# 16-bit Constant Current LED Sink Driver

## General Description

ET6024S is designed for LED displays. ET6024S contains a serial buffer and data latches which convert serial input data into parallel output format. At ET6024S output stage, sixteen regulated current ports are designed to provide uniform and constant current sinks for driving LEDs within a large range of $V_F$ variations.

ET6024S provides users with great flexibility and device performance while using ET6024S in their system design for LED display applications, e.g. LED panels. Users may adjust the output current from 3mA to 45mA through an external resistor, $R_{EXT}$, which gives users flexibility in controlling the light intensity of LEDs. ET6024S guarantees to endure maximum 20V at the output port. The high clock frequency, 25MHz, also satisfies the system requirements of high volume data transmission.

## Features

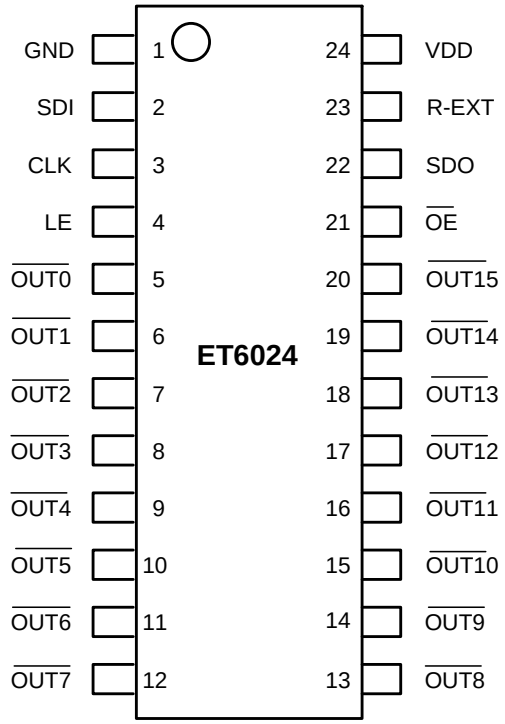
- 16 constant-current output channels
- Constant output current invariant to load voltage change
- Excellent output current accuracy:
- Current accuracy

| Current Accuracy | | Conditions |
|---|---|---|
| Between Channels | Between ICs | |
| <±3% | <±6% | $I_{OUT}$ =3mA～30mA@$V_{DS}$=0.8V,$V_{DD}$=3.3V<br>$I_{OUT}$ =3mA～45mA@$V_{DS}$=0.8V,$V_{DD}$=5.0V |

- Output current adjusted through an external resistor
- Constant output current range: 3～45mA
- Fast response of output current,
- $\overline{OE}$ (min) is 40ns ($V_{DD}$= 3.3V)
- 25MHz clock frequency
- Schmitt trigger input
- Supply voltage：3.3V～5.5V
- Part No. and package:

| Part No. | Package | Size |
|---|---|---|
| ET6024S | SSOP24-3 | 6mm x 13mm |

## Pin Assignments

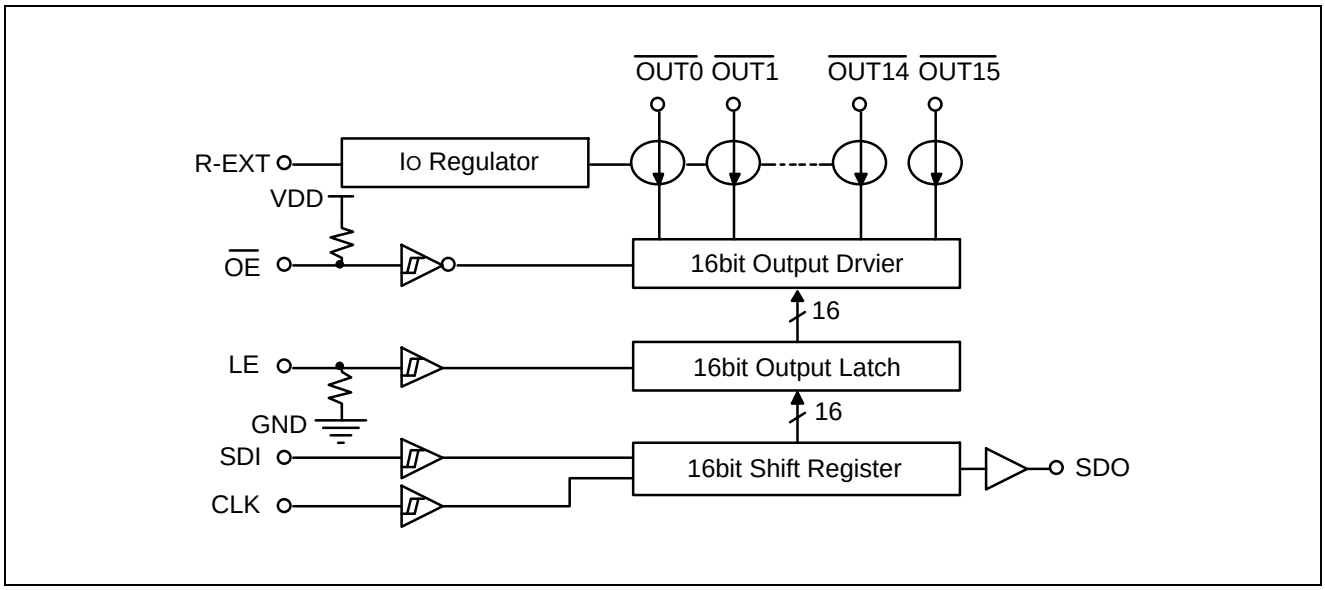



TOP VIEW

## Pin. Function

| No. | Pin Name | Function |
|---|---|---|
| 1 | GND | Ground terminal for control logic and current sink. |
| 2 | SDI | Serial-data input to the shift register. |
| 3 | CLK | Clock input terminal for data shift on rising edge. |
| 4 | LE | Data strobe input terminal.<br>Serial data is transferred to the output latch when LE is high.<br>The data is latched when LE goes low. |
| 5～20 | $\overline{OUT0}$ ～ $\overline{OUT15}$ | Constant current output terminals. |
| 21 | $\overline{OE}$ | Output enable terminal.<br>When $\overline{OE}$ (active) low, the output drivers are enabled;<br>when $\overline{OE}$ high, all output drivers are turned OFF (blanked). |
| 22 | SDO | Serial-data output to the following SDI of next driver IC. |
| 23 | R-EXT | Input terminal used to connect an external resistor for setting up output current for all output channels. |
| 24 | VDD | 5V supply voltage terminal |

## Block Diagram



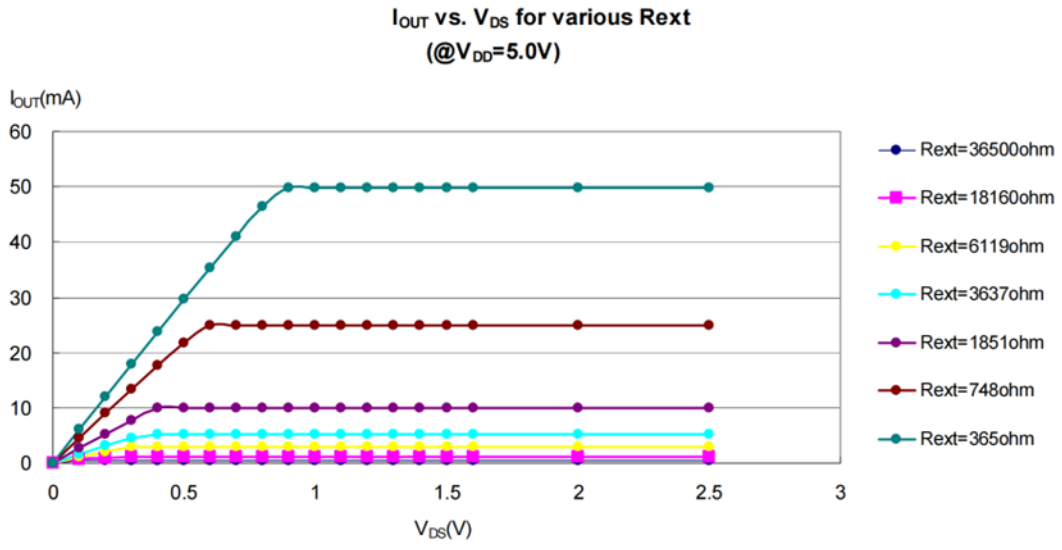

## Functional Description

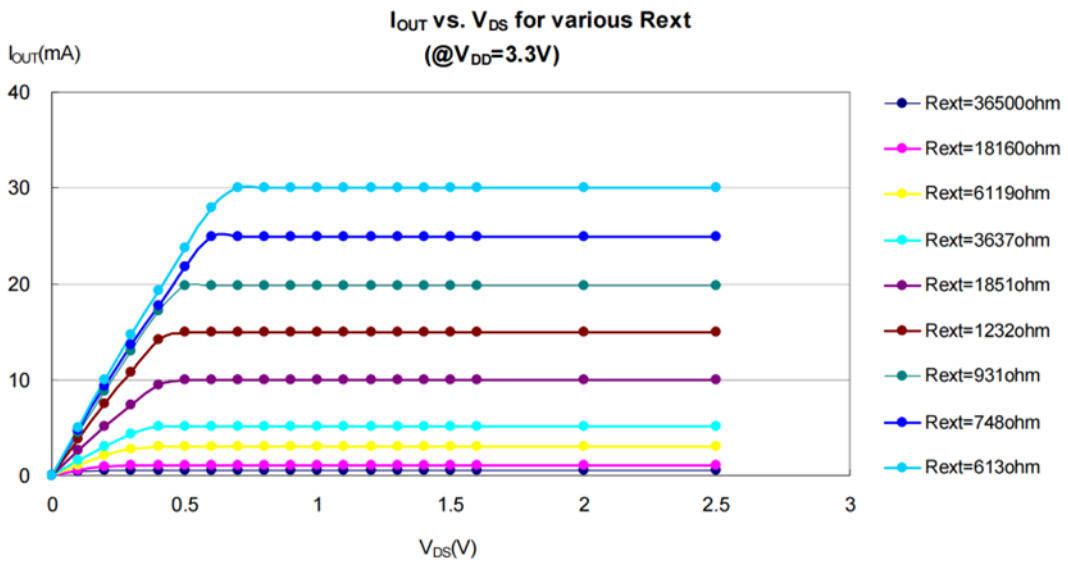
### Constant Current

In LED display application, ET6024S provides nearly no variations in current from channel to channel and from IC to IC. This can be achieved by:

1) The maximum current variation between channels is less than ±3%(typical), and that between ICs is less than ±6%(typical).

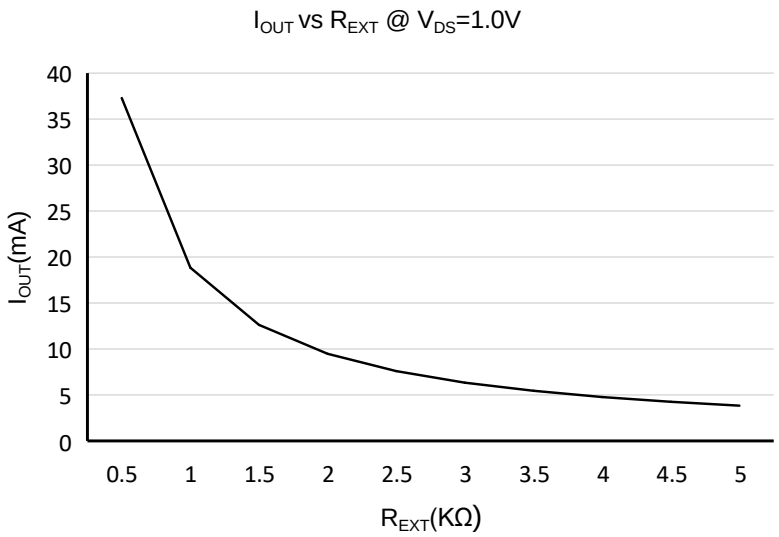
2) In addition, the current characteristic of output stage is flat and users can refer to the figure as shown below. The output current can be kept constant regardless of the variations of LED forward voltages (Vf). This performs as a perfection of load regulation.






**Adjusting Output Current**

The output current of each channel ($I_{OUT}$) is set by an external resistor, $R_{EXT}$. The relationship between Iout and $R_{EXT}$ is shown in the following figure.




Resistance of the external resistor, $R_{EXT}$(KΩ)

Also, the output current can be calculated from the equation:

**$V_{R\text{-}EXT}$ = 1.24V； $I_{OUT}$ = ($V_{R\text{-}EXT}$ / $R_{EXT}$ )×15**

Where $R_{EXT}$ is the resistance of the external resistor connected to R-EXT terminal and $V_{R\text{-}EXT}$ is the voltage of R-EXT terminal. The magnitude of current (as a function of $R_{EXT}$) is around 25mA at 744Ω and 10mA at 1860Ω.

### Package Power Dissipation ($P_D$)

The maximum allowable package power dissipation is determined as $P_D$ (max)=($T_J$-$T_A$)/ $R_{\theta(JA)}$.

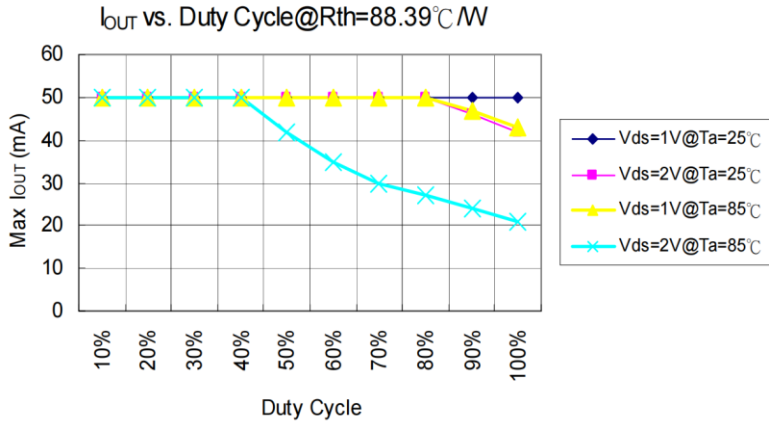
When 16 output channels are turned on simultaneously, the actual package power dissipation is

**$P_D$ (act)=($I_{DD}$×$V_{DD}$)+( $I_{OUT}$×Duty×$V_{DS}$×16).**

Therefore, to keep $P_D$ (act) ≤$P_D$ (max), the allowable maximum output current as a function of duty cycle is:

**$I_{OUT}$ = {[ ($T_J$ – $T_A$) / $R_{\theta(JA)}$ ] – ($I_{DD}$×$V_{DD}$)} / $V_{DS}$ / Duty / 16,**

where $T_J$ = 150°C.

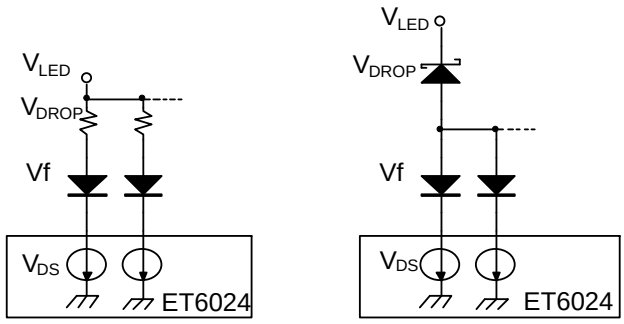



| Condition: $I_{OUT}$= 50mA,16 output Channels | |
|---|---|
| Device Package Type | $R_{\theta(JA)}$ (°C/W) |
| SSOP24-3 | 88 |

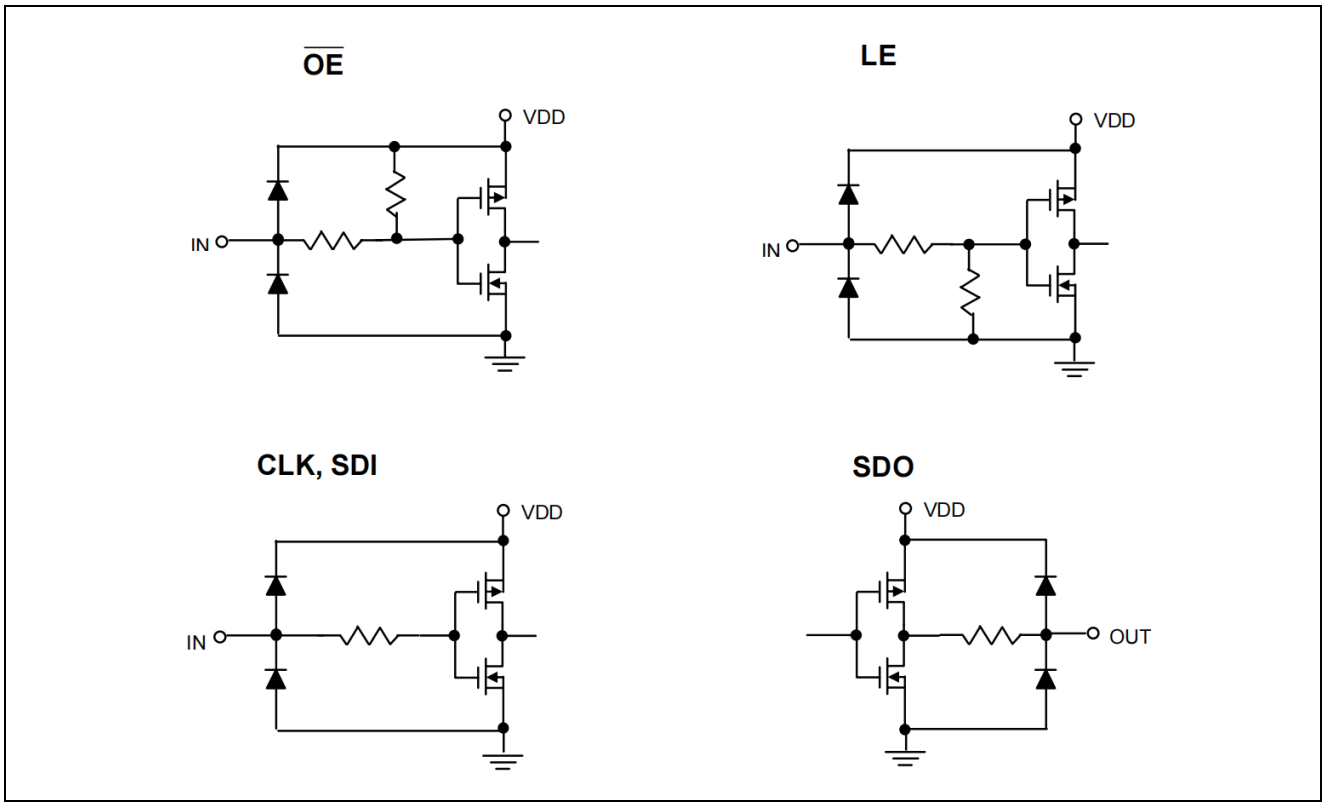
### Load Supply Voltage ($V_{LED}$)

ET6024S are designed to operate with $V_{DS}$ ranging from 0.4V to 1.0V considering the package power dissipating limits. $V_{DS}$ may be higher enough to make $P_D$(act) > $P_D$ (max); when $V_{LED}$= 5V and $V_{DS}$ = $V_{LED}$ – Vf, in which $V_{LED}$ is the load supply voltage. In this case, it is recommended to use the lowest possible supply voltage or to set an external voltage reducer, $V_{DROP}$. A voltage reducer lets $V_{DS}$ = ($V_{LED}$–Vf) – $V_{DROP}$.

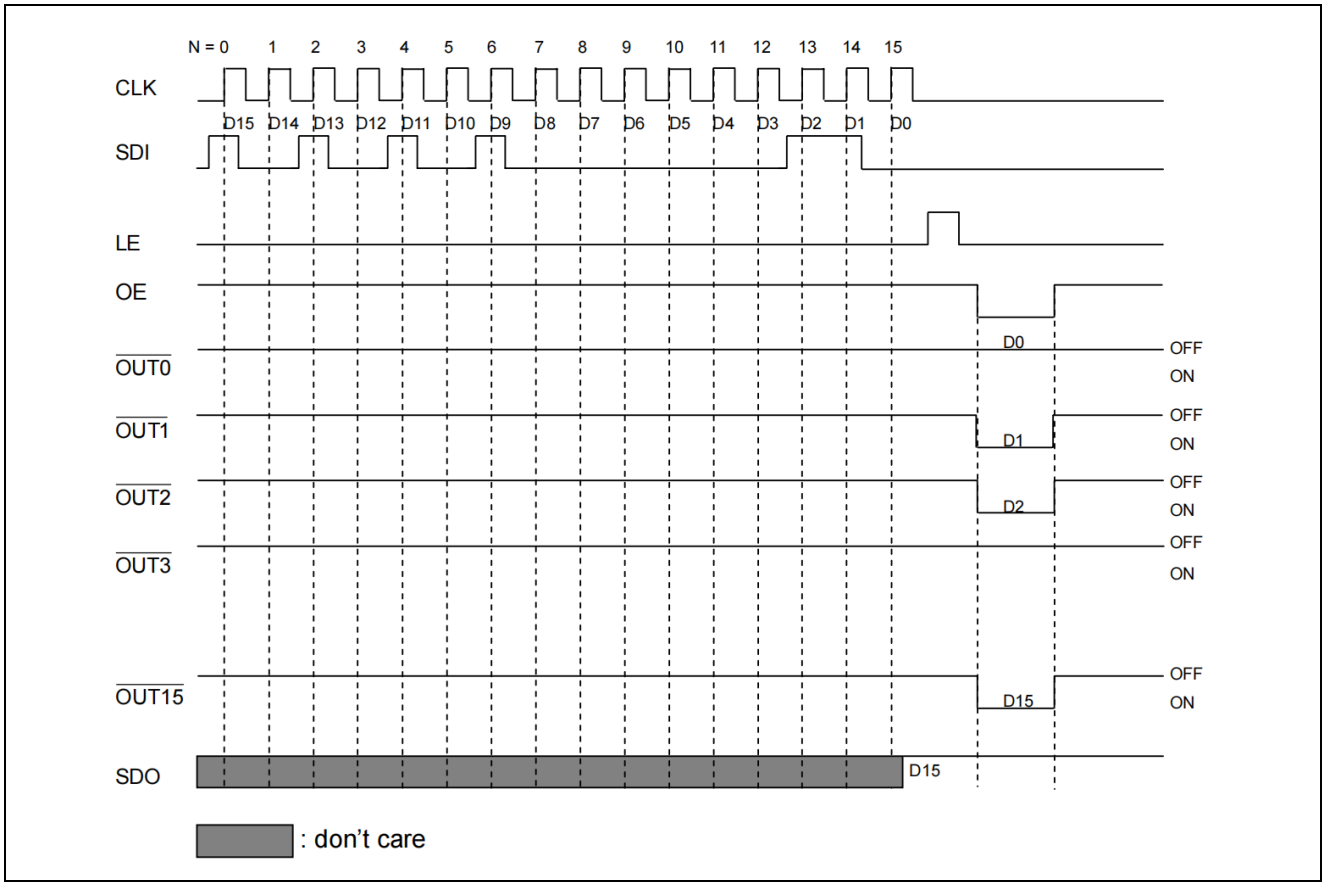
Resistors or Zener diode can be used in the applications as shown in the following figures.



## Equivalent Circuits of Inputs and Outputs




## Timing Diagram



**Truth Table**

| CLK | LE | $\overline{OE}$ | SDI | $\overline{OUT0}$ … $\overline{OUT7}$ … $\overline{OUT15}$ | SDO |
|---|---|---|---|---|---|
| ↑ | H | L | $D_n$ | $\overline{D_n}$ ..... $\overline{D_{n-7}}$ ..... $\overline{D_{n-15}}$ | $D_{n-15}$ |
| ↑ | L | L | $D_{n+1}$ | No Change | $D_{n-14}$ |
| ↑ | H | L | $D_{n+2}$ | $\overline{D_{n+2}}$ ..... $\overline{D_{n-5}}$ ..... $\overline{D_{n-13}}$ | $D_{n-13}$ |
| ↓ | X | L | $D_{n+3}$ | $\overline{D_{n+2}}$ ..... $\overline{D_{n-5}}$ ..... $\overline{D_{n-13}}$ | $D_{n-13}$ |
| ↓ | X | H | $D_{n+3}$ | Off | $D_{n-13}$ |

## Absolute Maximum Ratings

| Characteristic | Symbol | Rating | Unit |
|---|---|---|---|
| Supply Voltage | $V_{DD}$ | 0～7.0 | V |
| Input Voltage | $V_{IN}$ | -0.4～$V_{DD}$ +0.4 | V |
| Output Current | $I_{OUT}$ | +60 | mA |
| Output Voltage | $V_{DS}$ | -0.5～20.0 | V |
| Clock Frequency | $F_{CLK}$ | 25 | MHz |
| GND Terminal Current | $I_{GND}$ | 1000 | mA |
| Power Dissipation | $P_D$ | 1.4 | W |
| Operating Temperature | $T_A$ | -40～+85 | °C |
| Storage Temperature | $T_{STG}$ | -65～+150 | °C |

## Electrical Characteristics ($V_{DD}$=5V, $T_A$=25°C)

| Characteristic | | Symbol | Condition | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|---|
| Supply Voltage | | $V_{DD}$ | - | | 4.5 | 5.0 | 5.5 | V |
| Output Voltage | | $V_{DS}$ | $\overline{OUT0}$ ～ $\overline{OUT15}$ | | - | - | 20.0 | V |
| Output Current | | $I_{OUT}$ | DC Test Circuit | | 3 | - | 45 | mA |
| | | $I_{OH}$ | SDO | | - | - | -1.0 | mA |
| | | $I_{OL}$ | SDO | | - | - | 1.0 | mA |
| Input Voltage | "H" level | $V_{IH}$ | $T_A$=-40～85°C | | 0.7$V_{DD}$ | - | $V_{DD}$ | V |
| | "L" level | $V_{IL}$ | $T_A$=-40～85°C | | GND | - | 0.3$V_{DD}$ | V |
| Output Leakage Current | | $I_{OH}$ | $V_{OH}$ =20.0V | | - | - | 0.5 | μA |
| Output Voltage | SDO | $V_{OL}$ | $I_{OL}$ =+1.0mA | | - | - | 0.4 | V |
| | | $V_{OH}$ | $I_{OH}$ =-1.0mA | | 4.6 | - | - | V |
| Output Current 1 | | $I_{OUT1}$ | $V_{DS}$ =1.0V | $R_{EXT}$ =1240Ω | - | 15 | - | mA |
| Current Skew (between channels) | | $dI_{OUT1}$ | $I_{OL}$=15mA<br>$V_{DS}$ =1.0V | $R_{EXT}$=1240Ω | - | ±1.5 | ±3 | % |
| Output Current 2 | | $I_{OUT2}$ | $V_{DS}$ =1.0V | $R_{EXT}$ =620Ω | - | 30 | - | mA |
| Current Skew | | $dI_{OUT2}$ | $I_{OL}$=30mA | $R_{EXT}$ =620Ω | - | ±1.5 | ±3 | % |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (between channels) | | | $V_{DS}$ =1.0V | | | | | |
| Current Skew (between ICs) | | $dI_{OUT3}$ | $I_{OL}$=30mA $V_{DS}$ =1.0V | $R_{EXT}$ =620Ω | | ±3 | ±6 | % |
| Output Current vs. Output Voltage Regulation | | %/$dV_{DS}$ | $V_{DS}$ within 1.0V to 3.0V | | - | ±0.1 | - | %/V |
| Output Current vs. Supply Voltage Regulation | | %/$dV_{DD}$ | $V_{DD}$ within 4.5V to 5.5V | | - | ±1 | - | %/V |
| Pull-up Resistor | | $R_{IN}$ (up) | $\overline{OE}$ | | 250 | 500 | 800 | KΩ |
| Pull-down Resistor | | $R_{IN}$ (down) | LE | | 250 | 500 | 800 | KΩ |
| Supply Current | "OFF" | $I_{DD}$ (off)1 | $R_{EXT}$ =Unterminal, $\overline{OUT0}$ ～ $\overline{OUT15}$ =Off | | - | 2.5 | 5 | mA |
| | | $I_{DD}$ (off)2 | $R_{EXT}$ =1240Ω, $\overline{OUT0}$ ～ $\overline{OUT15}$ =Off | | - | 4.5 | 7.0 | |
| | | $I_{DD}$ (off)3 | $R_{EXT}$=620Ω, $\overline{OUT0}$ ～ $\overline{OUT15}$ =Off | | - | 6 | 9.0 | |
| | "ON" | $I_{DD}$ (on)1 | $R_{EXT}$ =1240Ω, $\overline{OUT0}$ ～ $\overline{OUT15}$ =On | | - | 5.2 | 8.5 | |
| | | $I_{DD}$ (on)2 | $R_{EXT}$=620Ω, $\overline{OUT0}$ ～ $\overline{OUT15}$ =On | | | 6.5 | 9.5 | |

## Electrical Characteristics ($V_{DD}$=3.3V, $T_A$=25°C)

| Characteristic | | Symbol | Condition | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|---|
| Supply Voltage | | $V_{DD}$ | - | | 3.0 | 3.3 | 4.5 | V |
| Output Voltage | | $V_{DS}$ | $\overline{OUT0}$ ～ $\overline{OUT15}$ | | - | - | 20.0 | V |
| Output Current | | $I_{OUT}$ | DC Test Circuit | | 3 | - | 30 | mA |
| | | $I_{OH}$ | SDO | | - | - | -1.0 | mA |
| | | $I_{OL}$ | SDO | | - | - | 1.0 | mA |
| Input Voltage | "H" level | $V_{IH}$ | $T_A$=-40～85°C | | 0.7$V_{DD}$ | - | $V_{DD}$ | V |
| | "L" level | $V_{IL}$ | $T_A$=-40～85°C | | GND | - | 0.3$V_{DD}$ | V |
| Output Leakage Current | | $I_{OH}$ | $V_{OH}$ =20.0V | | - | - | 0.5 | μA |
| Output Voltage | SDO | $V_{OL}$ | $I_{OL}$ =+1.0mA | | - | - | 0.4 | V |
| | | $V_{OH}$ | $I_{OH}$ =-1.0mA | | 2.9 | - | - | V |
| Output Current 1 | | $I_{OUT1}$ | $V_{DS}$ =1.0V | $R_{EXT}$=1860Ω | - | 10 | - | mA |
| Current Skew (between channels) | | $dI_{OUT1}$ | $I_{OL}$=10mA $V_{DS}$ =1.0V | $R_{EXT}$=1860Ω | - | ±1.5 | ±3 | % |
| Output Current 2 | | $I_{OUT2}$ | $V_{DS}$ =1.0V | $R_{EXT}$=744Ω | - | 30 | - | mA |
| Current Skew (between channels) | | $dI_{OUT2}$ | $I_{OL}$=25mA $V_{DS}$ =1.0V | $R_{EXT}$=744Ω | - | ±1.5 | ±3 | % |
| Current Skew (between ICs) | | $dI_{OUT3}$ | $I_{OL}$=25mA $V_{DS}$ =1.0V | $R_{EXT}$=744Ω | | ±3 | ±6 | % |
| Output Current vs. Output Voltage | | %/$dV_{DS}$ | $V_{DS}$ within 1.0V to 3.0V | | - | ±0.1 | - | %/V |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Regulation | | | | | | | |
| Output Current vs. Supply Voltage Regulation | | $\%/dV_{DD}$ | $V_{DD}$ within 3.0V to 3.6V | - | ±1 | - | %/V |
| Pull-up Resistor | | $R_{IN}$ (up) | $\overline{OE}$ | 250 | 500 | 800 | KΩ |
| Pull-down Resistor | | $R_{IN}$(down) | LE | 250 | 500 | 800 | KΩ |
| Supply Current | "OFF" | $I_{DD}$ (off)1 | $R_{EXT}$ = Unterminal, $\overline{OUT0} \sim \overline{OUT15}$ =Off | - | 1.8 | 5.0 | mA |
| | | $I_{DD}$ (off)2 | $R_{EXT}$ =1860Ω, $\overline{OUT0} \sim \overline{OUT15}$ =Off | - | 4.1 | 7.0 | |
| | | $I_{DD}$ (off)3 | $R_{EXT}$ =744Ω, $\overline{OUT0} \sim \overline{OUT15}$ =Off | - | 5.2 | 8.5 | |
| | "ON" | $I_{DD}$ (on)1 | $R_{EXT}$ =1860Ω, $\overline{OUT0} \sim \overline{OUT15}$ =On | - | 4.5 | 7.0 | |
| | | $I_{DD}$ (on)2 | $R_{EXT}$=744Ω, $\overline{OUT0} \sim \overline{OUT15}$ =On | | 5.4 | 8.5 | |

## Switching Characteristics ($V_{DD}$=5V, $T_A$=25°C)

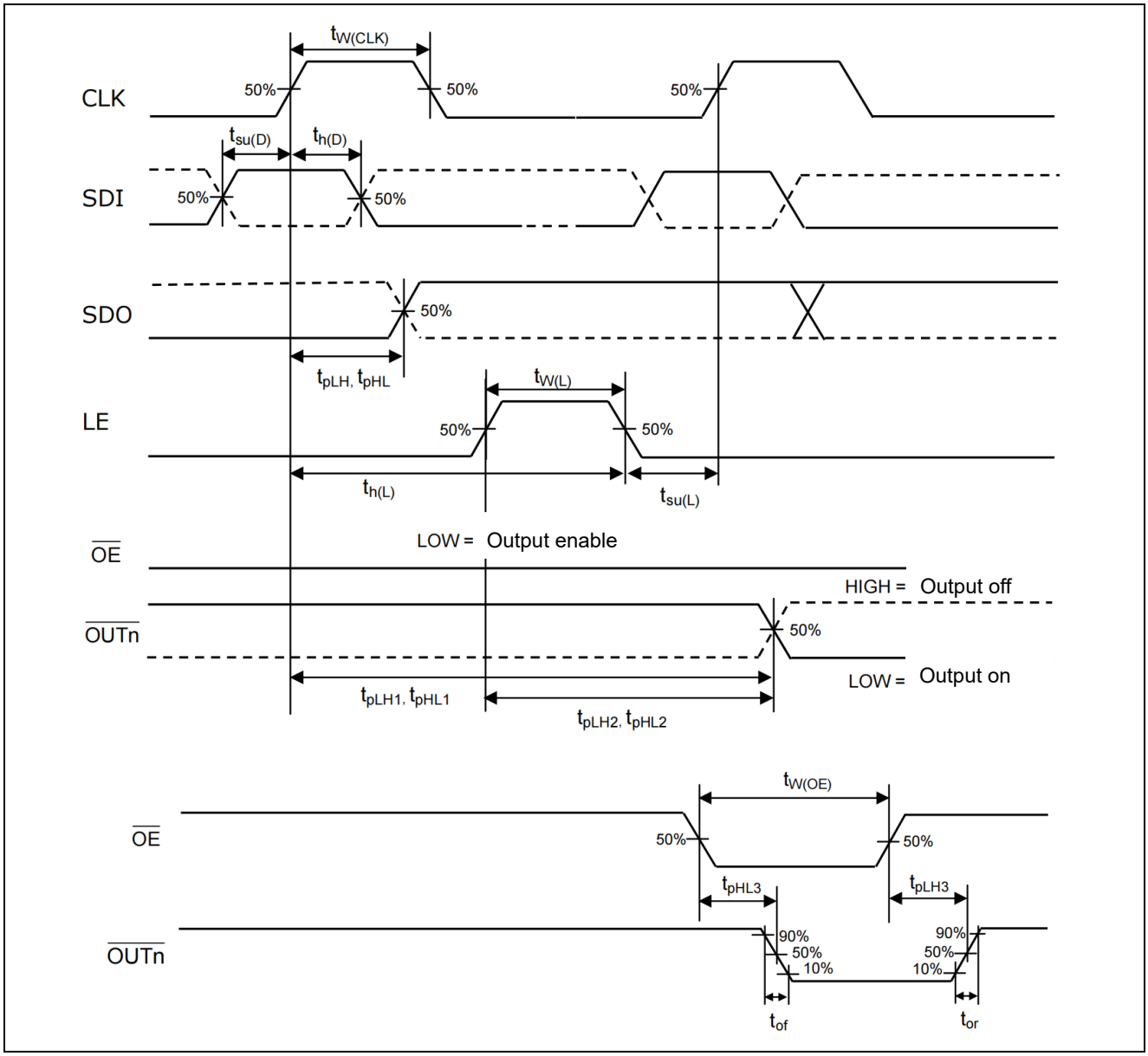
| Characteristic | | Symbol | Condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| Propagation Delay Time ("L" to "H") | CLK- $\overline{OUTn}$ | $t_{PLH1}$ | $V_{DD}$ =5.0V<br>$V_{DS}$ =1.0V<br>$V_{IH}$ = $V_{DD}$<br>$V_{IL}$ =GND<br>$R_{EXT}$ =930Ω<br>$V_L$ =4.5V<br>$R_L$ =162Ω<br>$C_L$ =10pF | - | 80 | 100 | ns |
| | LE - $\overline{OUTn}$ | $t_{PLH2}$ | | - | 80 | 100 | ns |
| | $\overline{OE}$ - $\overline{OUTn}$ | $t_{PLH3}$ | | - | 115 | 135 | ns |
| | CLK-SDO | $t_{PLH}$ | | - | 20 | 40 | ns |
| Propagation Delay Time ("H" to "L") | CLK- $\overline{OUTn}$ | $t_{PHL1}$ | | - | 80 | 100 | ns |
| | LE - $\overline{OUTn}$ | $t_{PHL2}$ | | - | 80 | 100 | ns |
| | $\overline{OE}$ - $\overline{OUTn}$ | $t_{PHL3}$ | | - | 115 | 135 | ns |
| | CLK-SDO | $t_{PHL}$ | | - | 20 | 40 | ns |
| Pulse Width | CLK | $t_{w(CLK)}$ | | 20 | - | - | ns |
| | LE | $t_{w(L)}$ | | 20 | - | - | ns |
| | $\overline{OE}$ | $t_{w(OE)}$ | | 250 | - | - | ns |
| Hold Time for LE | | $t_{h(L)}$ | | 5 | - | - | ns |
| Setup Time for LE | | $t_{su(L)}$ | | 5 | - | - | ns |
| Maximum CLK Rise Time | | $t_r$** | | - | - | 500 | ns |
| Maximum CLK Fall Time | | $t_f$** | | - | - | 500 | ns |
| Output Rise Time of Vout (turn off) | | $t_{or}$ | | - | 160 | 180 | ns |
| Output Fall Time of Vout (turn on) | | $t_{of}$ | | - | 70 | 90 | ns |

## Switching Characteristics ($V_{DD}$=3.3V, $T_A$=25°C)

| Characteristic | | Symbol | Condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| Propagation Delay Time ("L" to "H") | CLK- $\overline{OUTn}$ | $t_{PLH1}$ | $V_{DD}$ =3.3V<br>$V_{DS}$ =1.0V<br>$V_{IH}$ = $V_{DD}$<br>$V_{IL}$ =GND<br>$R_{EXT}$ =930Ω<br>$V_L$ =3.0V | - | 80 | 100 | ns |
| | LE - $\overline{OUTn}$ | $t_{PLH2}$ | | - | 80 | 100 | ns |
| | $\overline{OE}$ - $\overline{OUTn}$ | $t_{PLH3}$ | | - | 115 | 135 | ns |
| | CLK-SDO | $t_{PLH}$ | | - | 20 | 40 | ns |
| Propagation Delay Time ("H" to "L") | CLK- $\overline{OUTn}$ | $t_{PHL1}$ | | - | 100 | 120 | ns |
| | LE - $\overline{OUTn}$ | $t_{PHL2}$ | | - | 80 | 100 | ns |

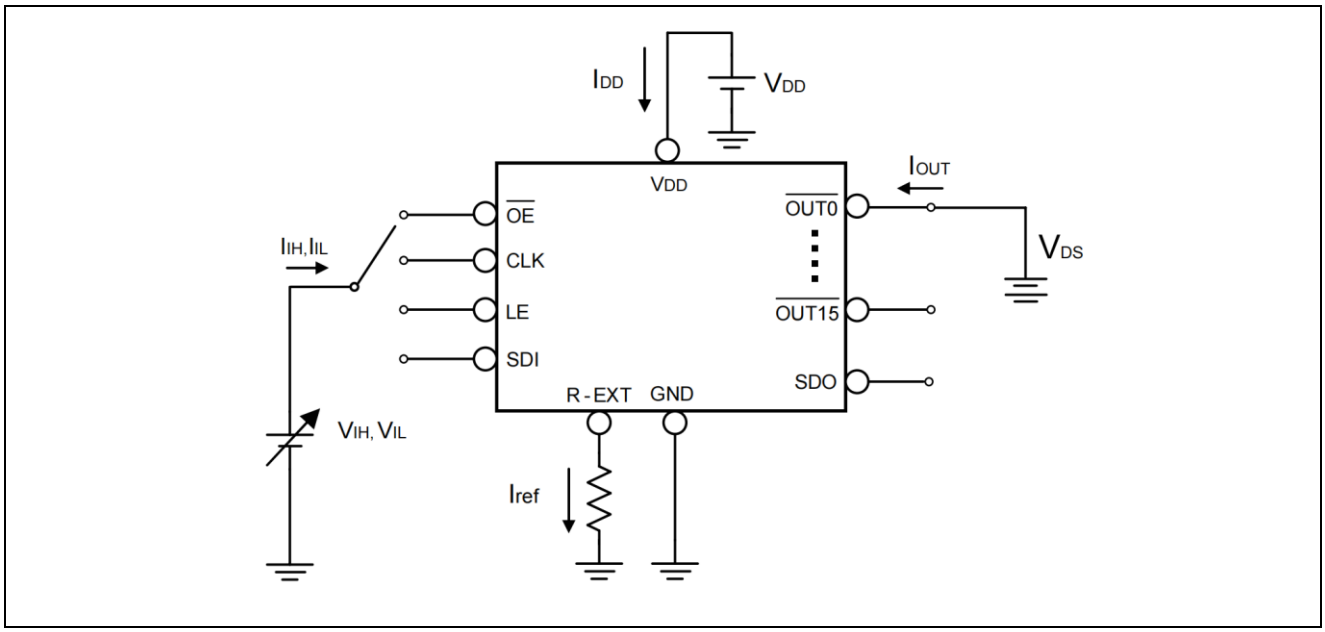
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\overline{OE}$ - $\overline{OUTn}$ | $t_{PHL3}$ | $R_L$ =100Ω | - | 115 | 135 | ns |
| | CLK-SDO | $t_{PHL}$ | $C_L$ =10pF | - | 20 | 40 | ns |
| Pulse Width | CLK | $t_{w(CLK)}$ | | 20 | - | - | ns |
| | LE | $t_{w(L)}$ | | 20 | - | - | ns |
| | $\overline{OE}$ | $t_{w(OE)}$ | | 300 | - | - | ns |
| Hold Time for LE | | $t_{h(L)}$ | | 5 | - | - | ns |
| Setup Time for LE | | $t_{su(L)}$ | | 5 | - | - | ns |
| Maximum CLK Rise Time | | $t_r$** | | - | - | 500 | ns |
| Maximum CLK Fall Time | | $t_f$** | | - | - | 500 | ns |
| Output Rise Time of Vout (turn off) | | $t_{or}$ | | - | 160 | 180 | ns |
| Output Fall Time of Vout (turn on) | | $t_{of}$ | | - | 70 | 90 | ns |

## Timing Waveform

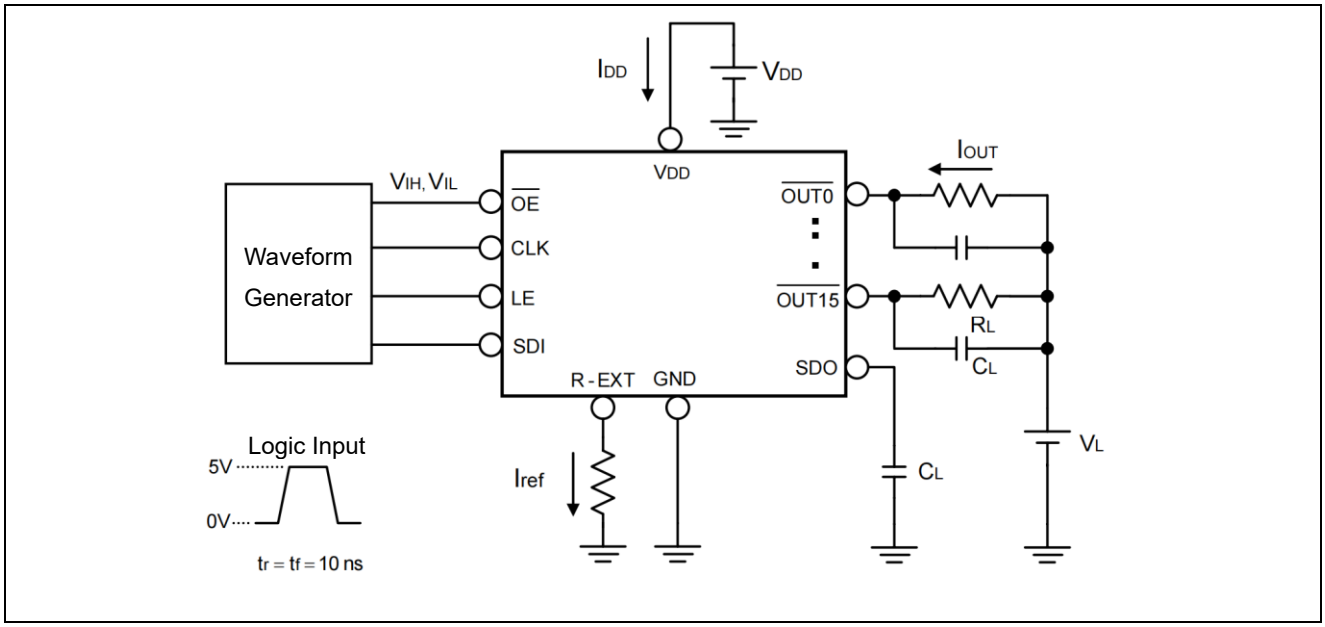


## Application Circuits

### Test Circuit for Electrical Characteristics

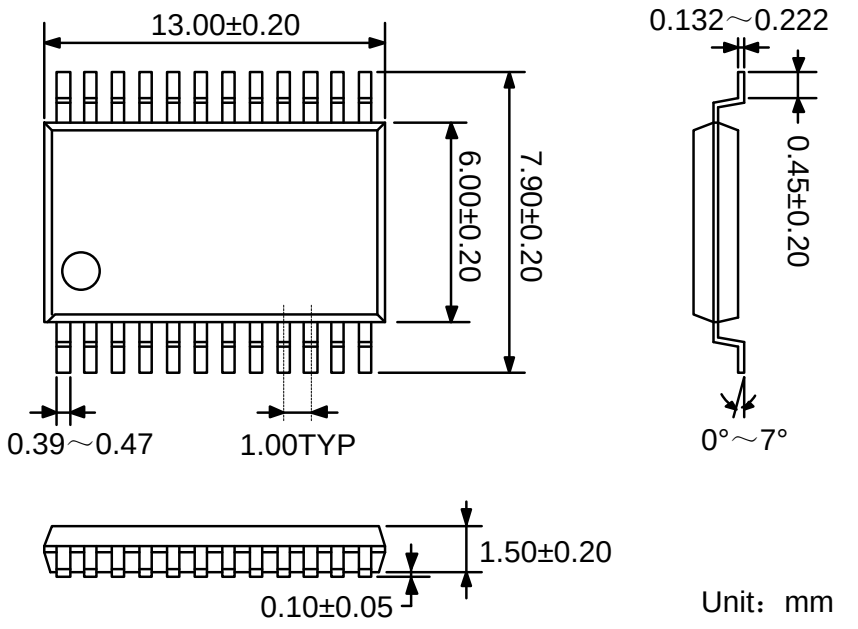



### Test Circuit for Switching Characteristics



## Package Dimension

SSOP24-3




## Tape and Reel

| Package Type | Units/ Reel | Reel /Inner Box | Inner Boxes/Outer Box | Units/Outer Box |
|---|---|---|---|---|
| SSOP24-3 | 4K | 2 | 1 | 8K |