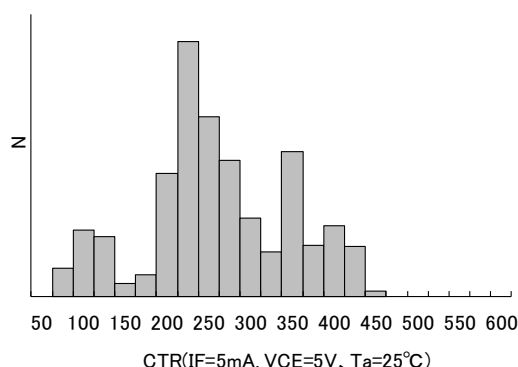
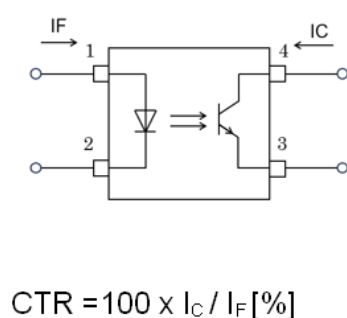


Figure 1.1 Pin Configuration

Figure 1.2 CTR Distribution example

When using transistor couplers, it is necessary to pay particular attention to the following. The section 2-4 shows the example of circuit design for transistor couplers.

(1) CTR degradation

Light output of the LED in the photocoupler decreases gradually over time, contributing to CTR degradation.

It is, therefore, advisable to provide a design margin to offset this anticipated CTR degradation.

(2) CTR - I_F dependency

When a transistor coupler is used with low input current, its CTR drops as shown in Figure 1.3. This effect should also be considered during circuit design.

(3) CTR - T_a dependency

At high temperatures, the decrease in LED light emission efficiency is dominant over the increase in h_{FE} , resulting in a reduction of the CTR. Attention should also be paid to this effect during circuit design.

(Figure 1.4)

(4) CTR- V_{CE} dependency

As with h_{FE} of general transistors, the rate of change of collector current decreases at saturation.

(Figure 1.5)

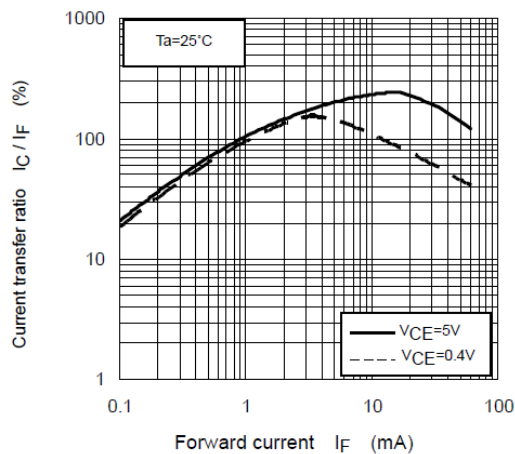


Figure 1.3 CTR (I_C/I_F) - I_F

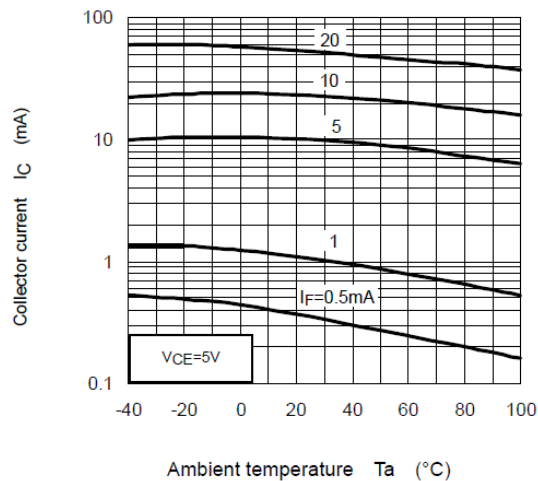


Figure 1.4 I_C - T_a

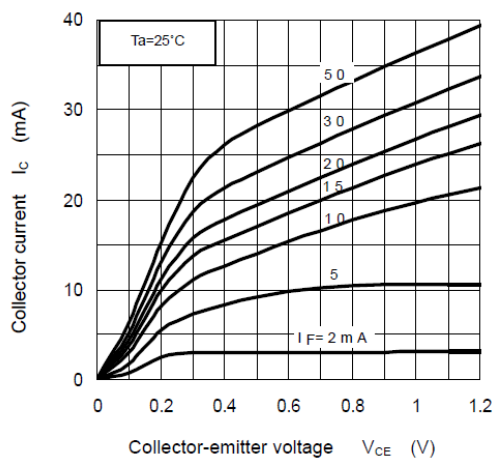


Figure 1.5 I_C - V_{CE}

1.2. Switching Time

When the phototransistor is used in a saturated switching mode, the switching time must be considered. Among a phototransistor's switching time characteristics, fall time (t_f), being the longest in duration, is the most significant. It is represented approximately by

$$t_f \text{ to } 2.2 \times C_{ob} \times h_{FE} \times R_L.$$

Where,

C_{ob} : collector-to-base capacitance

h_{FE} : DC current gain

R_L : load resistance

Switching time of is shown in Figure 1.6. Thus, if an application requires a response speed of 1 kbit/s and above, the design must consider the transistor coupler's R_L dependency.

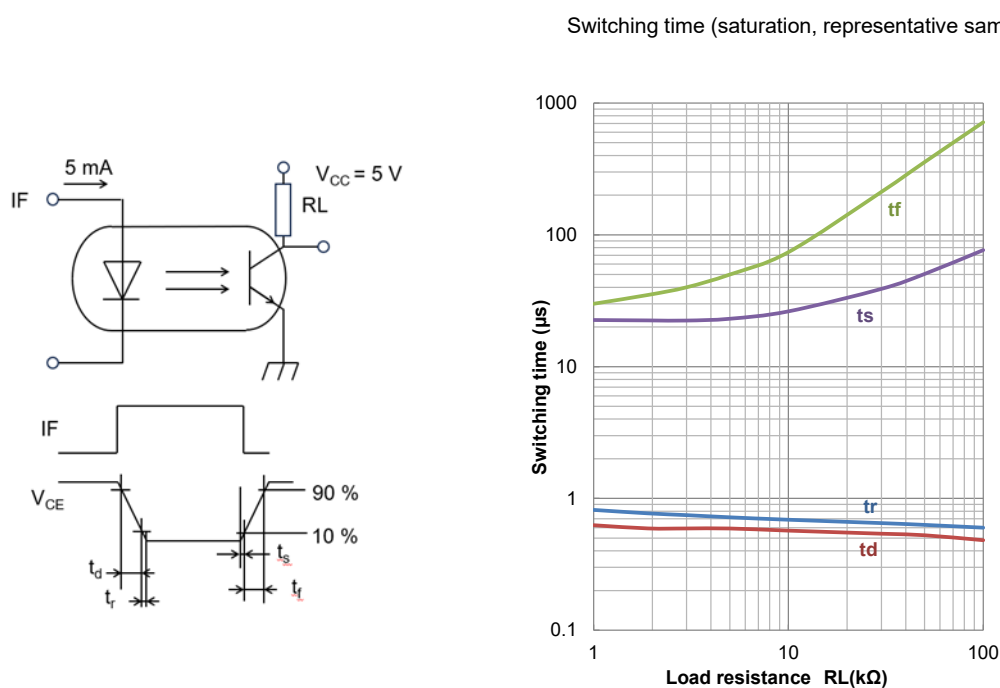


Figure 1.6 Switching Time - R_L

2. How to Use Transistor Couplers

2.1. LED Control Circuits

2.1.1. DC drive

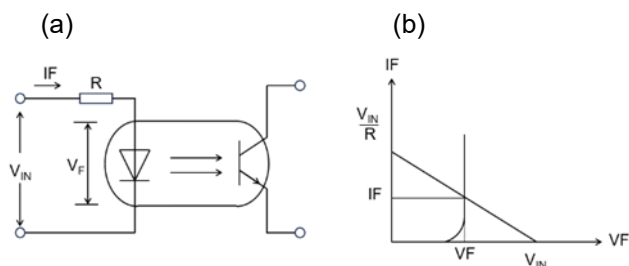
Figure 2.1(a) shows an example of controlling LED drive current by switching the supply voltage V_{IN} on and off.

Figure 2.1(b) indicates a load line in the (a) circuit.

In this case, the resistor R is as follows.

$$R = \frac{V_{IN} - V_F}{I_F}$$

Figure 2.1



For example, when $I_F = 10 \text{ mA}$, $V_{F(\text{max})} = 1.35 \text{ V}$, and $V_{IN} = 5 \text{ V}$,

$$R = \frac{(5 - 1.35) \text{ V}}{10 \text{ mA}} = 365 \Omega$$

Therefore, the resistor should be selected as $R = 360 \Omega$. In the case where $V_F = 0.9 \text{ V}$ due to the variation in different samples or the influence of operating temperature, the value of I_F is 11.4 mA .

2.1.2. Reverse Voltage Protection

To prevent a reverse surge voltage in the LED, a Si diode (for example, 1SS352) should be connected in reverse parallel with the LED, as shown in Figure 2.2, so that the reverse surge voltage bypasses the LED.

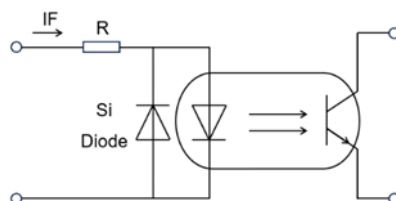


Figure 2.2

2.1.3. Reverse Voltage Protection

When the input voltage V_{IN} is not absolutely zero or some unnecessary current flow is in the data transmission line, the threshold voltage of the LED should be raised up to a certain level by connecting a resistor in parallel with the light-emitting diode. (Figure 2.3)

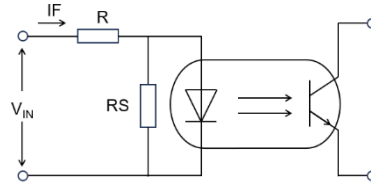


Figure 2.3

If the forward voltage of the LED in the zero-light-emission state V_T , the OFF-level input voltage $V_{IN(OFF)}$, and the OFF-level input current $I_{IN(OFF)}$ are given as follows.

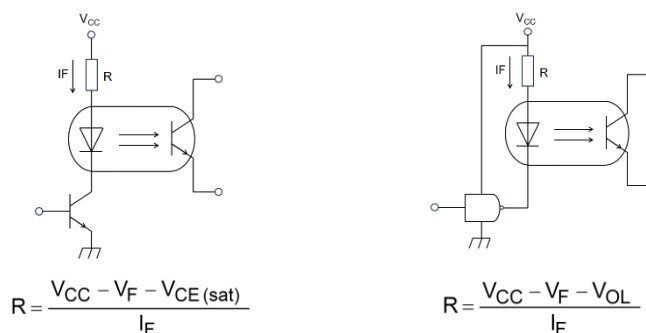
$$V_{IN(OFF)} \approx V_T + R \cdot \frac{V_T}{R_S} = \left(1 + \frac{R}{R_S}\right) V_T$$

$$I_{IN(OFF)} \approx \frac{V_T}{R_S}$$

In the case of the Toshiba infrared LED for transistor couplers), the value of V_T is 0.5 V.

2.1.4. Driving by Transistor or IC

Figure 2.4 shows examples of LED drive circuits controlled by (a) a transistor and (a) an IC.



(a) LED Drive Circuit Controlled by a Transistor (b) LED Drive Circuit Controlled by an IC

Figure 2.4

2.1.5. AC Drive

In this case, a bridge rectifier is used as shown in Figure 2.5.

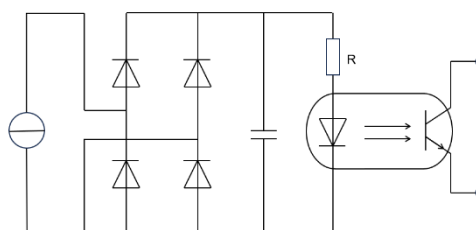


Figure 2.5

2.2. Examples of Application to Signal Transmission

Transistor couplers which have high photosensitivity and high current-transfer ratios are effective as interfaces for signal transmission. However, transmission lines are generally subjected to all kinds of noises, and it is therefore necessary to take countermeasures against these noises at the receiving side. In many cases, transistor couplers designed in a circuit similar to that shown in Figure 2.6 (b). However, this circuit design is vulnerable to certain kinds of interference in signal transmission. While common-mode noise do not pose a problem because of the isolation characteristics of transistor couplers, no measures have been taken against differential noise. Figure 2.6 (c) is an example of a circuit useful for eliminating differential noise. This circuit is the same as that of general-purpose transistors, with the addition of a resistor inserted between the base and the emitter.

High CTR transistor couplers are more effective in signal transmission applications. It can be seen from the graph that for a high CTR product, the cut-off area and the saturation area are closer than that of a low-CTR product. Because of this, it is possible to specify the threshold output voltage level with sufficient margin to allow for ease and flexibility in design. This circuit is recommended for that purpose.

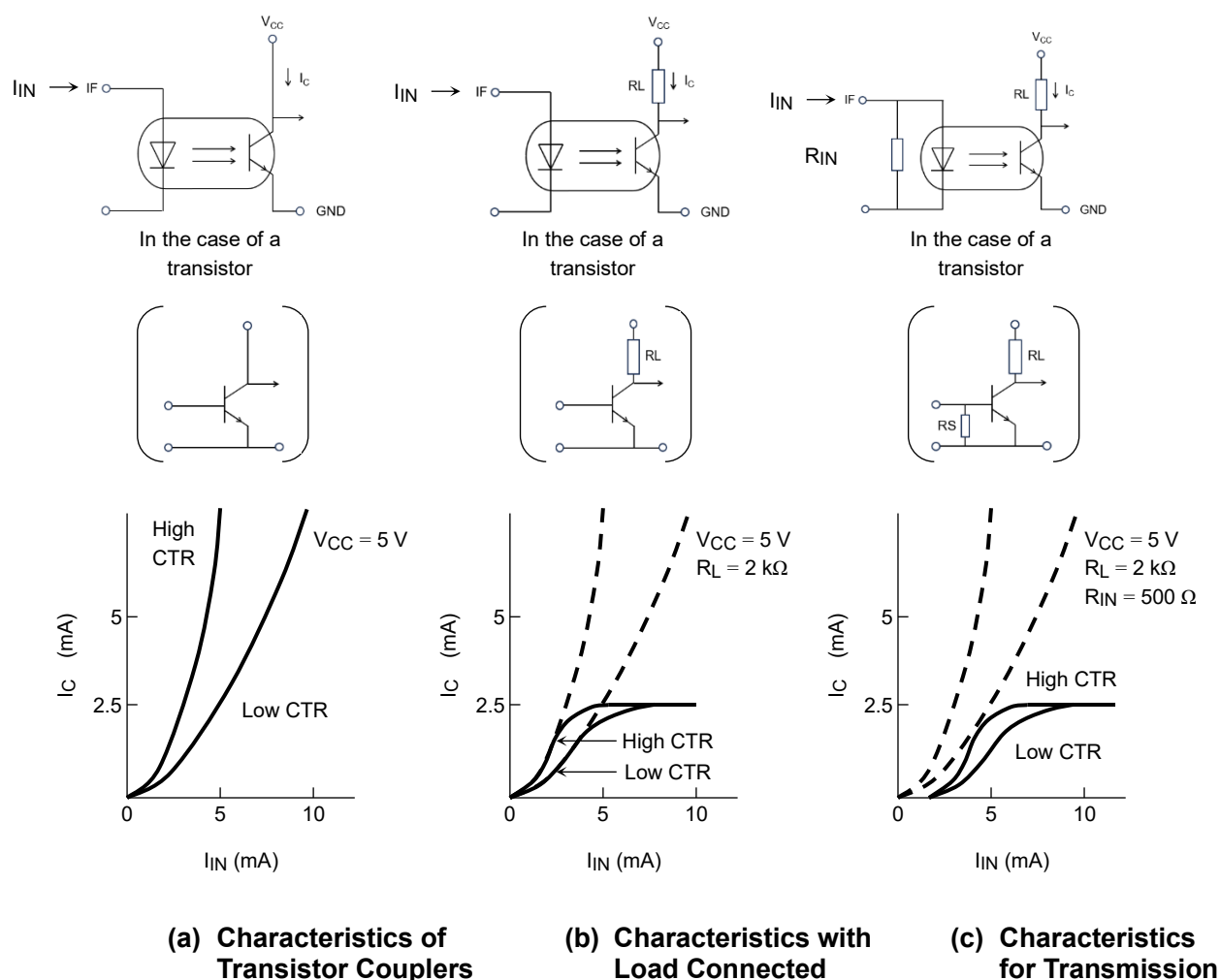


Figure 2.6 Load Characteristics of Transistor Couplers

2.3. Transistor Coupler Circuit Design for Signal Transmission

High CTR transistor couplers are more effective in signal transmission applications. It can be seen from the graph that for a high CTR product, the cut-off area and the saturation area are closer than that of a low-CTR product. Because of this, it is possible to specify the threshold output voltage level with sufficient margin to allow for ease and flexibility in design. This circuit is recommended for that purpose.

Figure 2.7 shows a basic transistor coupler interface circuit, where collector current I_C flows on the output side as LED current I_F is applied on the input side.

The following points are important in determining the values of the various parameters in the circuit:

(1) $I_{IN} = I_F = 0$ (OFF state)

Only a dark current I_D (I_{CEO}) flows at the output transistor in this state. In order to maintain the OFF state, the output voltage $V_{OUT(OFF)}$ should be higher than V_H (the required high level voltage) as follows:

$$V_{CC} - I_D \times R_L = V_{OUT(OFF)} > V_H$$

Where, V_{CC} : Applied voltage (supply voltage)

The leakage current I_D increases as the ambient temperature rises (see Figure 2.8 I_D vs. T_a), so the I_D value will have to be considered at the worst case, here being the maximum operating temperature. As such, the value of R_L should meet the following formula:

$$R_L < \frac{V_{CC} - V_H}{I_D}$$

(2) $I_{IN} = I_F$ (ON state)

When the collector current I_C ($I_{C(ON)}$) flows on the output side of the transistor coupler, output $V_{OUT(ON)}$ has to be less than V_L (the required low level voltage) as follows:

$$V_{CC} - I_{C(ON)} \times R_L = V_{OUT(ON)} < V_L$$

Therefore,

$$R_L > \frac{V_{CC} - V_L}{I_{C(ON)}}$$

Generally, when the R_L value is large, the switching response time increases, so the R_L value should be kept as small as possible.

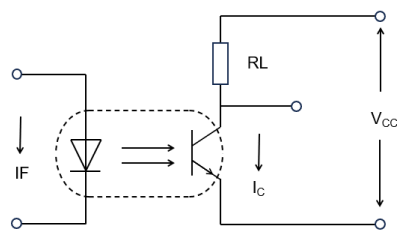


Figure 2.7 Transistor Coupler

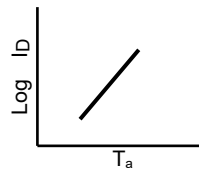


Figure 2.8 I_D vs. T_a

(3) Considerations for input current I_{IN} in the “ON” state

The characteristic curves of I_C vs. I_F , CTR vs. T_a , and CTR vs. t as shown in Figure 2.9, Figure 2.10 and Figure 2.11 respectively can be found in the product technical data sheet.

The transistor coupler CTR test is performed at the specific point ① in Figure 2.9. This point ① is not always the same as the actual operating point, so some compensation work is required to be done by the following procedure.

i) Draw the extrapolated CTR min curve B in parallel with the reference curve A.

The point of intersection ① shows the “CTR min” specification value.

Where, $CTR = I_C / I_F$, $I_C \text{ min} = CTR \text{ min} \times I_{F1}$

ii) Determine I_{F2} from the intersection point of $I_C = I_{C(ON)}$ with curve B.

I_{F2} indicates the minimum input current at $T_a = 25^\circ\text{C}$ and operating time $t = 0$ hour. When considering the relationship between CTR and T_a (Figure 2.10), as well as CTR degradation (Figure 2.11), the minimum input current I_{IN} has to conform to the following formula.;

$$I_{IN} > I_{F2} \times \frac{1}{D_{Ta}} \times \frac{1}{D_t} \times \alpha$$

Where, D_{Ta} : Rate of CTR fluctuation within the operating temperature range

D_t : CTR degradation rate after “t” hours of operation

α : System design margin

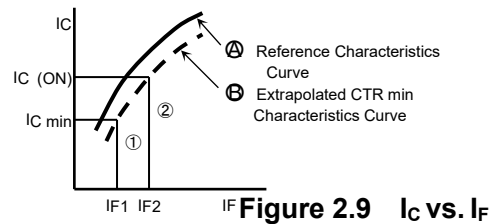


Figure 2.9 I_C vs. I_F

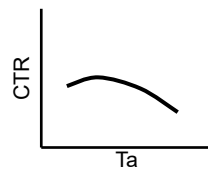


Figure 2.10 CTR vs. T_a

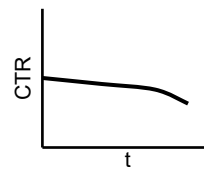


Figure 2.11 CTR vs. t

2.4. Design Example for Interface Circuit Using Transistor Coupler

Figure 2.12 shows a circuit using a 4 pin transistor coupler as an interface between TTLs. In order to ensure absolute ON/OFF operation of the TTL, the LED current I_F should be set to satisfy I_{OL} which is determined by R_C and I_{IL} .

Example of Design Specifications

Operating temperature T_{opr} : 0 to 70 °C
 Data transmission rate : 5 kbit/s
 Supply voltage : $V_{CC} = 5\text{ V} \pm 5\%$
 Operating life : 10 years (88,000 hours)
 System working ratio: 50 %

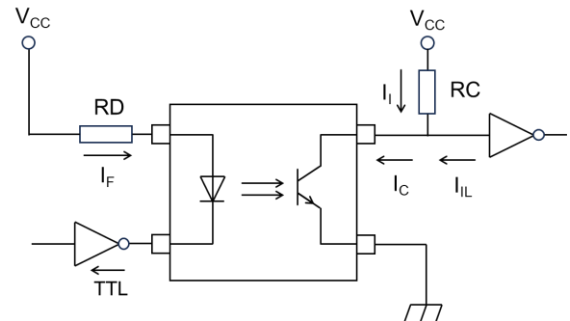


Figure2.12

Interface Circuit between TTLs Using a 4pin Transistor Coupler

CTR free rank is used. Specifications of products for designing interface circuits are shown in Table 2.1.

Table 2.1 Principal Characteristics Example

Item	Symbol	Test Condition ($T_a = 25^\circ\text{C}$)		min	typ.	max	Unit
Forward voltage	V_F	$I_F = 10\text{ mA}$		1.0	1.15	1.3	V
Collector to emitter Breakdown voltage	$V_{(BR)CEO}$	$I_C = 0.5\text{ mA}$		80	—	—	V
Emitter to collector Breakdown voltage	$V_{(BR)ECO}$	$I_E = 0.1\text{ mA}$		7	—	—	V
Collector dark current	I_{CEO}	$I_F = 0, V_{CE} = 24\text{ V}$		—	0.01	0.1	μA
		$I_F = 0, V_{CE} = 24\text{ V}, T_a = 85^\circ\text{C}$		—	0.6	50	μA
Current transfer ratio	CTR (I_C/I_F)	$I_F = 5\text{ mA}$ $V_{CE} = 5\text{ V}$	free	50	—	600	%
			GB rank	100	—	600	
			GR rank	100	—	300	
			BL rank	200	—	600	
Collector to emitter Saturation voltage	$V_{CE(sat)}$	$I_F = 8\text{ mA}, I_C = 2.4\text{ mA}$		—	0.2	0.4	V

2.4.1. Setting of Forward Current I_F

The maximum forward current I_F is typically 16 mA for TTL I_{OL} , and is subjected to the constrain $I_F \leq I_{OL}$. The maximum allowable value of I_F found from Figure 2.13 is 38 mA. However, I_F should be kept as small as possible because CTR degradation increases with the increase of forward current. Figure 2.14 shows the degradation of CTR. In order to realize the design of continuous operating life of 10 years (approximately 88,000 hours, 44,000 at system working ratio 50%), consider the degradation of CTR to be 50% ($D_t = 0.5$). The CTR measurement condition is at $I_F = 5$ mA, so forward current should be set at $I_F = 5 / 0.5 = 10$ mA for the initial design.

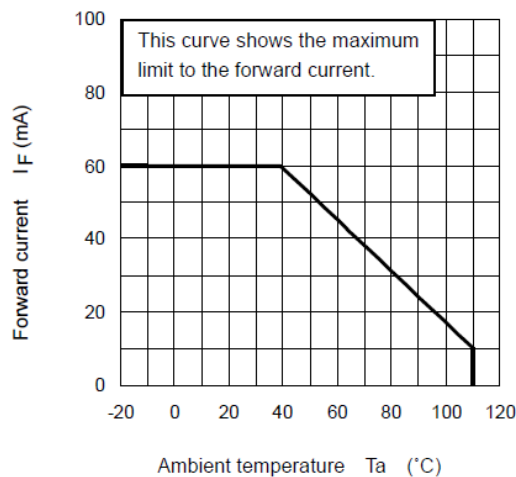


Figure 2.13 Ambient Temperature vs. Allowable Forward Current

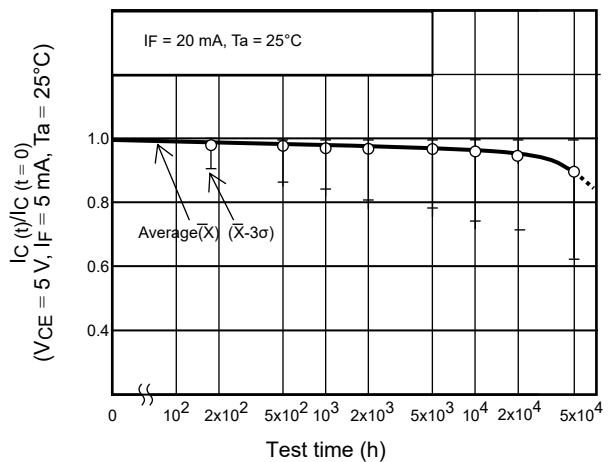


Figure 2.14 Lifetime Test Data * (CTR degradation)

Note: This data shows an example of the CTR degradation curve. Please design the circuit after confirming the reliability information on individual products.

2.4.2. Setting of the IF Limiting Resistance RD

Forward current (typ.) is expressed by the following formula:

$$I_{F(\text{typ.})} = \frac{V_{CC} - V_{F(\text{typ.})} - V_{OL}}{R_{D(\text{typ.})}}$$

where $V_{F(\text{typ.})}$ is obtained from the technical datasheet.

$$V_{F(\text{typ.})} = 1.15 \text{ V } (I_F = 10 \text{ mA})$$

R_D is determined as follows:

$$\begin{aligned} R_D &= \frac{5\text{V} - 1.15\text{V} - 0.4\text{V}}{10\text{mA}} \\ &= 345 \Omega \end{aligned}$$

Therefore, $R_D = 330 \Omega \pm 5\%$ will be optimum.

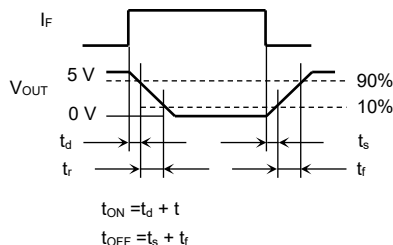
Then $I_{F(\text{min})}$ and $I_{F(\text{max})}$ should be checked to make sure that actual values of I_F will remain within allowable tolerances:

$$\begin{aligned} I_{F(\text{min})} &= \frac{V_{CC(\text{min})} - V_{F(\text{max})} - V_{OL}}{R_{D(\text{max})}} \\ &= \frac{4.75\text{V} - 1.3\text{V} - 0.4\text{V}}{347\Omega} \\ &= 8.8 \text{ mA} \end{aligned}$$

$$\begin{aligned} I_{F(\text{max})} &= \frac{V_{CC(\text{max})} - V_{F(\text{min})} - V_{OL}}{R_{D(\text{min})}} \\ &= \frac{5.25\text{V} - 1.0\text{V} - 0.4\text{V}}{314\Omega} \\ &= 12.3 \text{ mA} \end{aligned}$$

2.4.3. Setting of Pull-up Resistance R_C (max)

R_C (max) should be set according to the switching time and dark current I_{CEO} (max) at the maximum operating temperature of the transistor coupler.



Since the design specification for data transmission rate is 5 kbit/s, the total switching time should satisfy the below condition.

$$T = t_r + t_d + t_f + t_s \leq 200 \mu\text{s}$$

Switching time changes with various conditions, such as CTR (current transfer ratio), R_L (load resistance), and T_a (ambient temperature). R_L should be designed to accommodate these changes in these conditions. Please check the technical datasheet for the influence of change in I_F , V_{CC} etc. Here, T (max) is set at $T \leq 100 \mu\text{s}$ taking into consideration of a variation margin for I_F , V_{CC} etc.

The switching time t_{OFF} ($=t_s + t_f$) increases as the CTR rises (see Figure 2.15 CTR vs. Switching time), this is because the h_{FE} of phototransistor tends to increase as the CTR rises. Therefore, it will be desirable to choose a product with a small CTR rank when a maximum switching time is specified.

Products of CTR free rank (50 to 600%) seem suitable for satisfying the condition $T \leq 100 \mu\text{s}$. However, we can see from Figure 2.15 that switching time for products of similar rank can vary slightly (t_{OFF} has a difference for about $10 \mu\text{s}$ on the similar CTR=200% samples). Therefore, GR rank (100 to 300%) is selected taking into consideration such variation in characteristics and influences due to other parameter change (T_a , R_L etc.). Next, refer to Figure 2.16 T_a vs. switching time (CTR=300% sample). Switching time is increased by 40% when T_a is raised from 25°C to 70°C . Therefore, at $T_a=70^\circ\text{C}$, $T = 100 / 1.4 < 70 \mu\text{s}$.

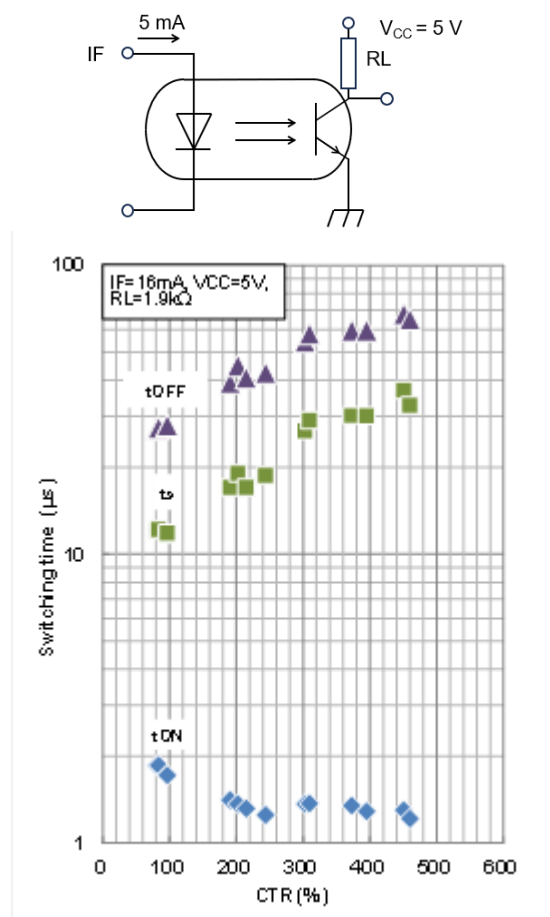


Figure 2.15 CTR vs. Switching time (saturated)

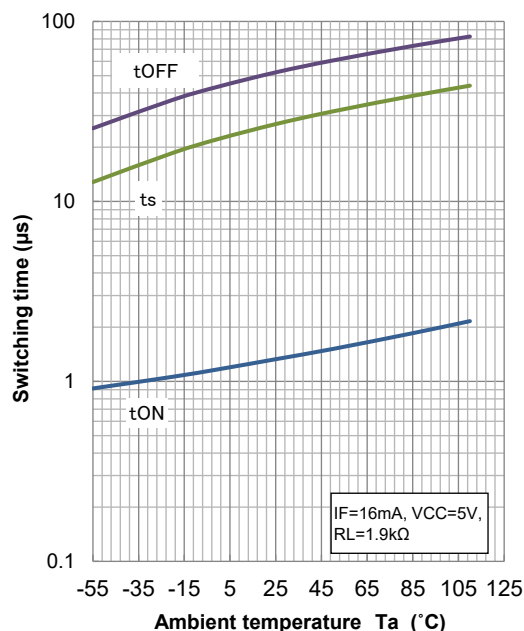


Figure 2.16 T_a vs. Switching time (saturated)

The load resistance R_L is obtained from the switching time characteristic (for saturated operation) in Figure 2.17. Reading off the graph, for $T \leq 70 \mu s$, load resistance should satisfy $R_L \leq 3 k\Omega$. R_L can be expressed in terms of R_C and the parallel resistance of the standard TTL input resistance R_{IN} (Figure 2.18). $R_{C(max)}$ is obtained as follows.

$$R_L = R_C / R_{IN}$$

$$R_L = 1 / ((1 / R_C) + (1 / R_{IN})) \leq 3 k\Omega$$

$$\text{As, } R_{IN} = 4 k\Omega$$

$$R_C \leq 12 k\Omega$$

Next, check $R_{C(max)}$ with regards to the dark current $I_{CEO(max)}$. The relation between $I_{CEO(max)}$ and $R_{C(max)}$ is shown below.

$$R_{C(max)} = \frac{V_{CC(min)} - V_{IH}}{I_{CEO}}$$

V_{IH} is high level input voltage for TTL.

Here, $I_{CEO(max)}$ is estimated at $T_a = 70^\circ C$. Temperature dependencies of $I_{CEO(typ.)}$ at alternative parameter values of $V_{CE} = 5 V$, $10 V$, and $24 V$ are shown in Figure 2.19.

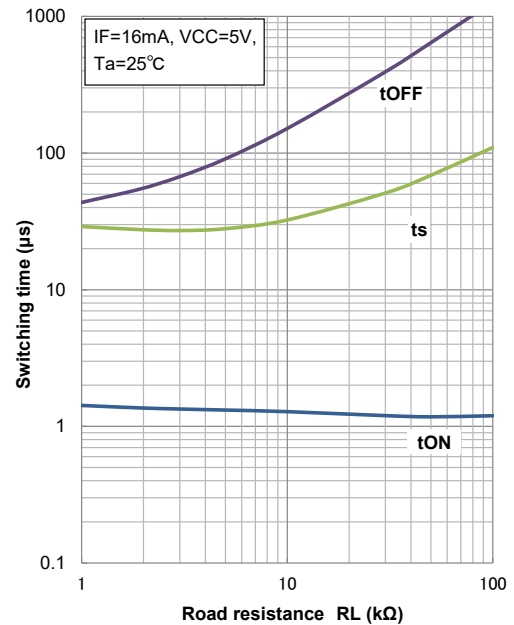


Figure 2.17 R_L vs. Switching Time (Saturated)

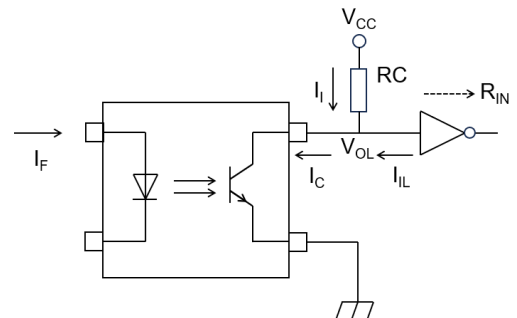


Figure 2.18 R_L can be Expressed by R_{IN} and R_C

In the case of general transistor coupler,
 $I_{CEO(max)} = 50 \mu A$ at $T_a = 85^\circ C$ and $V_{CE} = 24 V$ (technical datasheet specifications). Taking V_{CE} dependency and T_a dependency into consideration using Figure 2.19, $I_{CEO(max)}$ is estimated at $T_a = 70^\circ C$ and $V_{CE} = 5 V$.

V_{CE} dependency: $I_{CEO(typ.)}$ is reduced by 1/3 when V_{CE} is varied from 24 to 5 V.

T_a dependency: $I_{CEO(typ.)}$ is reduced by 1/4 when T_a is varied from 85 to $70^\circ C$.

Therefore, $I_{CEO(max)}$ at $T_a = 70^\circ C$ and $V_{CE} = 5 V$ is estimated to be,

$$I_{CEO} = 50 \mu A \times \frac{1}{3} \times \frac{1}{4} = 4.2 \mu A$$

At $I_{IH} = 40 \mu A$ for general TTLs and $R_{C(max)}$ will be obtained as follows.

$$R_{C(max)} = \frac{4.75V - 2V}{4.2 \mu A + 40 \mu A} = 62 k\Omega$$

Since this is a larger value than $12k\Omega$ set up from switching time, $R_{C(max)}$ is set at $12k\Omega$.

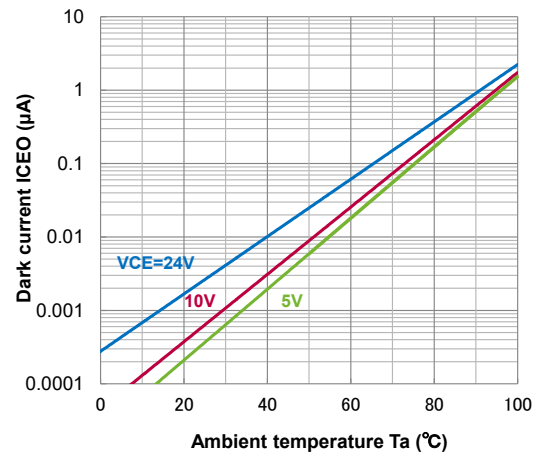


Figure 2.19 I_{CEO} vs. Temperature

2.4.4. Setting of Pull-up Resistance R_C

Assuming the worst-case scenario where the collector current I_C is at its minimum in Figure 2.18, R_C can be expressed by the following relation.

$$R_C \geq \frac{V_{CC(max)} - V_{OL}}{\min I_C - I_{IL}}$$

$$\min I_C = I_{C(min)} \times D_{IF} \times D_t \times D_{VCE} \times D_{Ta}$$

Were,

D_t : I_C degradation rate after a certain time has passed.

D_{IF} : I_C change rate at an I_F setting for your designing.

D_{VCE} : I_C drop rate under $V_{CE(sat)}$ condition.

D_{Ta} : I_C fluctuation rate with changes in the operating temperature T_{opr} .

These values are obtained from technical data.

From Figure 2.14, $D_t = 0.5$ ($t = 44,000$ h, 50% operating ratio)

From Figure 2.20, $D_{IF} = 2.3$ (at $I_F = 10$ mA)

From Figure 2.21, $D_{VCE} = 0.7$ (at $V_{CE} = 0.4$ V)

From Figure 2.22, $D_{Ta} = 0.75$ (at $T_a = 70^\circ C$)

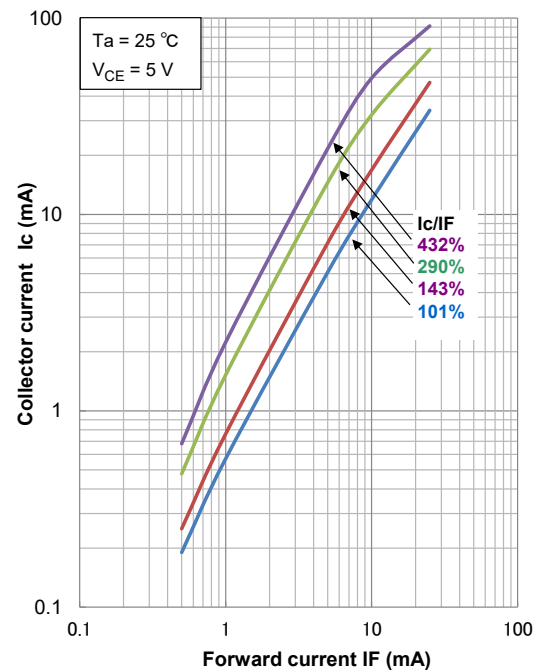


Figure 2.20 I_C vs. I_F Curves Varying According to Different I_C/I_F Ratios

On the other hand, GR rank is selected at section 2.4.3 as $I_{C(min)} = 5 \text{ mA}$ (at $I_F = 5 \text{ mA} \times I_C/I_F (min) = 100\%$), and

$$\begin{aligned} \min I_C &= 5 \text{ mA} \times 2.3 \times 0.5 \times 0.7 \times 0.75 \\ &= 3 \text{ mA} \end{aligned}$$

Accordingly, I_{IL} is 1.6 mA for general TTLs and $R_{C(min)}$ can be obtained as follows:

$$R_{C(min)} = \frac{5.25\text{V} - 0.4\text{V}}{3.0\text{mA} - 1.6\text{mA}} \approx 3.5\text{k}\Omega$$

In other words, R_C can be set from 3.5 k Ω to 12 k Ω , but it is also necessary to consider the switching speed required by the system and the importance of absolute ON or OFF conditions. If the switching speed is relatively more important, R_C should be set to a value close to $R_{C(min)}$. On the other hand, if the certainty of ON and OFF operation is considered to be the most important criterion, a value close to $R_{C(max)}$ should be selected (the operating life of the device may be defined as the period during which there is certainty of the ON and OFF conditions being properly set.). In this case, since D_t is assumed to be 0.5 with a relatively high margin the switching speed should be more important. So, R_C is set at 4.7 k Ω .

$R_D = 330 \text{ }\Omega$ and $R_C = 4.7 \text{ k}\Omega$ are calculated values determined by the procedures above. Please perform a thorough check of the waveform and the operation with your system and redesign a R_D and R_C as necessary. When faster data speed is required for a system, you can also select an IC coupler with guarantee of the maximum switching time. When using a transistor coupler as an interface between CMOS, circuit design can also be conducted in the same way as the above TTLs. Please note that in the case of CMOS, I_{IL} and I_{IH} are smaller than TTLs. Also, the input voltage level of CMOS is different from that of TTLs. As such, please pay careful attention to the characteristics of CMOS during circuit design.

Note: All the electrical data on this document is a reference of a representative sample.

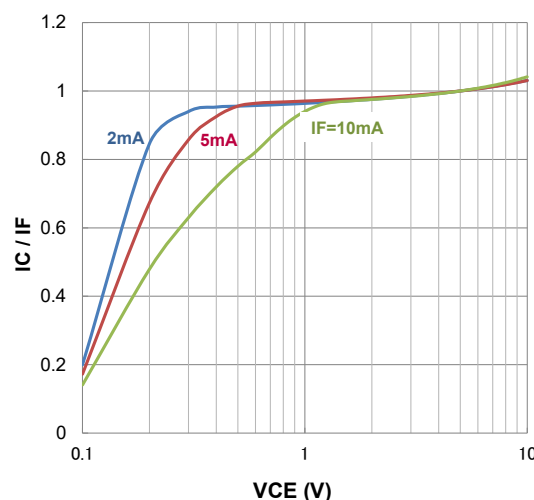


Figure 2.21 I_C/I_F vs. V_{CE}

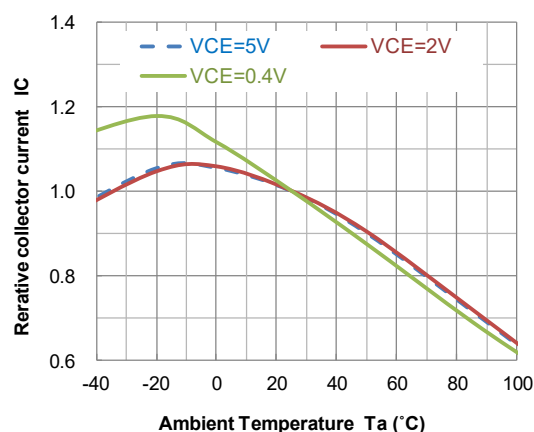


Figure 2.22 Collector Current vs. T_a

3. Terms

(General terms)

Term	Symbol	Description
Absolute Maximum Rating		Maximum value that must not be exceeded even for an instant during operation
Isolation Voltage	BV_S	Isolating voltage between input and output under the specified conditions
Capacitance (Input to Output), Total Capacitance (Input to Output)	C_S	Electrostatic capacitance between the input and output pins
Capacitance (Input), Input Capacitance	C_T C_t	Electrostatic capacitance between the anode and cathode pins of the LED
Forward Current, Input Forward Current	I_F	Rated current that can flow continuously in the forward direction of the LED
Pulse Forward Current, Input Forward Current (Pulsed)	I_{FP}	Rated current that can flow momentarily in the forward direction of the LED
Peak Transient Forward Current	I_{FPT}	Rated current that can flow momentarily in the forward direction of the LED
Reverse Voltage, Input Reverse Voltage	V_R	Rated reverse voltage that can be applied across the LED's cathode and anode
Reverse Current, Input Reverse Current	I_R	Leakage current flowing in the reverse direction of the LED (from cathode to anode)
Forward Voltage, Input Forward Voltage	V_F	Voltage drop across the anode and cathode pins of the LED under the specified forward-current condition
LED Power Dissipation, Input Power Dissipation	P_D	Rated power that can be dissipated in the LED
Total Power Dissipation	P_T	Total rated power that can be dissipated in both the input and output devices
Isolation Resistance	R_S	Resistance between the input and output pins at the specified voltage
Junction Temperature	T_j	Permissible temperature of the junction of the photodetector or LED
Operating Temperature	T_{opr}	Ambient temperature range in which the device can operate without loss of functionality
Lead Soldering Temperature	T_{sol}	Rated temperature at which the device pins can be soldered without loss of functionality
Storage Temperature	T_{stg}	Ambient temperature range in which the device can be stored without operation
Creepage Distance		Shortest distance along the surface of insulation between the path of two conductive parts (input and output)
Clearance (Clearance Distance)		Shortest distance through air between the path of two conductive parts (input and output)
Internal Isolation Thickness, Insulation Thickness		Distance through insulation. Shortest thickness through internal insulation between the path of two conductive parts (input and output)

(Transistor output)

Term	Symbol	Description
Collector Current	I_C	Rated current allowed to flow to collector
Current Transfer Ratio	I_C/I_F (CTR)	Ratio of output current, I_C , to input current, I_F : $I_C/I_F \times 100$ (unit: %)
Collector Dark Current, Dark Current	I_{CEO} I_{DARK}	Leakage current flowing between collector and emitter
OFF-state Collector Current	$I_{C(off)}$	Leakage current flowing between collector and emitter when Low voltage is applied to input
Current Gain Factor	h_{FE}	h_{FE} for phototransistor
Base Photo-Current	I_{PB}	Photo-current generated by the specified input current, I_F , in the phototransistor base block
Collector Power Dissipation	P_C	Rated power that can be dissipated in collector
Turn-On Time	t_{ON} t_{on}	Time required for the output waveform to change from 100% (0%) to 10% (90%) when the input is turned off and back on under the specified conditions
Turn-Off Time	t_{OFF} t_{off}	Time required for the output waveform to change from 0% (100%) to 90% (10%) when the input is turned on and back off under the specified conditions
Storage Time	t_S	Time required for the output waveform to change from 0% (100%) to 10% (90%) when input is turned on and back off under the specified conditions
Fall Time	t_f	Time required for the output waveform to change from 90% to 10%
Rise Time	t_r	Time required for the output waveform to change from 10% to 90%
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	Voltage between collector and emitter under the specified saturation conditions
Collector-Base Breakdown Voltage	$V_{(BR)CBO}$	Breakdown voltage between collector and base when emitter is open
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	Breakdown voltage between collector and emitter (when base is open)
Emitter-Base Breakdown Voltage	$V_{(BR)EBO}$	Breakdown voltage between emitter and base when collector is open
Emitter-Collector Breakdown Voltage	$V_{(BR)ECO}$	Breakdown voltage between emitter and collector (when base is open)
Collector-Base Voltage	V_{CBO}	Rated voltage that can be applied across collector and base
Collector-Emitter Voltage	V_{CEO}	Rated voltage that can be applied across collector and emitter
Emitter-Base Voltage	V_{EBO}	Rated voltage that can be applied across emitter and base
Emitter-Collector Voltage	V_{ECO}	Rated voltage which can be applied across emitter and collector
Capacitance (Collector to Emitter), Collector-Emitter Capacitance	C_{CE}	Electrostatic capacitance between the collector and emitter pins

4. Appendix (Representative Product Characteristics)

Representative Product

- TLP183
- TLP184(SE)
- TLP185(SE)
- TLP188
- TLP383
- TLP385
- TLP620M
- TLP621M
- TLP2301

Product Characteristics

- Collector current (I_C) – Collector-emitter voltage (V_{CE})
- Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)
- Collector current (I_C) – Input forward current (I_F)
- Current transfer ratio (I_C / I_F) – Input forward current (I_F)
- Collector current (I_C) – Ambient temperature (T_a)
- Switching time – Ambient temperature (T_a)
- Frequency characteristics (Relative output (G_V), Phase (θ))

Note: All the electrical data on this document is a reference of a representative sample.

TLP183

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

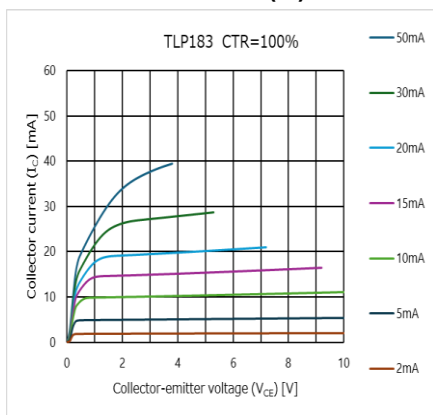


Figure 4.1 $I_C - V_{CE}$
(CTR=100%)

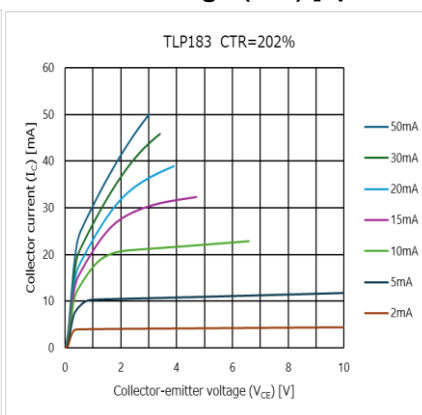


Figure 4.2 $I_C - V_{CE}$
(CTR=202%)

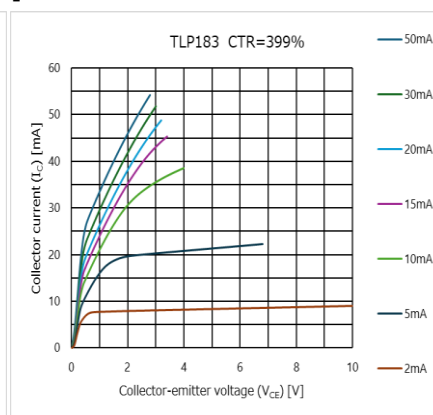


Figure 4.3 $I_C - V_{CE}$
(CTR=399%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

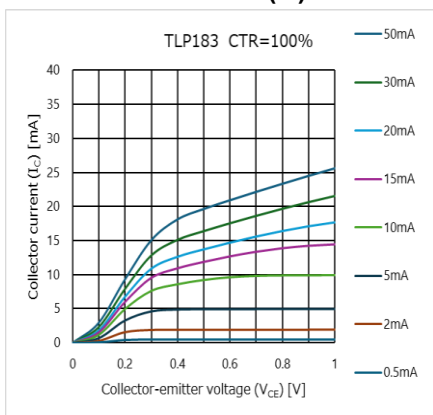


Figure 4.4 $I_C - V_{CE}$
(CTR=100%)

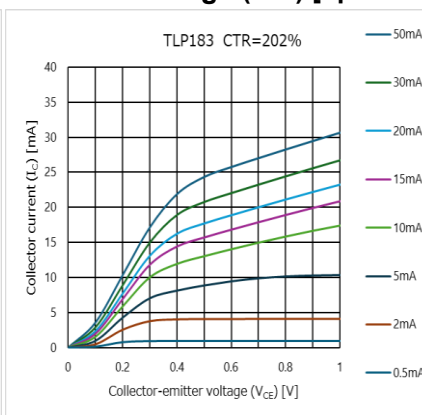


Figure 4.5 $I_C - V_{CE}$
(CTR=202%)

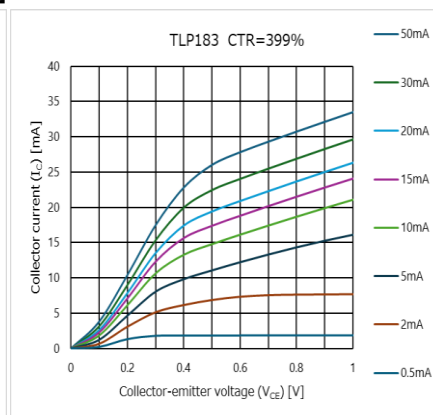


Figure 4.6 $I_C - V_{CE}$
(CTR=399%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

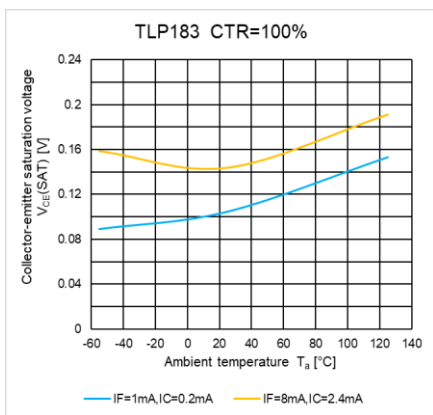


Figure 4.7 $V_{CE} - T_a$
(CTR=100%)

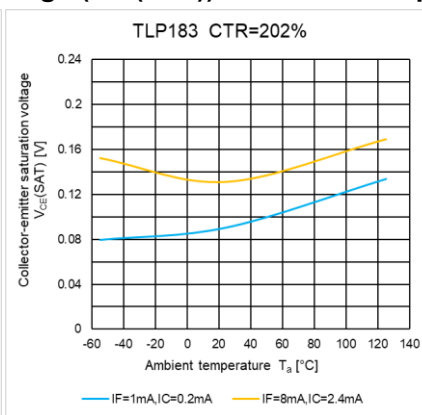


Figure 4.8 $V_{CE} - T_a$
(CTR=202%)

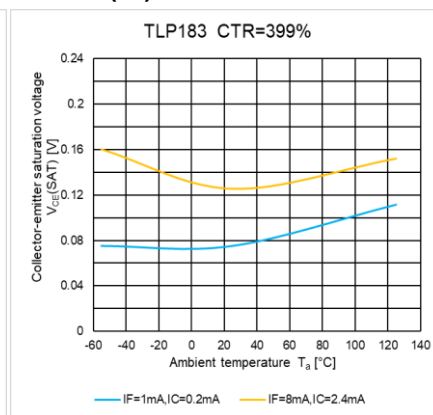
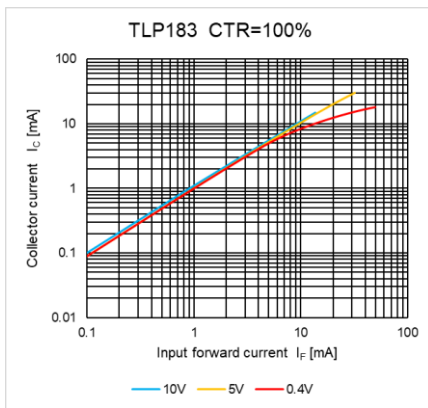
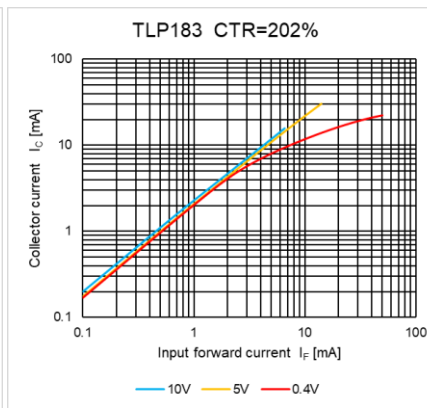


Figure 4.9 $V_{CE} - T_a$
(CTR=399%)

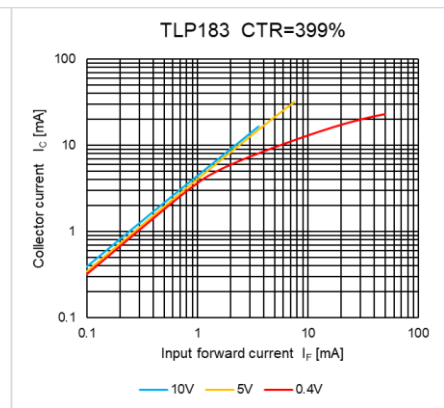
Collector current (I_C) – Input forward current (I_F)



**Figure 4.10 $I_C - I_F$
(CTR=100%)**

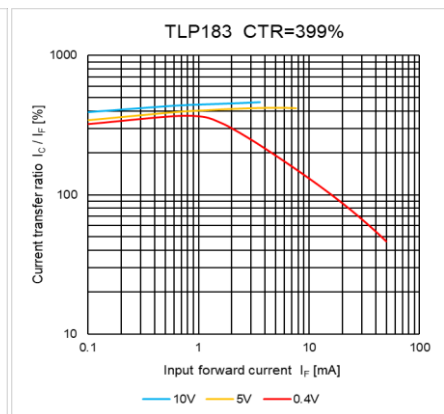
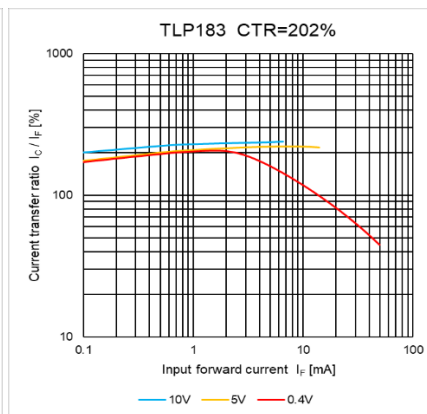
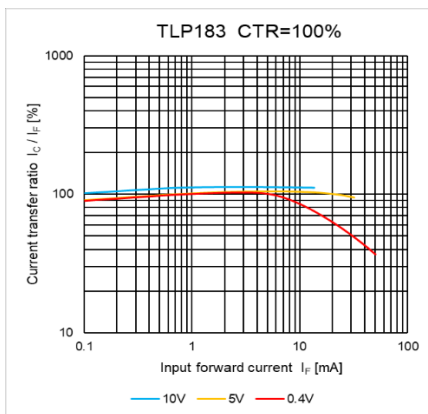


**Figure 4.11 $I_C - I_F$
(CTR=202%)**



**Figure 4.12 $I_C - I_F$
(CTR=399%)**

Current transfer ratio (I_C / I_F) – Input forward current (I_F)



Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

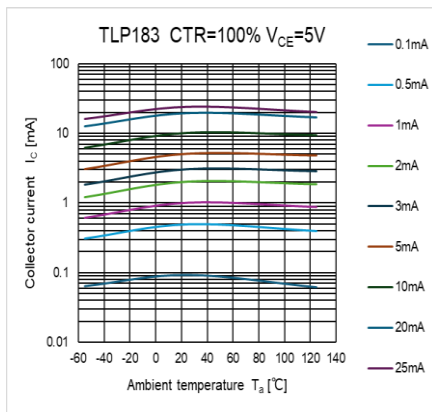


Figure 4.16 $I_C - T_a$
(CTR=100%)

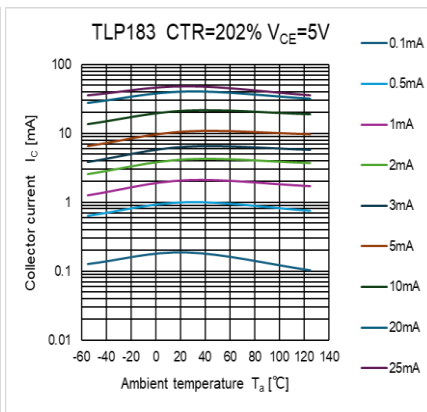


Figure 4.17 $I_C - T_a$
(CTR=202%)

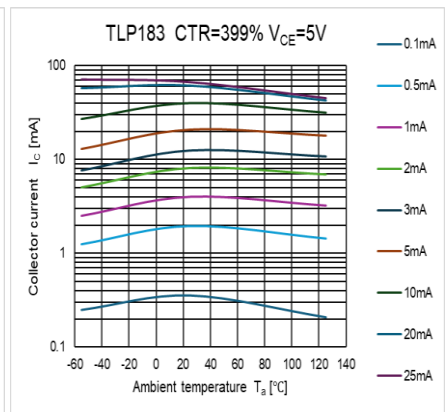


Figure 4.18 $I_C - T_a$
(CTR=399%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

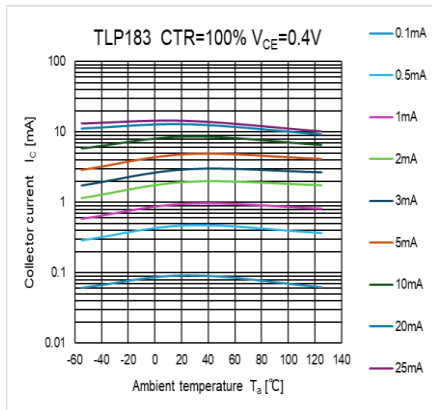


Figure 4.19 $I_C - T_a$
(CTR=100%)

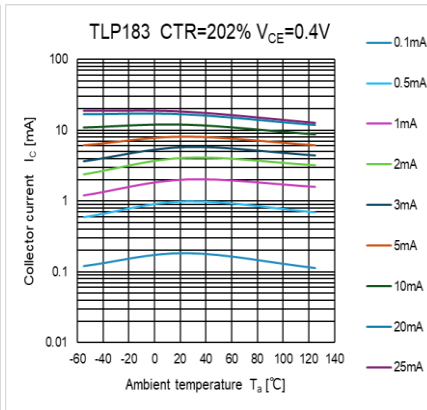


Figure 4.20 $I_C - T_a$
(CTR=202%)

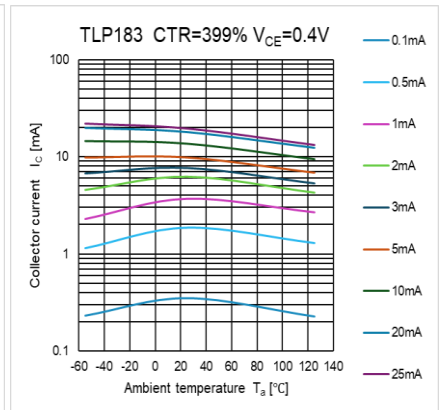
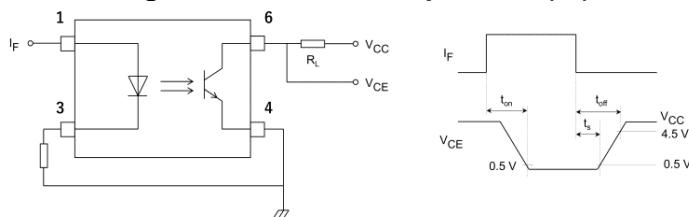


Figure 4.21 $I_C - T_a$
(CTR=399%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP183

$R_L=1.9k\Omega$ low input, $I_F=5mA$

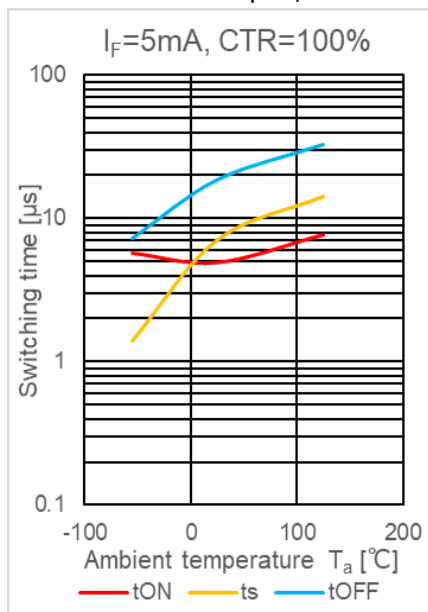


Figure 4.22 Switching time - T_a
(CTR=100%)

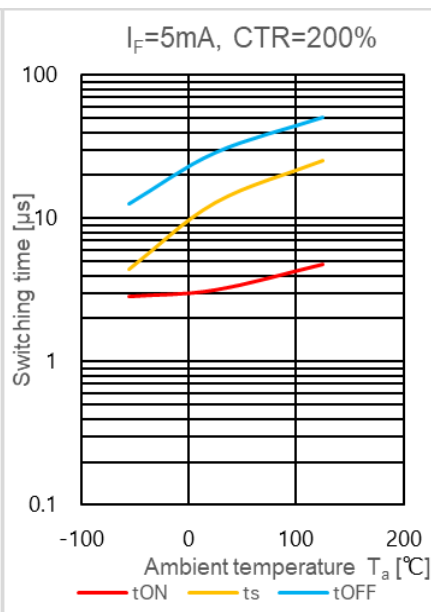


Figure 4.23 Switching time - T_a
(CTR=200%)

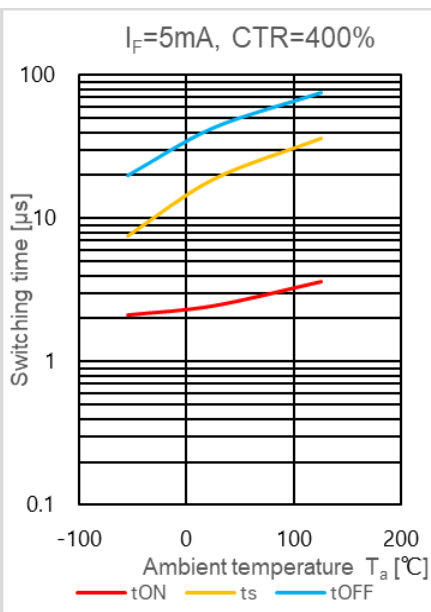


Figure 4.24 Switching time - T_a
(CTR=400%)

$R_L=1.9k\Omega$ low input, $I_F=16mA$

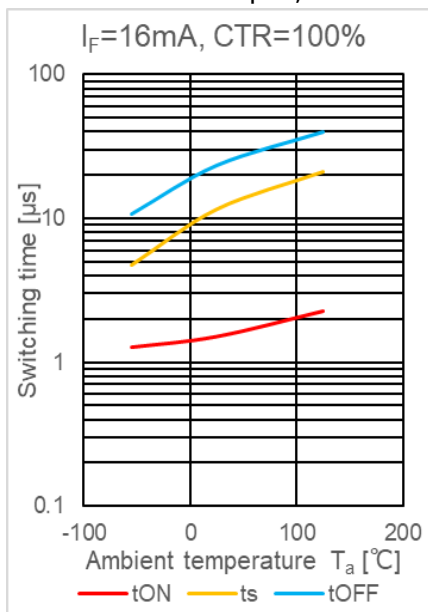


Figure 4.25 Switching time - T_a
(CTR=100%)

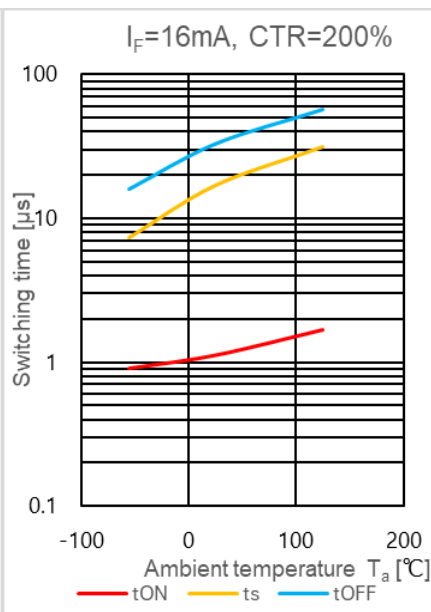


Figure 4.26 Switching time - T_a
(CTR=200%)

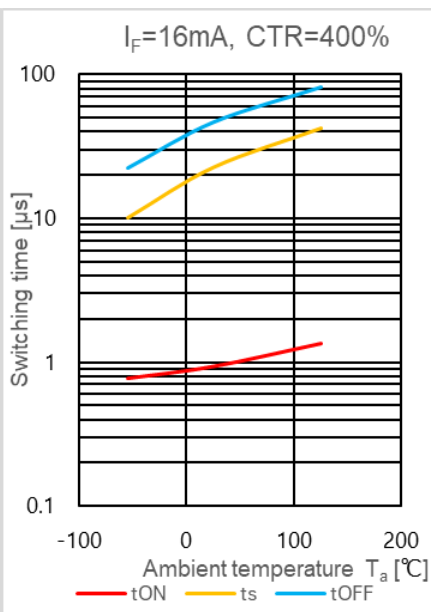
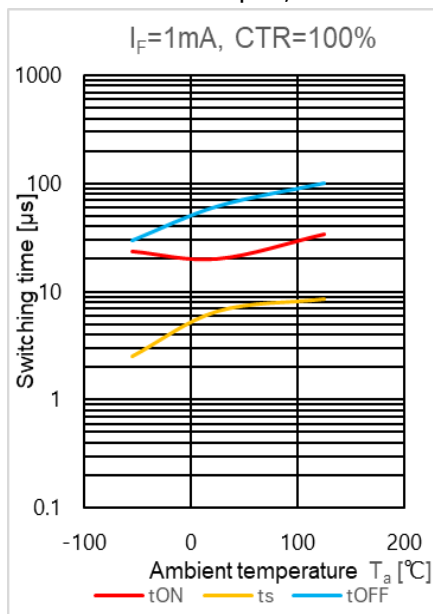
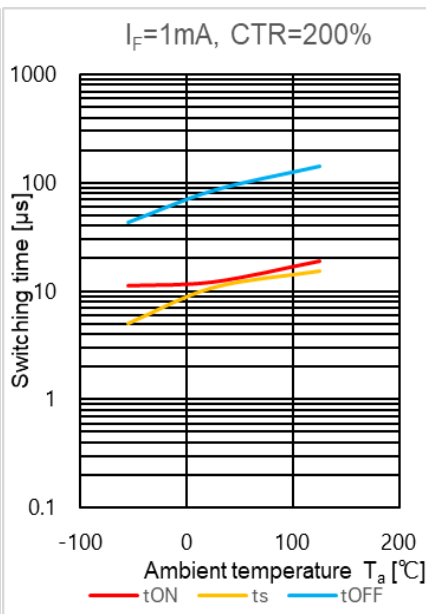


Figure 4.27 Switching time - T_a
(CTR=400%)

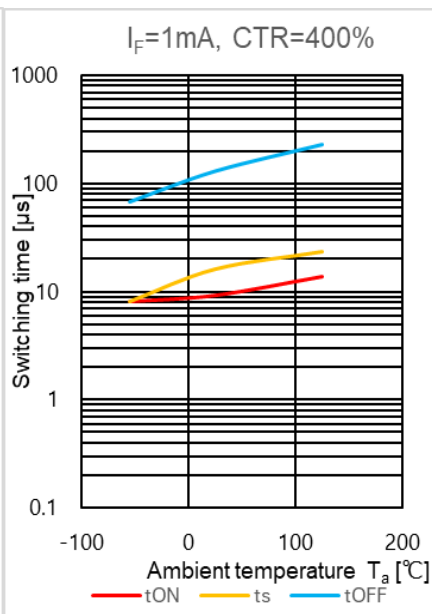
$R_L=10k\Omega$ low input, $I_F=1mA$



**Figure 4.28 Switching time - T_a
(CTR=100%)**

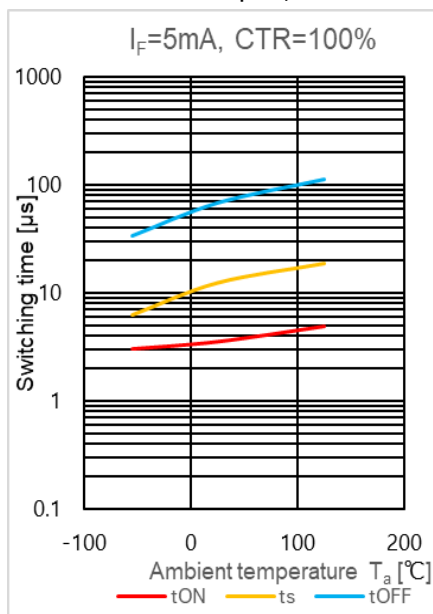


**Figure 4.29 Switching time - T_a
(CTR=200%)**

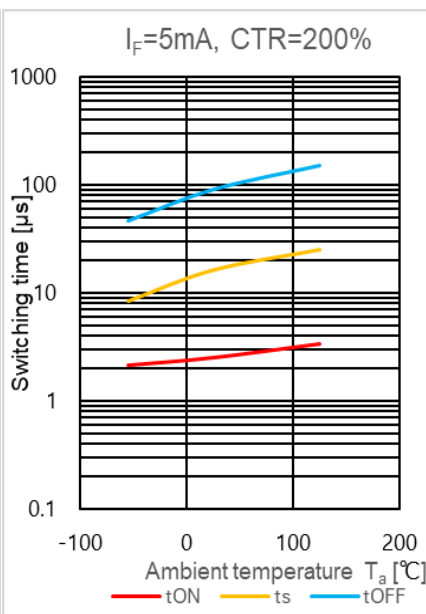


**Figure 4.30 Switching time - T_a
(CTR=400%)**

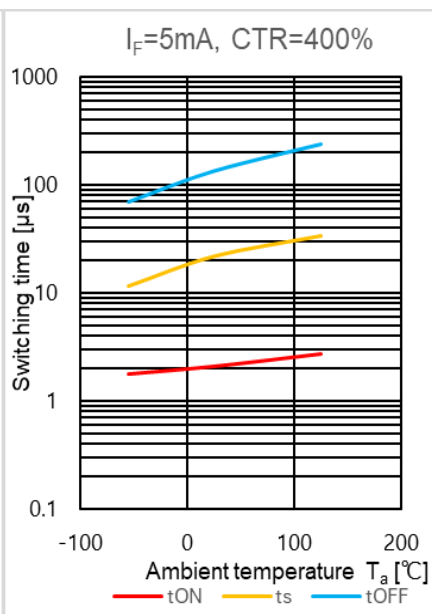
$R_L=10k\Omega$ low input, $I_F=5mA$



**Figure 4.31 Switching time - T_a
(CTR=100%)**

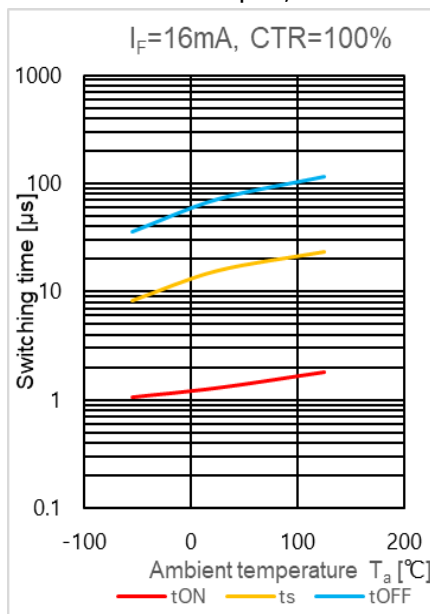


**Figure 4.32 Switching time - T_a
(CTR=200%)**

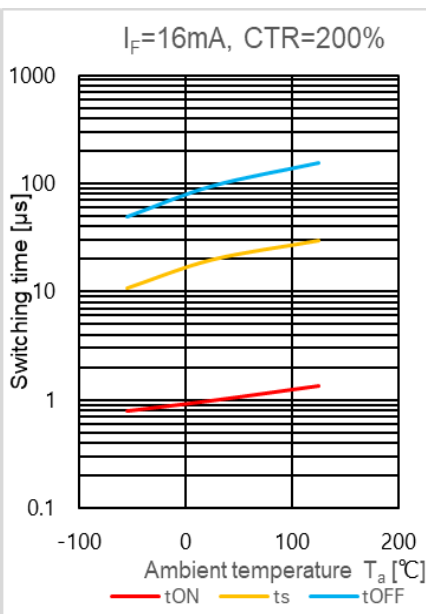


**Figure 4.33 Switching time - T_a
(CTR=400%)**

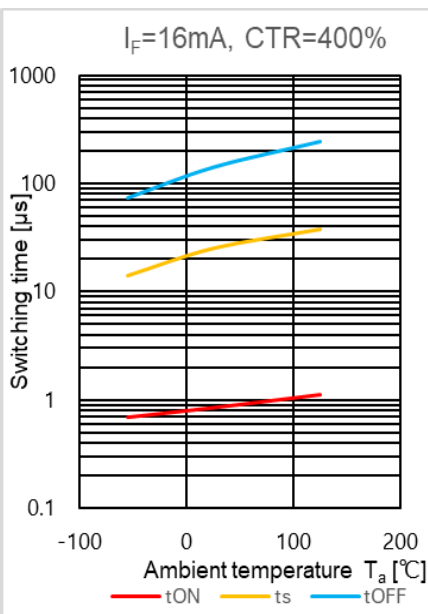
$R_L=10k\Omega$ low input, $I_F=16mA$



**Figure 4.34 Switching time - T_a
(CTR=100%)**

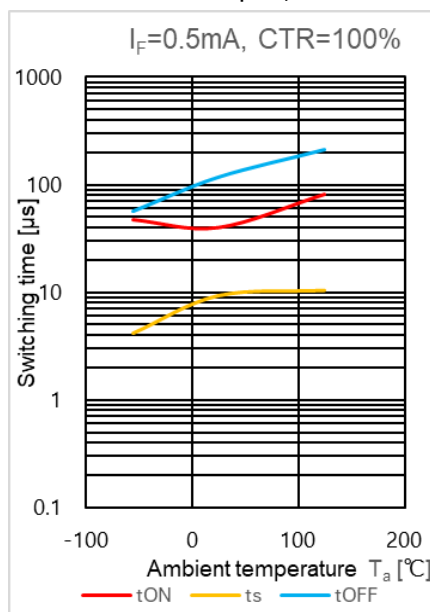


**Figure 4.35 Switching time - T_a
(CTR=200%)**

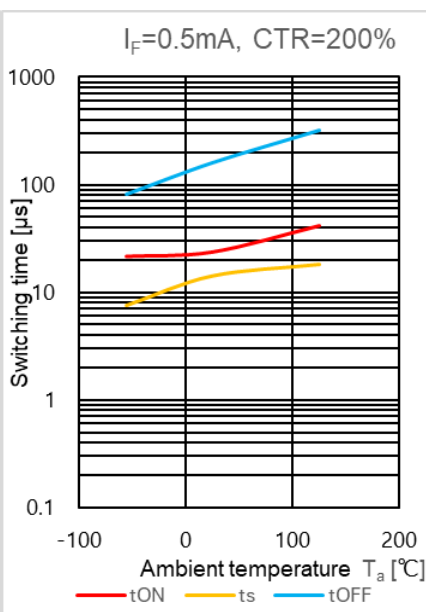


**Figure 4.36 Switching time - T_a
(CTR=400%)**

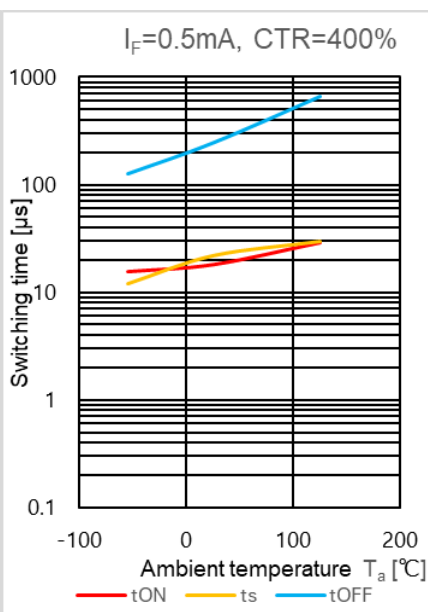
$R_L=20k\Omega$ low input, $I_F=0.5mA$



**Figure 4.37 Switching time - T_a
(CTR=100%)**



**Figure 4.38 Switching time - T_a
(CTR=200%)**



**Figure 4.39 Switching time - T_a
(CTR=400%)**

Frequency characteristics (Relative output (G_V), Phase (θ)), $T_a=25^\circ\text{C}$, $V_{cc}=5\text{V}$, $I_C(\text{DC})=2\text{mA}$, $I_C(\text{AC})=1\text{mA}_{\text{p-p}}$

$R_L=1\text{k}\Omega$

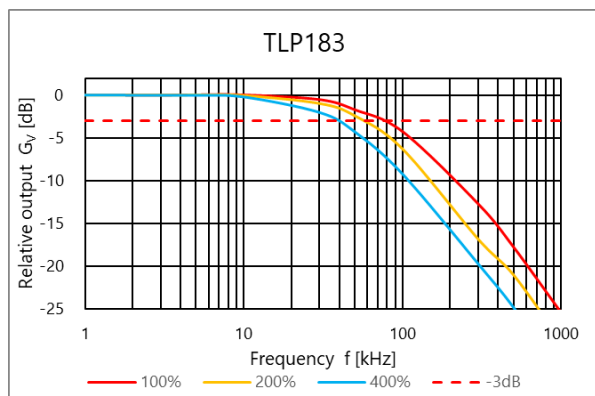


Figure 4.40 Relative output G_V - Frequency

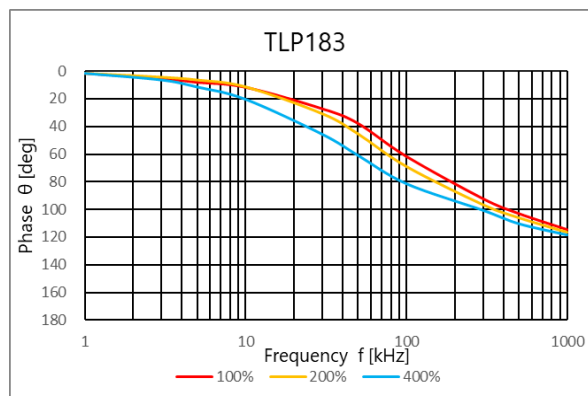


Figure 4.41 Phase θ - Frequency

$R_L=100\Omega$

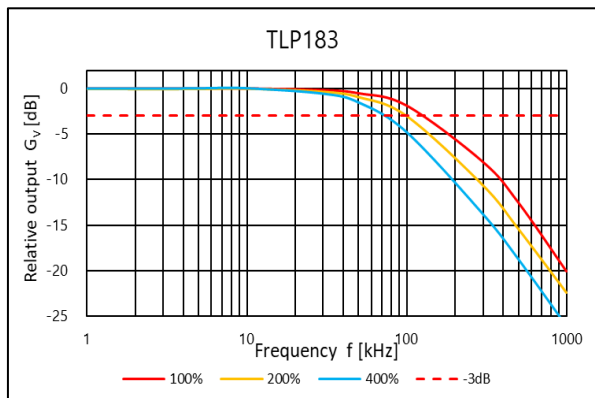


Figure 4.42 Relative output G_V - Frequency

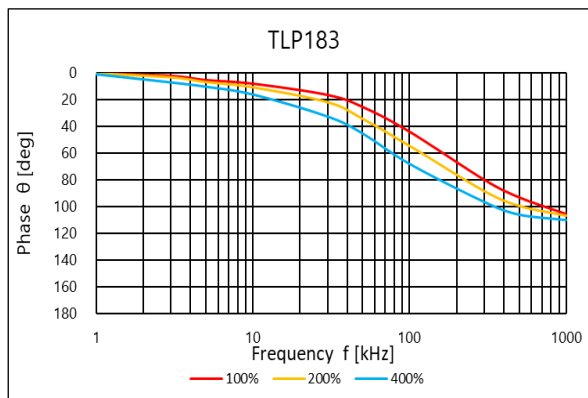


Figure 4.43 Phase θ - Frequency

TLP184(SE)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

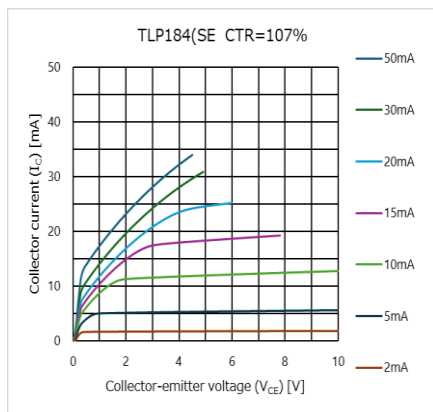


Figure 4.44 $I_C - V_{CE}$
(CTR=107%)

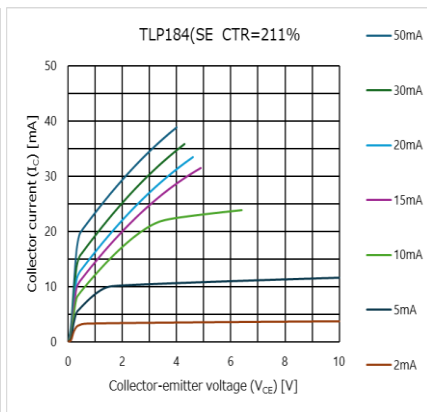


Figure 4.45 $I_C - V_{CE}$
(CTR=211%)

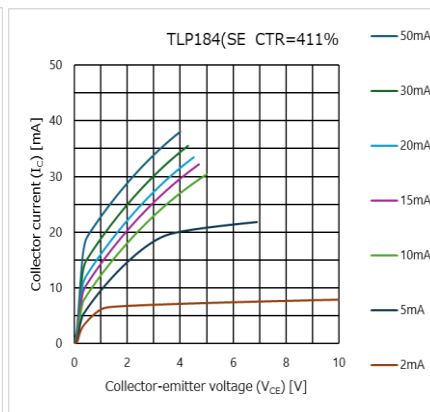


Figure 4.46 $I_C - V_{CE}$
(CTR=411%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

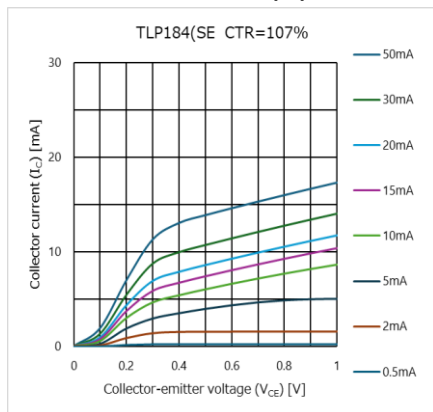


Figure 4.47 $I_C - V_{CE}$
(CTR=107%)

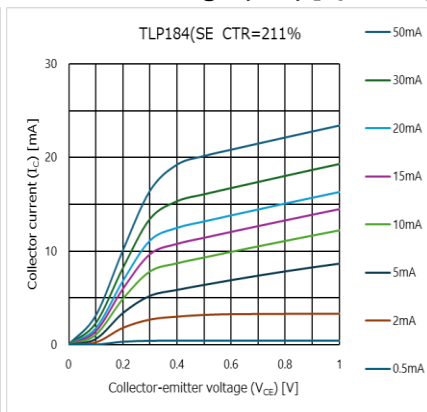


Figure 4.48 $I_C - V_{CE}$
(CTR=211%)

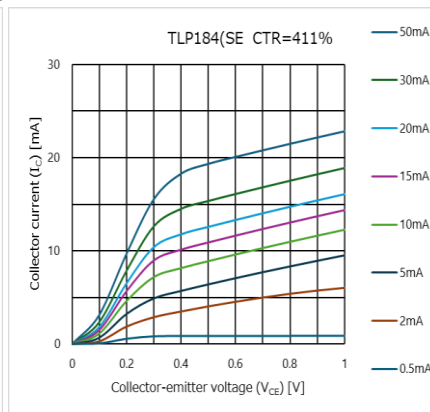


Figure 4.49 $I_C - V_{CE}$
(CTR=411%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

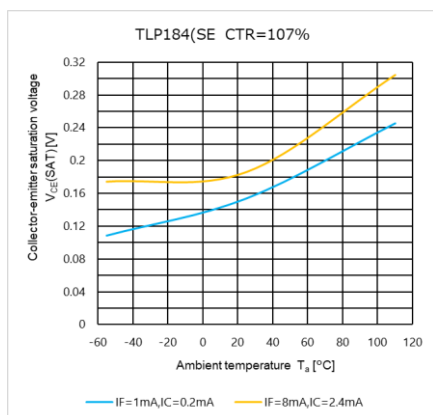


Figure 4.50 $V_{CE} - T_a$
(CTR=107%)

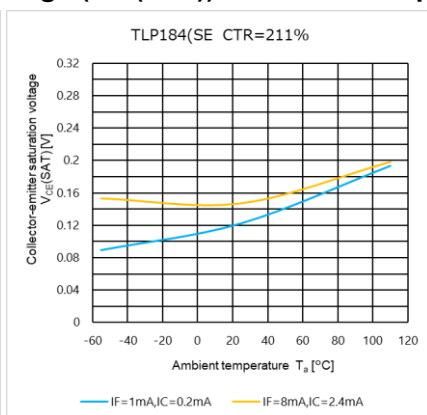


Figure 4.51 $V_{CE} - T_a$
(CTR=211%)

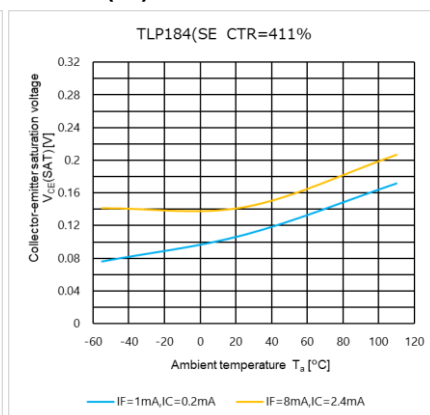
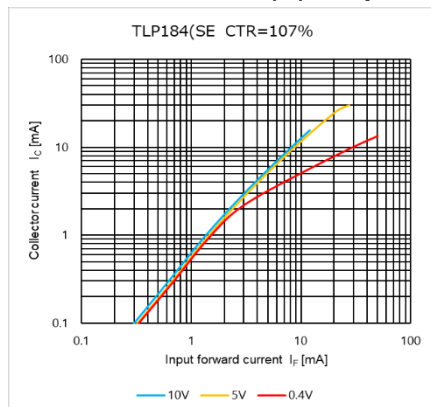
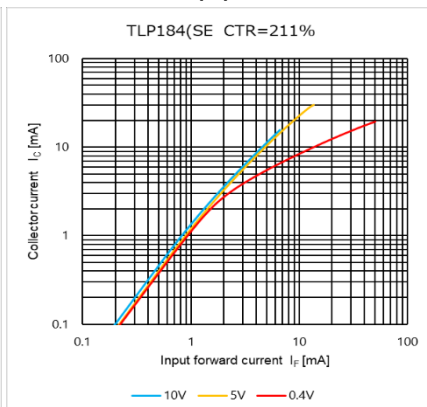


Figure 4.52 $V_{CE} - T_a$
(CTR=411%)

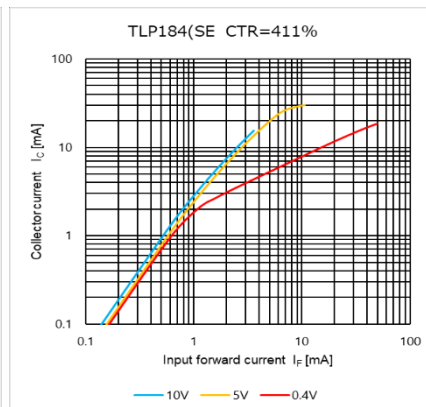
Collector current (I_C) – Input forward current (I_F)



**Figure 4.53 $I_C - I_F$
(CTR=107%)**

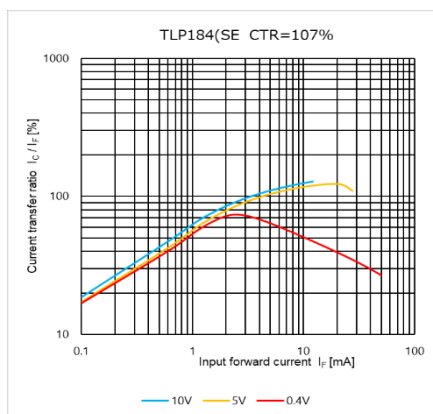


**Figure 4.54 $I_C - I_F$
(CTR=211%)**

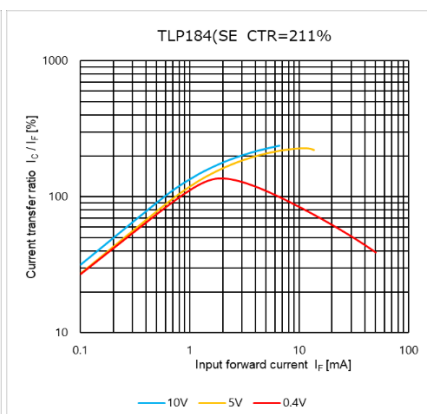


**Figure 4.55 $I_C - I_F$
(CTR=411%)**

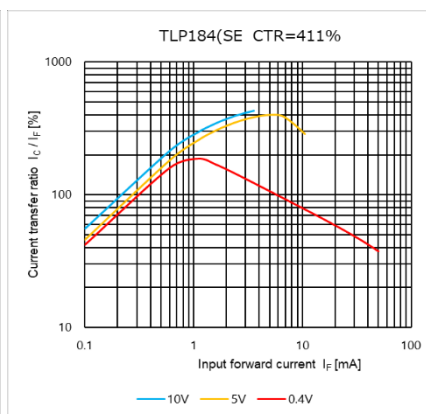
Current transfer ratio (I_C / I_F) – Input forward current (I_F)



**Figure 4.56 $I_C / I_F - I_F$
(CTR=107%)**



**Figure 4.57 $I_C / I_F - I_F$
(CTR=211%)**



**Figure 4.58 $I_C / I_F - I_F$
(CTR=411%)**

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

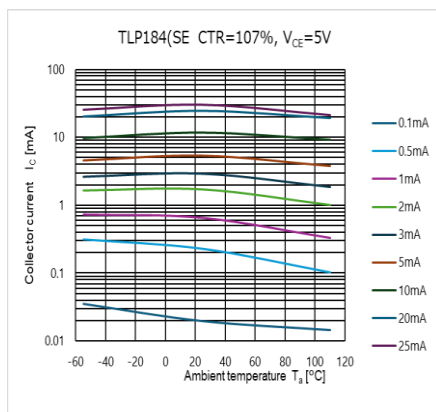


Figure 4.59 $I_C - T_a$
(CTR=107%)

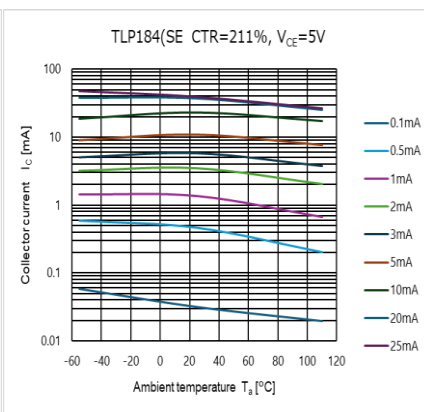


Figure 4.60 $I_C - T_a$
(CTR=211%)

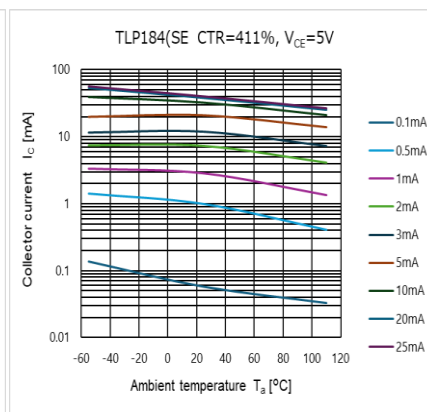


Figure 4.61 $I_C - T_a$
(CTR=411%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

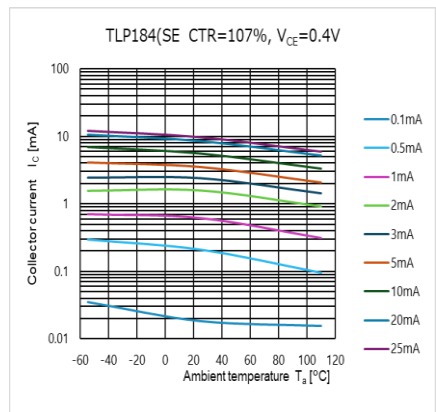


Figure 4.62 $I_C - T_a$
(CTR=107%)

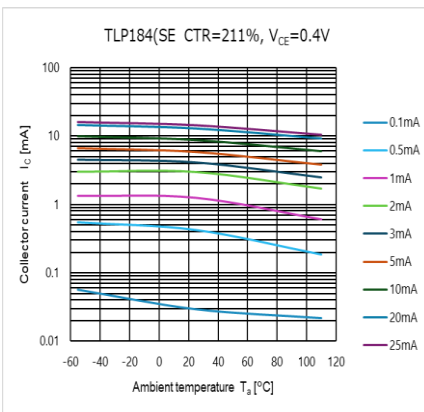


Figure 4.63 $I_C - T_a$
(CTR=211%)

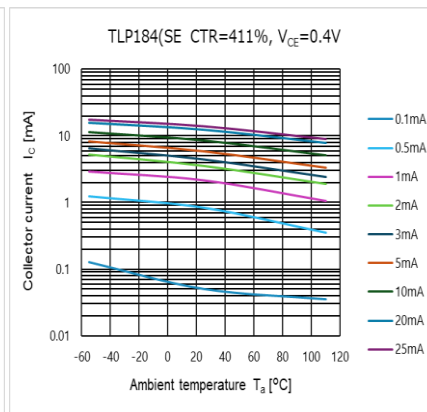
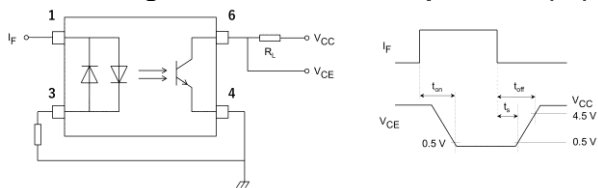


Figure 4.64 $I_C - T_a$
(CTR=411%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP184(SE)

$R_L=1.9k\Omega$, $I_F=5mA$

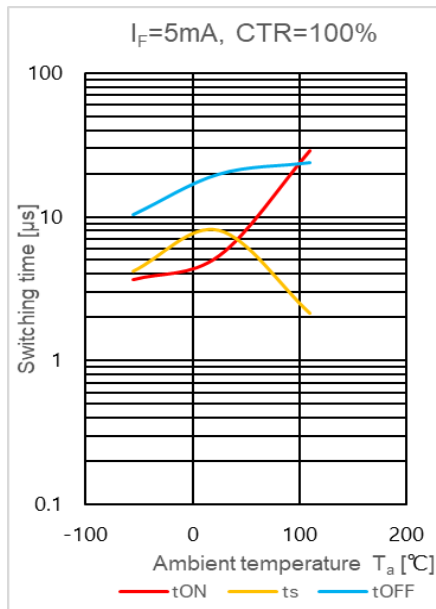


Figure 4.65 Switching time - T_a
(CTR=100%)

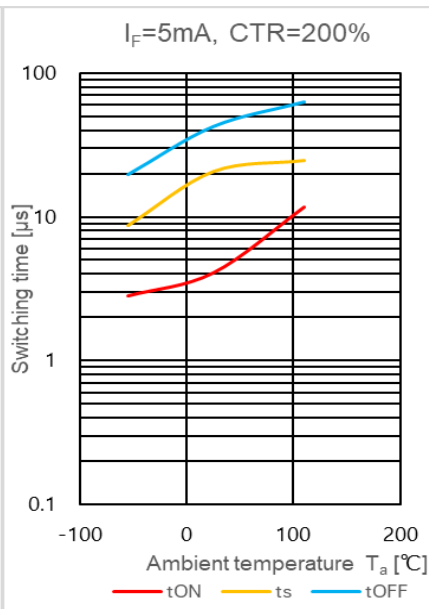


Figure 4.66 Switching time - T_a
(CTR=200%)

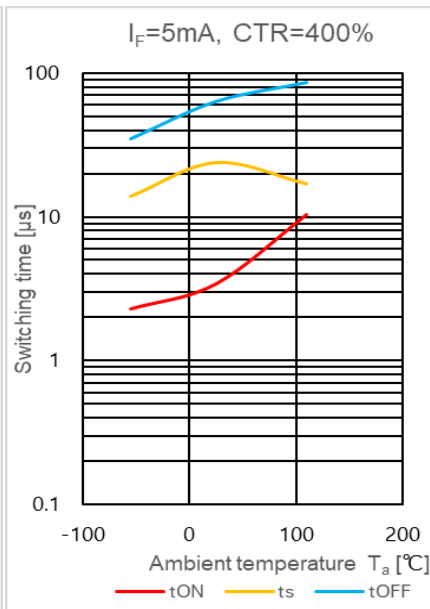


Figure 4.67 Switching time - T_a
(CTR=400%)

$R_L=1.9k\Omega$, $I_F=16mA$

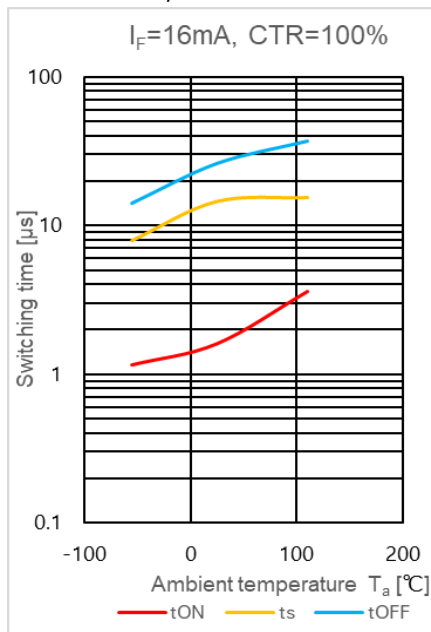


Figure 4.68 Switching time - T_a
(CTR=100%)

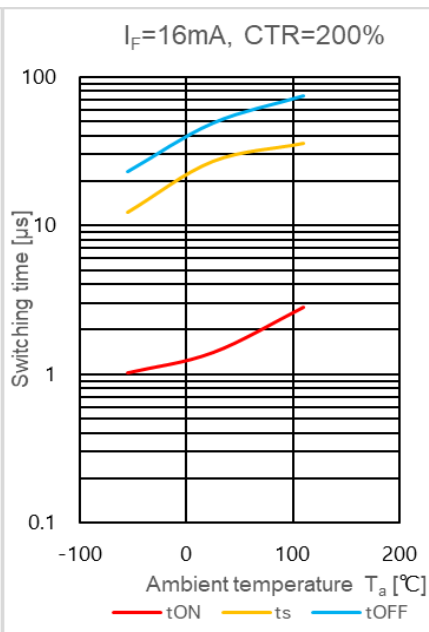


Figure 4.69 Switching time - T_a
(CTR=200%)

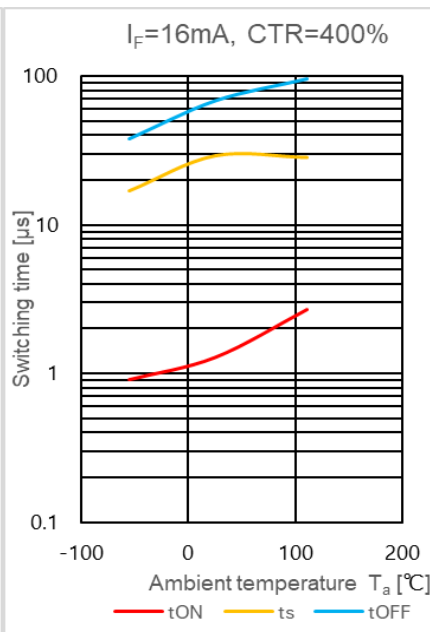


Figure 4.70 Switching time - T_a
(CTR=400%)

$R_L = 10k\Omega$, $I_F = 2mA$

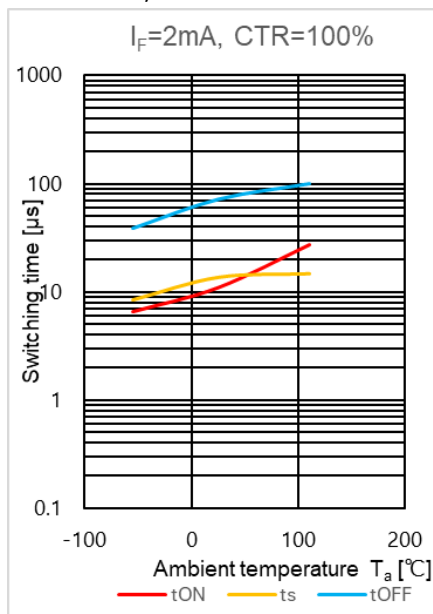


Figure 4.71 Switching time - T_a (CTR=100%)

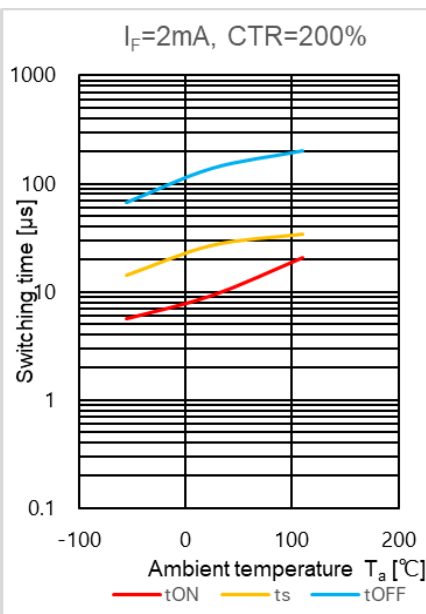


Figure 4.72 Switching time - T_a (CTR=200%)

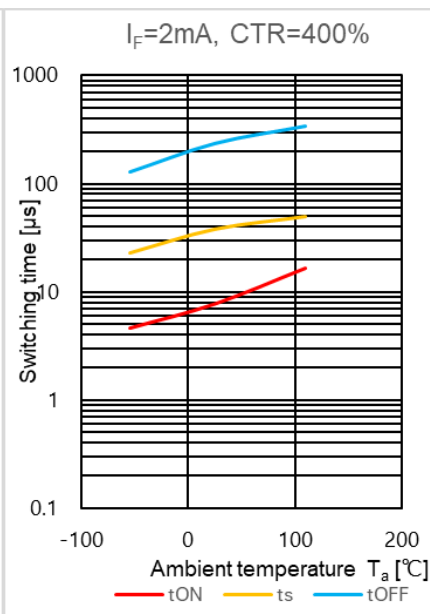


Figure 4.73 Switching time - T_a (CTR=400%)

$R_L = 10k\Omega$, $I_F = 5mA$

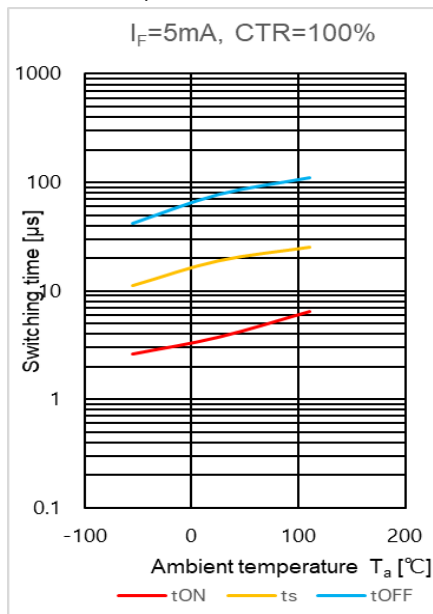


Figure 4.74 Switching time - T_a (CTR=100%)

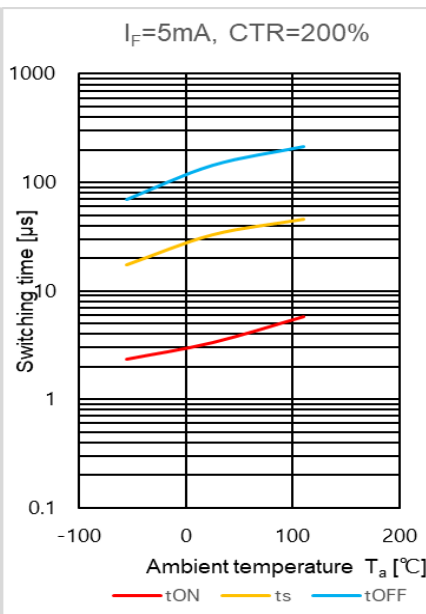


Figure 4.76 Switching time - T_a (CTR=200%)

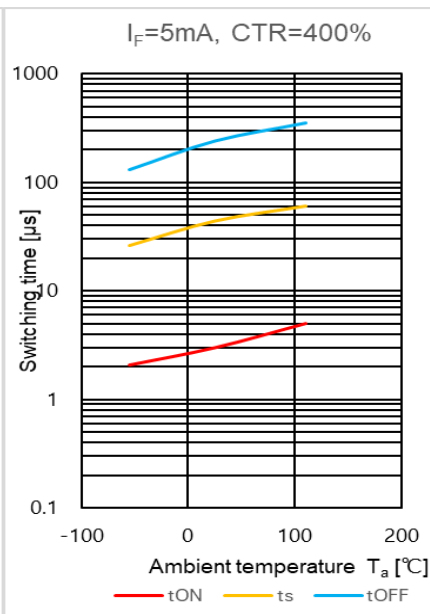


Figure 4.77 Switching time - T_a (CTR=400%)

$R_L = 10k\Omega$, $I_F = 16mA$

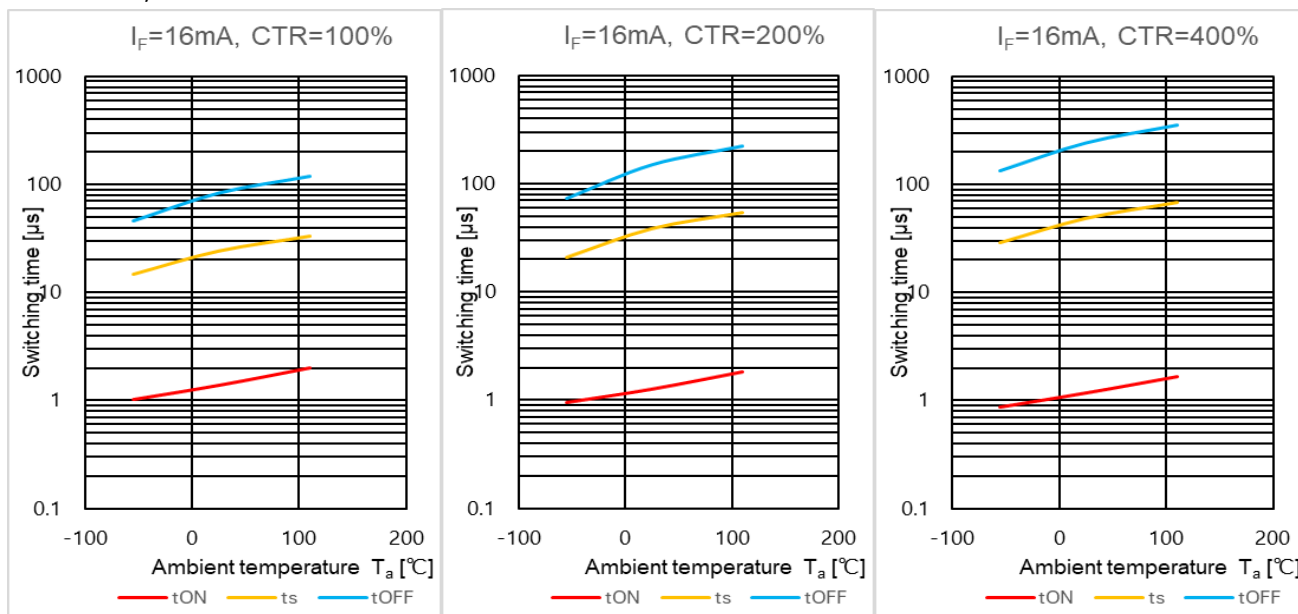


Figure 4.78 Switching time - T_a (CTR=100%)

Figure 4.79 Switching time - T_a (CTR=200%)

Figure 4.80 Switching time - T_a (CTR=400%)

Frequency characteristics (Relative output (G_V), Phase (θ)), $T_a = 25^{\circ}C$, $V_{CC} = 5V$, $I_C(DC) = 2mA$, $I_C(AC) = 1mA_{p-p}$, $R_L = 1k\Omega$

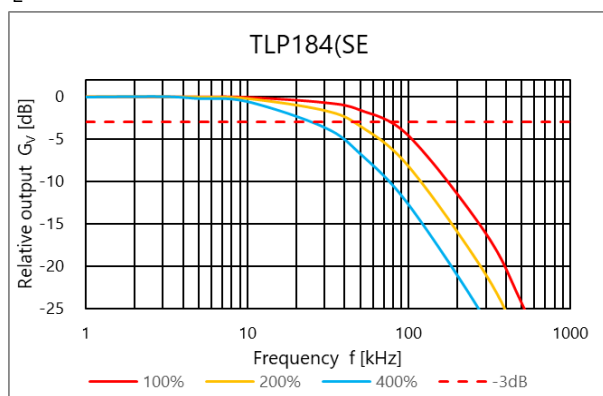


Figure 4.81 Relative output G_V - Frequency

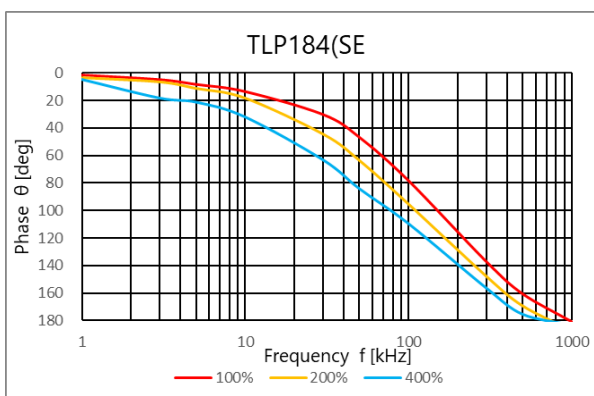


Figure 4.82 Phase θ - Frequency

$R_L = 100\Omega$

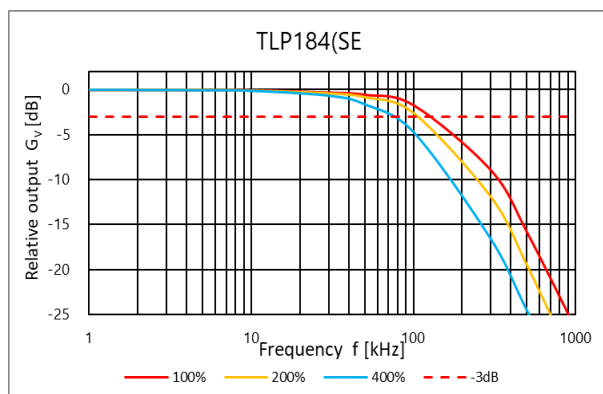


Figure 4.83 Relative output G_V - Frequency

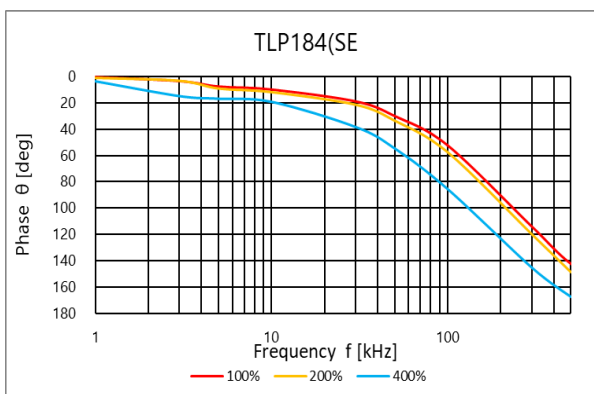


Figure 4.84 Phase θ - Frequency

TLP185(SE)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

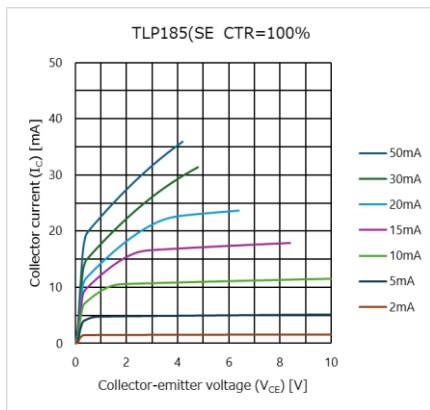


Figure 4.85 $I_C - V_{CE}$
(CTR=100%)

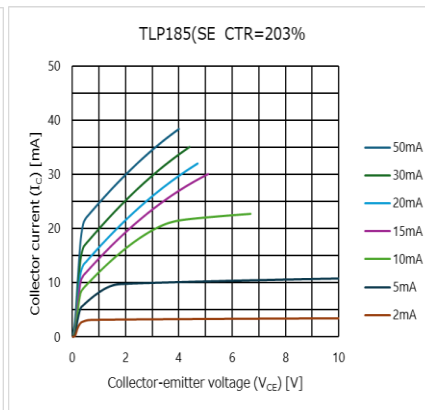


Figure 4.86 $I_C - V_{CE}$
(CTR=203%)

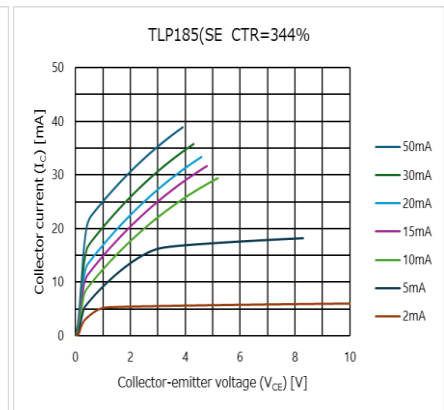


Figure 4.87 $I_C - V_{CE}$
(CTR=344%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

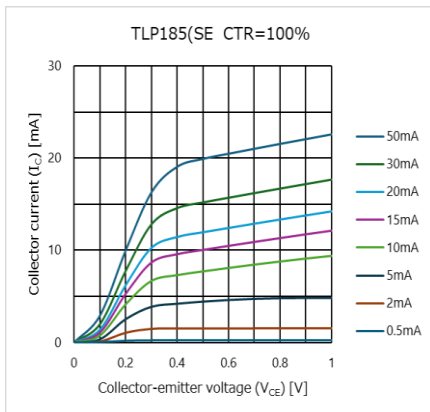


Figure 4.88 $I_C - V_{CE}$
(CTR=100%)

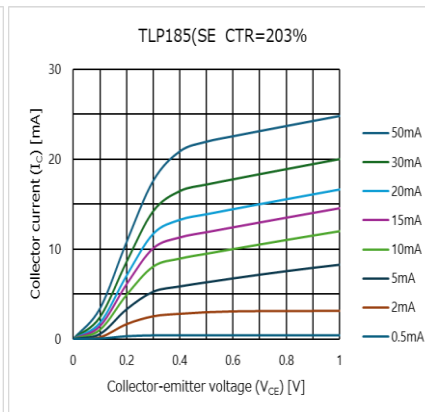


Figure 4.89 $I_C - V_{CE}$
(CTR=203%)

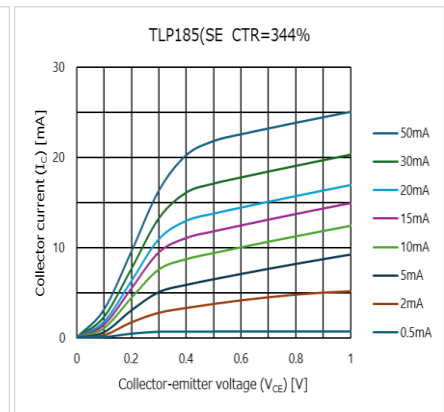


Figure 4.90 $I_C - V_{CE}$
(CTR=344%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

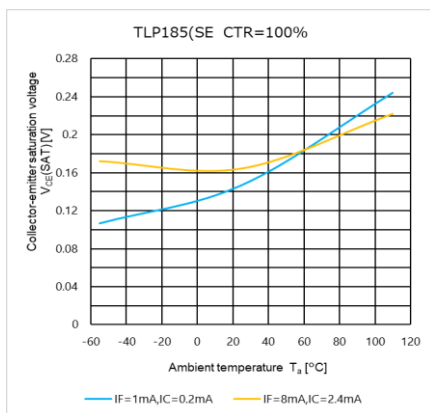


Figure 4.91 $V_{CE} - T_a$
(CTR=100%)

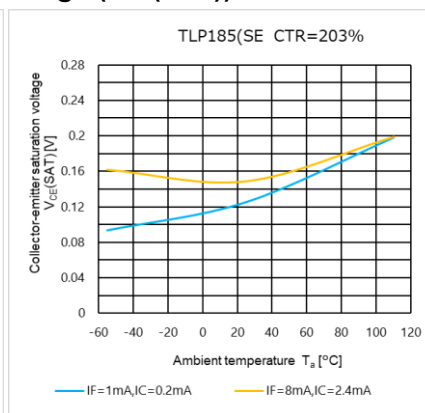


Figure 4.92 $V_{CE} - T_a$
(CTR=203%)

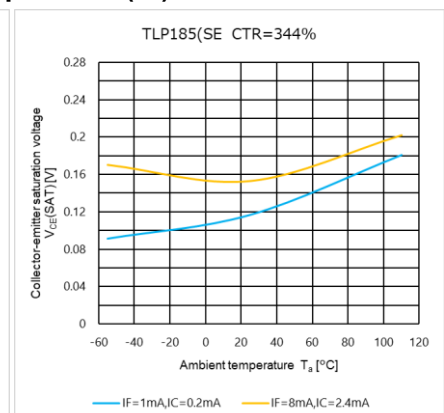
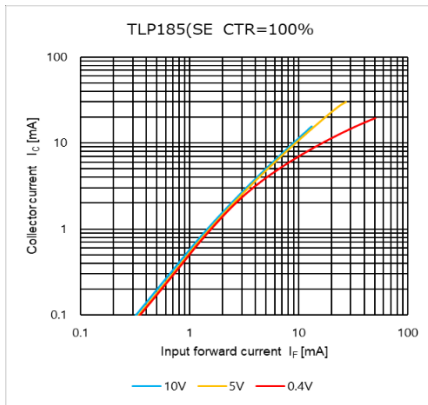
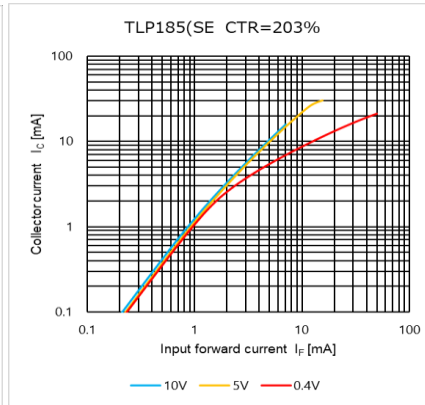


Figure 4.93 $V_{CE} - T_a$
(CTR=344%)

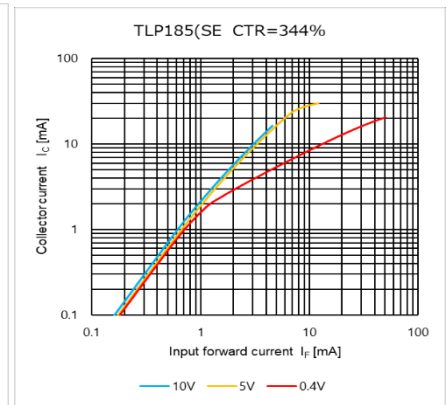
Collector current (I_C) – Input forward current (I_F)



**Figure 4.94 $I_C - I_F$
(CTR=100%)**

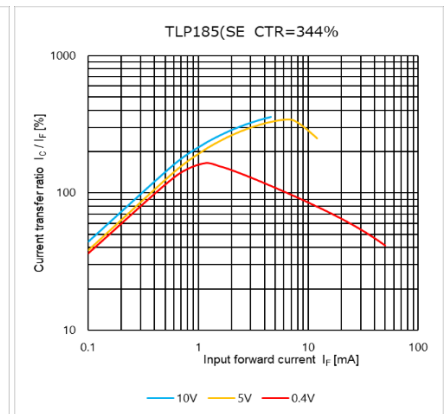
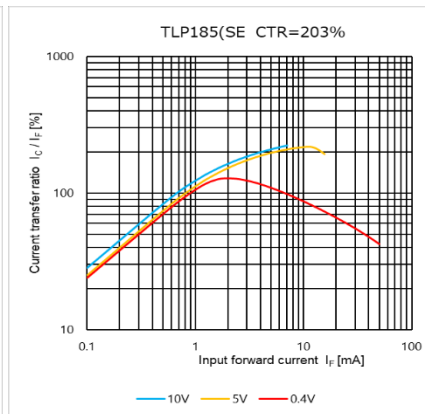
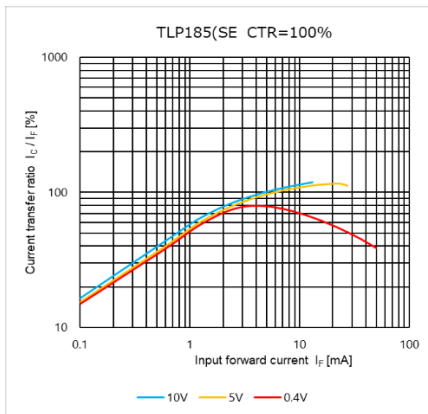


**Figure 4.95 $I_C - I_F$
(CTR=203%)**



**Figure 4.96 $I_C - I_F$
(CTR=344%)**

Current transfer ratio (I_C / I_F) – Input forward current (I_F)



Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

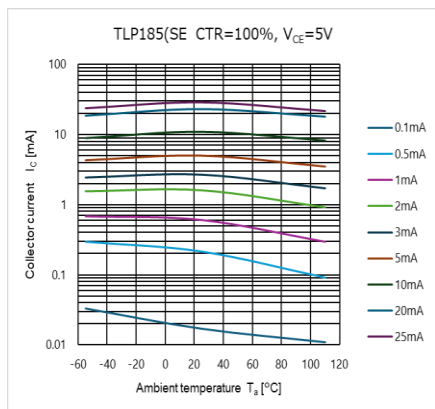


Figure 4.100 $I_C - T_a$
(CTR=100%)

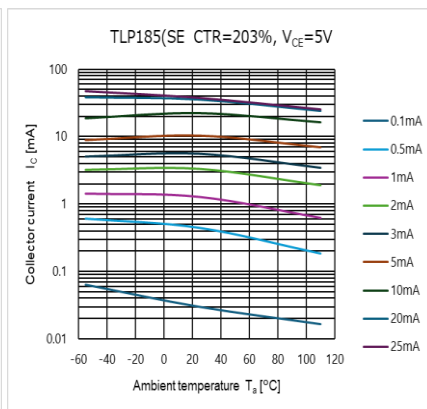


Figure 4.101 $I_C - T_a$
(CTR=203%)

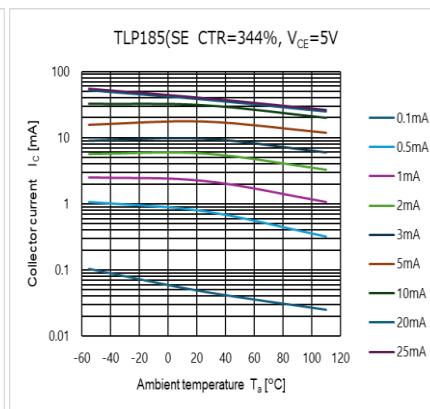


Figure 4.102 $I_C - T_a$
(CTR=344%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

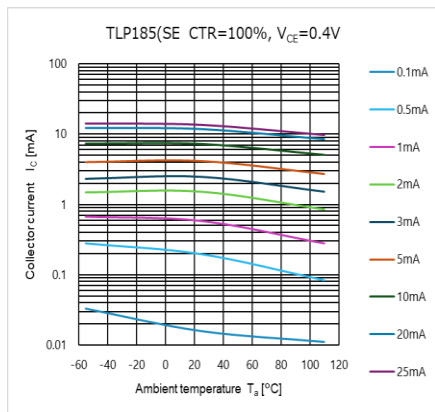


Figure 4.103 $I_C - T_a$
(CTR=100%)

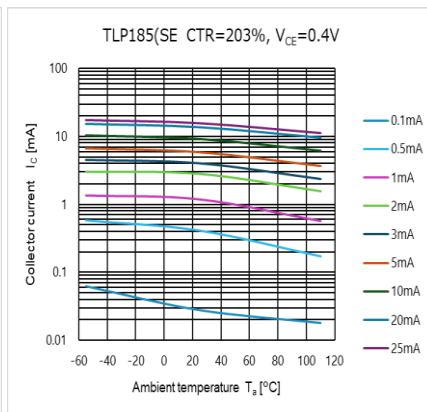


Figure 4.104 $I_C - T_a$
(CTR=203%)

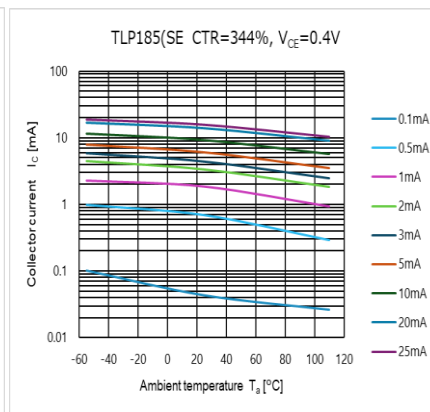
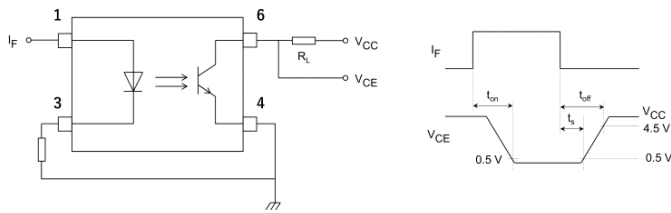


Figure 4.105 $I_C - T_a$
(CTR=344%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP185(SE)

$R_L=1.9k\Omega$, $I_F=5mA$

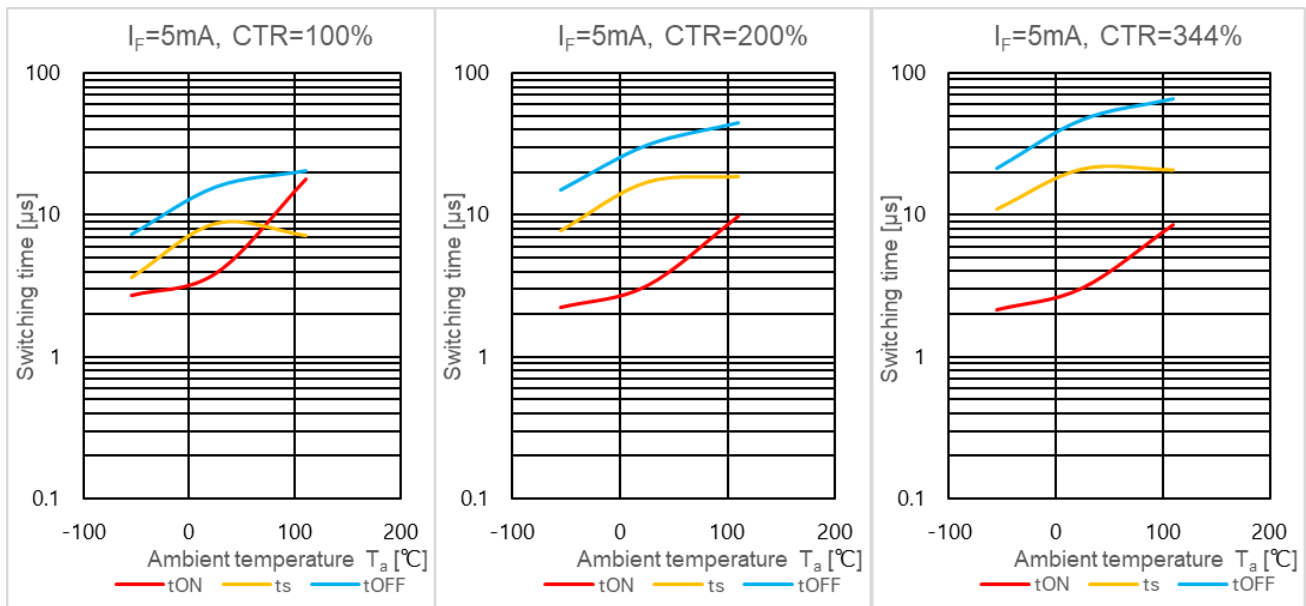


Figure 4.106 Switching time - T_a (CTR=100%)

Figure 4.107 Switching time - T_a (CTR=200%)

Figure 4.108 Switching time - T_a (CTR=344%)

$R_L=1.9k\Omega$, $I_F=16mA$

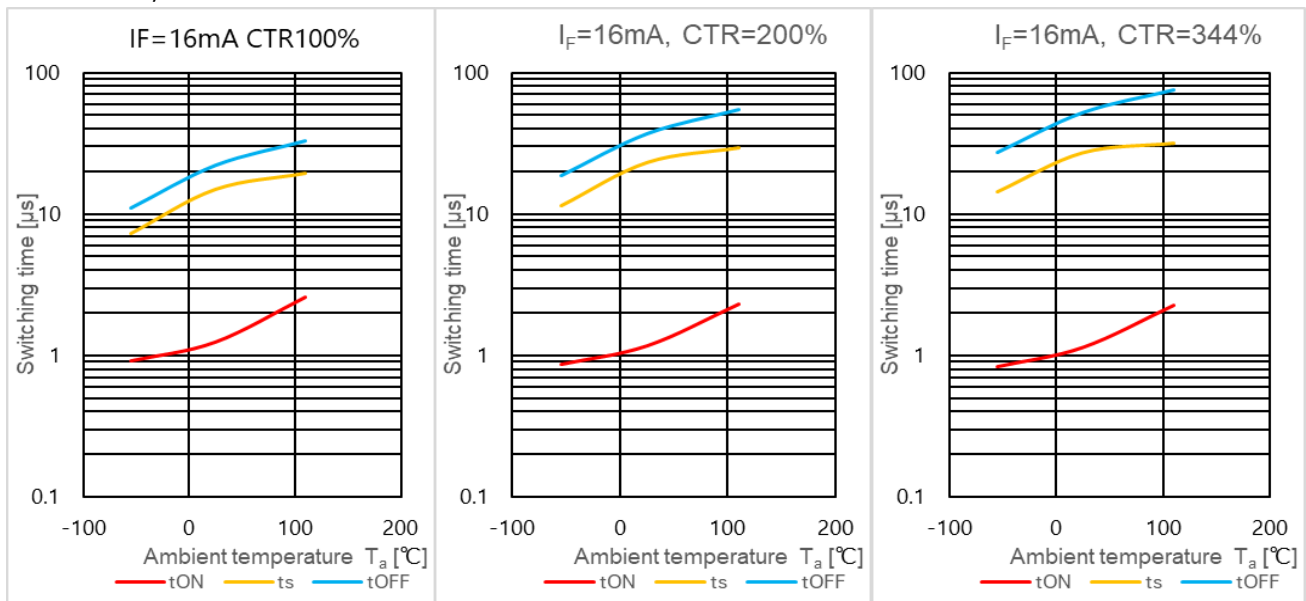


Figure 4.109 Switching time - T_a (CTR=100%)

Figure 4.110 Switching time - T_a (CTR=200%)

Figure 4.111 Switching time - T_a (CTR=344%)

$R_L = 10k\Omega$, $I_F = 2mA$

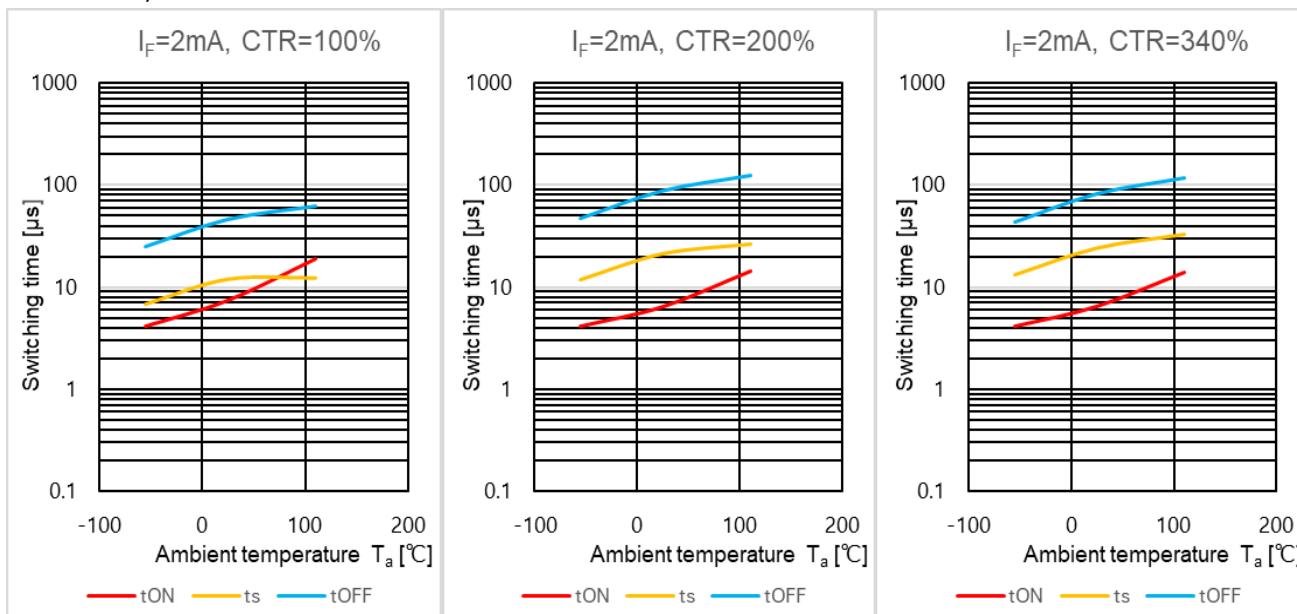


Figure 4.112 Switching time - T_a (CTR=100%)

Figure 4.113 Switching time - T_a (CTR=200%)

Figure 4.114 Switching time - T_a (CTR=340%)

$R_L = 10k\Omega$, $I_F = 5mA$

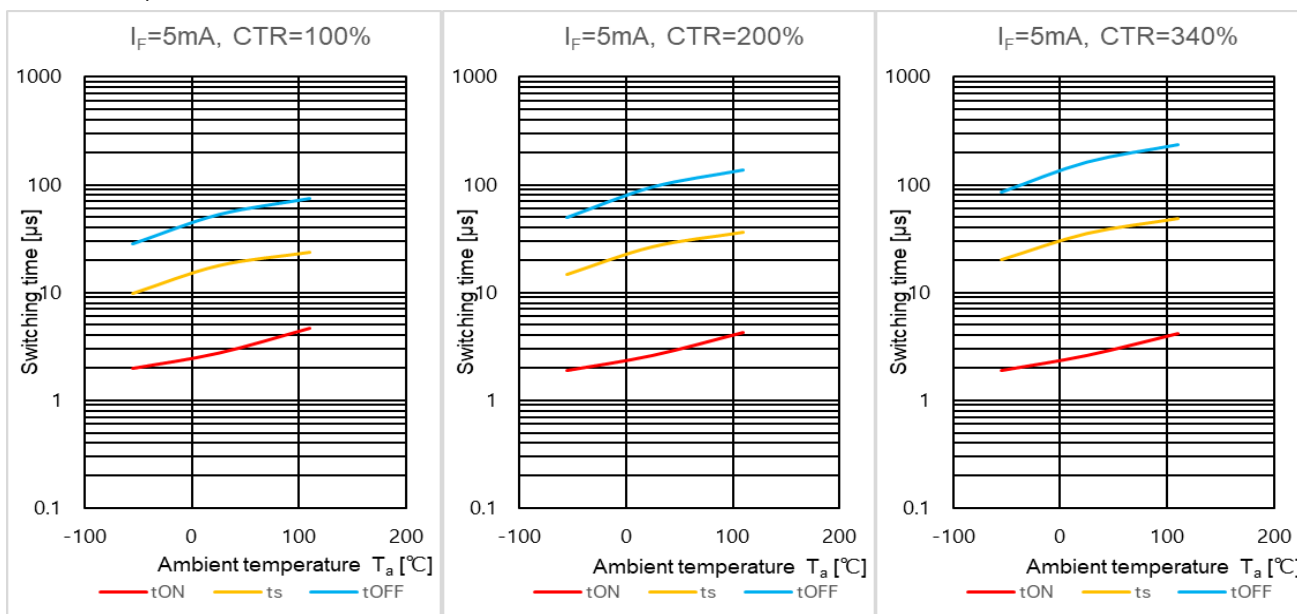


Figure 4.115 Switching time - T_a (CTR=100%)

Figure 4.116 Switching time - T_a (CTR=200%)

Figure 4.117 Switching time - T_a (CTR=340%)

$R_L = 10k\Omega$, $I_F = 16mA$

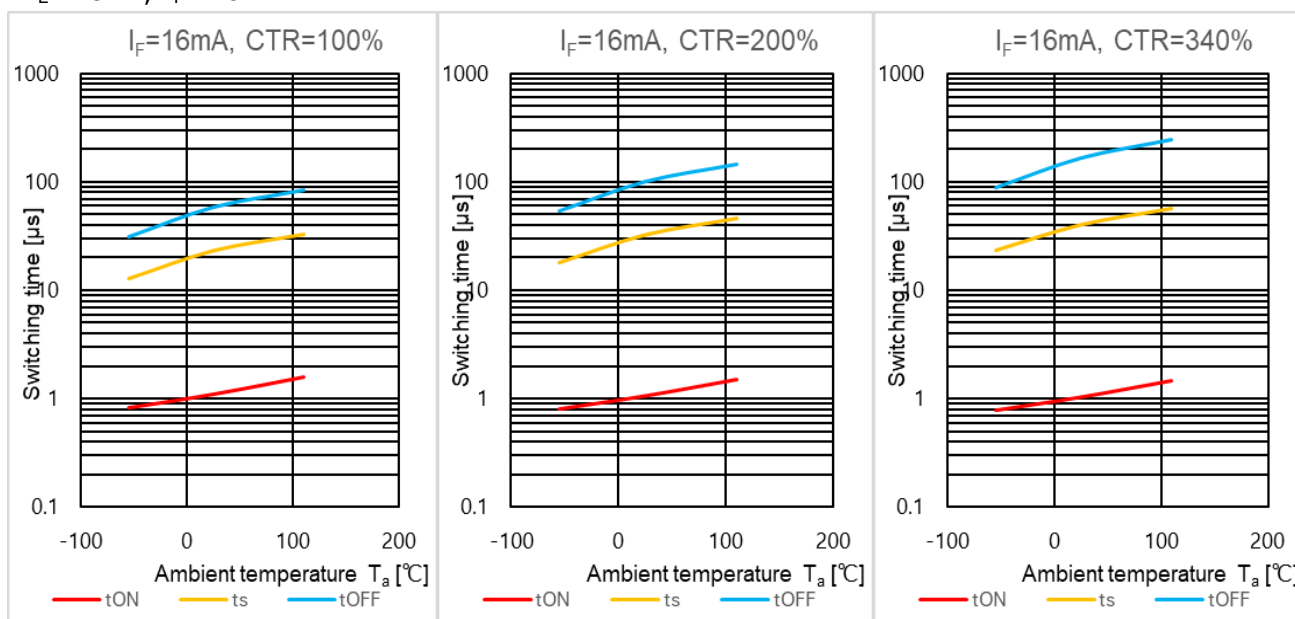


Figure 4.118 Switching time - T_a (CTR=100%) **Figure 4.119 Switching time - T_a (CTR=200%)** **Figure 4.120 Switching time - T_a (CTR=340%)**

Frequency characteristics (Relative output (G_V), Phase (θ)), $T_a = 25^{\circ}C$, $V_{CC} = 5V$, $I_C(DC) = 2mA$, $I_C(AC) = 1mA_{p-p}$, $R_L = 1k\Omega$

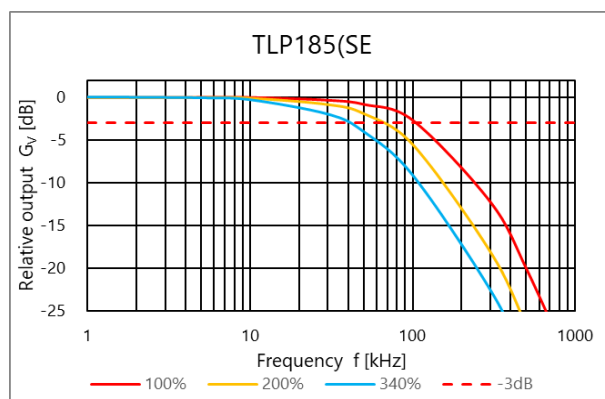


Figure 4.121 Relative output G_V - Frequency

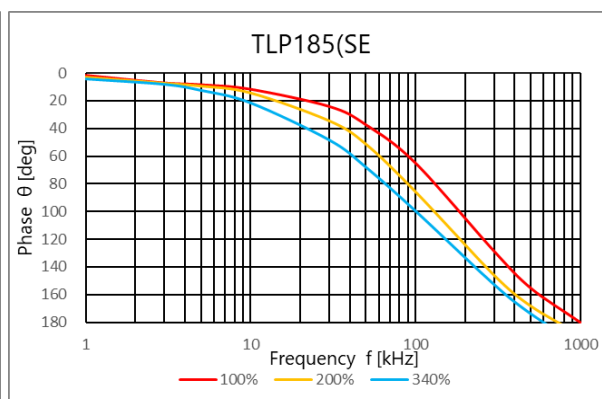


Figure 4.122 Phase θ - Frequency

$R_L = 100\Omega$

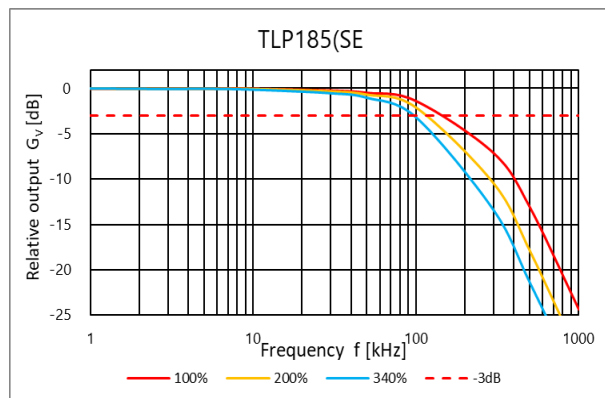


Figure 4.123 Relative output G_V - Frequency

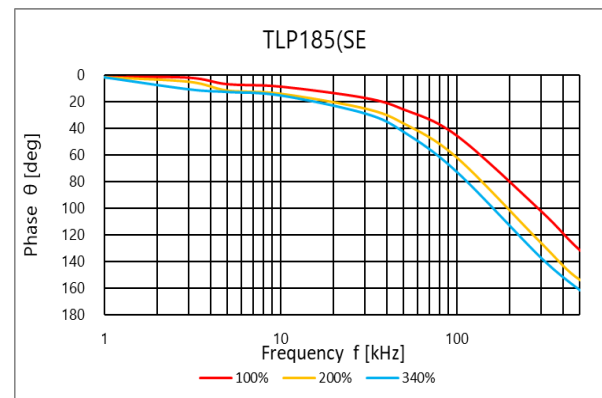


Figure 4.124 Phase θ - Frequency

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Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

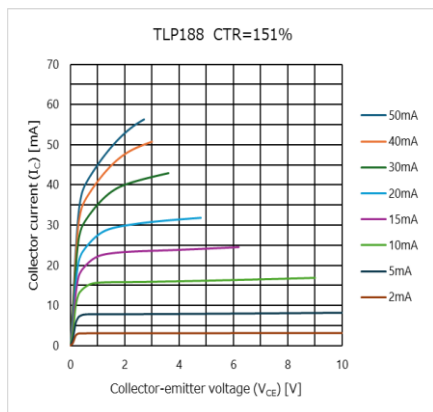


Figure 4.125 $I_C - V_{CE}$
(CTR=151%)

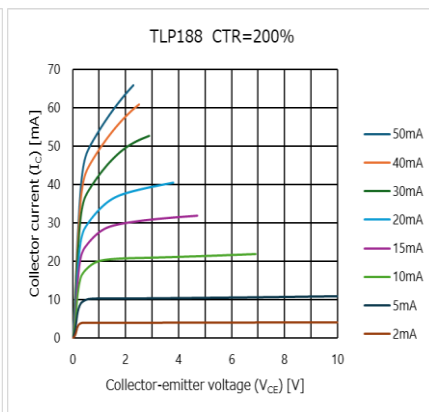


Figure 4.126 $I_C - V_{CE}$
(CTR=200%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

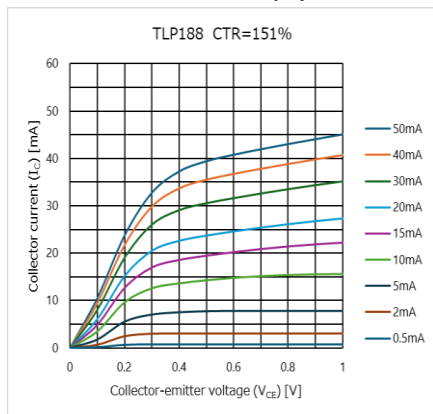


Figure 4.127 $I_C - V_{CE}$
(CTR=151%)

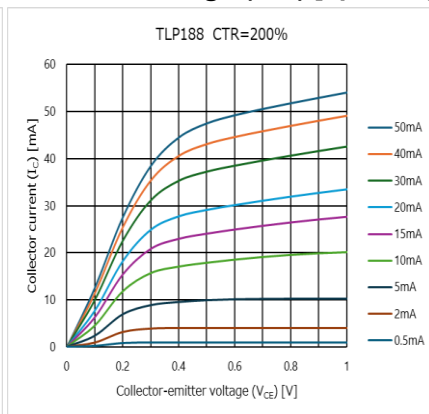


Figure 4.128 $I_C - V_{CE}$
(CTR=200%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

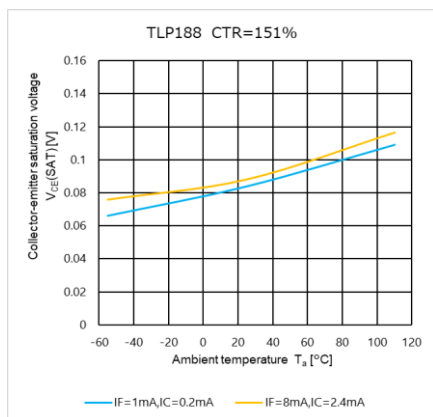


Figure 4.129 $V_{CE} - T_a$
(CTR=151%)

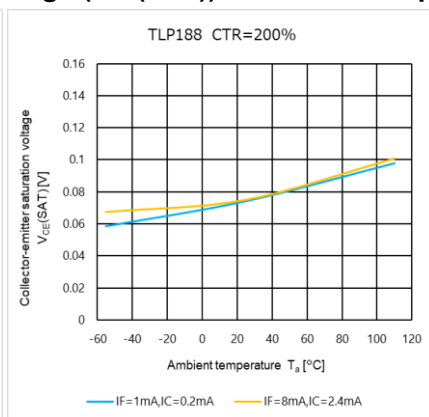
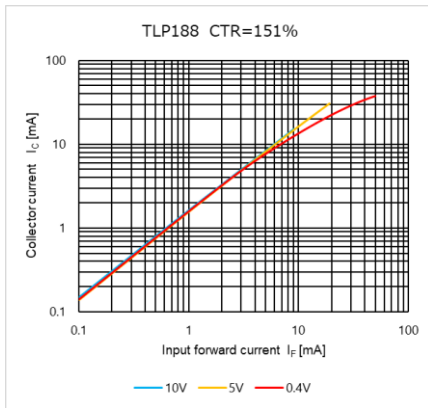
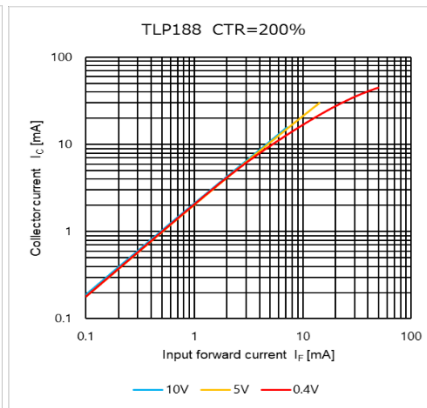


Figure 4.130 $V_{CE} - T_a$
(CTR=200%)

Collector current (I_C) – Input forward current (I_F)

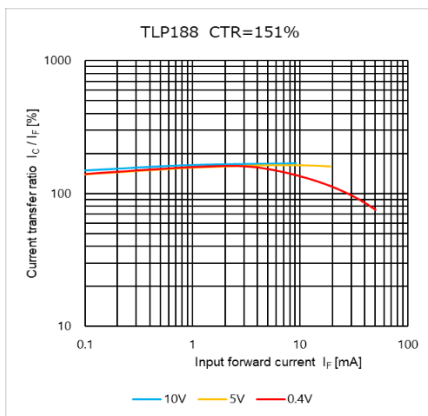


**Figure 4.131 $I_C - I_F$
(CTR=151%)**

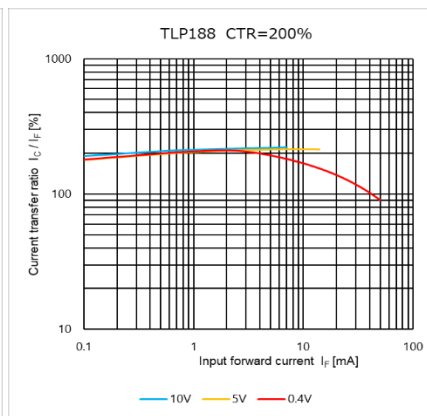


**Figure 4.132 $I_C - I_F$
(CTR=200%)**

Current transfer ratio (I_C / I_F) – Input forward current (I_F)



**Figure 4.133 $I_C / I_F - I_F$
(CTR=151%)**



**Figure 4.134 $I_C / I_F - I_F$
(CTR=200%)**

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

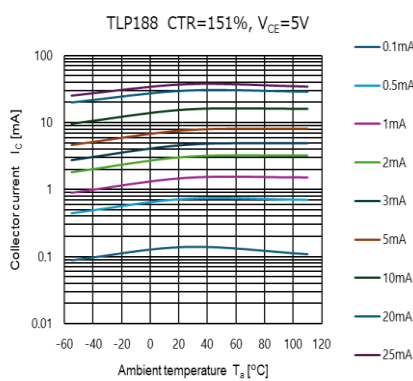


Figure 4.135 $I_C - T_a$
(CTR=151%)

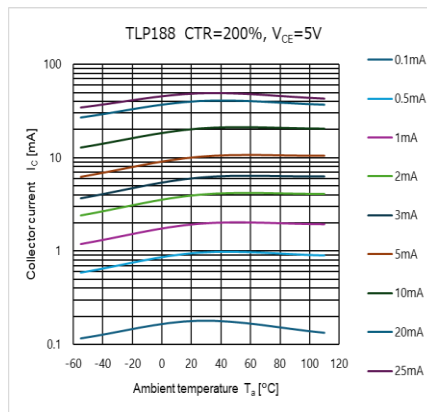


Figure 4.136 $I_C - T_a$
(CTR=200%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

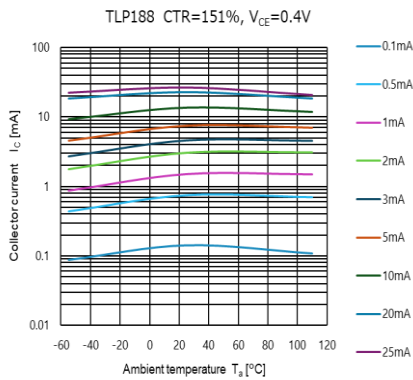


Figure 4.137 $I_C - T_a$
(CTR=151%)

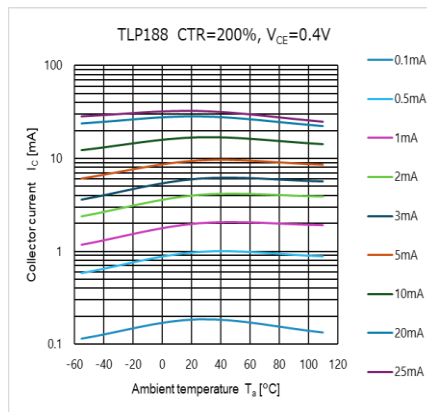
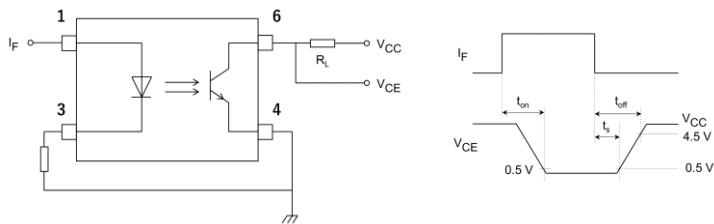


Figure 4.138 $I_C - T_a$
(CTR=200%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



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$R_L=1.9k\Omega$, $I_F=5mA$

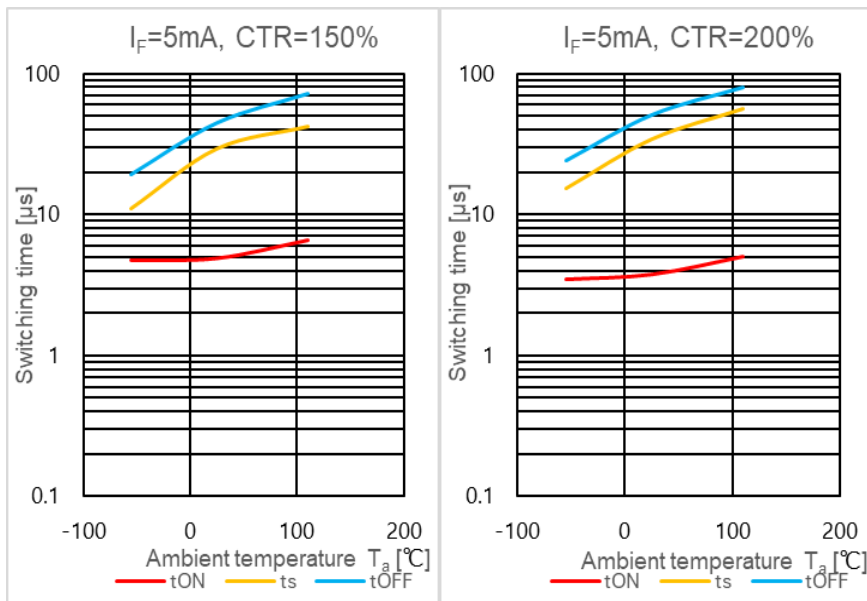


Figure 4.139 Switching time - T_a (CTR=150%) Figure 4.140 Switching time - T_a (CTR=200%)

$R_L=1.9k\Omega$, $I_F=16mA$

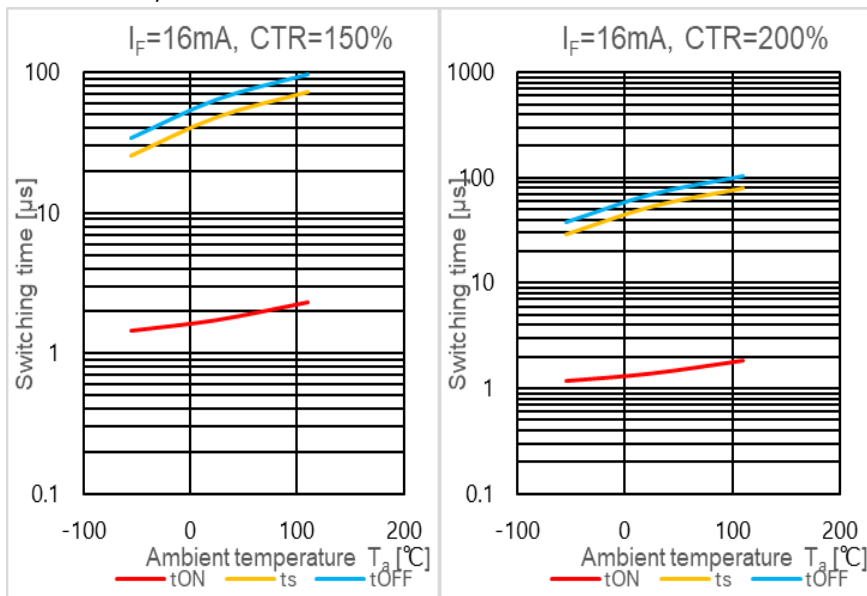


Figure 4.141 Switching time - T_a (CTR=150%) Figure 4.142 Switching time - T_a (CTR=200%)

$R_L = 10k\Omega$, $I_F = 2mA$

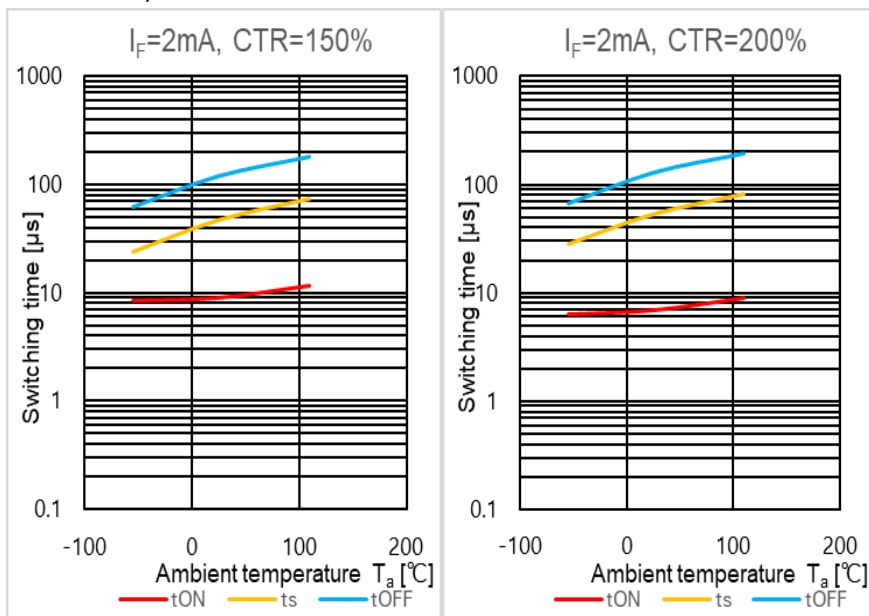


Figure 4.143 Switching time - T_a (CTR=150%) **Figure 4.144 Switching time - T_a (CTR=200%)**

$R_L = 10k\Omega$, $I_F = 5mA$

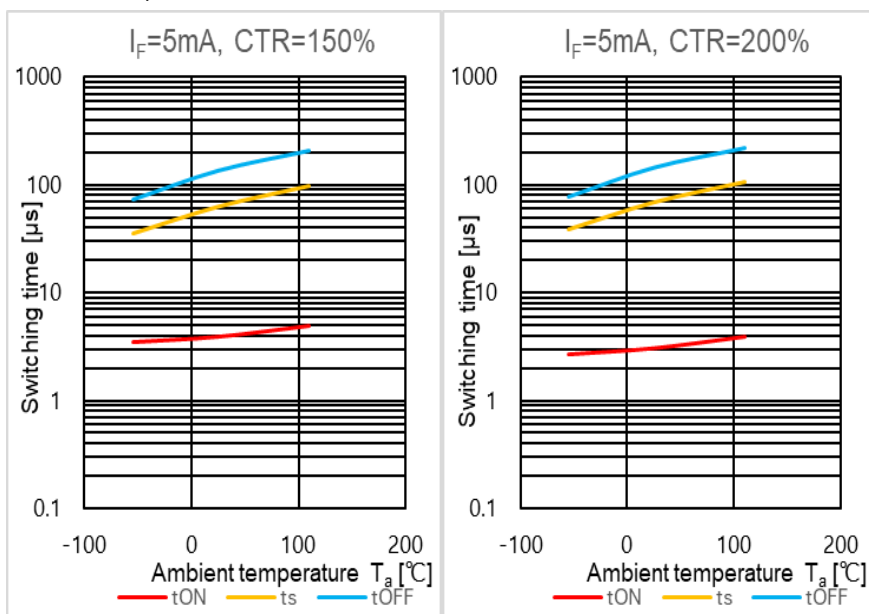


Figure 4.145 Switching time - T_a (CTR=100%) **Figure 4.146 Switching time - T_a (CTR=200%)**

$R_L = 10k\Omega$, $I_F = 16mA$

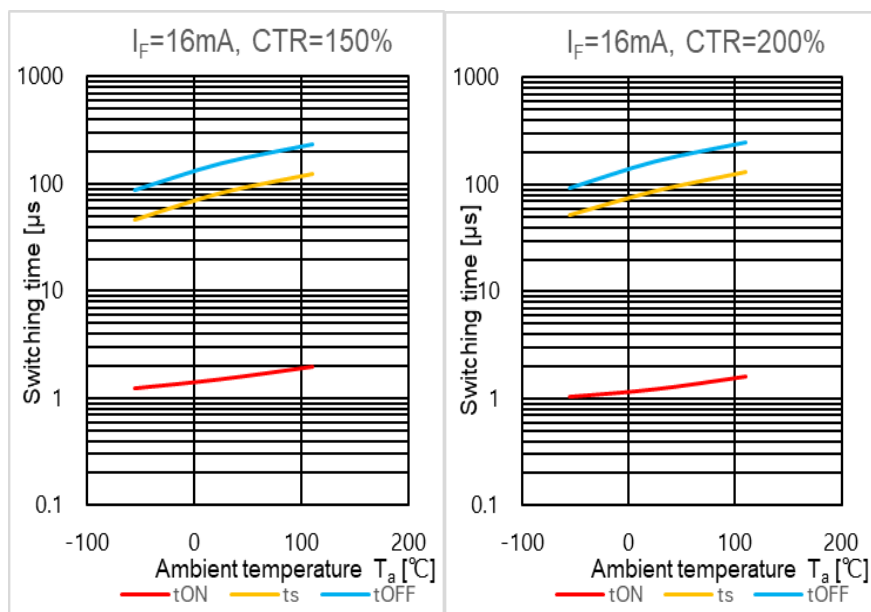


Figure 4.147 Switching time - T_a (CTR=150%) **Figure 4.148 Switching time - T_a (CTR=200%)**

Frequency characteristics (Relative output (G_V), Phase (θ)), $T_a = 25^{\circ}C$, $V_{CC} = 5V$, $I_C(DC) = 2mA$, $I_C(AC) = 1mA_{p-p}$

$R_L = 1k\Omega$

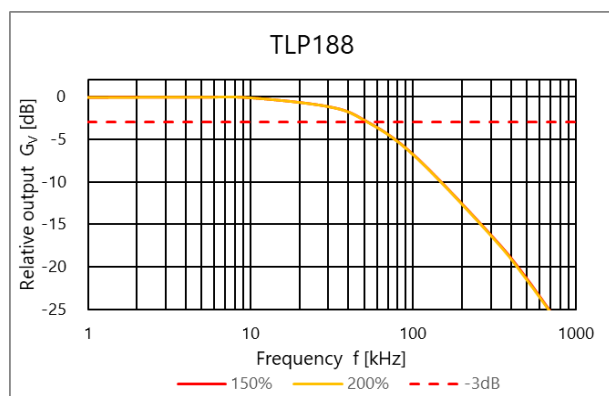


Figure 4.149 Relative output G_V - Frequency

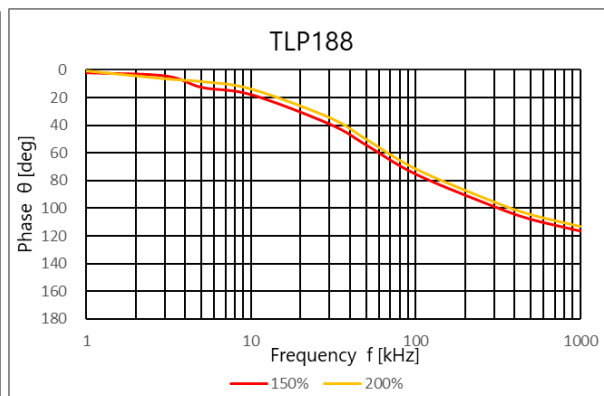


Figure 4.150 Phase θ - Frequency

$R_L = 100\Omega$

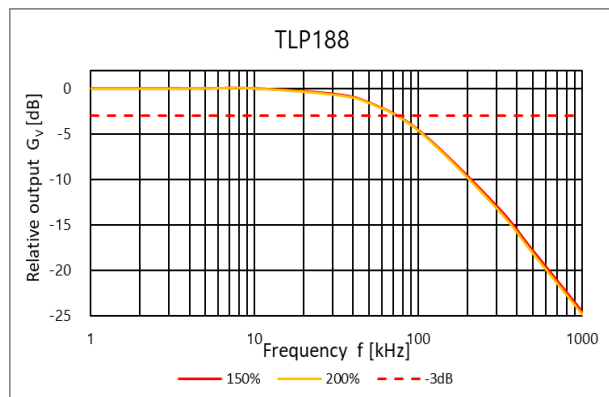


Figure 4.151 Relative output G_V - Frequency

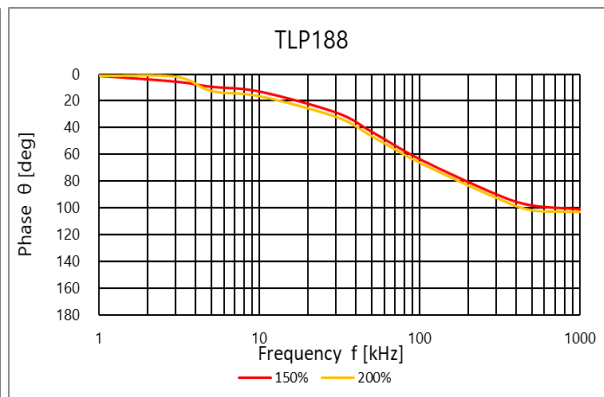


Figure 4.152 Phase θ - Frequency

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Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

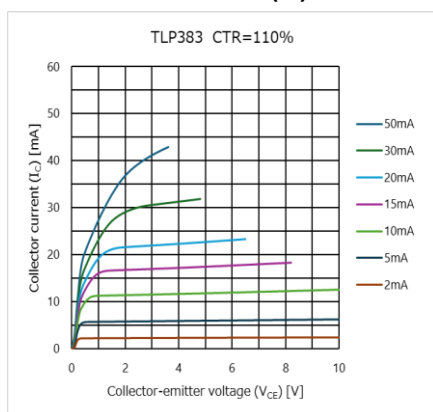


Figure 4.153 $I_C - V_{CE}$
(CTR=110%)

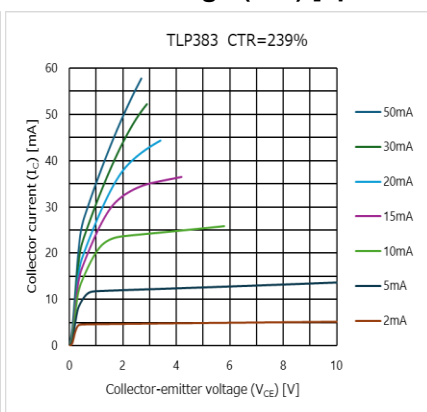


Figure 4.154 $I_C - V_{CE}$
(CTR=239%)

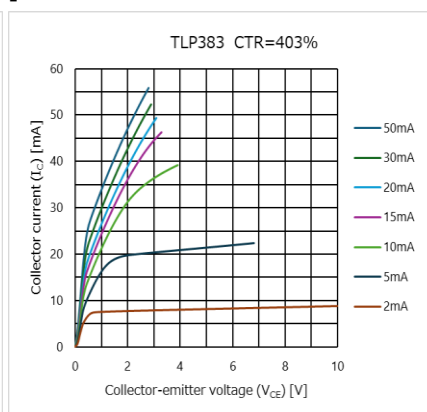


Figure 4.155 $I_C - V_{CE}$
(CTR=403%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

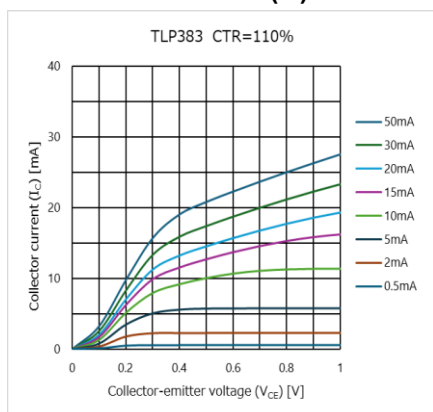


Figure 4.156 $I_C - V_{CE}$
(CTR=110%)

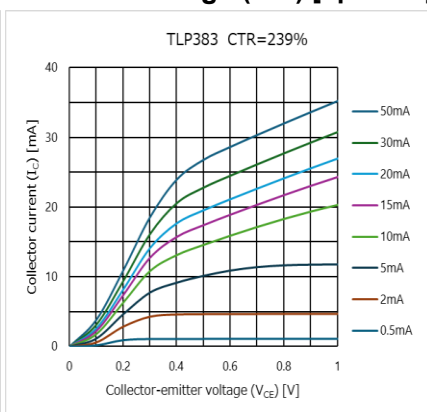


Figure 4.157 $I_C - V_{CE}$
(CTR=239%)

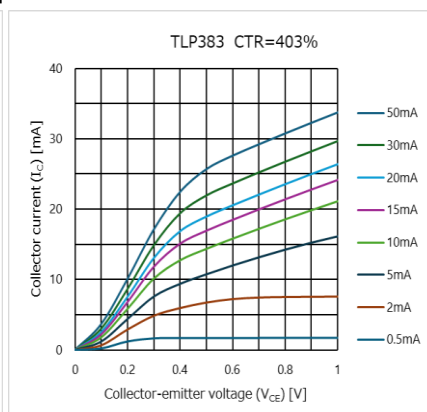


Figure 4.158 $I_C - V_{CE}$
(CTR=403%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

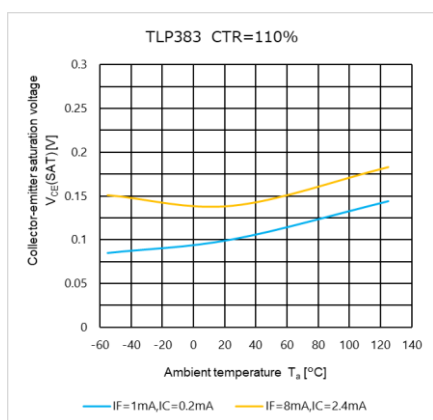


Figure 4.159 $V_{CE} - T_a$
(CTR=110%)

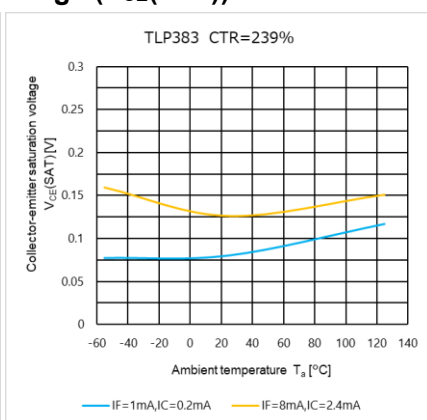


Figure 4.160 $V_{CE} - T_a$
(CTR=239%)

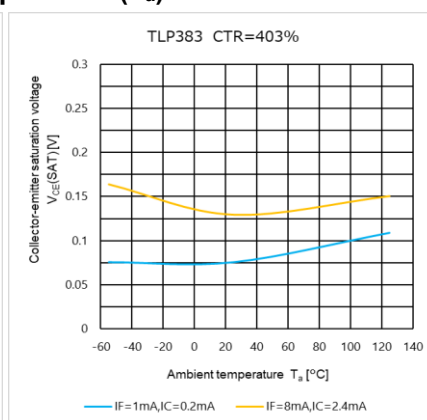


Figure 4.161 $V_{CE} - T_a$
(CTR=403%)

Collector current (I_C) – Input forward current (I_F)

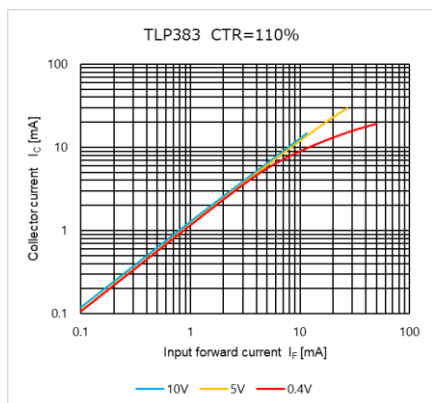


Figure 4.162 $I_C - I_F$
(CTR=110%)

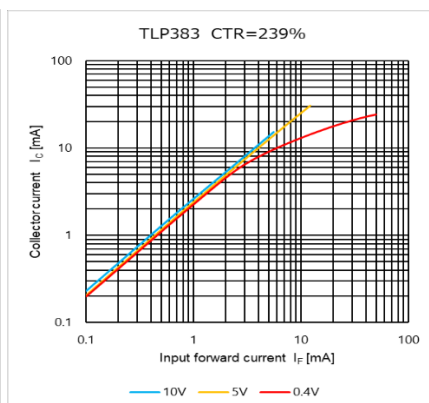


Figure 4.163 $I_C - I_F$
(CTR=239%)

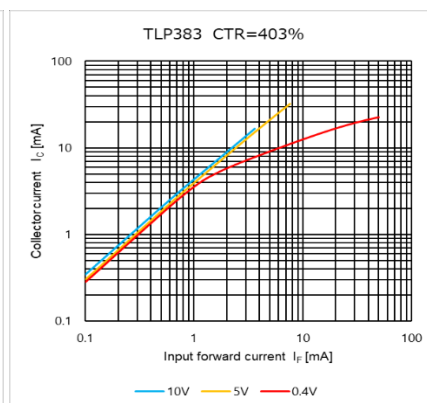


Figure 4.164 $I_C - I_F$
(CTR=403%)

Current transfer ratio (I_C / I_F) – Input forward current (I_F)

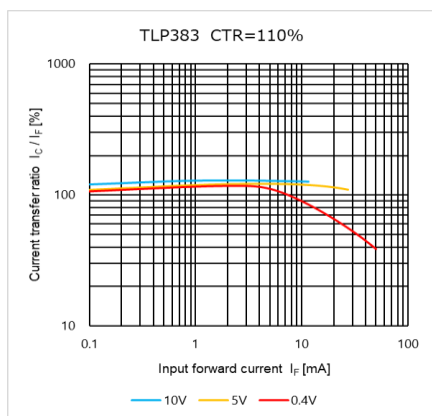


Figure 4.165 $I_C/I_F - I_F$
(CTR=110%)

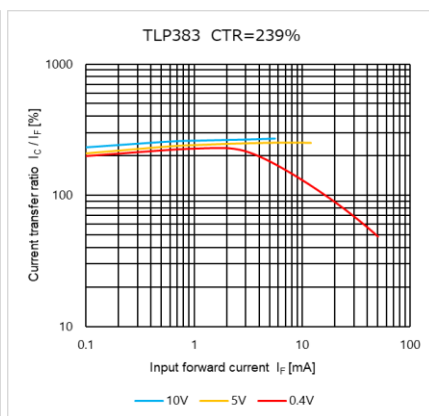


Figure 4.166 $I_C/I_F - I_F$
(CTR=239%)

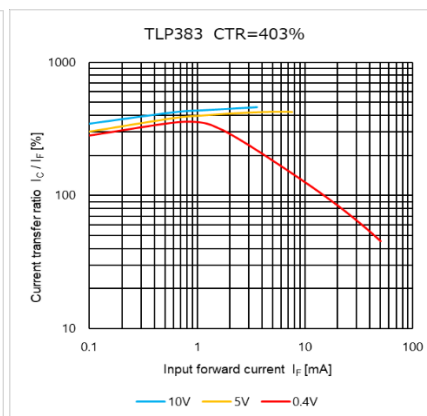


Figure 4.167 $I_C/I_F - I_F$
(CTR=403%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

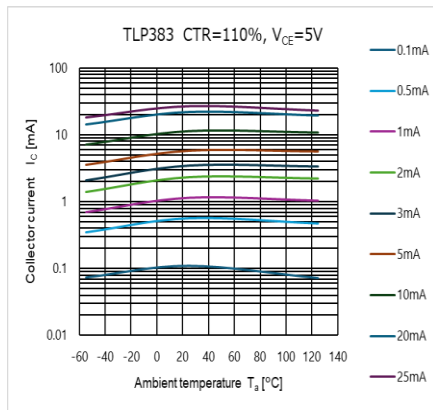


Figure 4.168 $I_C - T_a$
(CTR=110%)

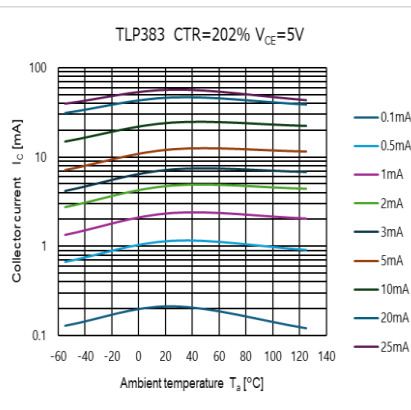


Figure 4.169 $I_C - T_a$
(CTR=239%)

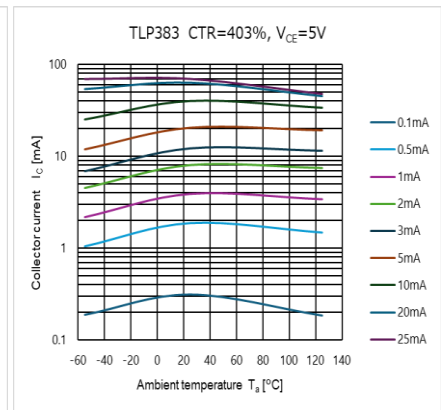


Figure 4.170 $I_C - T_a$
(CTR=403%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

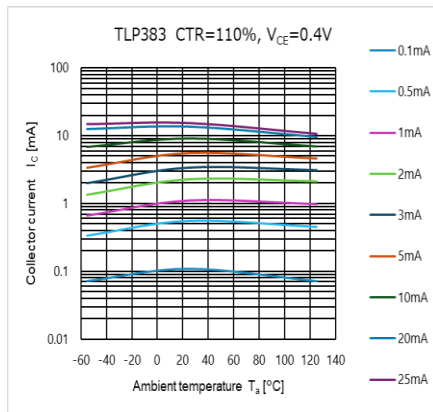


Figure 4.171 $I_C - T_a$
(CTR=110%)

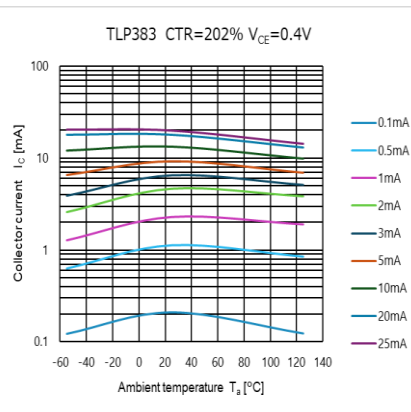


Figure 4.172 $I_C - T_a$
(CTR=239%)

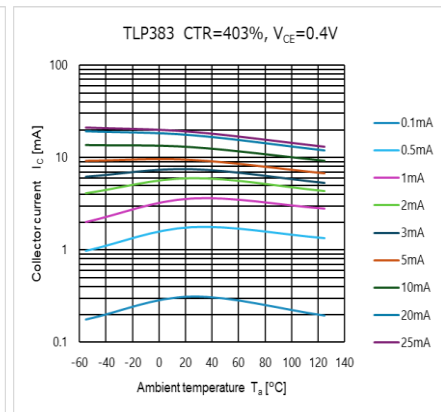
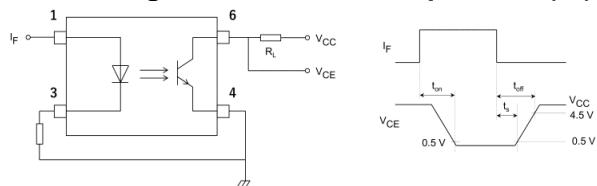


Figure 4.173 $I_C - T_a$
(CTR=403%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



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$R_L=1.9k\Omega$ low input, $I_F=5mA$

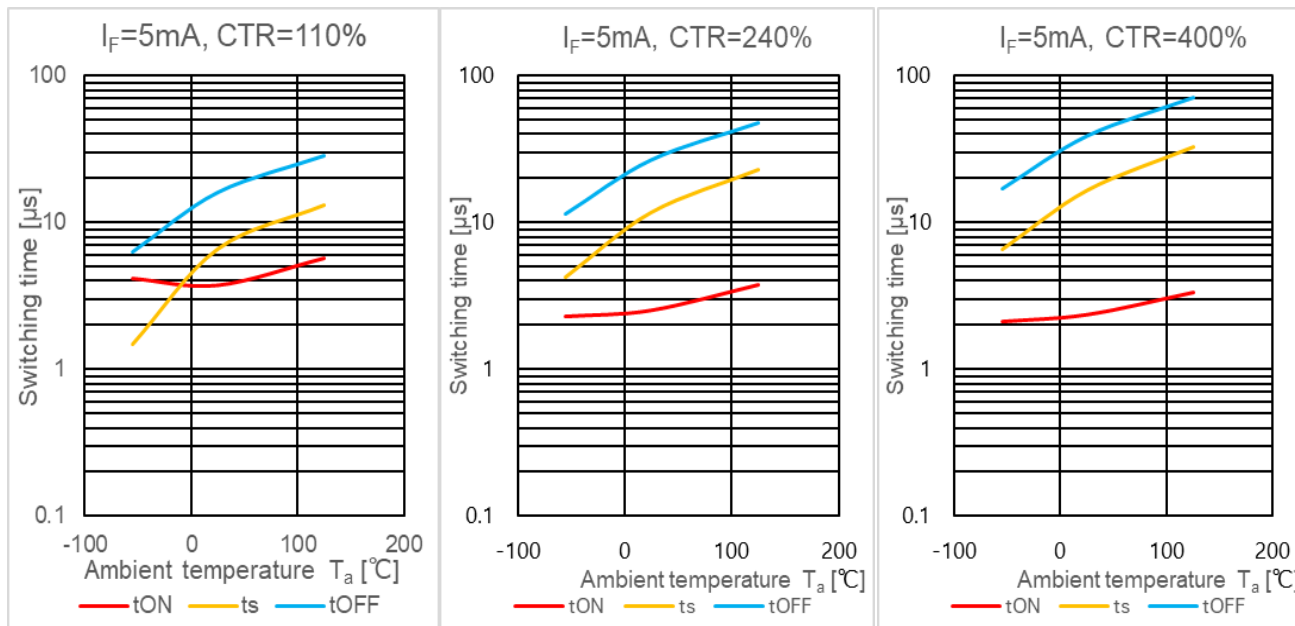


Figure 4.174 Switching time - T_a (CTR=110%) Figure 4.175 Switching time - T_a (CTR=240%) Figure 4.176 Switching time - T_a (CTR=400%)

$R_L=1.9k\Omega$ low input, $I_F=16mA$

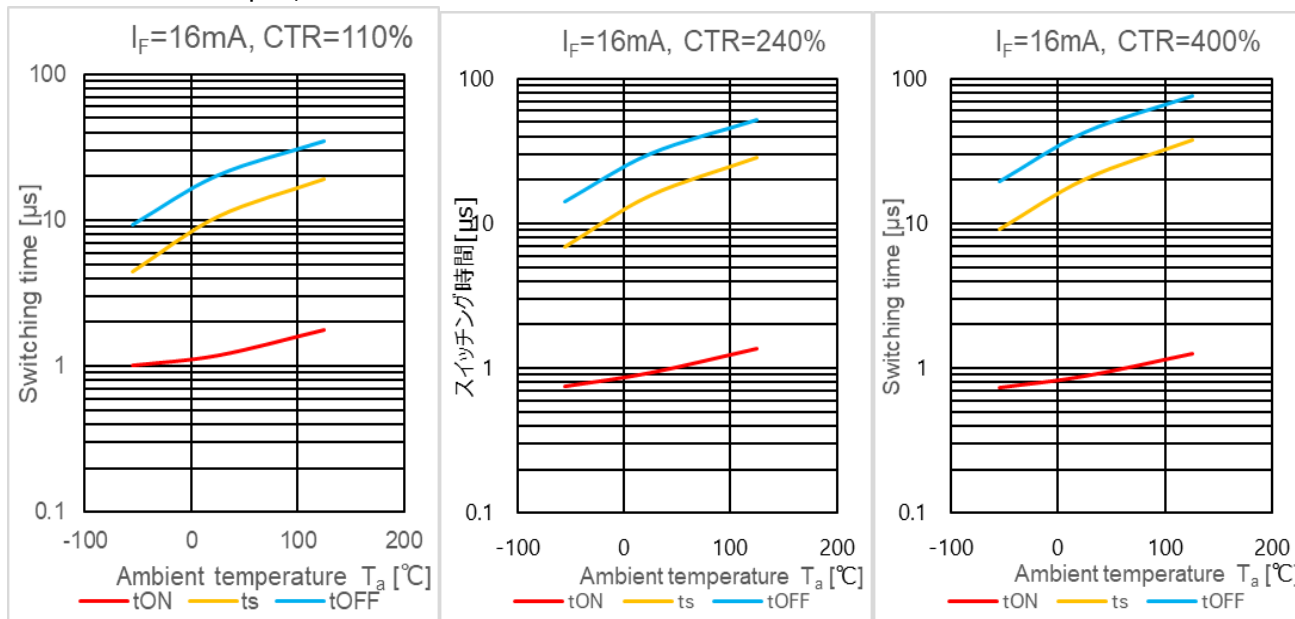


Figure 4.177 Switching time - T_a (CTR=110%) Figure 4.178 Switching time - T_a (CTR=240%) Figure 4.179 Switching time - T_a (CTR=400%)

$R_L=10k\Omega$ low input, $I_F=1mA$

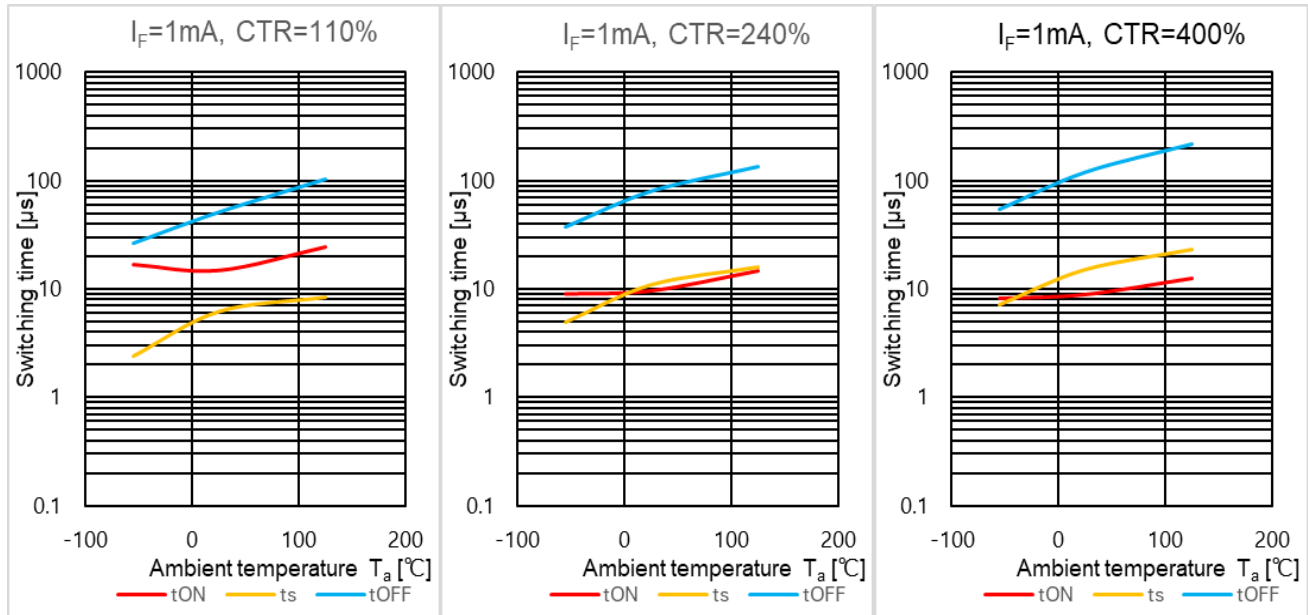


Figure 4.180 Switching time - T_a (CTR=110%) **Figure 4.181 Switching time - T_a (CTR=240%)** **Figure 4.182 Switching time - T_a (CTR=400%)**

$R_L=10k\Omega$ low input, $I_F=5mA$

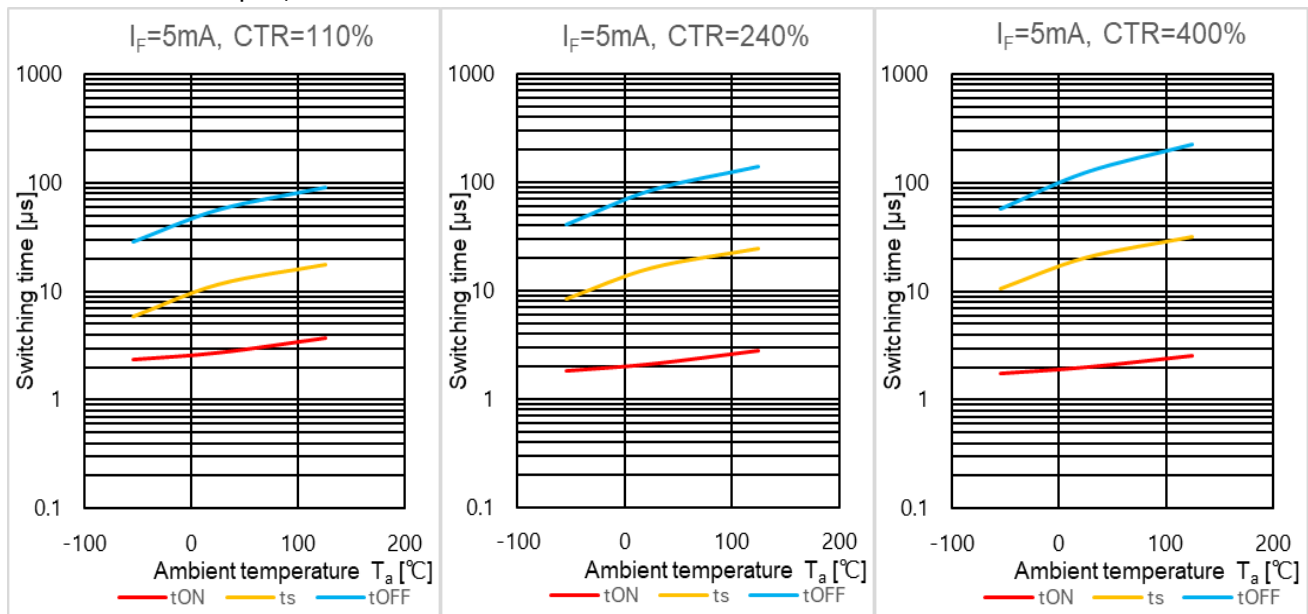


Figure 4.183 Switching time - T_a (CTR=110%) **Figure 4.184 Switching time - T_a (CTR=240%)** **Figure 4.185 Switching time - T_a (CTR=400%)**

$R_L=10k\Omega$ low input, $I_F=16mA$

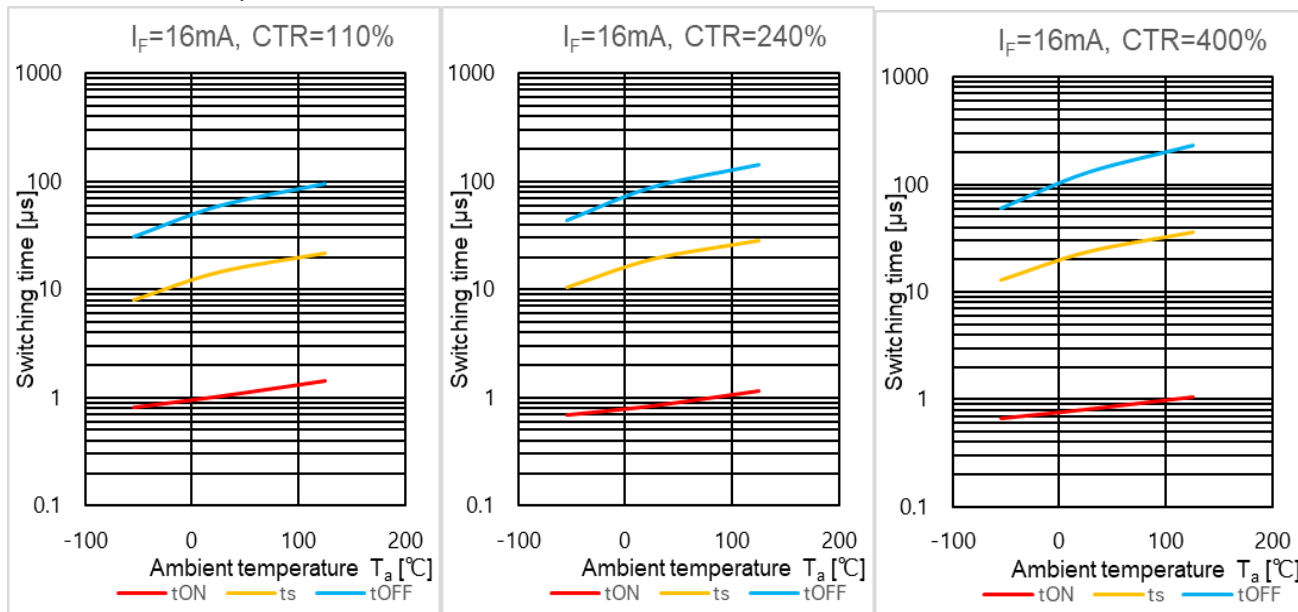


Figure 4.186 Switching time - T_a (CTR=110%) **Figure 4.187 Switching time - T_a (CTR=240%)** **Figure 4.188 Switching time - T_a (CTR=400%)**

$R_L=20k\Omega$ low input, $I_F=0.5mA$

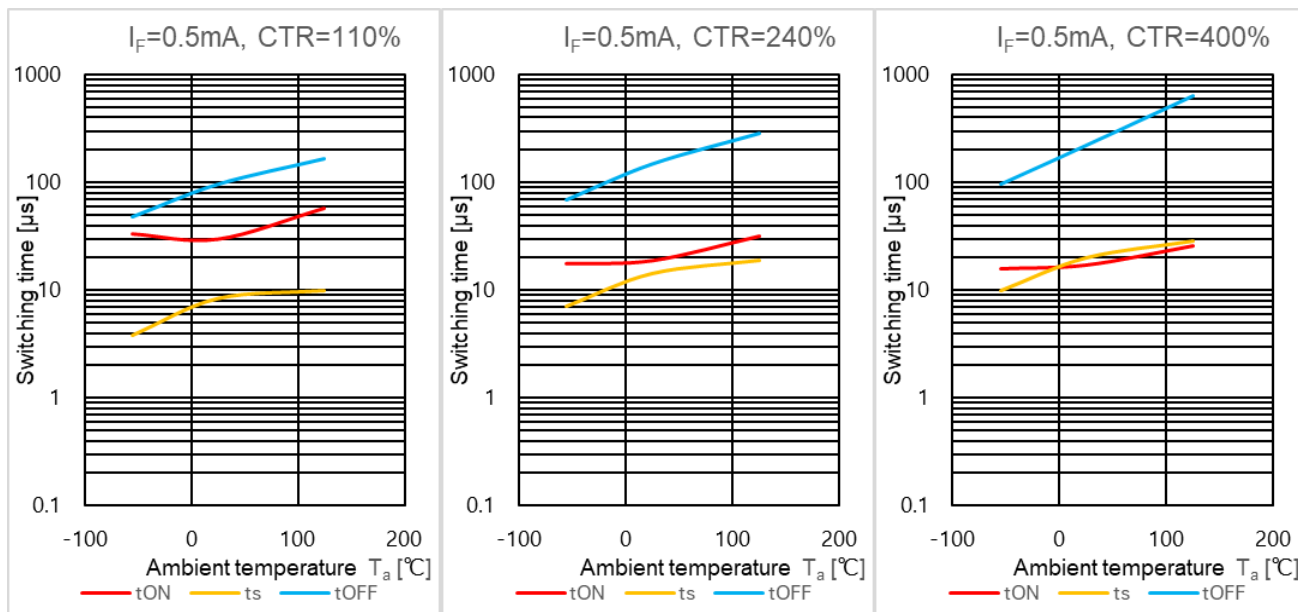


Figure 4.189 Switching time - T_a (CTR=110%) **Figure 4.190 Switching time - T_a (CTR=240%)** **Figure 4.191 Switching time - T_a (CTR=400%)**

Frequency characteristics (Relative output (G_V), Phase (θ)), $T_a=25^\circ\text{C}$, $V_{cc}=5\text{V}$, $I_C(\text{DC})=2\text{mA}$, $I_C(\text{AC})=1\text{mA}_{\text{p-p}}$

$R_L=1\text{k}\Omega$

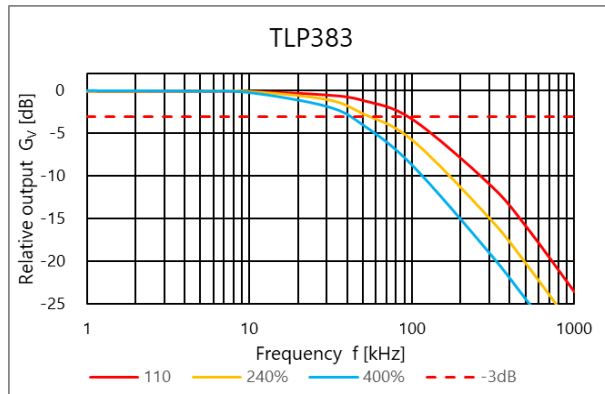


Figure 4.192 Relative output G_V - Frequency

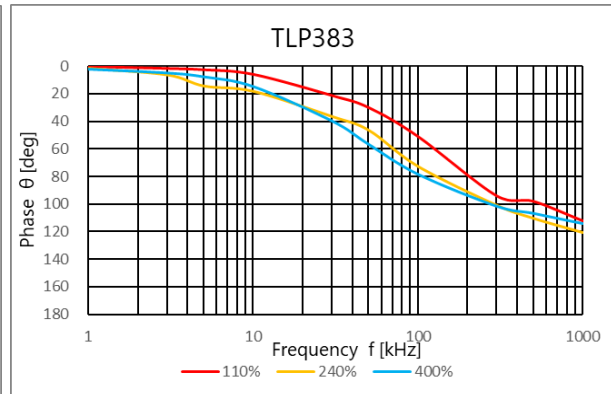


Figure 4.193 Phase θ - Frequency

$R_L=100\Omega$

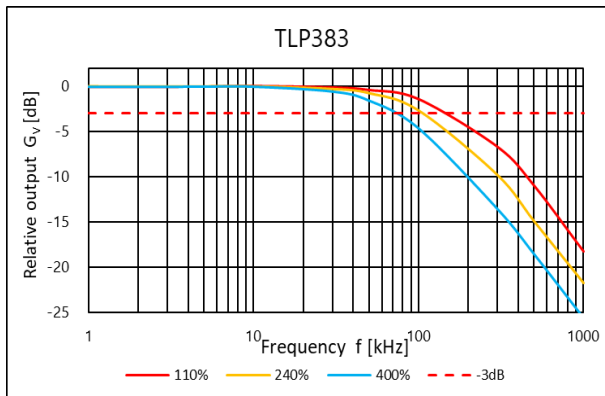


Figure 4.194 Relative output G_V - Frequency

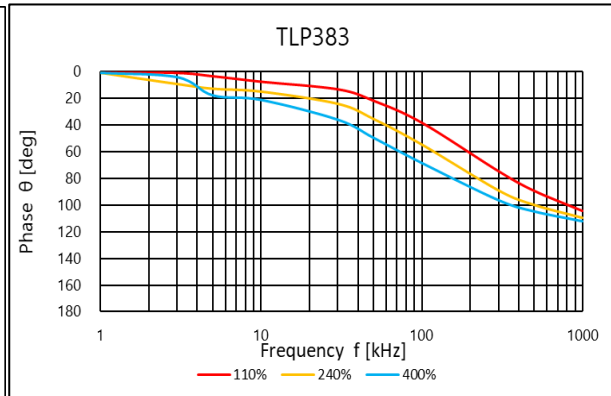


Figure 4.195 Phase θ - Frequency

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Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

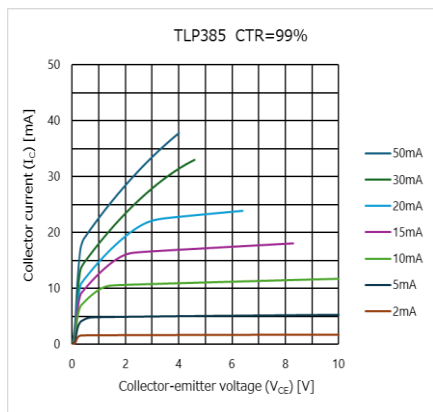


Figure 4.196 $I_C - V_{CE}$
(CTR=99%)

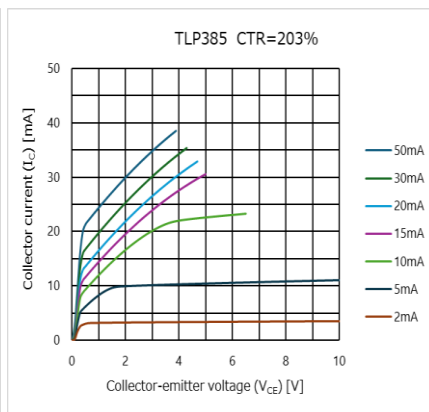


Figure 4.197 $I_C - V_{CE}$
(CTR=203%)

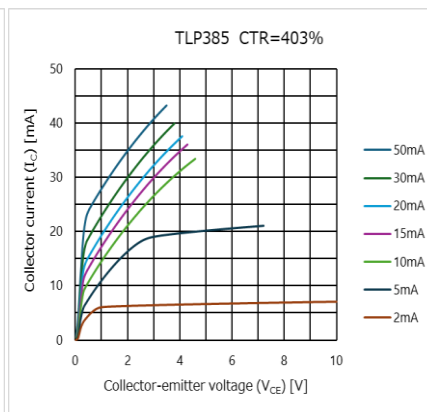


Figure 4.198 $I_C - V_{CE}$
(CTR=403%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

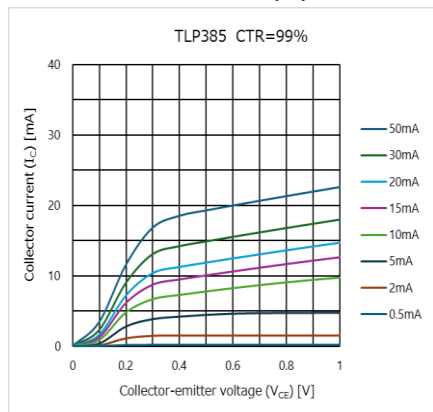


Figure 4.199 $I_C - V_{CE}$
(CTR=99%)

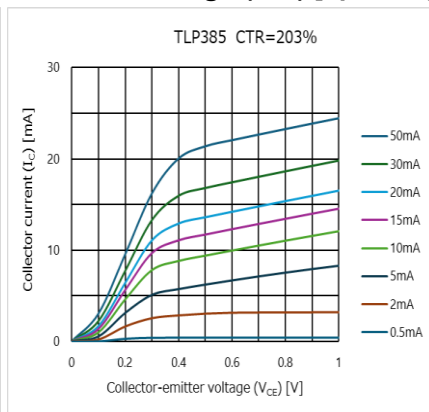


Figure 4.200 $I_C - V_{CE}$
(CTR=203%)

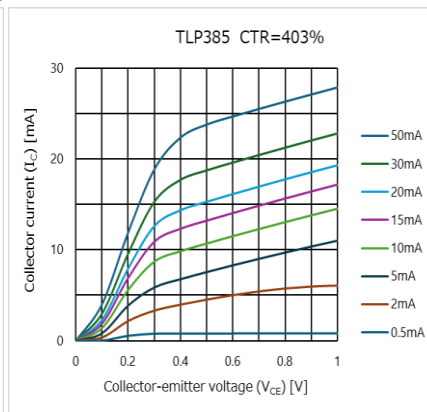


Figure 4.201 $I_C - V_{CE}$
(CTR=403%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

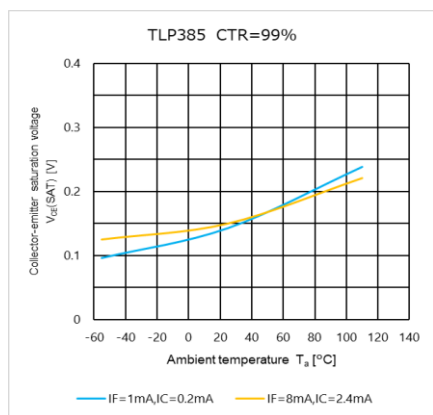


Figure 4.202 $V_{CE} - T_a$
(CTR=99%)

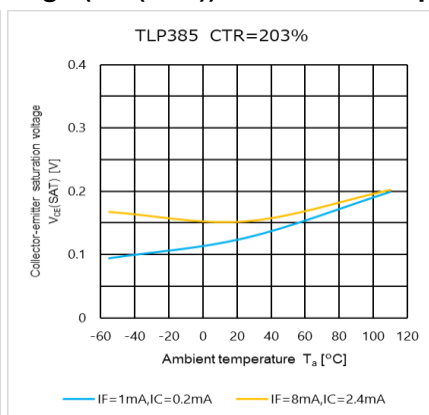


Figure 4.203 $V_{CE} - T_a$
(CTR=203%)

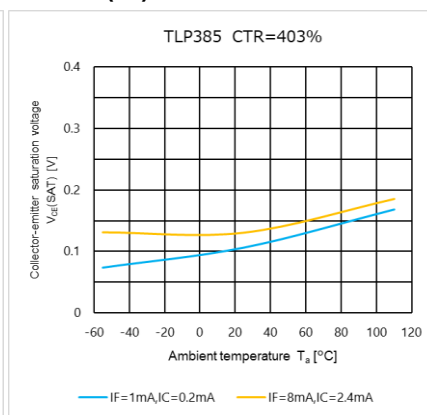
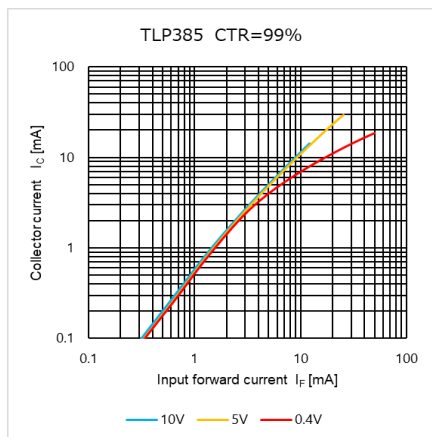
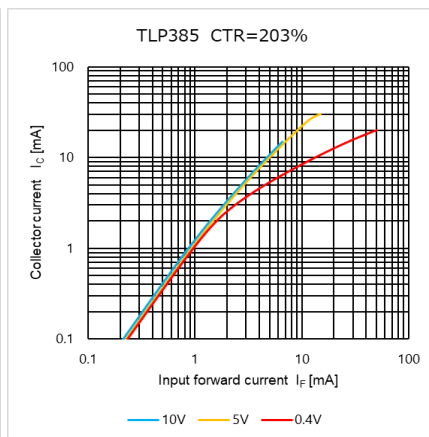


Figure 4.204 $V_{CE} - T_a$
(CTR=403%)

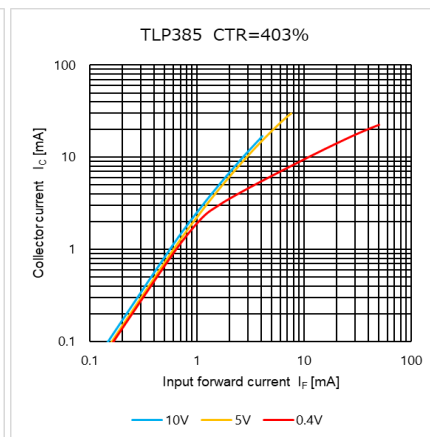
Collector current (I_C) – Input forward current (I_F)



**Figure 4.205 $I_C - I_F$
(CTR=99%)**

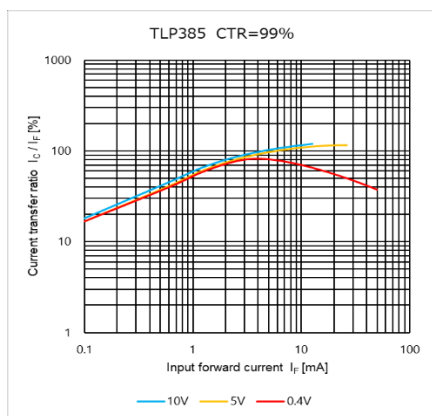


**Figure 4.206 $I_C - I_F$
(CTR=203%)**

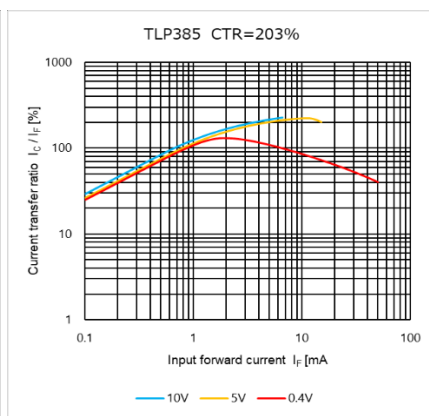


**Figure 4.207 $I_C - I_F$
(CTR=403%)**

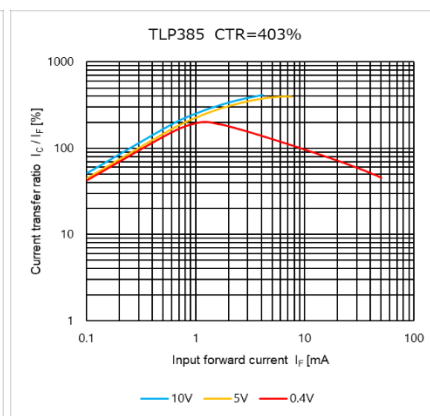
Current transfer ratio (I_C / I_F) – Input forward current (I_F)



**Figure 4.208 $I_C / I_F - I_F$
(CTR=99%)**

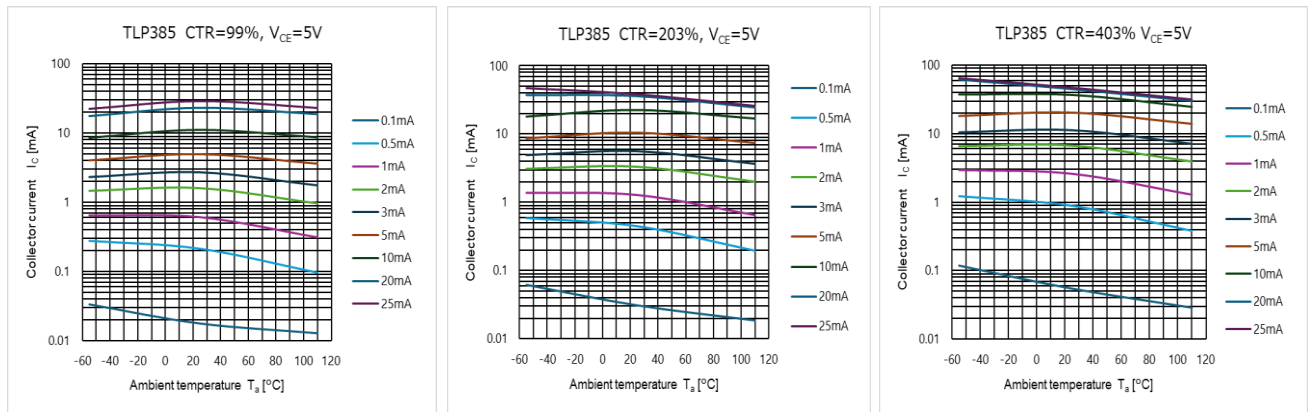


**Figure 4.209 $I_C / I_F - I_F$
(CTR=203%)**



**Figure 4.210 $I_C / I_F - I_F$
(CTR=403%)**

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$



Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

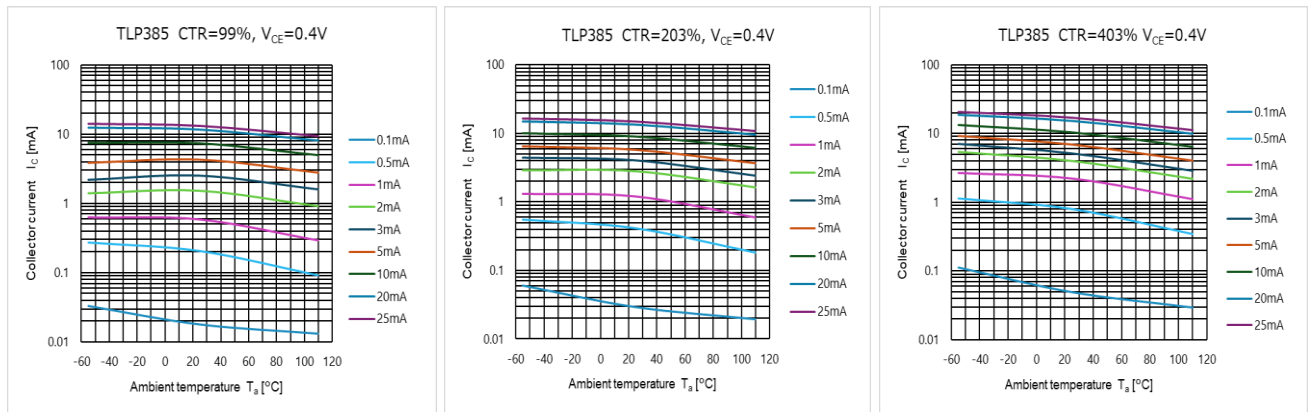
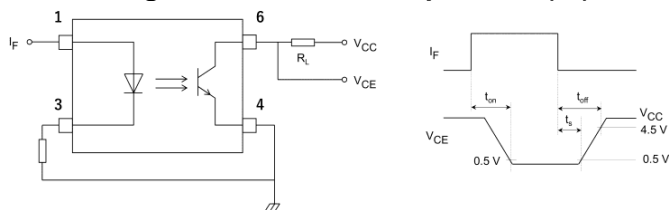


Figure 4.214 $I_C - T_a$
(CTR=99%)

Figure 4.215 $I_C - T_a$
(CTR=203%)

Figure 4.216 $I_C - T_a$
(CTR=403%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP385

$R_L=1.9k\Omega$, $I_F=5mA$

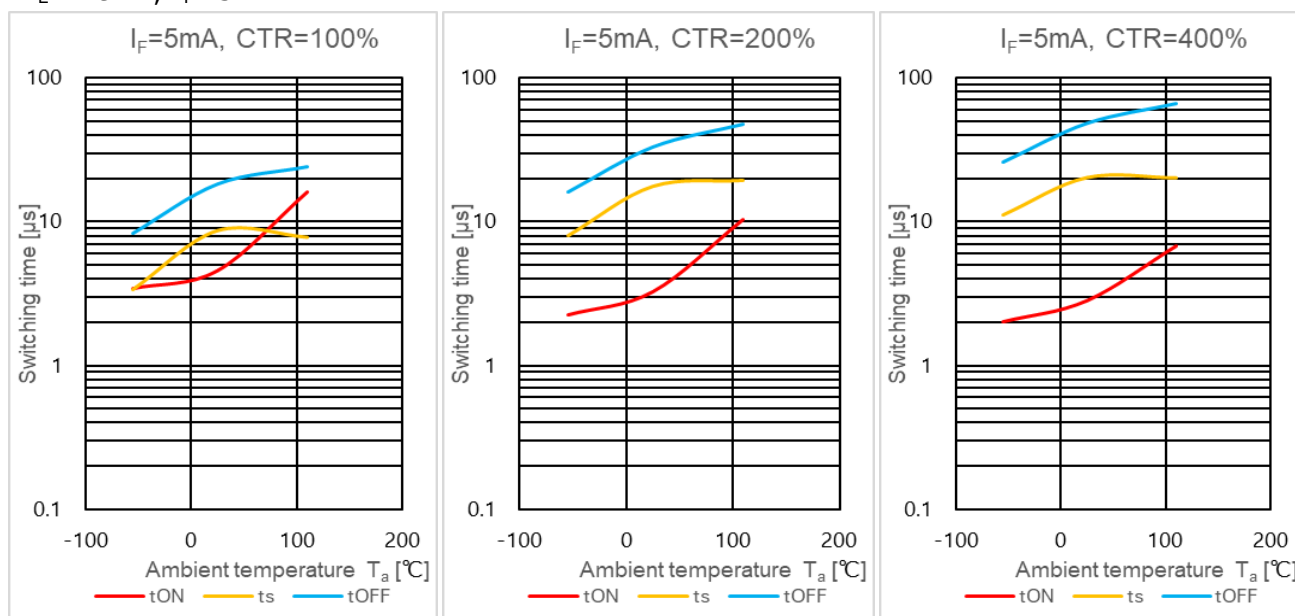


Figure 4.217 Switching time - T_a (CTR=100%) Figure 4.218 Switching time - T_a (CTR=200%) Figure 4.219 Switching time - T_a (CTR=400%)

$R_L=1.9k\Omega$, $I_F=16mA$

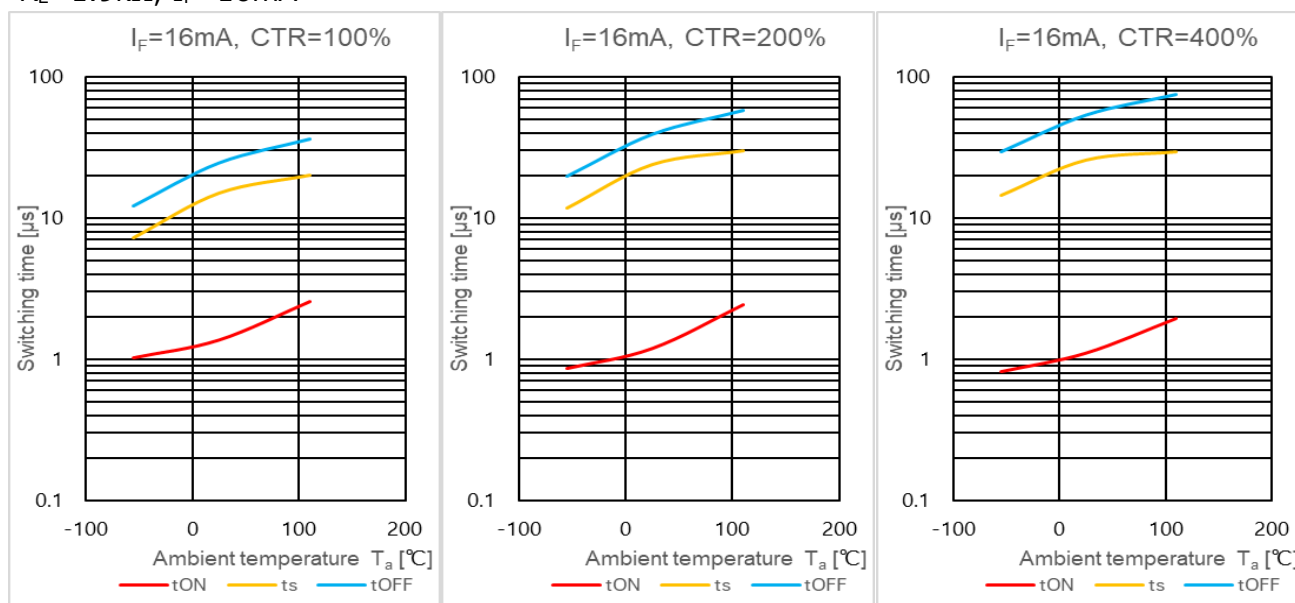


Figure 4.220 Switching time - T_a (CTR=100%) Figure 4.221 Switching time - T_a (CTR=200%) Figure 4.222 Switching time - T_a (CTR=400%)

$R_L = 10k\Omega$, $I_F = 2mA$

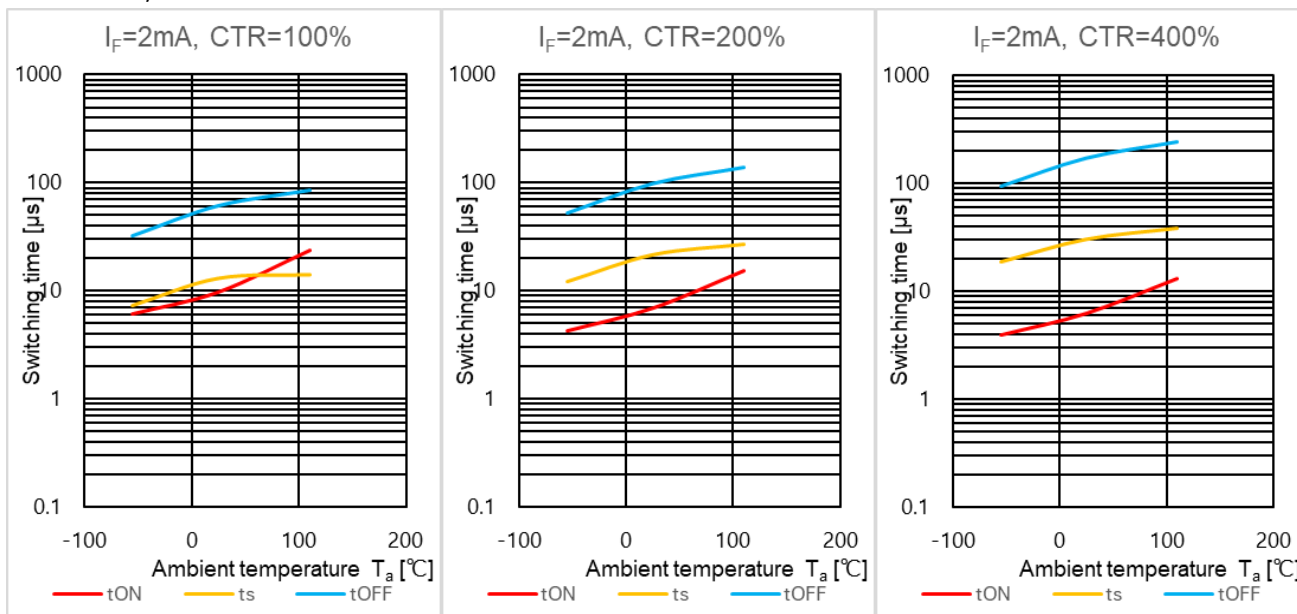


Figure 4.223 Switching time - T_a
(CTR=100%)

Figure 4.224 Switching time - T_a
(CTR=200%)

Figure 4.225 Switching time - T_a
(CTR=400%)

$R_L = 10k\Omega$, $I_F = 5mA$

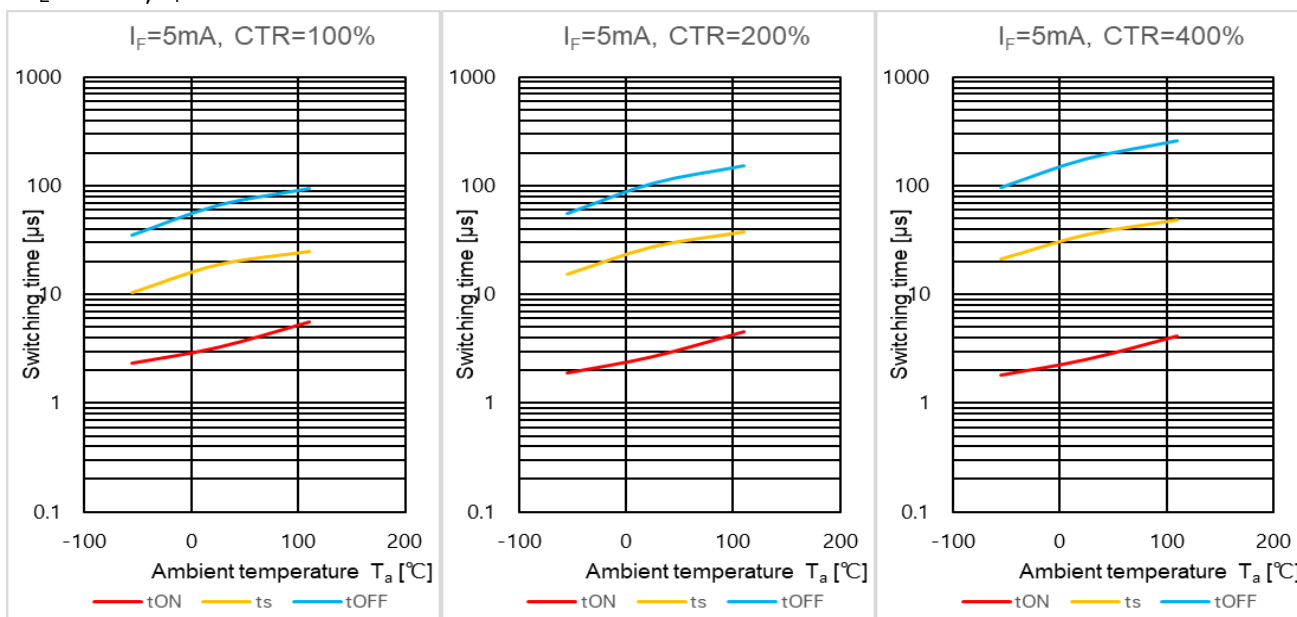


Figure 4.226 Switching time - T_a
(CTR=100%)

Figure 4.227 Switching time - T_a
(CTR=200%)

Figure 4.228 Switching time - T_a
(CTR=400%)

$R_L = 10k\Omega$, $I_F = 16mA$

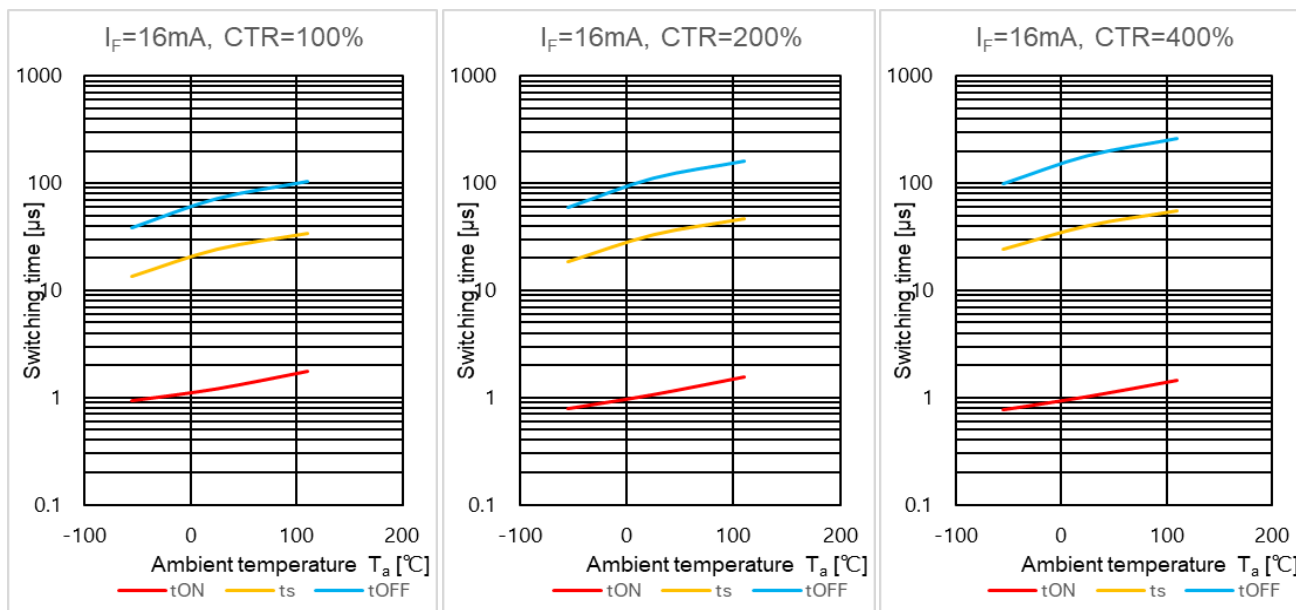


Figure 4.229 Switching time - T_a (CTR=100%) Figure 4.230 Switching time - T_a (CTR=200%) Figure 4.231 Switching time - T_a (CTR=400%)

Frequency characteristics (Relative output (G_v), Phase (θ)), $T_a = 25^{\circ}C$, $V_{cc} = 5V$, $I_C(DC) = 2mA$, $I_C(AC) = 1mA_{p-p}$

$R_L = 1k\Omega$

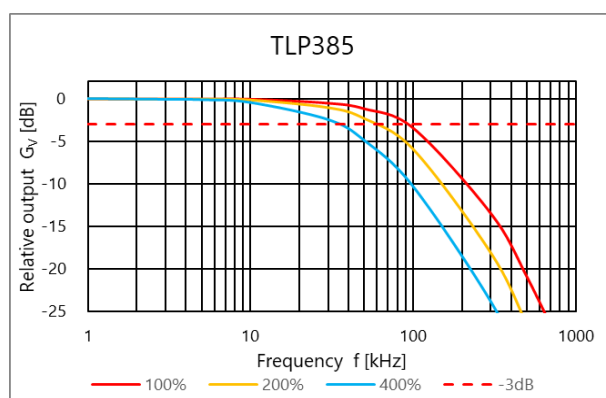


Figure 4.232 Relative output G_v - Frequency

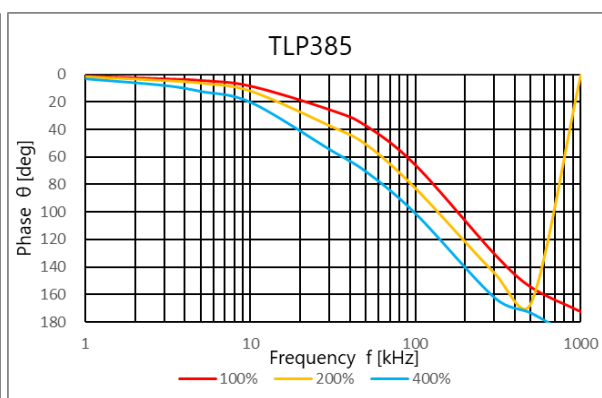


Figure 4.233 Phase θ - Frequency

$R_L = 100\Omega$

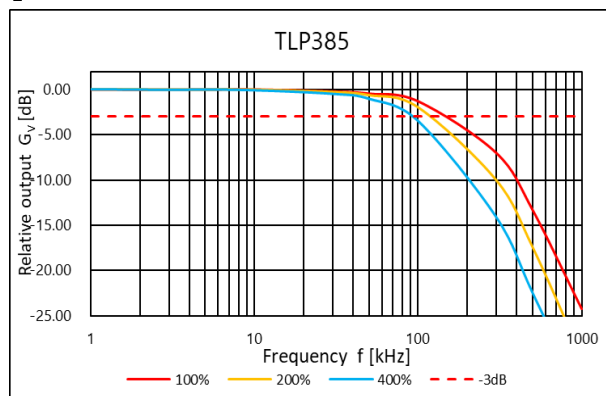


Figure 4.234 Relative output G_v - Frequency

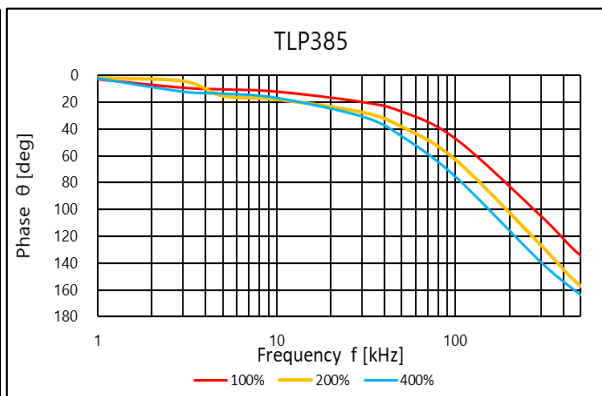


Figure 4.235 Phase θ - Frequency

TLP620M

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

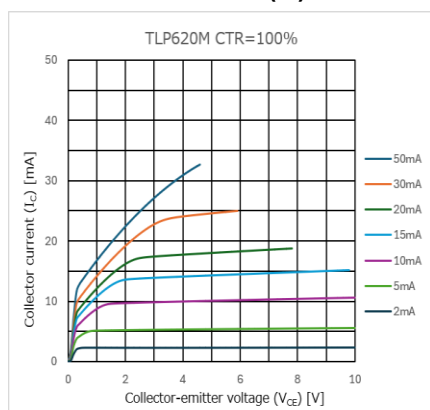


Figure 4.236 $I_C - V_{CE}$
(CTR=100%)

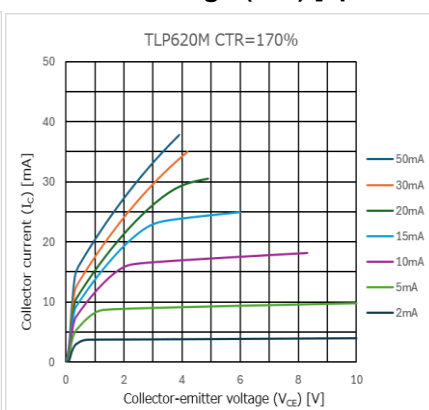


Figure 4.237 $I_C - V_{CE}$
(CTR=170%)

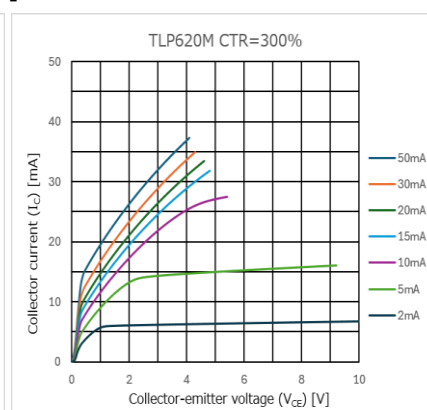


Figure 4.238 $I_C - V_{CE}$
(CTR=300%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

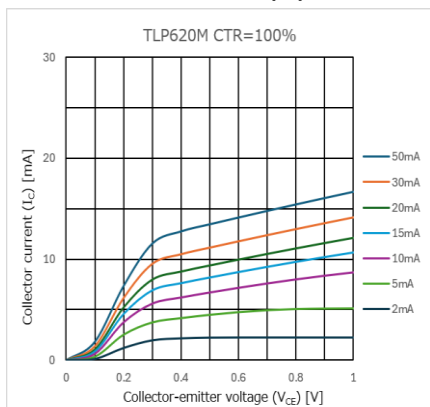


Figure 4.239 $I_C - V_{CE}$
(CTR=100%)

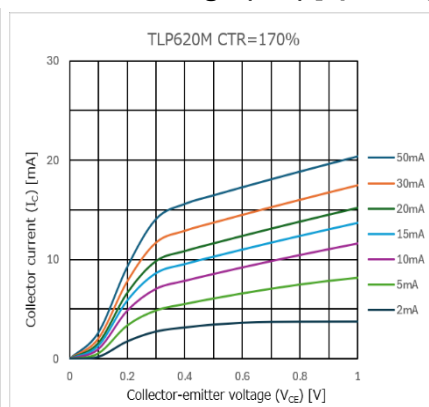


Figure 4.240 $I_C - V_{CE}$
(CTR=170%)

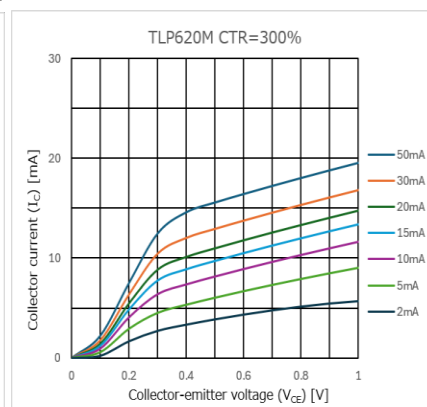


Figure 4.241 $I_C - V_{CE}$
(CTR=300%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

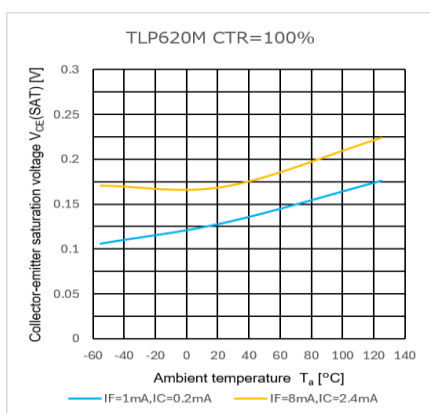


Figure 4.242 $V_{CE} - T_a$
(CTR=100%)

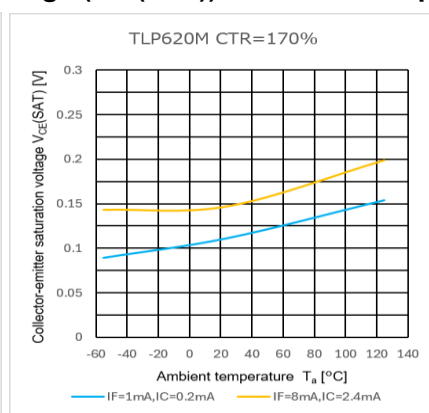


Figure 4.243 $V_{CE} - T_a$
(CTR=170%)

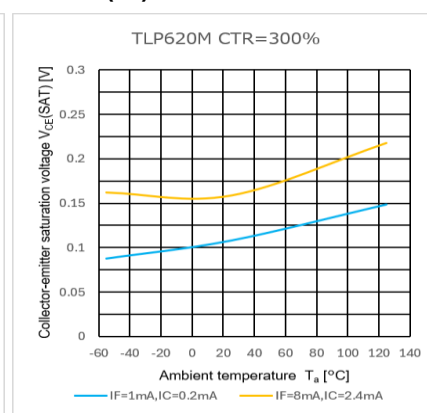


Figure 4.244 $V_{CE} - T_a$
(CTR=300%)

Collector current (I_C) – Input forward current (I_F)

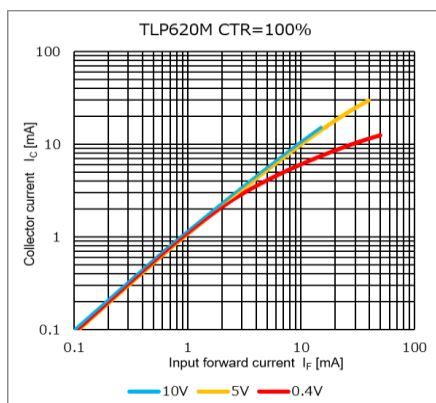


Figure 4.245 $I_C - I_F$
(CTR=100%)

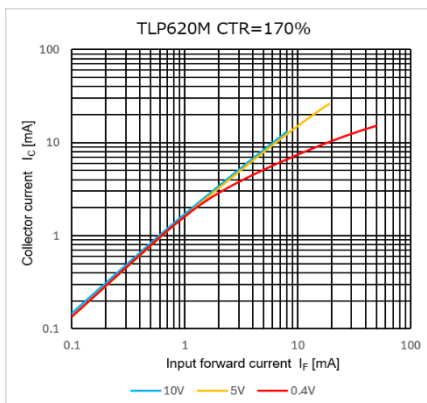


Figure 4.246 $I_C - I_F$
(CTR=170%)

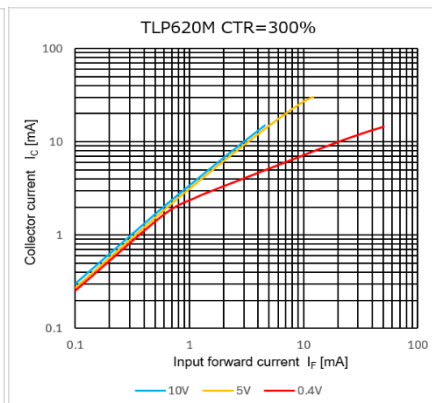


Figure 4.247 $I_C - I_F$
(CTR=300%)

Current transfer ratio (I_C / I_F) – Input forward current (I_F)

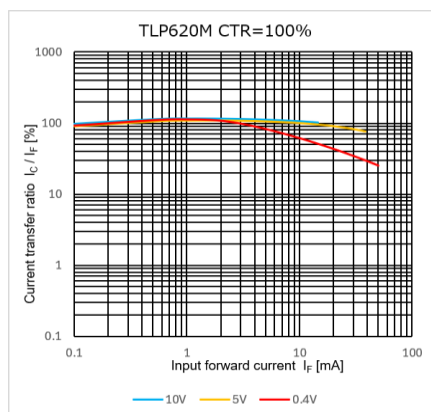


Figure 4.248 $I_C / I_F - I_F$
(CTR=100%)

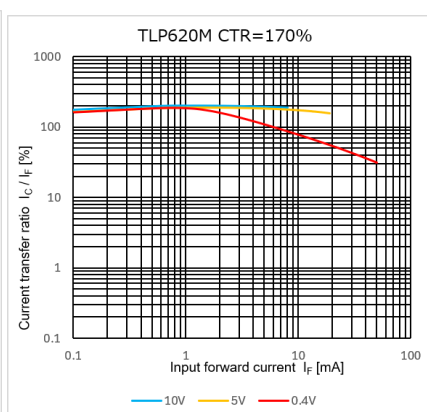


Figure 4.249 $I_C / I_F - I_F$
(CTR=170%)

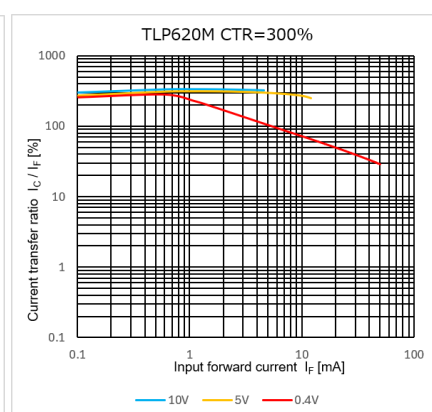


Figure 4.250 $I_C / I_F - I_F$
(CTR=300%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

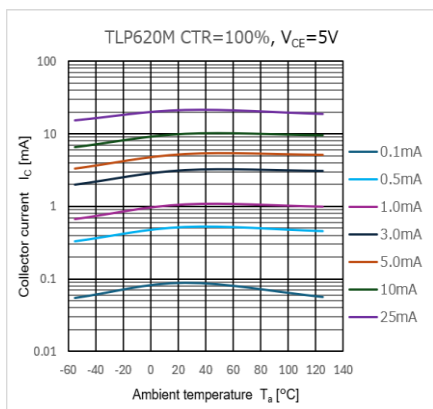


Figure 4.251 $I_C - T_a$
(CTR=100%)

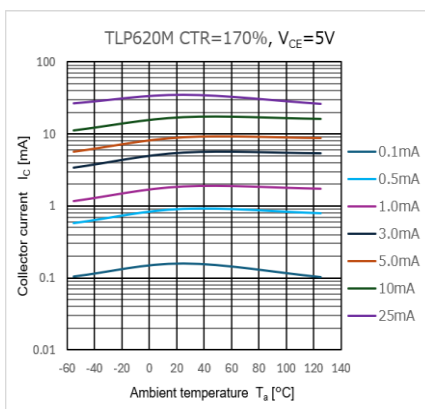


Figure 4.252 $I_C - T_a$
(CTR=170%)

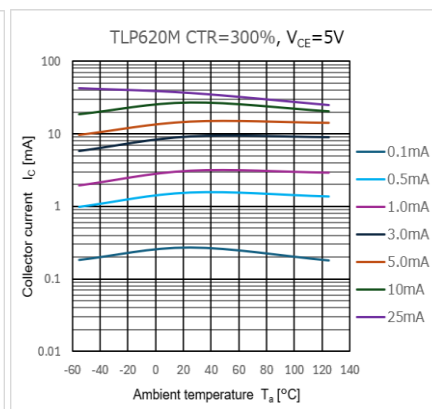


Figure 4.253 $I_C - T_a$
(CTR=300%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

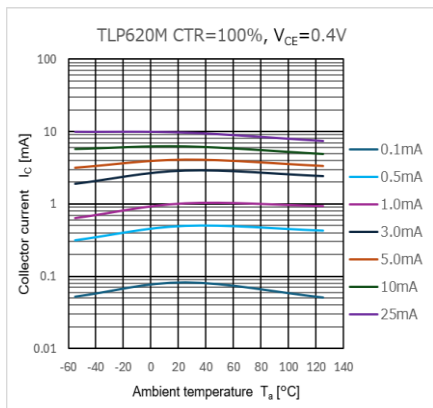


Figure 4.254 $I_C - T_a$
(CTR=100%)

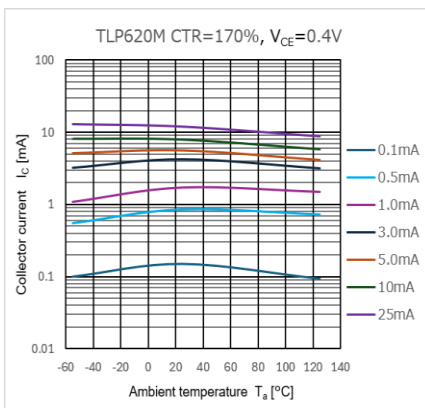


Figure 4.255 $I_C - T_a$
(CTR=170%)

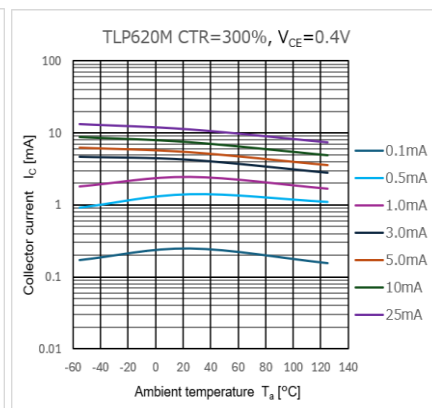
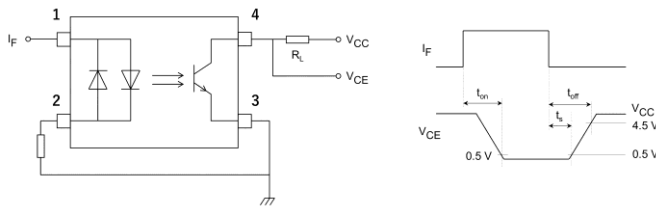


Figure 4.256 $I_C - T_a$
(CTR=300%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP620M

$R_L=1.9k\Omega$ low input, $I_F=5mA$

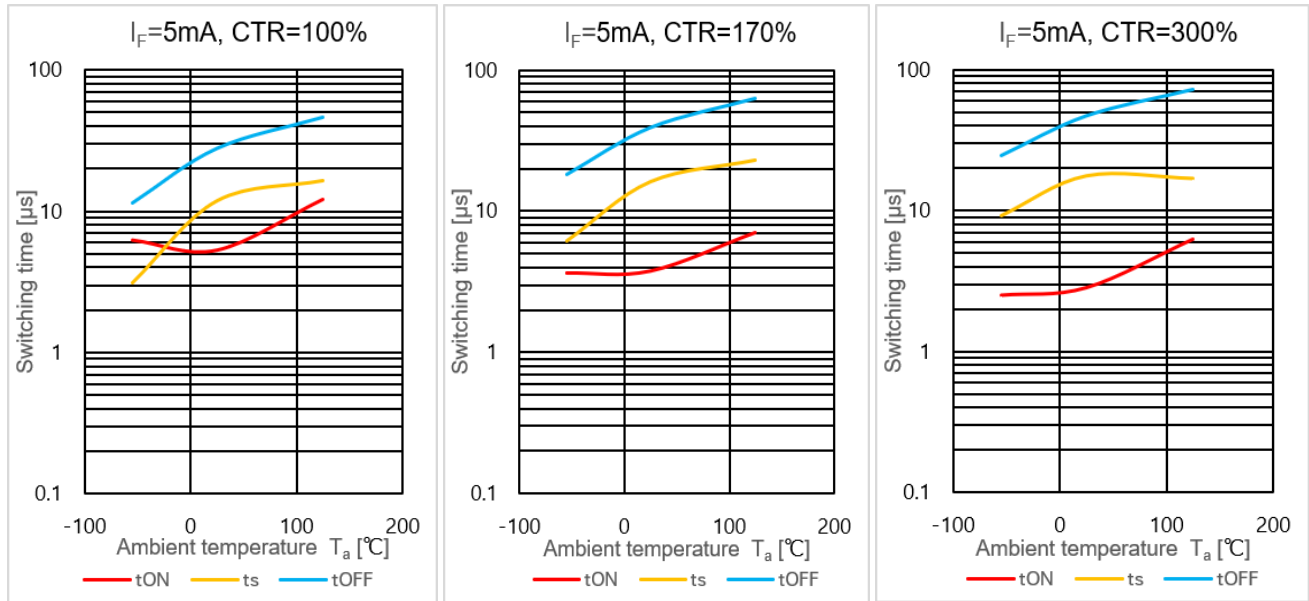


Figure 4.257 Switching time - T_a (CTR=100%) Figure 4.258 Switching time - T_a (CTR=170%) Figure 4.259 Switching time - T_a (CTR=300%)

$R_L=1.9k\Omega$ low input, $I_F=16mA$

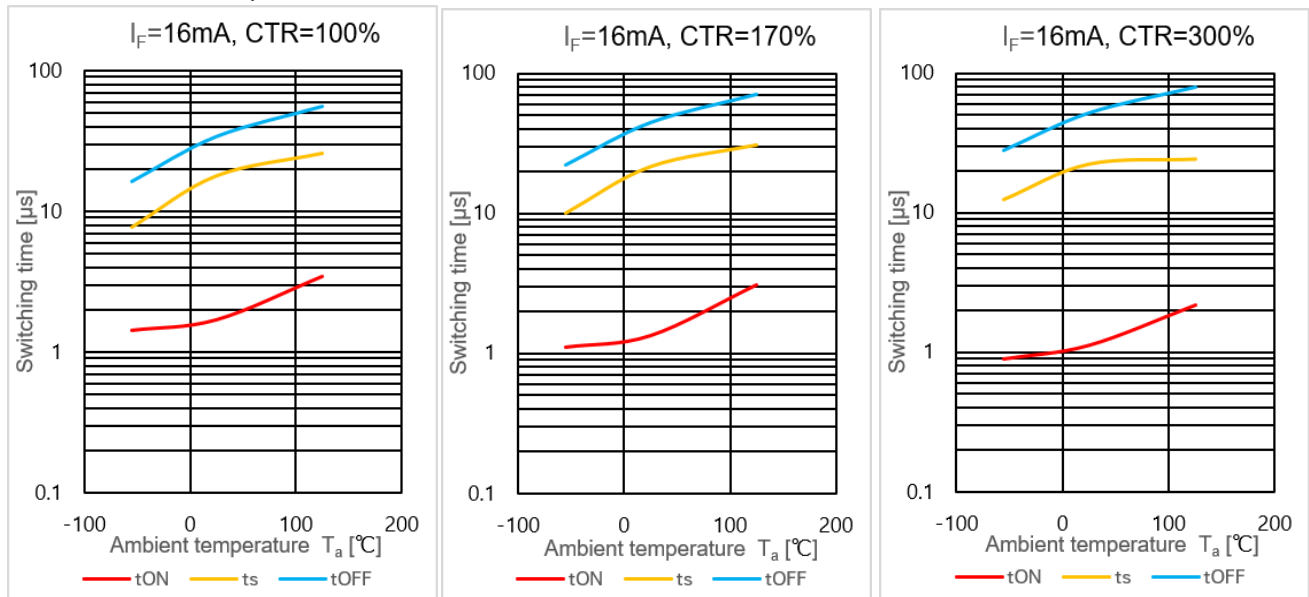


Figure 4.260 Switching time - T_a (CTR=100%) Figure 4.261 Switching time - T_a (CTR=170%) Figure 4.262 Switching time - T_a (CTR=300%)

$R_L=10k\Omega$ low input, $I_F=1mA$

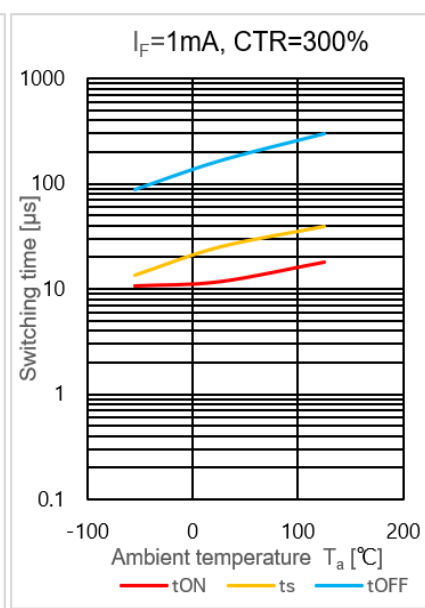
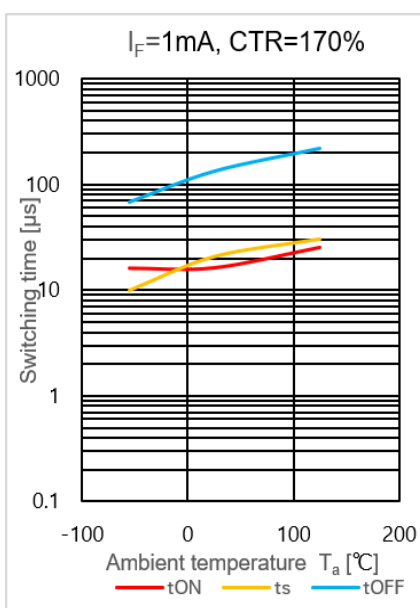
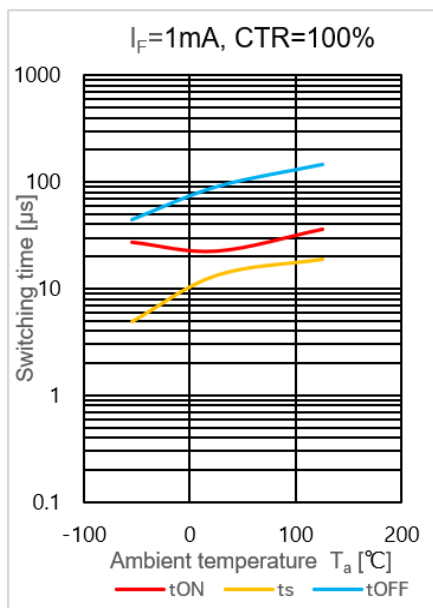


Figure 4.263 Switching time - T_a (CTR=100%)

Figure 4.264 Switching time - T_a (CTR=170%)

Figure 4.265 Switching time - T_a (CTR=300%)

$R_L=10k\Omega$ low input, $I_F=5mA$

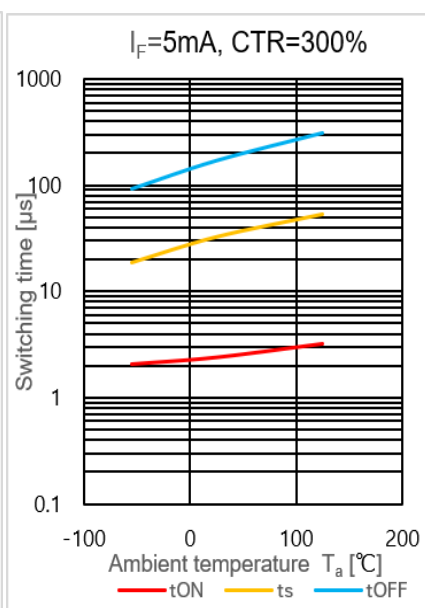
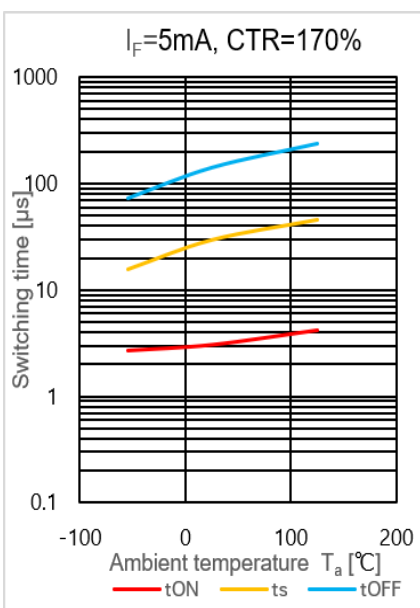
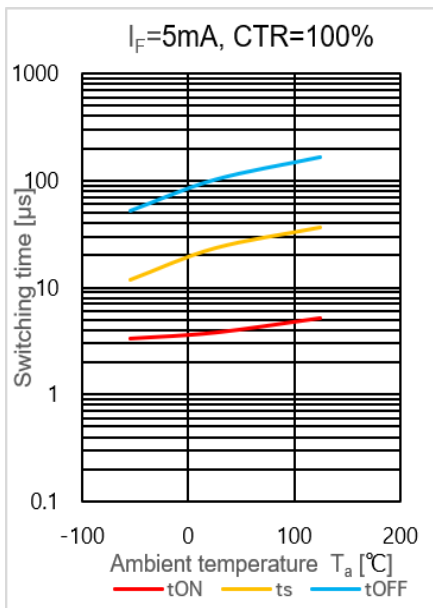


Figure 4.266 Switching time - T_a (CTR=100%)

Figure 4.267 Switching time - T_a (CTR=170%)

Figure 4.268 Switching time - T_a (CTR=300%)

$R_L=10k\Omega$ low input, $I_F=16mA$

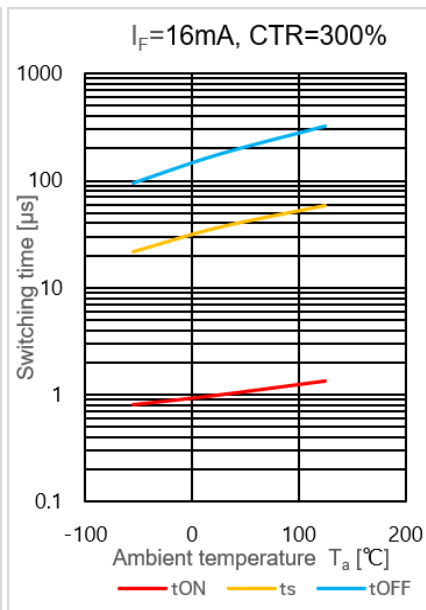
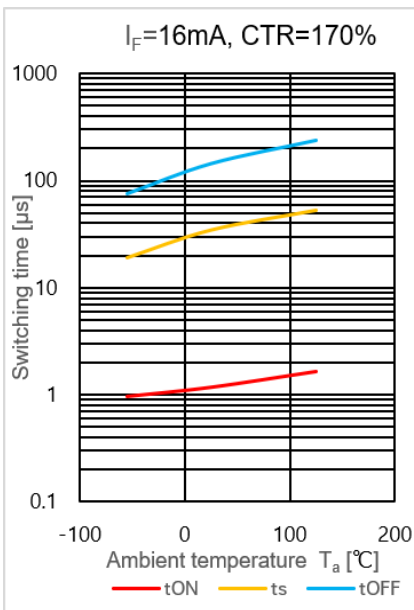
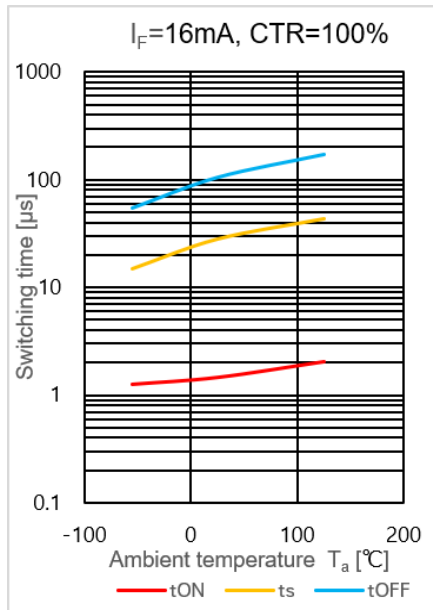


Figure 4.269 Switching time - T_a (CTR=100%)

Figure 4.270 Switching time - T_a (CTR=170%)

Figure 4.271 Switching time - T_a (CTR=300%)

$R_L=20k\Omega$ low input, $I_F=0.5mA$

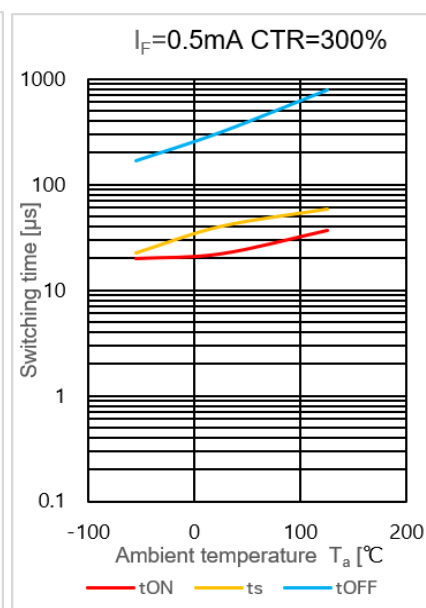
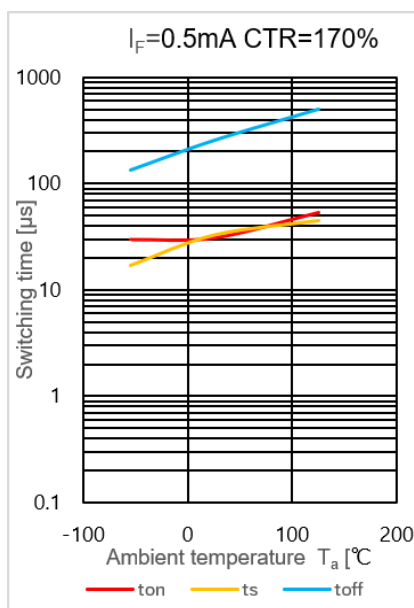
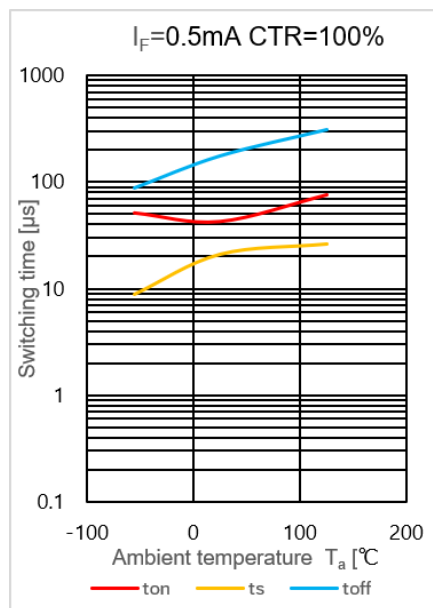


Figure 4.272 Switching time - T_a (CTR=100%)

Figure 4.273 Switching time - T_a (CTR=170%)

Figure 4.274 Switching time - T_a (CTR=300%)

Frequency characteristics (Relative output (G_v), Phase (θ)), $T_a=25^\circ\text{C}$, $V_{cc}=5\text{V}$, $I_C(\text{DC})=2\text{mA}$, $I_C(\text{AC})=1\text{mA}_{\text{p-p}}$

$R_L=1\text{k}\Omega$

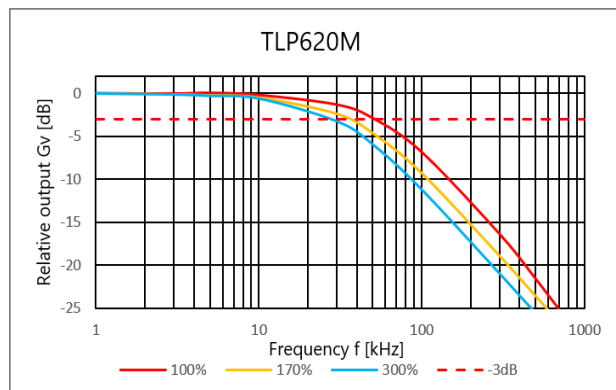


Figure 4.275 Relative output G_v - Frequency

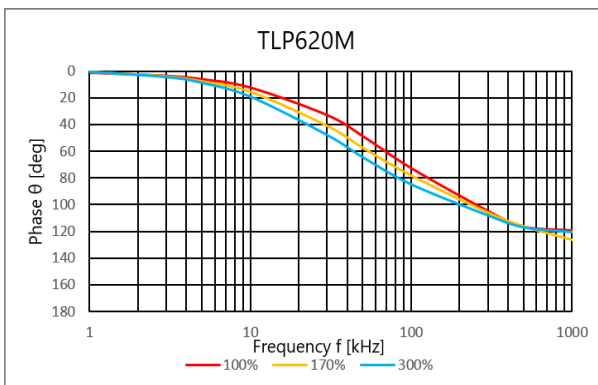


Figure 4.276 Phase θ - Frequency

$R_L=100\Omega$

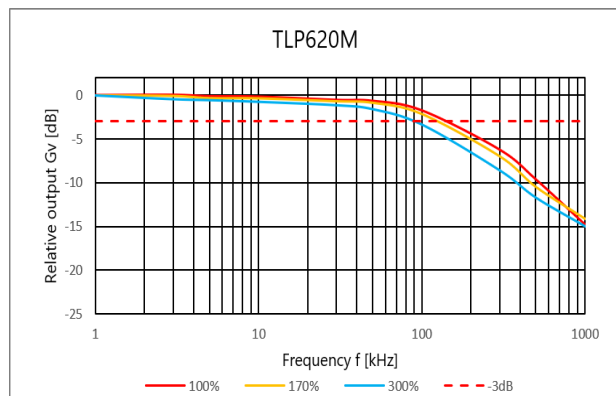


Figure 4.277 Relative output G_v - Frequency

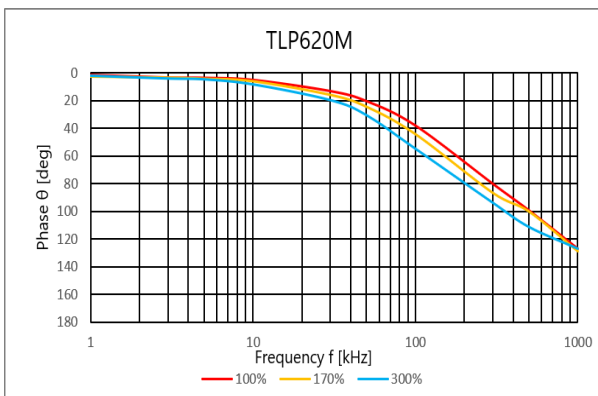


Figure 4.278 Phase θ - Frequency

TLP621M

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

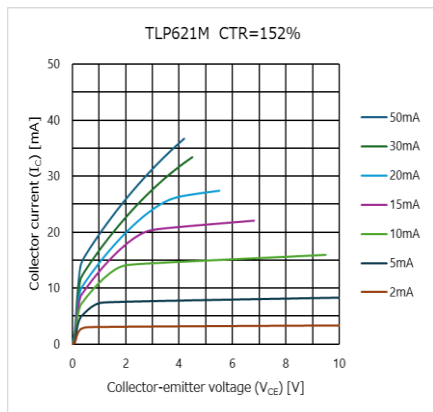


Figure 4.279 $I_C - V_{CE}$
(CTR=152%)

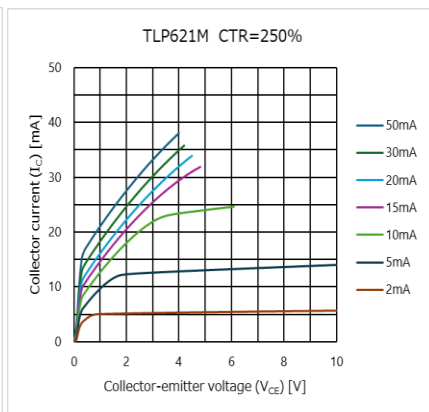


Figure 4.280 $I_C - V_{CE}$
(CTR=250%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

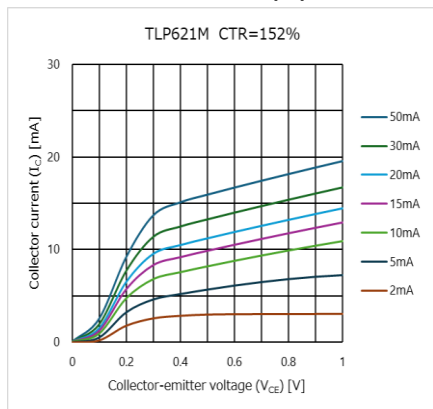


Figure 4.281 $I_C - V_{CE}$
(CTR=152%)

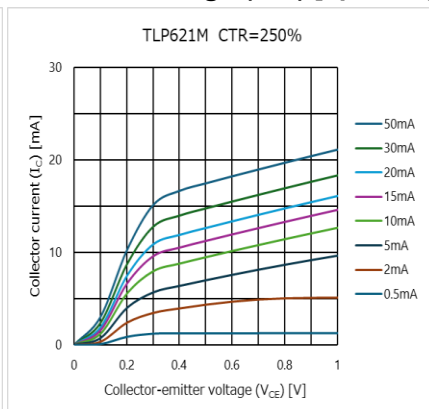


Figure 4.282 $I_C - V_{CE}$
(CTR=250%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

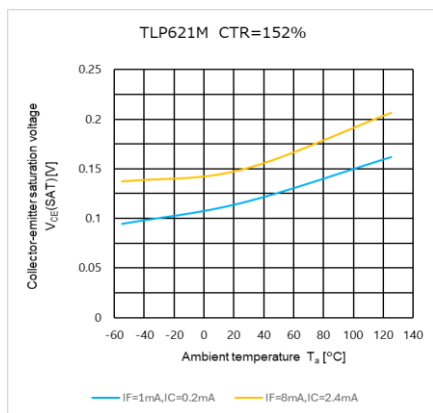


Figure 4.283 $V_{CE} - T_a$
(CTR=152%)

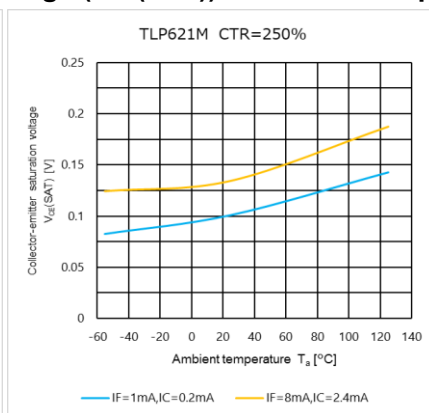
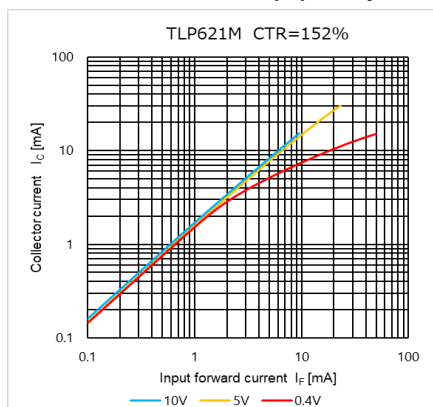
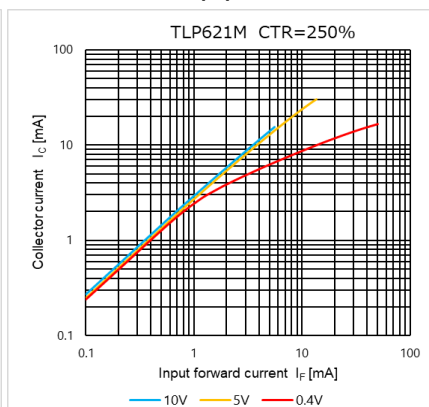


Figure 4.284 $V_{CE} - T_a$
(CTR=250%)

Collector current (I_C) – Input forward current (I_F)

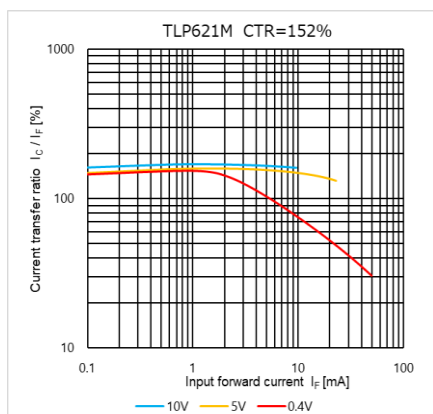


**Figure 4.285 $I_C - I_F$
(CTR=152%)**

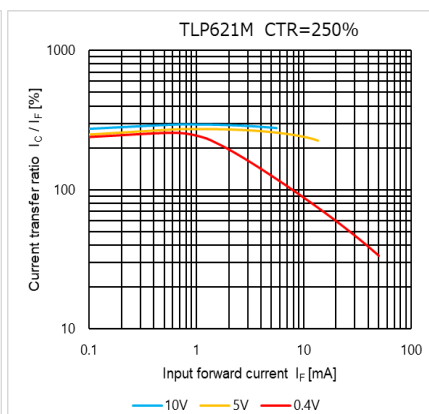


**Figure 4.286 $I_C - I_F$
(CTR=250%)**

Current transfer ratio (I_C / I_F) – Input forward current (I_F)



**Figure 4.287 $I_C / I_F - I_F$
(CTR=152%)**



**Figure 4.288 $I_C / I_F - I_F$
(CTR=250%)**

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5\text{ V}$

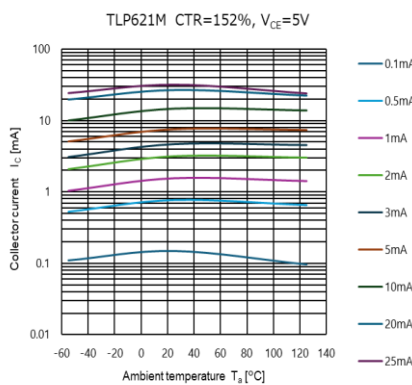


Figure 4.289 $I_C - T_a$
(CTR=152%)

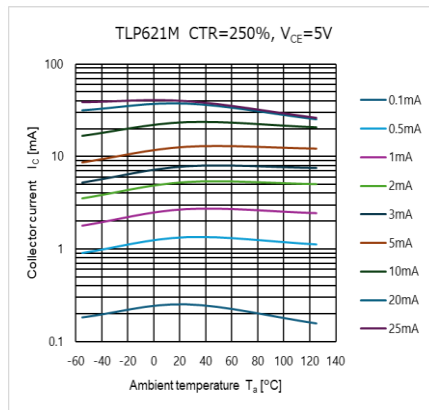


Figure 4.290 $I_C - T_a$
(CTR=250%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4\text{ V}$

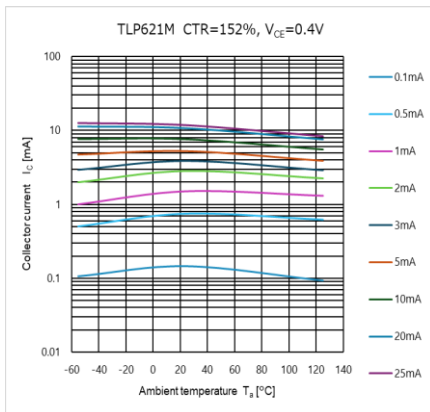


Figure 4.291 $I_C - T_a$
(CTR=152%)

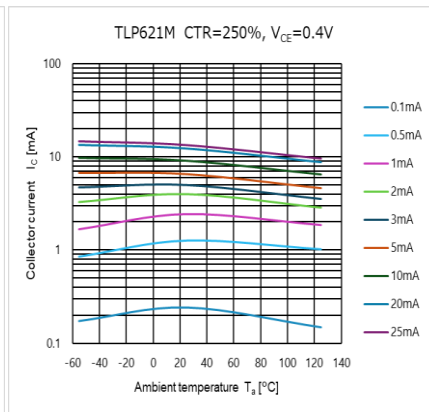
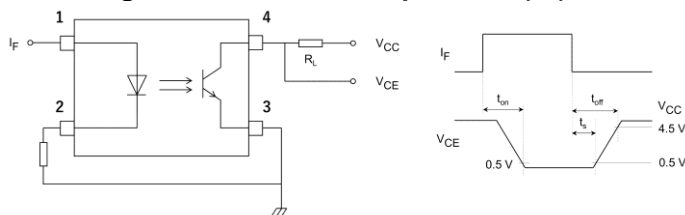


Figure 4.292 $I_C - T_a$
(CTR=250%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP621M

$R_L=1.9k\Omega$ low input, $I_F=5mA$

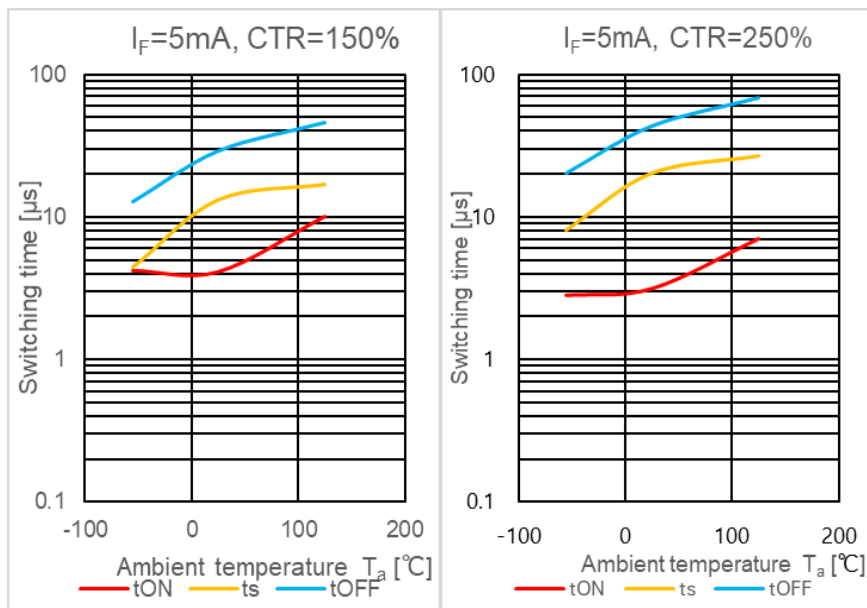


Figure 4.293 Switching time - T_a (CTR=150%) Figure 4.294 Switching time - T_a (CTR=250%)

$R_L=1.9k\Omega$ low input, $I_F=16mA$

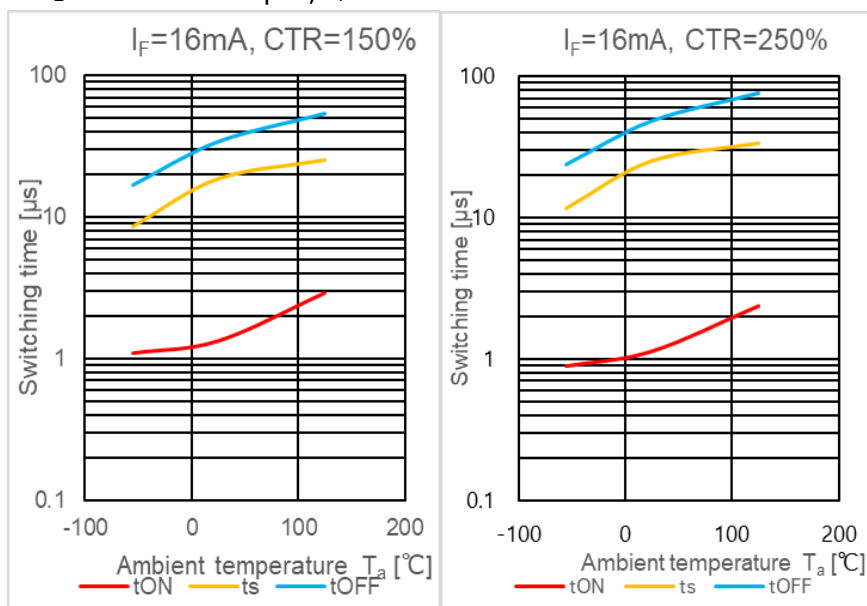


Figure 4.295 Switching time - T_a (CTR=150%) Figure 4.296 Switching time - T_a (CTR=250%)

$R_L=10k\Omega$ low input, $I_F=1mA$

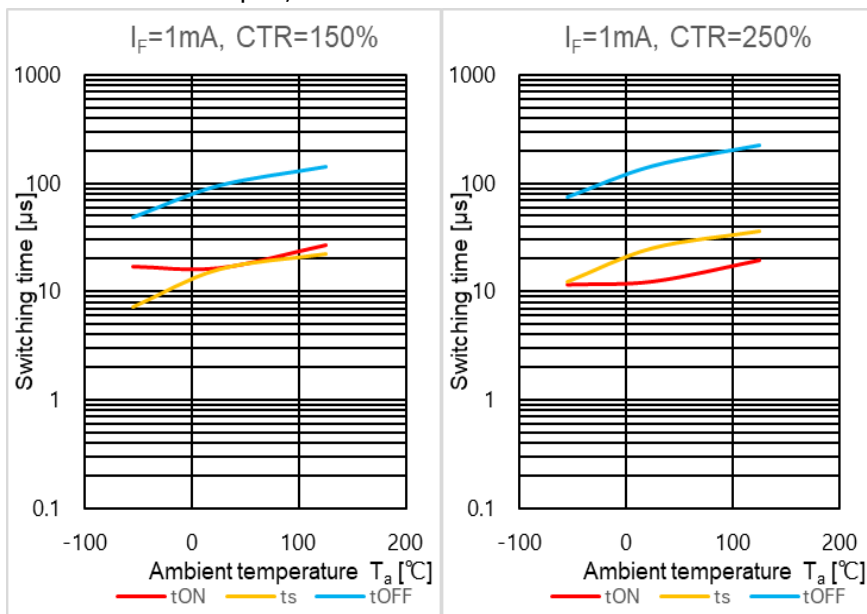


Figure 4.297 Switching time - T_a (CTR=150%) **Figure 4.298 Switching time - T_a (CTR=250%)**

$R_L=10k\Omega$ low input, $I_F=5mA$

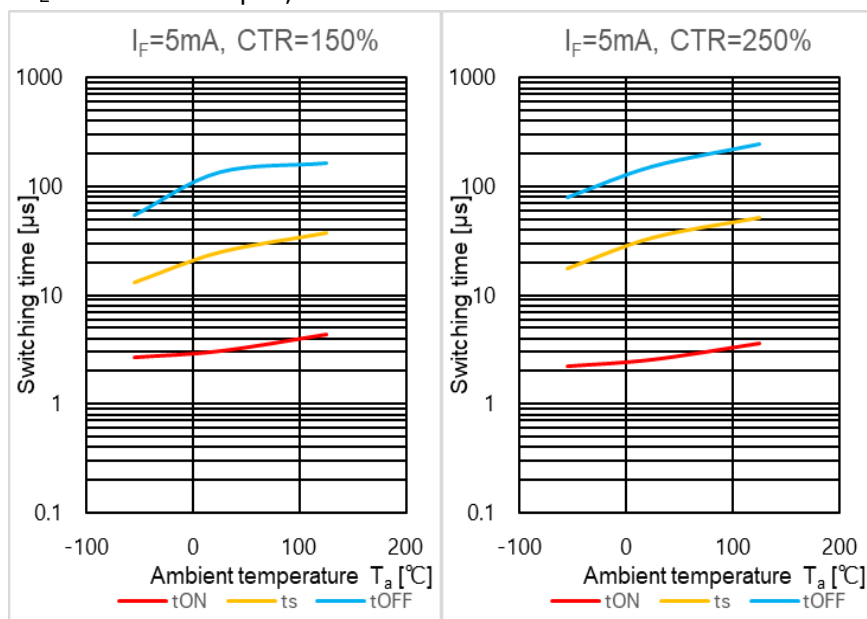


Figure 4.299 Switching time - T_a (CTR=150%) **Figure 4.300 Switching time - T_a (CTR=250%)**

$R_L=10k\Omega$ low input, $I_F=16mA$

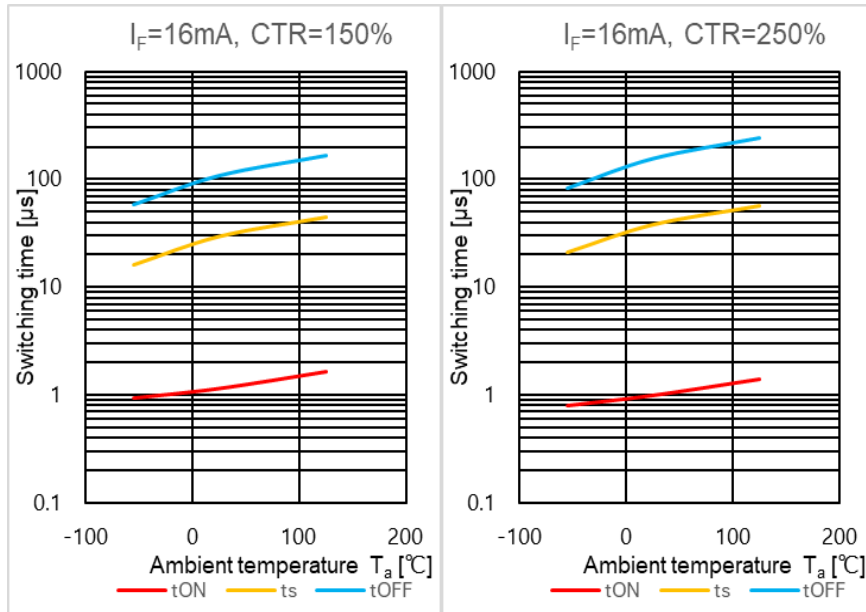


Figure 4.301 Switching time - T_a (CTR=150%) **Figure 4.302 Switching time - T_a (CTR=250%)**

$R_L=20k\Omega$ low input, $I_F=0.5mA$

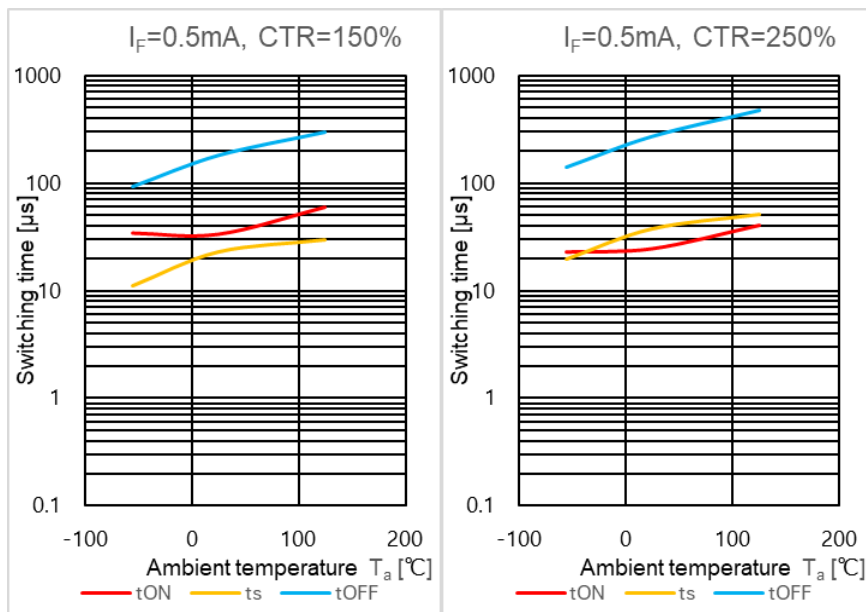


Figure 4.303 Switching time - T_a (CTR=150%) **Figure 4.304 Switching time - T_a (CTR=250%)**

Frequency characteristics (Relative output (G_v), Phase (θ)), $T_a=25^\circ\text{C}$, $V_{cc}=5\text{V}$, $I_C(\text{DC})=2\text{mA}$, $I_C(\text{AC})=1\text{mA}_{\text{p-p}}$

$R_L=1\text{k}\Omega$

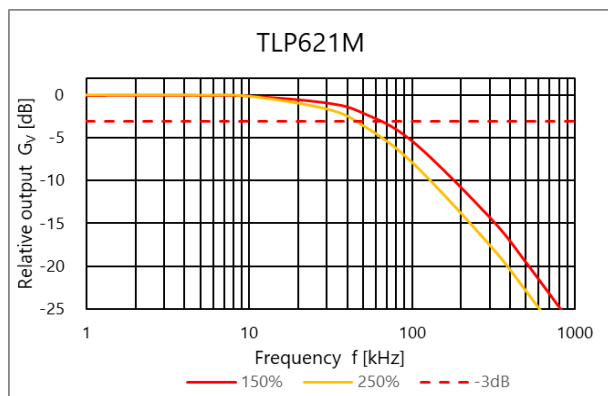


Figure 4.305 Relative output G_v - Frequency

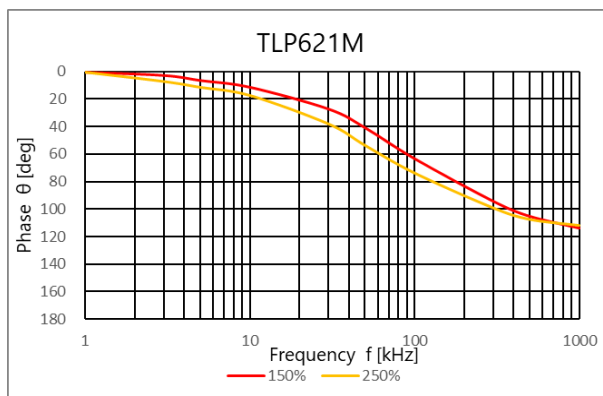


Figure 4.306 Phase θ - Frequency

$R_L=100\Omega$

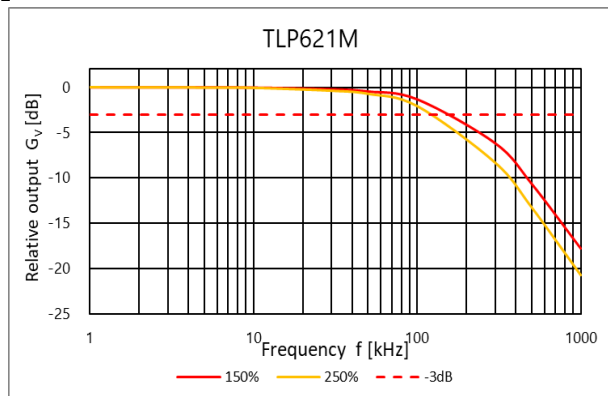


Figure 4.307 Relative output G_v - Frequency

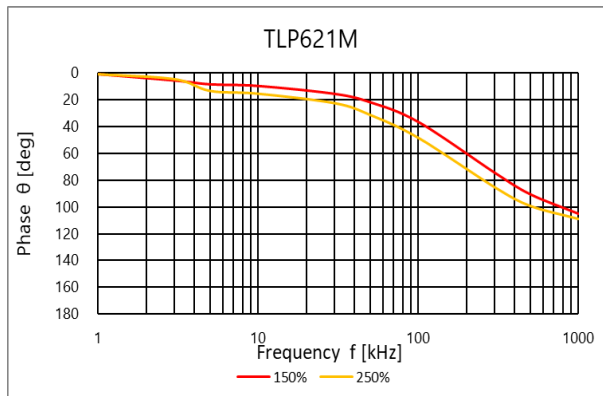


Figure 4.308 Phase θ - Frequency

TLP2301

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 10V]

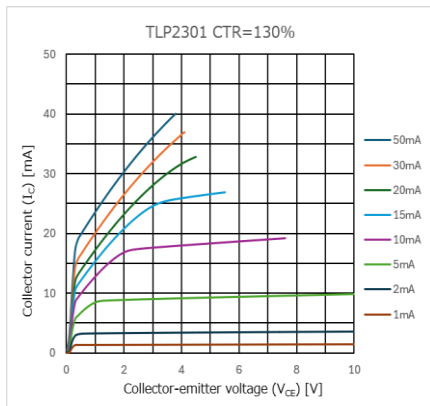


Figure 4.309 $I_C - V_{CE}$
(CTR=130%)

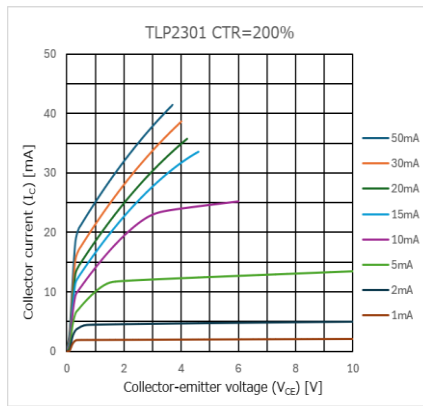


Figure 4.310 $I_C - V_{CE}$
(CTR=200%)

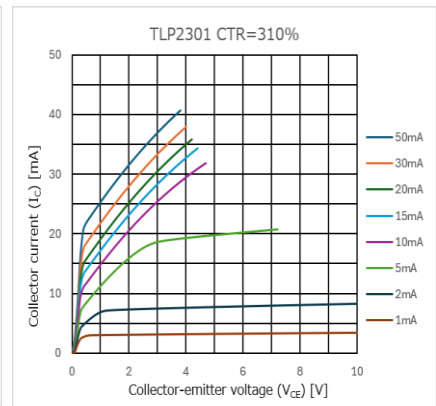


Figure 4.311 $I_C - V_{CE}$
(CTR=310%)

Collector current (I_C) – Collector-emitter voltage (V_{CE}) [up to 1V]

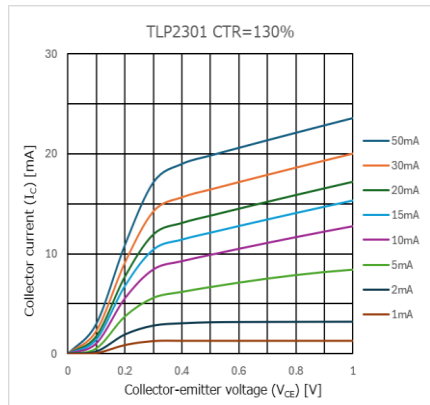


Figure 4.312 $I_C - V_{CE}$
(CTR=130%)

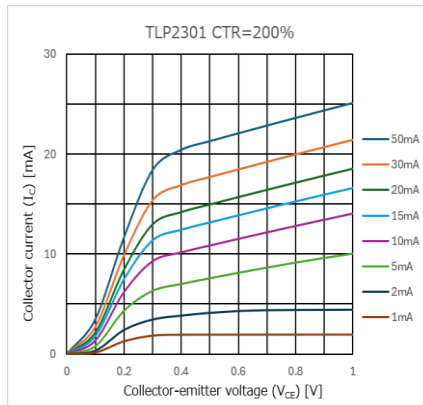


Figure 4.313 $I_C - V_{CE}$
(CTR=200%)

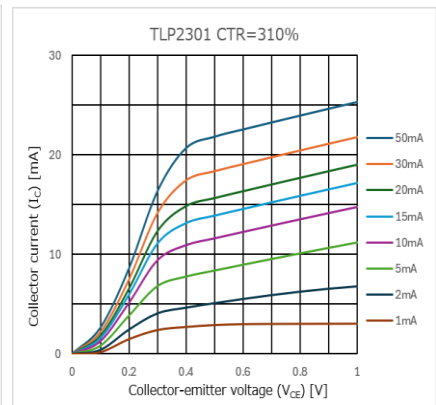


Figure 4.314 $I_C - V_{CE}$
(CTR=310%)

Collector-emitter saturation voltage ($V_{CE(SAT)}$) – Ambient temperature (T_a)

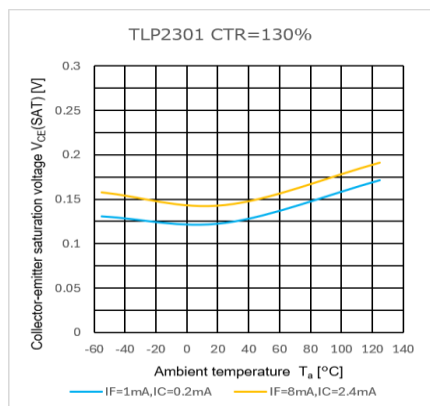


Figure 4.315 $V_{CE} - T_a$
(CTR=130%)

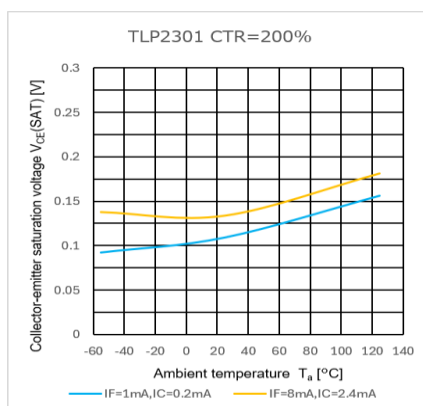


Figure 4.316 $V_{CE} - T_a$
(CTR=200%)

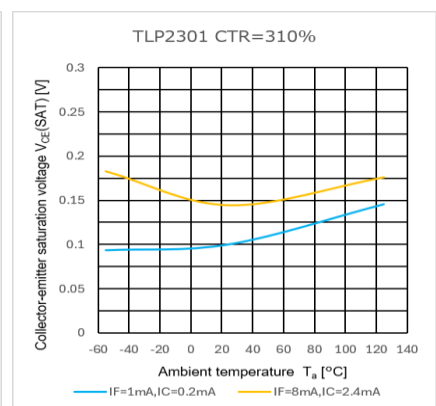


Figure 4.317 $V_{CE} - T_a$
(CTR=310%)

Collector current (I_C) – Input forward current (I_F)

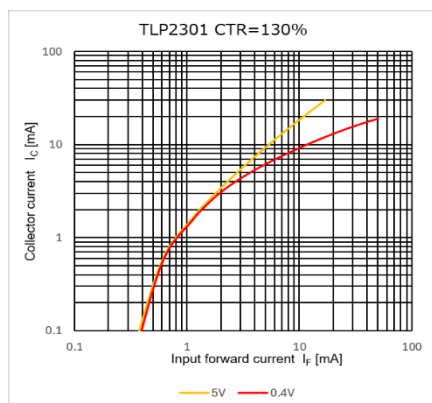


Figure 4.318 $I_C - I_F$
(CTR=130%)

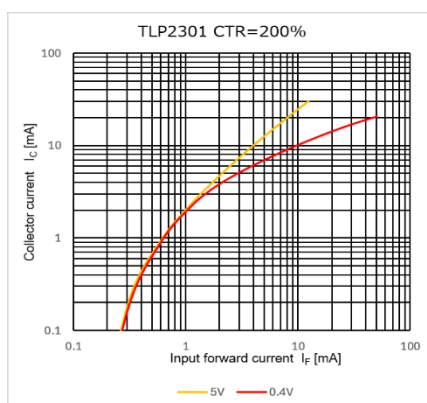


Figure 4.319 $I_C - I_F$
(CTR=200%)

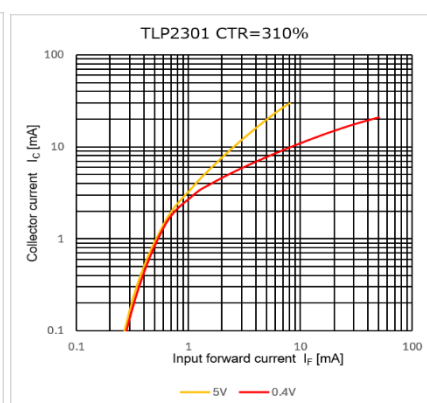


Figure 4.320 $I_C - I_F$
(CTR=310%)

Current transfer ratio (I_C / I_F) – Input forward current (I_F)

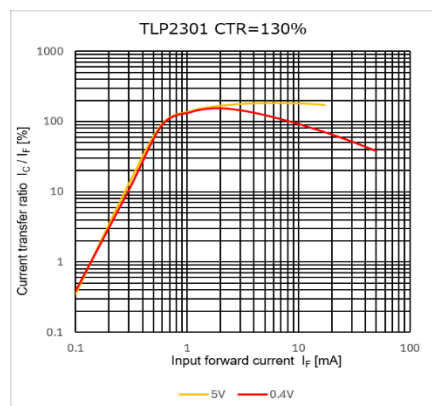


Figure 4.321 $I_C/I_F - I_F$
(CTR=130%)

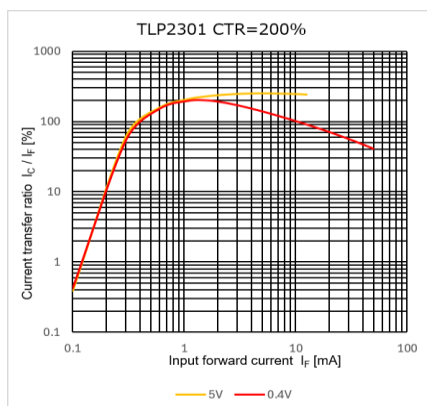


Figure 4.322 $I_C/I_F - I_F$
(CTR=200%)

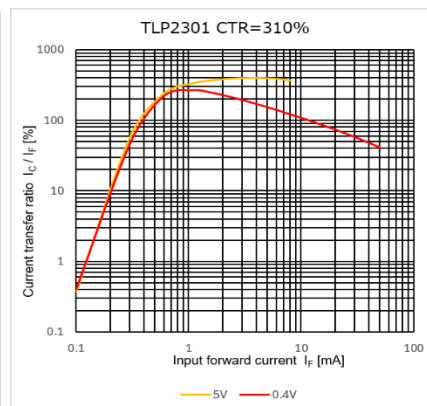


Figure 4.323 $I_C/I_F - I_F$
(CTR=310%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 5V$

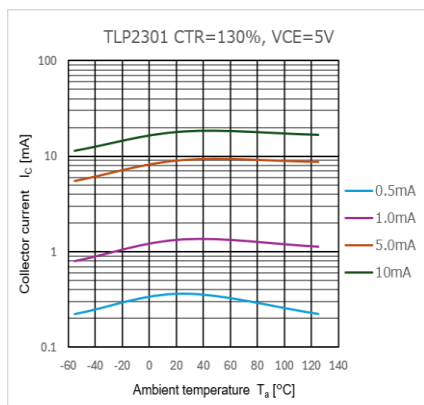


Figure 4.324 $I_C - T_a$
(CTR=130%)

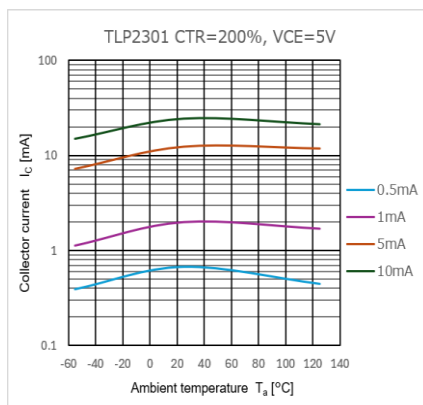


Figure 4.325 $I_C - T_a$
(CTR=200%)

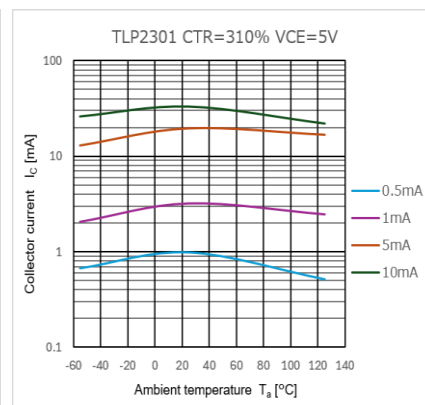


Figure 4.326 $I_C - T_a$
(CTR=310%)

Collector current (I_C) – Ambient temperature (T_a), $V_{CE} = 0.4V$

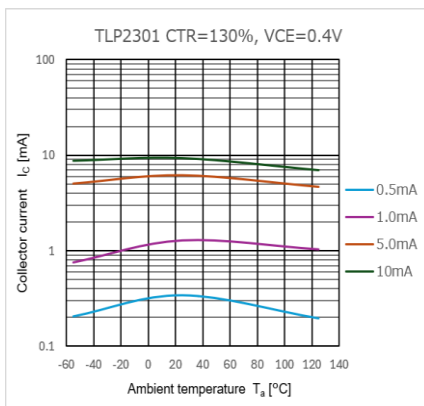


Figure 4.327 $I_C - T_a$
(CTR=130%)

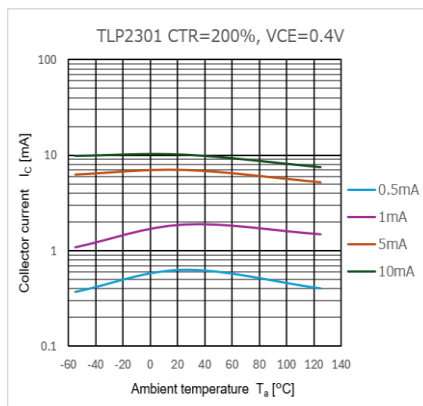


Figure 4.328 $I_C - T_a$
(CTR=200%)

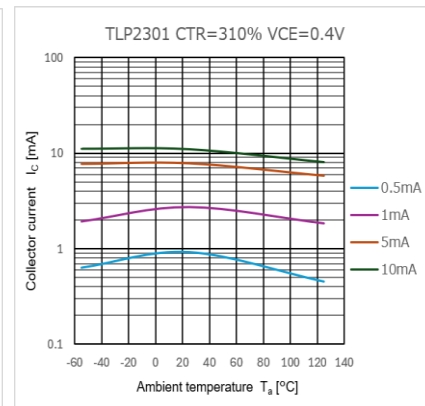
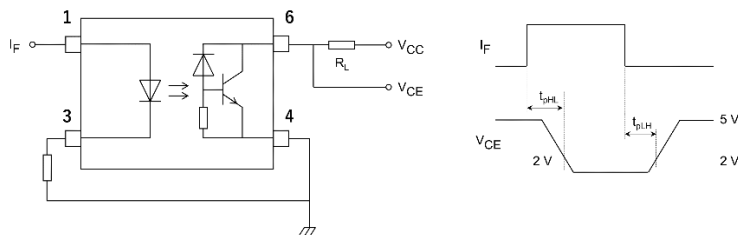


Figure 4.329 $I_C - T_a$
(CTR=310%)

Switching time – Ambient temperature (T_a), $V_{CC}=5V$



TLP2301

$R_L=1.9k\Omega$ low input, $I_F=2mA$

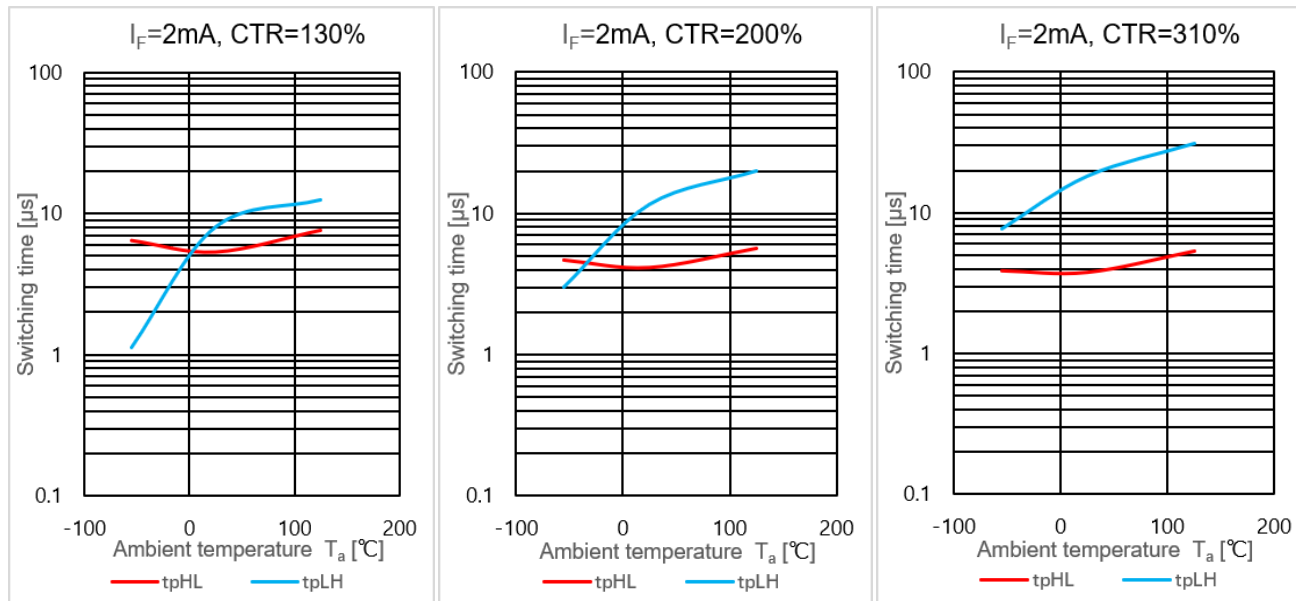


Figure 4.330 Switching time - T_a Figure 4.331 Switching time - T_a Figure 4.332 Switching time - T_a
(CTR=130%) (CTR=200%) (CTR=310%)

$R_L=1.9k\Omega$ low input, $I_F=5mA$

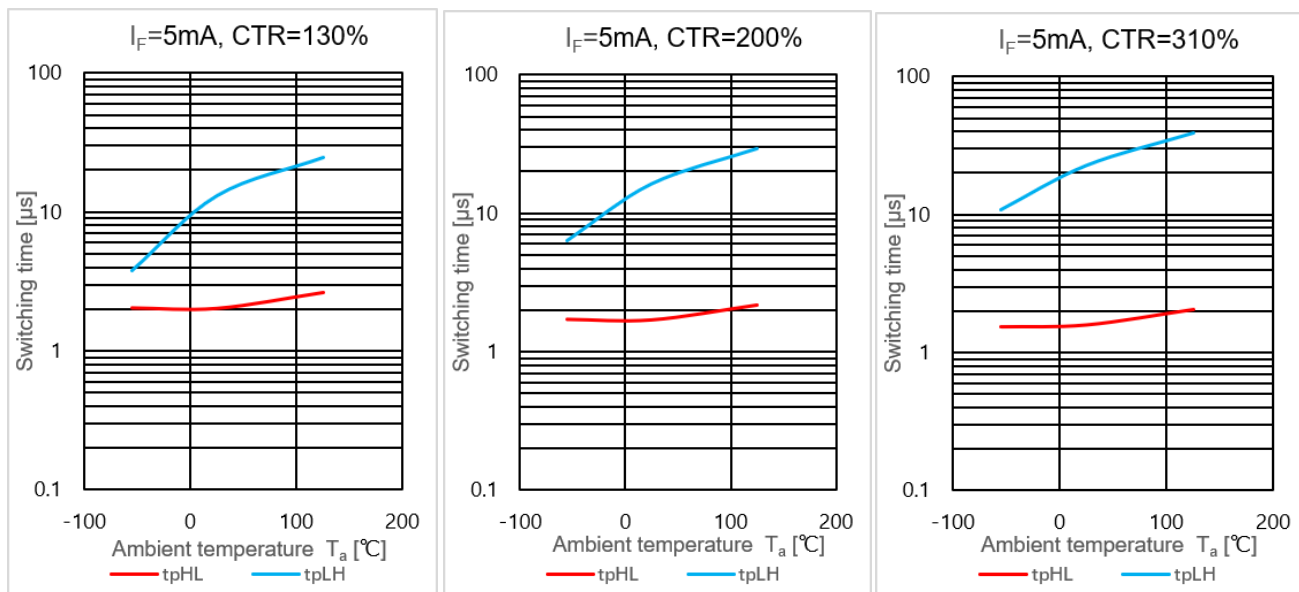


Figure 4.333 Switching time - T_a Figure 4.334 Switching time - T_a Figure 4.335 Switching time - T_a
(CTR=130%) (CTR=200%) (CTR=310%)

$R_L=1.9k\Omega$ low input, $I_F=16mA$

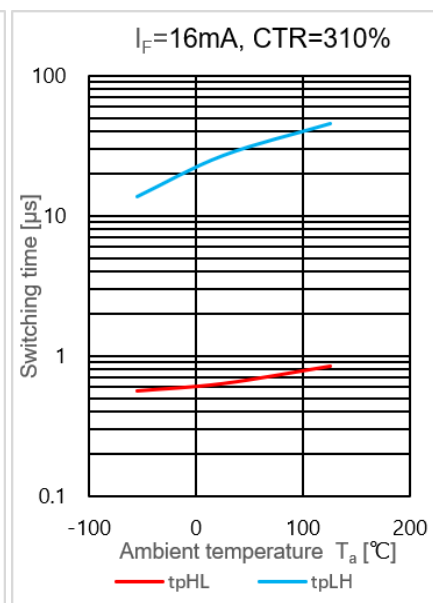
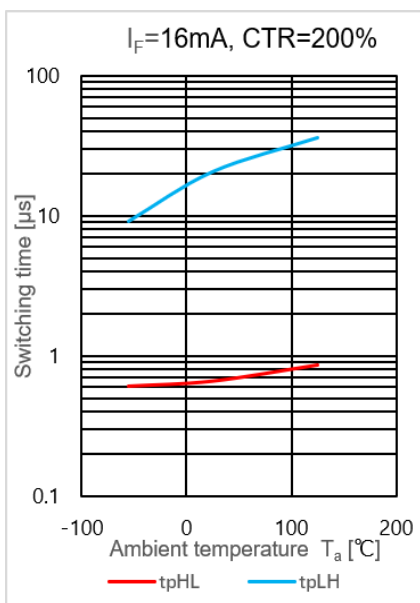
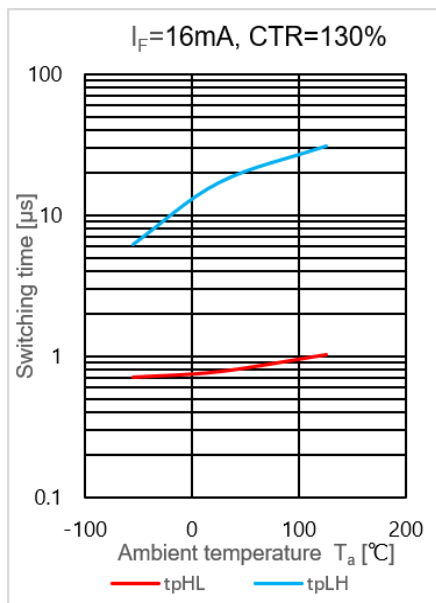


Figure 4.336 Switching time - T_a (CTR=130%)

Figure 4.337 Switching time - T_a (CTR=200%)

Figure 4.338 Switching time - T_a (CTR=310%)

$R_L=10k\Omega$ low input, $I_F=1mA$

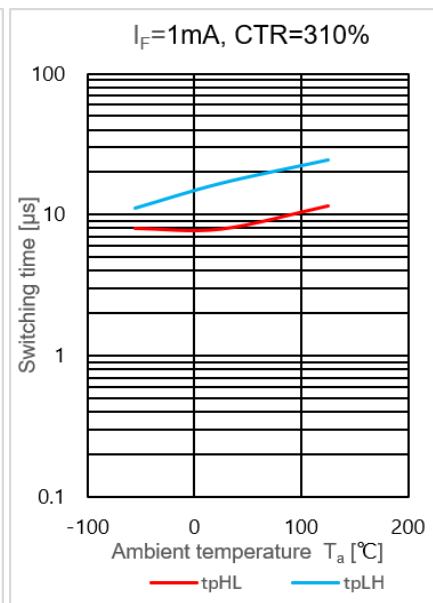
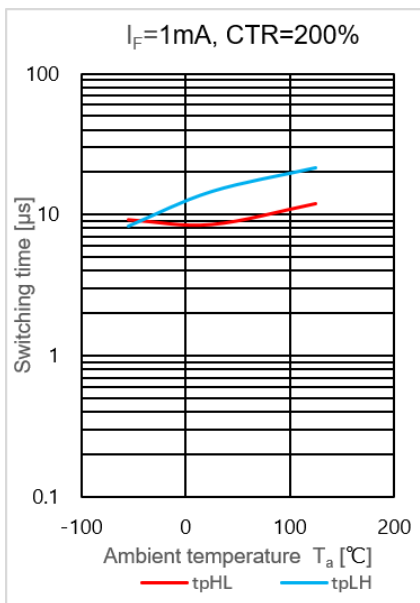
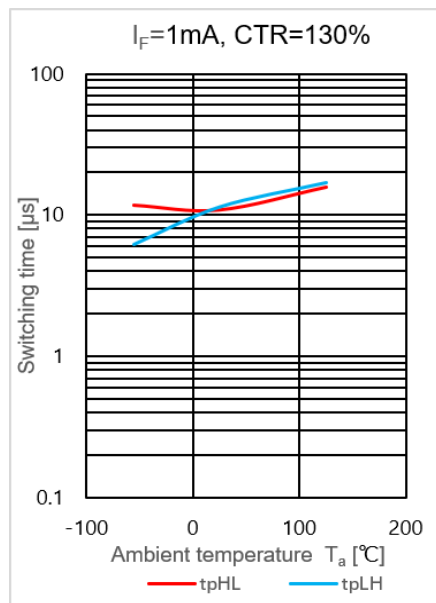


Figure 4.339 Switching time - T_a (CTR=130%)

Figure 4.340 Switching time - T_a (CTR=200%)

Figure 4.341 Switching time - T_a (CTR=310%)

$R_L=10k\Omega$ low input, $I_F=5mA$

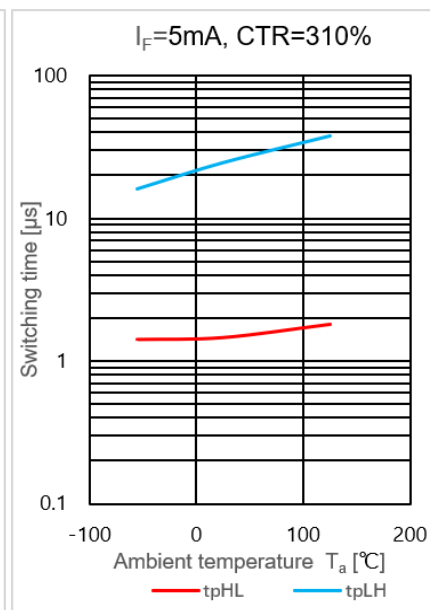
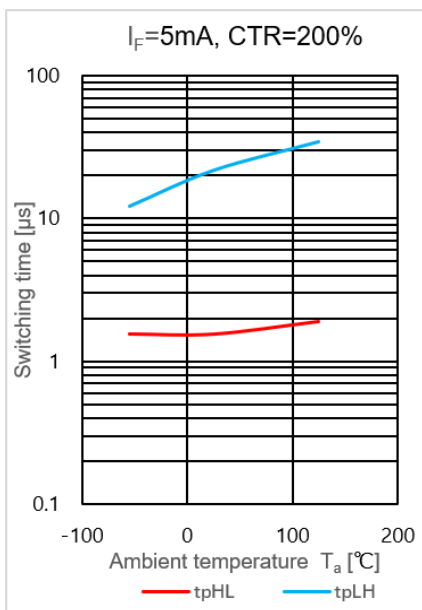
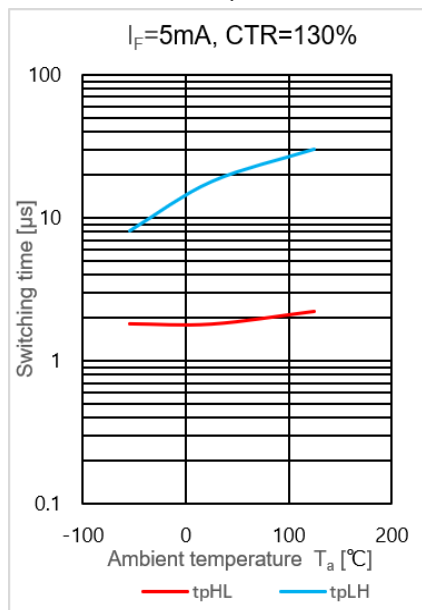


Figure 4.342 Switching time - T_a (CTR=130%)

Figure 4.343 Switching time - T_a (CTR=200%)

Figure 4.344 Switching time - T_a (CTR=310%)

$R_L=10k\Omega$ low input, $I_F=16mA$

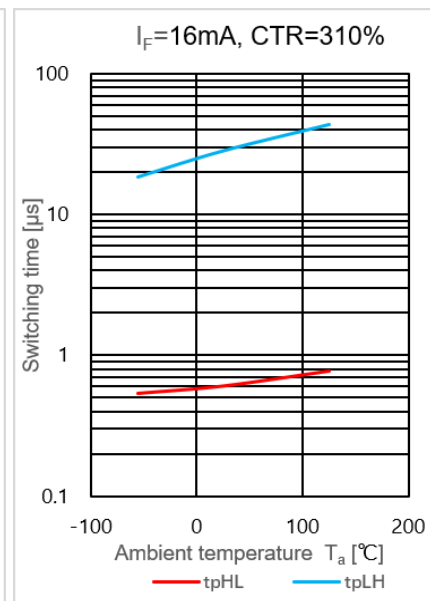
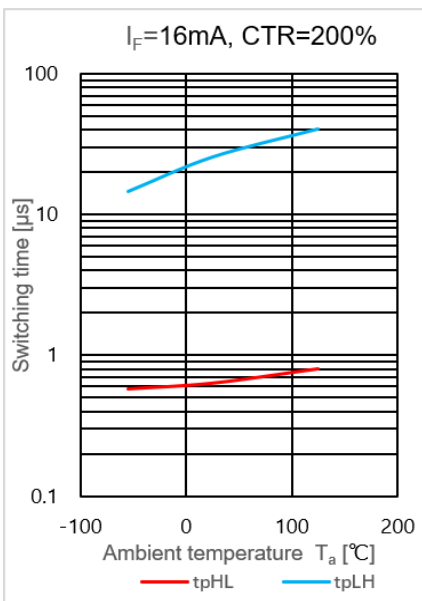
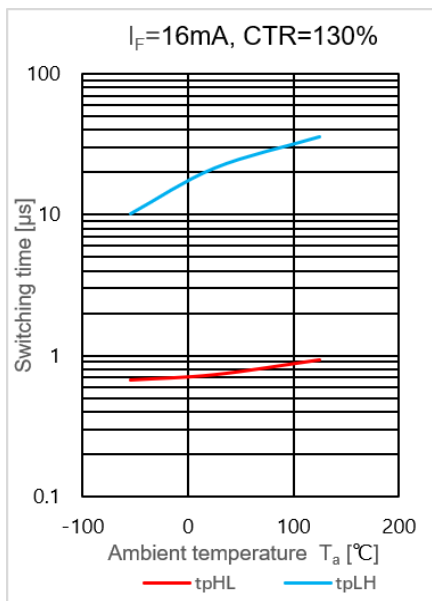


Figure 4.345 Switching time - T_a (CTR=130%)

Figure 4.346 Switching time - T_a (CTR=200%)

Figure 4.347 Switching time - T_a (CTR=310%)

Frequency characteristics (Relative output (G_v), Phase (θ)), $T_a=25^\circ\text{C}$, $V_{cc}=5\text{V}$, $I_C(\text{DC})=2\text{mA}$, $I_C(\text{AC})=1\text{mA}_{\text{p-p}}$

$R_L=1\text{k}\Omega$

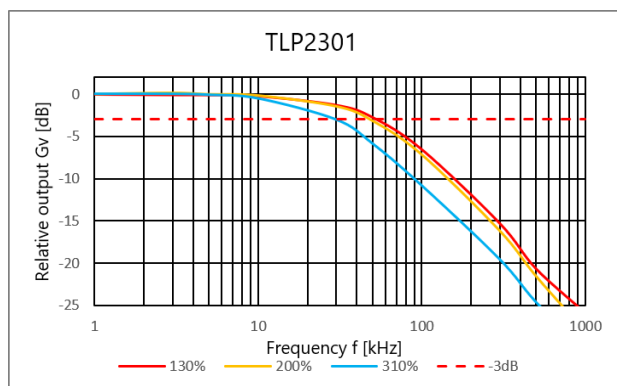


Figure 4.348 Relative output G_v - Frequency

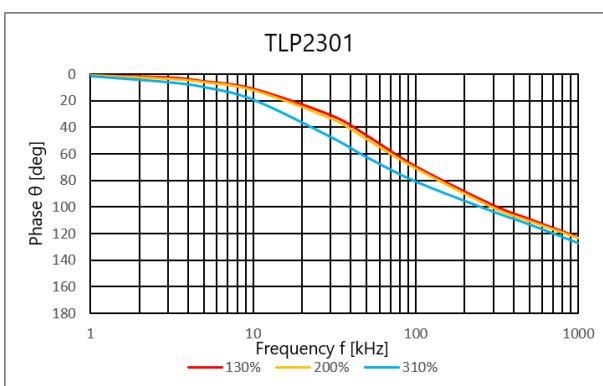


Figure 4.349 Phase θ - Frequency

$R_L=100\Omega$

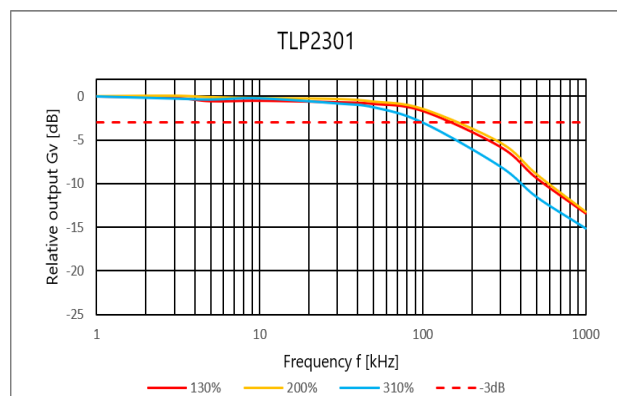


Figure 4.350 Relative output G_v - Frequency

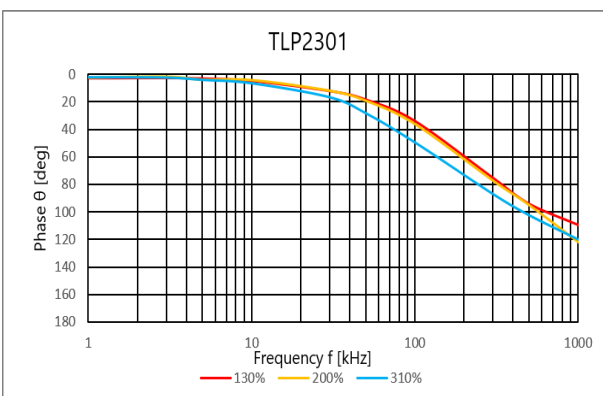


Figure 4.351 Phase θ - Frequency

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