

Comparator Series

# Input Common-mode Voltage Range for Open-Collector Comparator

This application note explains the behavior of an open-collector comparator when the input voltage applied to the comparator is outside the Input Common-mode Voltage Range.

Applicable part numbers

LM2901xx/LM2903xxx/LM339xx /LM393xxx

BA2901xx/BA2903xxx/BA8391G

LM2901DT, PT/LM2903DT, PT, ST, WDT, WPT /LM339DT, PT /LM393DT, PT, ST, WDT, WPT

## Determination of Input Common-mode Voltage Range

The Input Common-mode Voltage Range generally indicates the range of input voltage within which an IC operates normally. When the input voltage is outside the Input Common-mode Voltage Range, the offset voltage is rapidly increased beyond the normal operation region.

### • VCC side of Input Common-mode Voltage Range

First, consider the VCC side of the input voltage range. In the equivalent circuit shown in Figure 1, the transistors Q1, Q2, and Q5 are located between the +IN input and the VCC. It is necessary to secure a voltage at which these transistors can normally operate.

$$V_{+IN} + V_{be1} + V_{be2} + V_{sat5} = V_{CC}$$

Suppose that the voltage between the base emitters of the transistor is  $V_{be1}(Q1) = V_{be2}(Q2) = V_{be}$ , and the saturation voltage is  $V_{sat}$ . Then, the operating condition is described as follows.

$$V_{+IN} < V_{CC} - 2V_{be} - V_{sat}$$

### • VEE (ground) side of Input Common-mode Voltage Range

Similarly, when the pathways on the VEE side are considered, the following equation is obtained.

$$V_{-IN} + V_{be4} + V_{be3} - V_{sat3} - V_{be6} = V_{EE}$$

If  $V_{be3} = V_{be4} = V_{be6} = V_{be}$  and  $V_{sat3} = V_{sat}$ , the operating condition is described as follows.

$$V_{-IN} > V_{EE} - V_{be} + V_{sat}$$

### • Input Common-mode Voltage Range $V_{icm}$

Therefore, the Input Common-mode Voltage Range is described as follows.

$$V_{EE} - V_{be} + V_{sat} < V_{icm} < V_{CC} - 2V_{be} - V_{sat}$$

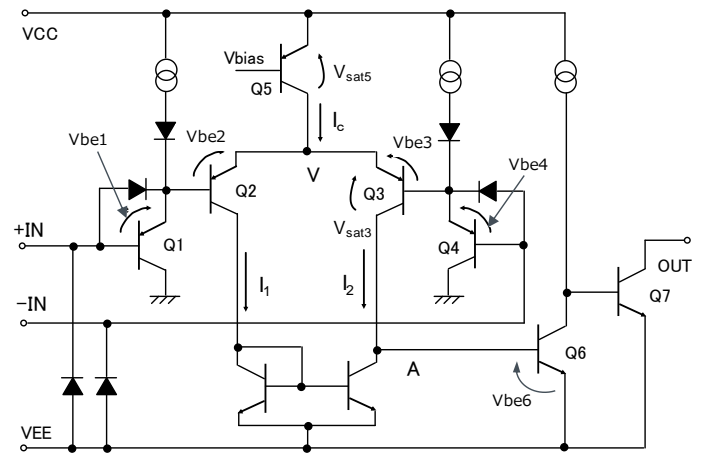


Figure 1. Equivalent circuit diagram of open-collector comparator

Example: When  $V_{be} = 0.55\text{ V}$  and  $V_{sat} = 0.3\text{ V}$ , the above calculation gives the Input Common-mode Voltage Range:

$$VEE - 0.25\text{ V} < V_{icm} < VCC - 1.4\text{ V}.$$

### Operation outside the Input Common-mode Voltage Range, case 1 (the voltage is outside the Input Common-mode Voltage Range only on the +IN terminal)

In this section, we consider an operation when the voltage is outside the Input Common-mode Voltage Range only on one of the input terminals.

We consider the case where the -IN terminal is used as a reference terminal and the input is applied to the +IN terminal.

- -IN terminal (reference voltage): Within the Input Common-mode Voltage Range
- +IN terminal: Within the Input Common-mode Voltage Range  
→ transition to outside the Input Common-mode Voltage Range
- Maximum value of the Input Common-mode Voltage Range:  
 $VCC - 2V_{be} - V_{sat}$

(1) Maximum value of the input voltage range  $> V_{ref}(-IN) > V_{in}(+IN)$

A current flows into the Q2 side. The potential at point A is reduced to Low.

Since the supply of base current to Q6 is cut off, Q6 is turned OFF. As Q6 is turned OFF, a base current is supplied to Q7 and turns ON Q7. The output changes to Low.

(2) Maximum value of the input voltage range  $> V_{in}(+IN) > V_{ref}(-IN)$

A current flows to the Q3 side. The base current is supplied to Q6 and turns ON Q6.

As a result, Q7 is turned OFF and the output of the comparator changes to High.

(3)  $V_{in}(+IN) >$  maximum value of the input voltage range  $> V_{ref}(-IN)$

Since the voltage on the +IN terminal is outside the Input Common-mode Voltage Range, Q1 and Q2 are turned OFF.

A current flows to the Q3 side and Q6 is turned ON. As a result, Q7 is turned OFF and the output of comparator changes to High.

Consequently, although the voltage is outside the Input Common-mode Voltage Range, the operation logic is the same as for the normal operation.

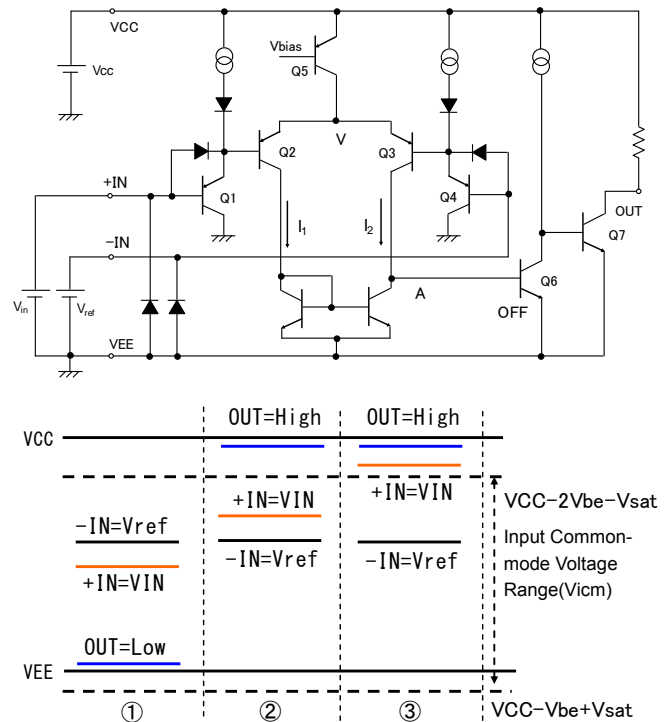


Figure 2. When the voltage on the -IN terminal is taken as the reference voltage ( $V_{ref}$ )

# Input Common-mode Voltage Range for Open-Collector Comparator

## Operation outside the Input Common-mode Voltage Range, case 2 (the voltage is outside the Input Common-mode Voltage Range only on the -IN terminal)

Next, we consider the case where the +IN terminal is used as a reference terminal and the input is applied to the -IN terminal.

- +IN terminal (reference voltage): Within the Input Common-mode Voltage Range
- -IN terminal: Within the Input Common-mode Voltage Range  
→ transition to outside the Input Common-mode Voltage Range
- Maximum value of the input range:  $V_{CC} - 2V_{be} - V_{sat}$

- (1) Maximum value of the input voltage range  $> V_{ref}(+IN) > V_{in}(-IN)$   
A current flows to the Q3 side. The base current is supplied to Q6 and turns ON Q6. As Q6 is turned ON, the supply of base current to Q7 is cut off. Q7 is turned OFF and the output changes to High.
- (2) Maximum value of the input voltage range  $> V_{in}(-IN) > V_{ref}(+IN)$   
A current flows to the Q2 side. The base current to Q6 is cut off and Q6 is turned OFF. As a result, Q7 is turned ON and the output of comparator changes to Low.

- (3)  $V_{in}(-IN) > \text{maximum value of the input voltage range} > V_{ref}(+IN)$   
Since the voltage on the -IN terminal is outside the Input Common-mode Voltage Range, Q3 and Q4 are turned OFF.  
A current flows to the Q2 side and Q6 is turned OFF. As a result, Q7 is turned ON and the output of comparator becomes Low.  
Consequently, although the voltage is outside the Input Common-mode Voltage Range, the operation logic is the same as for the normal operation.

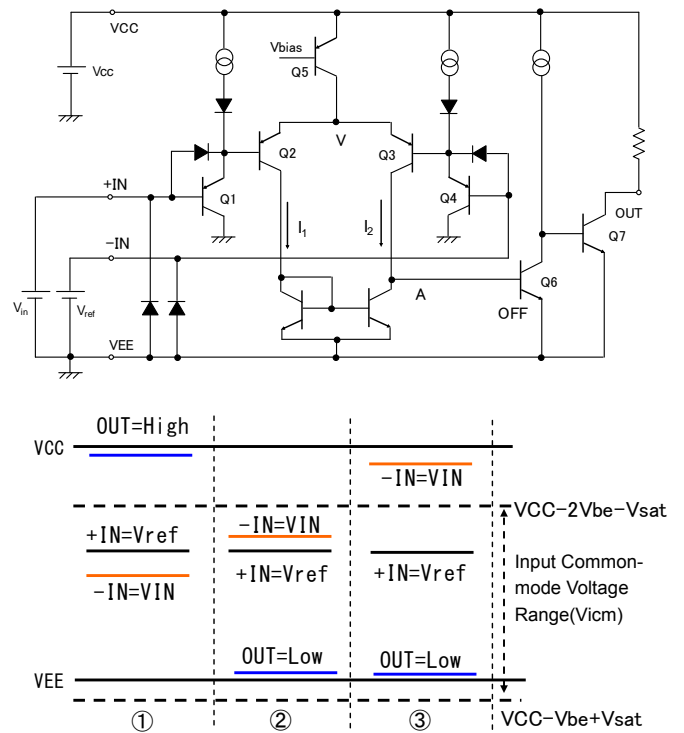


Figure 3. When the voltage on the +IN terminal is taken as the reference voltage (Vref)

### Operation outside the Input Common-mode Voltage Range, case 3 (the voltages are outside the Input Common-mode Voltage Range on both the -IN/+IN terminals)

We consider the case where the voltages on both the terminals are outside the Input Common-mode Voltage Range. The -IN terminal is taken as a reference terminal.

We consider the case where the input is applied to the +IN terminal.

- -IN terminal: Within the Input Common-mode Voltage Range  
→ outside the Input Common-mode Voltage Range
- +IN terminal: Within the Input Common-mode Voltage Range  
→ outside the Input Common-mode Voltage Range
- Maximum value of the input range:  $V_{CC} - 2V_{be} - V_{sat}$

(1) Maximum value of the input range  $> V_{ref}(-IN) > V_{in}(+IN)$

A current flows to the Q2 side. The supply of base current to Q6 is cut off and Q6 is turned OFF. As Q6 is turned OFF, a current is supplied to the Q7 base and turns ON Q7. The output becomes Low.

(2)  $V_{in}(+IN) > \text{maximum value of the input range} > V_{ref}(-IN)$

Since the voltage on the +IN terminal is outside the input range, Q1 and Q2 are turned OFF. A current flows to the Q3 side and Q6 is turned ON. As a result, Q7 is turned OFF and the output of comparator changes to High. Although the voltage is outside the Input Common-mode Voltage Range, the operation logic is the same as for the normal operation.

(3)  $V_{in}(+IN), V_{ref}(-IN) > \text{Input Common-mode Voltage Range}$

Since the voltages on both the +IN/-IN terminals are outside the Input Common-mode Voltage Range, Q1, Q2, Q3, and Q4 are turned OFF. The supply of current to Q6 is cut off and Q6 is turned OFF. Q7 is then turned ON and the output becomes Low. Irrespective of the potential difference between the +IN/-IN terminals, the output is Low.

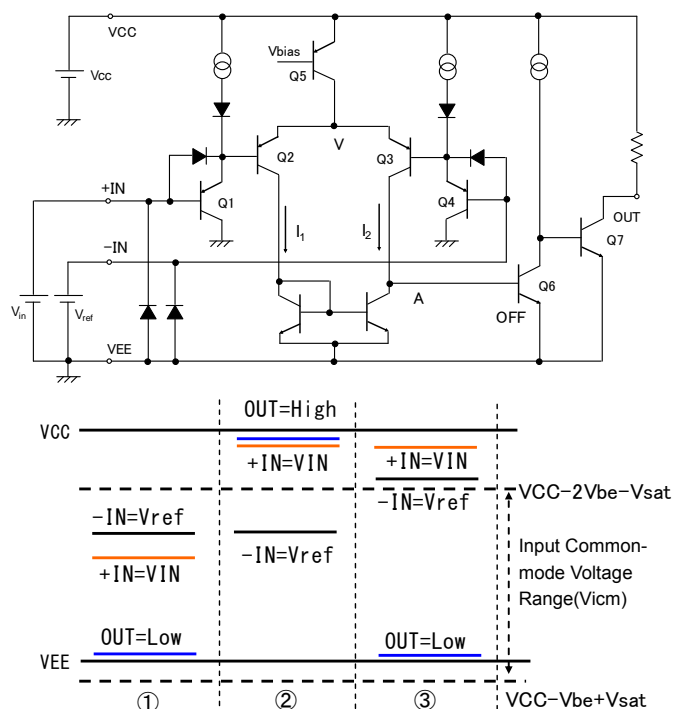


Figure 4. When the voltages on the +IN/-IN terminals are outside the Input Common-mode Voltage Range

### Input voltage outside the Input Common-mode Voltage Range and above the power supply voltage

Since the following products have no protection diode against the power supply, the voltage can be applied within a range between the power supply voltage and the absolute maximum rating as the input outside the Input Common-mode Voltage Range.

LM2901xx/LM2903xxx/LM339xx /LM393xxx

BA2901xx/BA2903xxx/BA8391G

LM2901DT, PT/LM2903DT, PT, ST, WDT, WPT /LM339DT, PT /LM393DT, PT, ST, WDT, WPT

Note:

For BA10393F/BA10339xx

These products have no protection diode against the power supply. Although the input is possible outside the Input Common-mode Voltage Range, the voltage cannot be applied above the power supply voltage due to the limit imposed by the breakdown voltage.

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