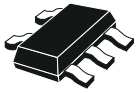
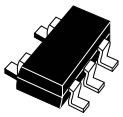
TS3121, TS3121A

Datasheet

Rail-to-rail, open-drain comparator with embedded fail-safe input/output



SC70-5



SOT23-5

Maturity status link
TS3121, TS3121A

Related products	
TS880	For lower supply current
TS3011	For higher speed
TS3021	For push-pull output

Features

- Low offset voltage: 2 mV max @ 25 °C (A-grade version)
- Low power consumption: 70 µA typ.
- Wide supply voltage: 1.7 to 5.5 V
- Propagation delay: 60 ns
- Rail-to-rail input
- Open-drain output
- Fail-safe input/output pins
- Input/output pins withstand voltages higher than V_{CC}
- Fail-safe architecture keeps output in high impedance when V_{CC} = 0 V
- Guaranteed start-up time allows sequential on/off cycles of V_{CC}
- High ESD tolerance: 4 kV HBM
- Extended temperature range: -40 to +125 °C
- AEC-Q100 qualified
- Safety capable: documentation available to aid functional safety system design

Applications

- Industrial
- Automotive
- Power tools
- Overcurrent protection
- Controllers, sensors

Description

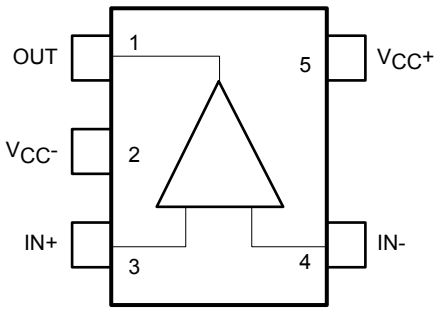
The TS3121 and the TS3121A single comparators permit high-speed response time at low power consumption over a supply voltage specified from 1.7 to 5.5 V. These devices operate over a wide temperature range from -40 °C to +125 °C making them ideal for industrial and automotive applications with the associated qualification.

Thanks to an embedded fail-safe circuit, the TS3121 and the TS3121A can operate with input/output pins biased while the supply pin is shut down to V_{CC} = 0 V for energy saving applications. A guaranteed start-up time ensures a stable output condition after activating the supply rail.

Thanks to their small package size, the TS3121 and the TS3121A can be used in applications where space on the board is limited. It can thus reduce the overall cost of the PCB.

1 Pin configuration

Figure 1. Pin connection (top view)



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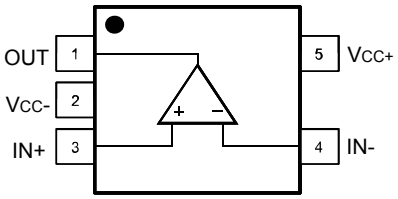

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Table 1. Pin description

Pin n°	Pin name	Description
1	OUT	Output
2	V_{CC-}	Negative supply voltage
3	IN+	Positive input voltage
4	IN-	Negative input voltage
5	V_{CC+}	Positive supply voltage

2 Maximum ratings

Table 2. Absolute maximum ratings

Symbol	Parameter		Value	Unit
V_{CC}	Supply voltage (1)		6	V
V_{in}	Input voltage from V_{CC-}		-0.3 to +6	V
I_{in}	Input current (2)		10	mA
V_{out}	Output voltage		6	V
T_{stg}	Storage temperature		-65 to +150	°C
T_j	Junction temperature		150	°C
R_{th-ja}	Thermal resistance junction to ambient (3) (4)	SOT23-5	250	°C/W
		SC70-5	205	
ESD	Human Body Model (HBM) (5)		4000	V
	Charged Device Model (CDM) (6)		1500	

1. *All voltage values, except differential voltage, are with respect to the network ground terminal.*
2. *Input current must be limited by a resistor in series with the inputs.*
3. *R_{th} are typical values.*
4. *Short circuits can cause excessive heating and destructive dissipation.*
5. *According to JEDEC standard JESD22-A114F.*
6. *According to ANSI/ESD STM5.3.1.*

Table 3. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	1.7 to 5.5	V
V_{in}	Common mode input voltage range(1)	-0.2 to V_{CC+} + 0.2	V
V_{out}	Output voltage	0 to 5.5	V
T	Operating free-air temperature range	-40 to +125	°C

1. *As long as one input is within the common mode input voltage range, the second one can be within -0.2 V to 5.5 V and the comparator operates properly*

3 Electrical characteristics

Table 4. Electrical characteristics - V_{CC} = 5 V, V_{icm} = V_{CC}/2, T = 25 °C (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
		DC performance				
V_{IO}	Input offset voltage	TS3121A, T = 25 °C	-2	0.5	+2	mV
		TS3121A, Tmin < T < Tmax	-4		+4	
		TS3121, T = 25 °C	-6	0.5	+6	
		TS3121, Tmin < T < Tmax	-8		+8	
$\lvert\Delta V_{IO}/\Delta T\rvert$	Input offset voltage drift	Tmin< T < Tmax		3	20	µV/°C
V_{HYST}	Input hysteresis voltage(1)			1		mV
$\lvert I_{IB}\rvert$	Input bias current	T = 25 °C		5	50	pA
		Tmin < T < Tmax			200	
$\lvert I_{IO}\rvert$	Input offset current	T = 25 °C		1	20	
		Tmin < T < Tmax			100	
CMRR	Common-mode rejection ratio: 20 log ($\Delta V_{icm}/\Delta V_{io}$)	0 < V_{icm} < V_{CC}	55	70		dB
		Tmin < T < Tmax				
SVR	Supply voltage rejection: 20 log ($\Delta V_{cc}/\Delta V_{io}$)	ΔV_{cc} = 1.8 V to 5.0 V, V_{icm} = 0 V, T = 25 °C	58	80		
		ΔV_{cc} = 1.8 V to 5.0 V, V_{icm} = 0 V, Tmin < T < Tmax				
I_{sink}	Output sink current	V_{OUT} = V_{CC+},V_{ID} = - 0.1 V	100	140		mA
		Tmin < T < Tmax	70			
I_{OH}	High-level output leakage current, V_{OUT} = V_{CC} (2)	V_{OUT} = V_{CC}, V_{ID} = +0.1 V		460	800	pA
		Tmin < T < Tmax			250	nA
V_{OL}	Low-level output voltage I_{sink} = 1 mA	T = 25 °C		18	30	mV
		Tmin< T < Tmax			45	
I_{CC}	Supply current	Output low, V_{ID} = - 0.1 V		73	125	µA
		Tmin < T < Tmax			155	
		Output high, V_{ID} = +0.1 V		57	125	
		Tmin < T < Tmax			155	
$t_{start-up}$	Start-up time	V_{CC} > 1.5 V		10	15	µs
t_{PLH}(3)	Propagation delay (low to high), C_L = 15 pF, overdrive = 20 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		170	235	ns
		Tmin < T < Tmax			250	
	C_L = 15 pF, overdrive = 100 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		130	160	
		Tmin < T < Tmax			185	
t_{PHL}(4)	Propagation delay (high to low), C_L = 15 pF, overdrive = 20 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		100	135	
		Tmin < T < Tmax			185	
	C_L = 15 pF, overdrive = 100 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		60	85	
		Tmin < T < Tmax			125	
t_F	Fall time (90% to 10%)	C_L = 15 pF, R_{PU} = 2.5 kΩ, overdrive = 100 mV		2.5		

1. *Hysteresis is a built-in feature of the TS3121. It is defined as the voltage difference between the trip points.*

2. *Maximum high-level output leakage current at T = 25 °C is guaranteed by design.*
3. *t_{PLH} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting inputvoltage (IN-) = V_{ICM} and non-inverting input voltage (IN+) moving from V_{ICM} - 100 mV to V_{ICM} + overdrive.*
4. *t_{PHL} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting inputvoltage (IN-) = V_{ICM} and non-inverting input voltage (IN+) moving from V_{ICM} + 100 mV to V_{ICM} - overdrive.*

Table 5. Electrical characteristics - V_{CC} = 3.3 V, V_{icm} = V_{CC}/2, T = 25 °C (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
		DC performance				
V_{IO}	Input offset voltage	TS3121A, T = 25 °C	-2	0.5	+2	mV
		TS3121A, Tmin < T < Tmax	-4		+4	
		TS3121, T = 25 °C	-6	0.5	+6	
		TS3121, Tmin < T < Tmax	-8		+8	
$\lvert\Delta V_{IO}/\Delta T\rvert$	Input offset voltage drift	Tmin < T < Tmax		3	20	µV/°C
V_{HYST}	Input hysteresis voltage(1)			1		mV
$\lvert I_{IB}\rvert$	Input bias current	T = 25 °C		5	50	pA
		Tmin < T < Tmax			200	
$\lvert I_{IO}\rvert$	Input offset current	T = 25 °C		1	20	
		Tmin < T < Tmax			100	
CMRR	Common-mode rejection ratio: 20 log ($\Delta V_{icm}/\Delta V_{io}$)	0 < V_{icm} < V_{CC}	50	70		dB
		Tmin < T < Tmax				
SVR	Supply voltage rejection: 20 log ($\Delta V_{cc}/\Delta V_{io}$)	ΔV_{cc}= 1.8 V to 5.0 V, V_{icm} = 0 V, T = 25 °C		80		
		ΔV_{cc}= 1.8 V to 5.0 V, V_{icm} = 0 V, Tmin < T < Tmax	58			
I_{sink}	Output sink current	V_{OUT} = V_{CC+},V_{ID} = -0.1 V	45	70		mA
		Tmin < T < Tmax	35			
I_{OH}	High-level output leakage current, V_{OUT} = V_{CC} (2)	V_{OUT} = V_{CC}, V_{ID} = +0.1 V		425	700	pA
		Tmin < T < Tmax			200	nA
V_{OL}	Low-level output voltage I_{sink} = 1 mA	T = 25 °C		20	35	mV
		Tmin< T < Tmax			50	
I_{CC}	Supply current	Output low, V_{ID} = -0.1 V		71	125	µA
		Tmin < T < Tmax			155	
		Output high, V_{ID} = +0.1 V		56	125	
		Tmin < T < Tmax			155	
$t_{start-up}$	Start-up time	V_{CC} > 1.5 V		10	15	µs
t_{PLH}(3)	Propagation delay (low to high), C_L = 15 pF, overdrive = 20 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		160	220	ns
		Tmin < T < Tmax			240	
	C_L = 15 pF, overdrive = 100 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		130	160	
		Tmin < T < Tmax			175	
t_{PHL}(4)	Propagation delay (high to low), C_L = 15 pF, overdrive = 20 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C		90	115	
		Tmin < T < Tmax			160	
	C_L = 15 pF,	R_{PU} = 2.5 kΩ, T = 25 °C		60	85	

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{PHL}[4]	overdrive = 100 mV, $V_{PU} = V_{CC}$	Tmin < T < Tmax			125	ns
t_F	Fall time (90% to 10%)	C_L = 15 pF, R_{PU} = 2.5 kΩ, overdrive = 100 mV		3.5		

1. *Hysteresis is a built-in feature of the TS3121. It is defined as the voltage difference between the trip points.*
2. *Maximum high-level output leakage current at T = 25 °C is guaranteed by design.*
3. *t_{PLH} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting inputvoltage (IN-) = V_{ICM} and non-inverting input voltage (IN+) moving from V_{ICM} - 100 mV to V_{ICM} + overdrive.*
4. *t_{PHL} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting inputvoltage (IN-) = V_{ICM} and non-inverting input voltage (IN+) moving from V_{ICM} + 100 mV to V_{ICM} - overdrive.*

Table 6. Electrical characteristics - V_{CC} = 1.8 V, V_{icm} = V_{CC}/2, T = 25 °C (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{IO}	Input offset voltage	TS3121A, T = 25 °C	-2	0.5	+2	mV
		TS3121A, Tmin < T < Tmax	-4		+4	
		TS3121, T = 25 °C	-6	0.5	+6	
		TS3121, Tmin < T < Tmax	-8		+8	
$\lvert\Delta V_{IO}/\Delta T\rvert$	Input offset voltage drift	Tmin < T < Tmax		3	20	µV/°C
V_{HYST}	Input hysteresis voltage[1]			1		mV
$\lvert I_{IB}\rvert$	Input bias current	T = 25 °C		5	50	pA
		Tmin < T < Tmax			200	
$\lvert I_{IO}\rvert$	Input offset current	T = 25 °C		1	20	
		Tmin < T < Tmax			100	
CMRR	Common-mode rejection ratio: 20 log ($\Delta V_{icm}/\Delta V_{io}$)	0 < V_{icm} < V_{CC}	50	70		dB
		Tmin < T < Tmax				
SVR	Supply voltage rejection: 20 log ($\Delta V_{cc}/\Delta V_{io}$)	ΔV_{cc}= 1.8 V to 5.0 V, V_{icm} = 0 V, T = 25 °C		80		
		ΔV_{cc}= 1.8 V to 5.0 V, V_{icm} = 0 V, Tmin < T < Tmax	58			
I_{sink}	Output sink current	$V_{OUT} = V_{CC+}$, V_{ID} = - 0.1 V	11	18		mA
		Tmin < T < Tmax	9			
I_{OH}	High-level output leakage current, $V_{OUT} = V_{CC}$ [2]	$V_{OUT} = V_{CC}$, V_{ID} = +0.1 V		193	700	pA
		Tmin < T < Tmax			200	nA
V_{OL}	Low-level output voltage I_{sink} = 1 mA	T = 25 °C		36	60	mV
		Tmin< T < Tmax			80	
I_{CC}	Supply current	Output low, V_{ID} = -0.1 V		78	125	µA
		Tmin < T < Tmax			155	
		Output high, V_{ID} = +0.1 V		81	125	
		Tmin < T < Tmax			155	
$t_{start-up}$	Start-up time	V_{CC} > 1.5 V		10	15	µs
t_{PLH}[3]	Propagation delay (low to high), C_L = 15 pF, overdrive = 20 mV, $V_{PU} = V_{CC}$	R_{PU} = 2.5 kΩ, T = 25 °C		160	220	ns
		Tmin < T < Tmax			225	
	C_L = 15 pF, overdrive = 100 mV, $V_{PU} = V_{CC}$	R_{PU} = 2.5 kΩ, T = 25 °C		130	160	
		Tmin < T < Tmax			175	

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{PHL} (4)	Propagation delay (high to low), C_L = 15 pF, overdrive = 20 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C Tmin < T < Tmax		90	115 165	ns
	C_L = 15 pF, overdrive = 100 mV, V_{PU} = V_{CC}	R_{PU} = 2.5 kΩ, T = 25 °C Tmin < T < Tmax		60	85 125	
t_F	Fall time (90% to 10%)	C_L = 15 pF, R_{PU} = 2.5 kΩ, overdrive = 100 mV		3.5		

1. *Hysteresis is a built-in feature of the TS3121. It is defined as the voltage difference between the trip points.*
2. *Maximum high-level output leakage current at T = 25 °C is guaranteed by design.*
3. *t_{PLH} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting inputvoltage (IN-) = V_{ICM} and non-inverting input voltage (IN+) moving from V_{ICM} - 100 mV to V_{ICM} + overdrive.*
4. *t_{PHL} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting inputvoltage (IN-) = V_{ICM} and non-inverting input voltage (IN+) moving from V_{ICM} + 100 mV to V_{ICM} - overdrive.*

4 Typical performance characteristics

Figure 2. Supply current vs. supply voltage at $V_{icm} = V_{CC}$, output high

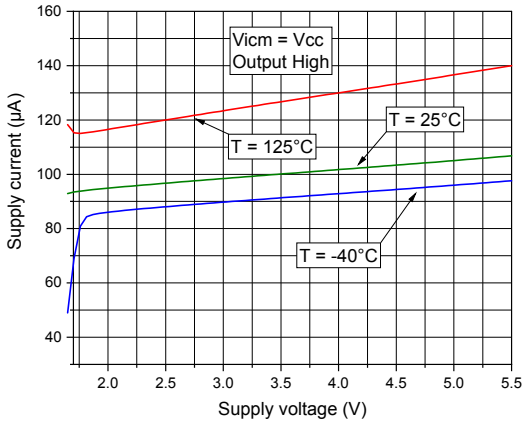


Figure 3. Supply current vs. supply voltage at $V_{icm} = V_{CC}/2$, output high

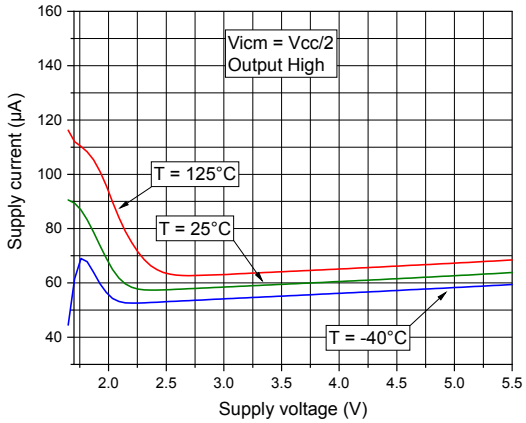


Figure 4. Supply current vs. supply voltage at $V_{icm} = V_{CC}$-, output high

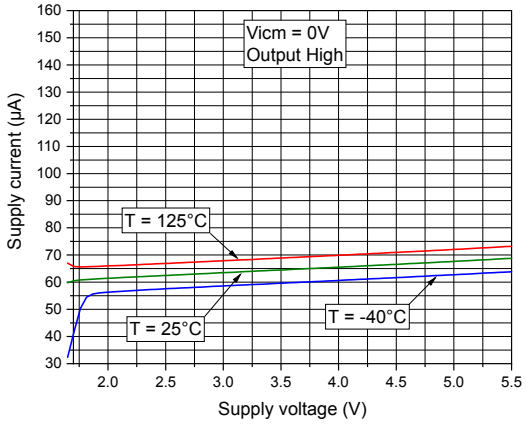


Figure 5. Supply current vs. supply voltage at $V_{icm} = V_{CC}$, output high

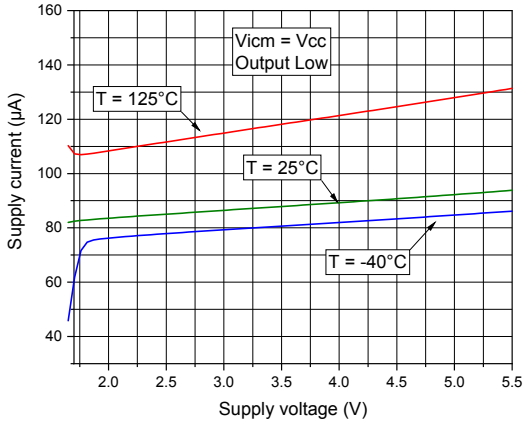


Figure 6. Supply current vs. supply voltage at $V_{icm} = V_{CC}/2$, output low

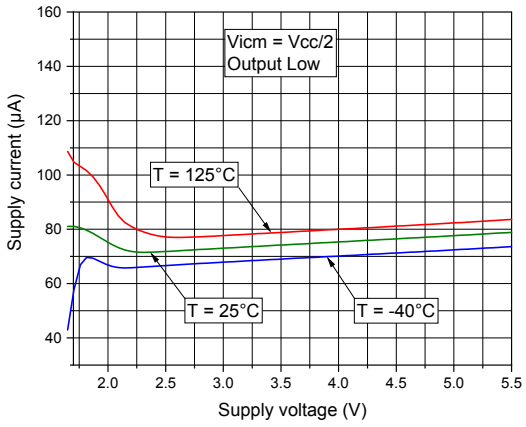


Figure 7. Supply current vs. supply voltage at $V_{icm} = V_{CC}$-, output low

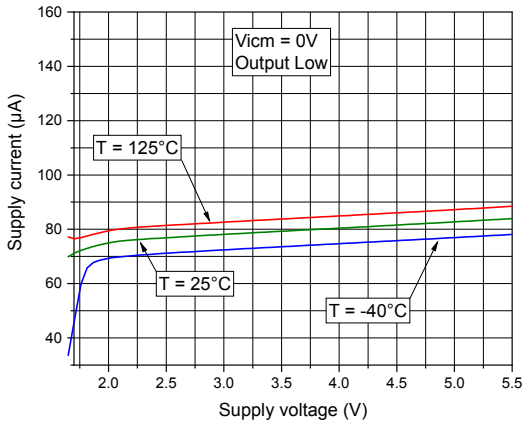


Figure 8. Supply current vs. input common-mode voltage at V_{CC} = 1.8 V, output high

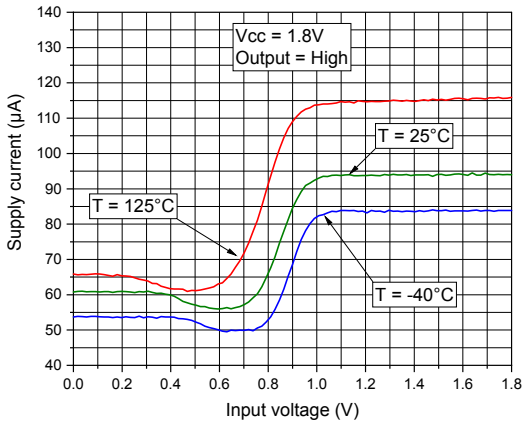


Figure 9. Supply current vs. input common-mode voltage at V_{CC} = 3.3 V, output high

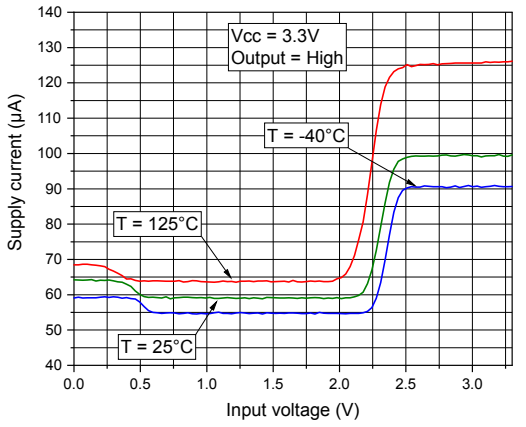


Figure 10. Supply current vs. input common-mode voltage at V_{CC} = 5.0 V, output high

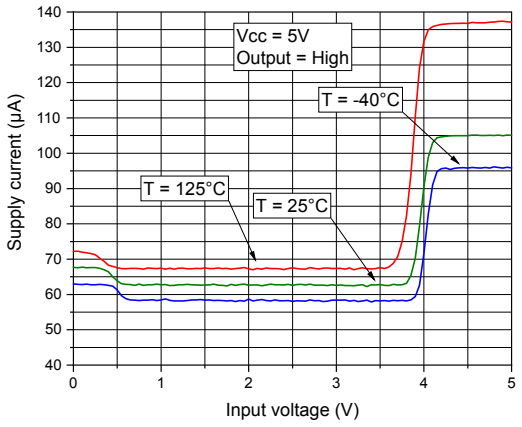


Figure 11. Input bias current vs. input common-mode voltage at V_{CC} = 1.8 V

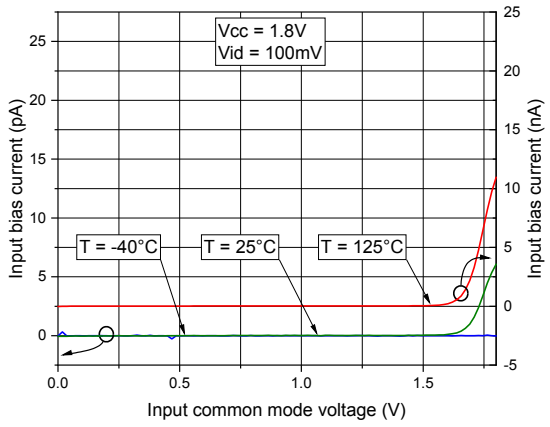


Figure 12. Input bias current vs. input common-mode voltage at V_{CC} = 3.3 V

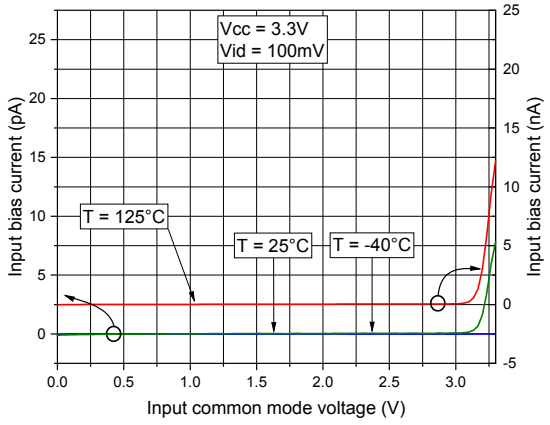


Figure 13. Input bias current vs. input common-mode voltage at V_{CC} = 5.0 V

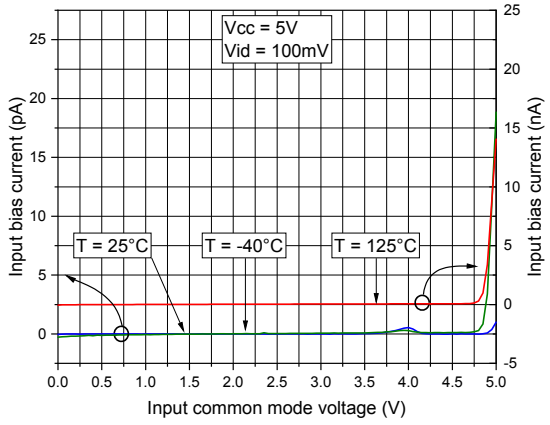


Figure 14. Input bias current vs. supply voltage at $V_{icm} = V_{CC}/2$

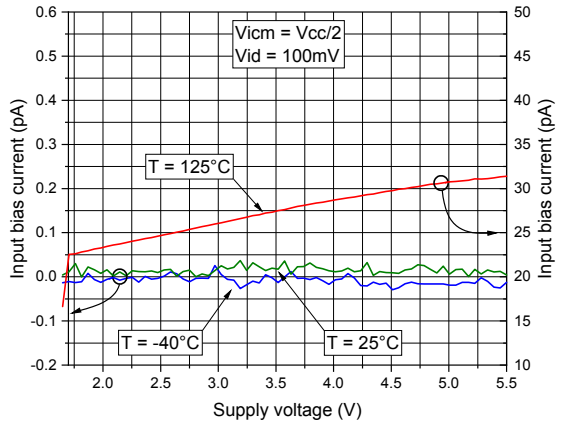


Figure 15. Input offset voltage vs. input common-mode voltage at V_{CC} = 1.8 V

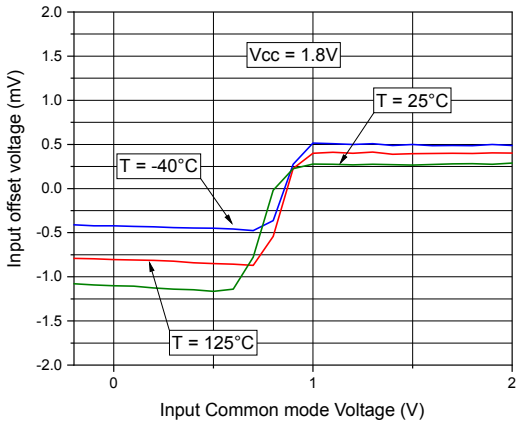


Figure 16. Input offset voltage vs. input common-mode voltage at V_{CC} = 3.3 V

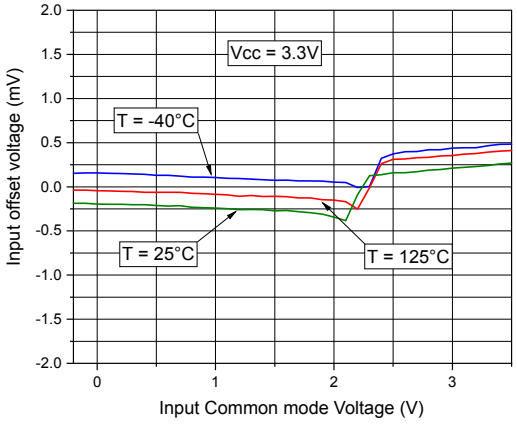


Figure 17. Input offset voltage vs. input common-mode voltage at V_{CC} = 5.0 V

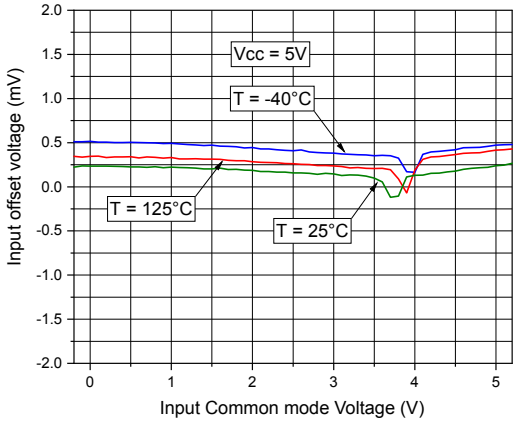


Figure 18. Input offset voltage vs. supply voltage at $V_{icm} = V_{CC}$-

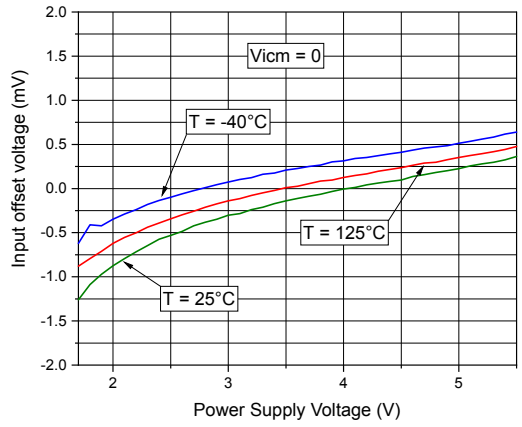


Figure 19. Input offset voltage vs. supply voltage at $V_{icm} = V_{CC}/2$

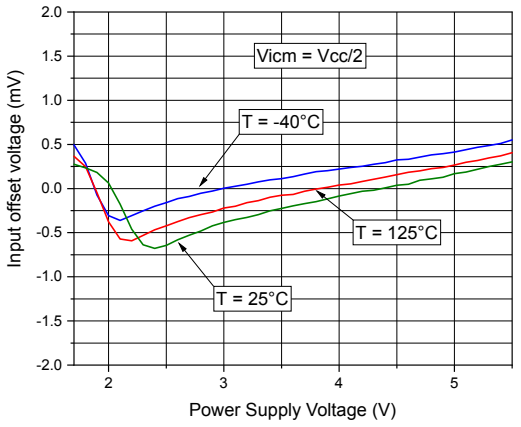


Figure 20. Input offset voltage vs. supply voltage at $V_{icm} = V_{CC}$

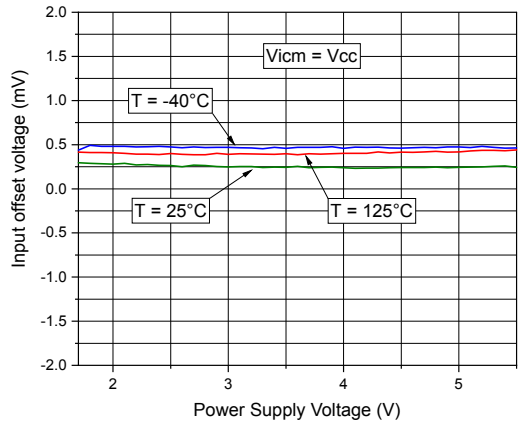


Figure 21. Input offset voltage drift vs. temperature from -40 °C to +25 °C

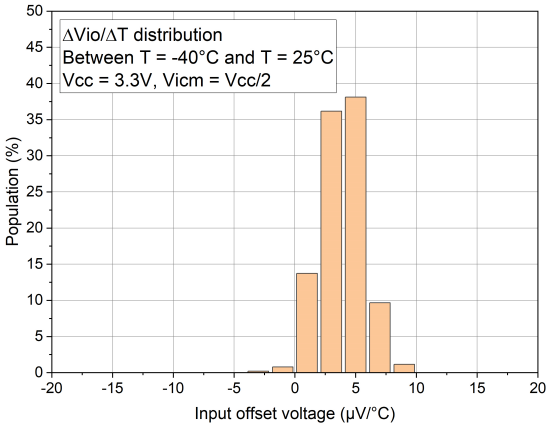


Figure 22. Input offset voltage drift vs. temperature from -25 °C to +125 °C

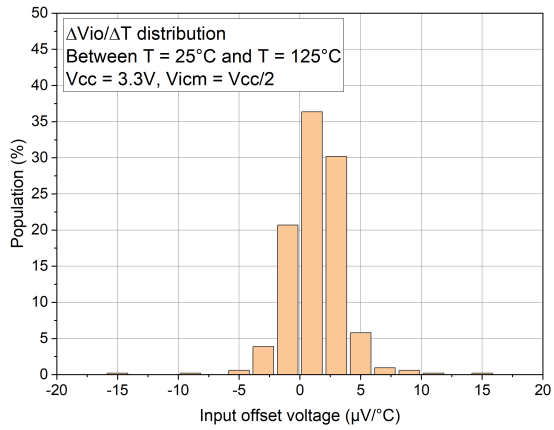


Figure 23. Input offset voltage vs. temperature at V_{CC} = 1.8 V

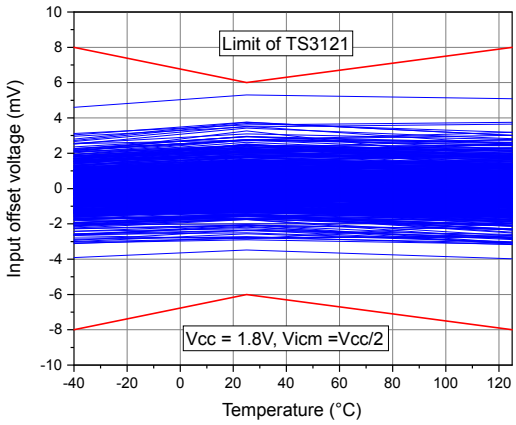


Figure 24. Input offset voltage vs. temperature at V_{CC} = 5.0 V

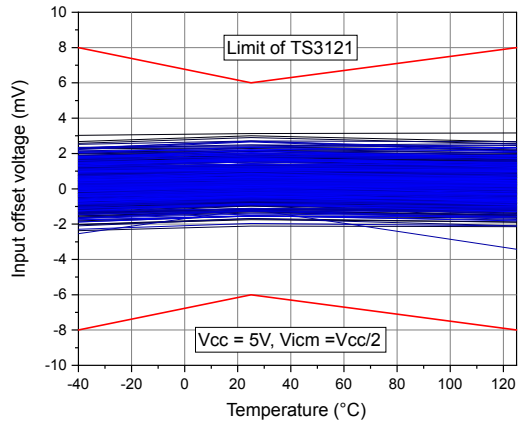


Figure 25. Input offset voltage distribution at V_{CC} = 1.8 V

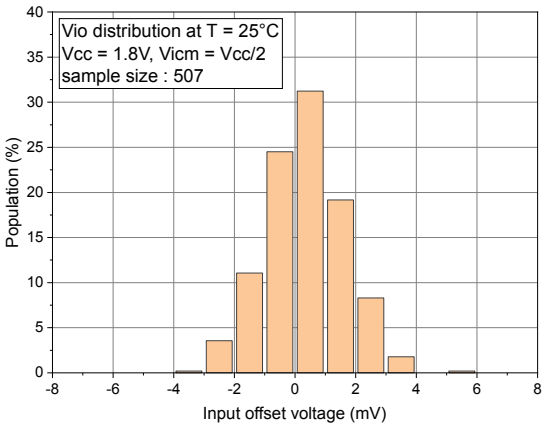


Figure 26. Input offset voltage distribution at V_{CC} = 3.3 V

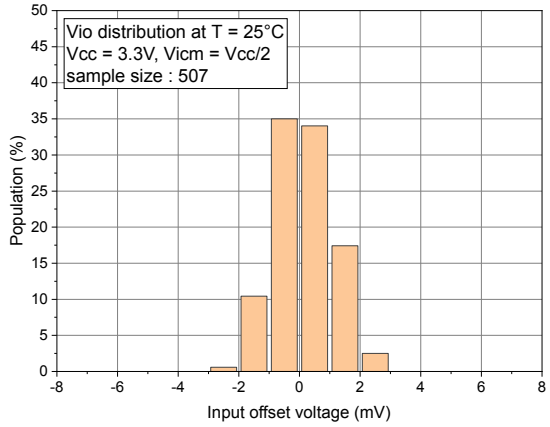


Figure 27. Input offset voltage distribution at V_{CC} = 5.0 V

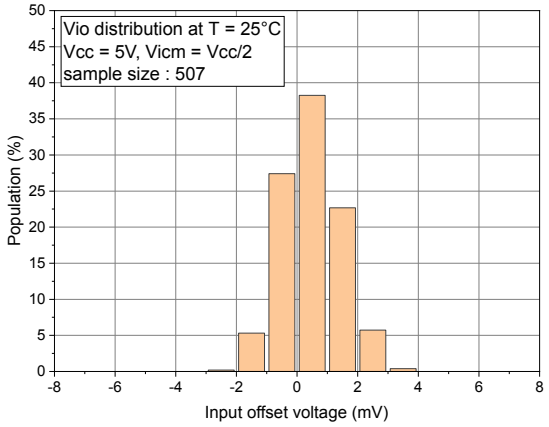


Figure 28. Output drop voltage vs. output sink current at V_{CC} = 1.8 V

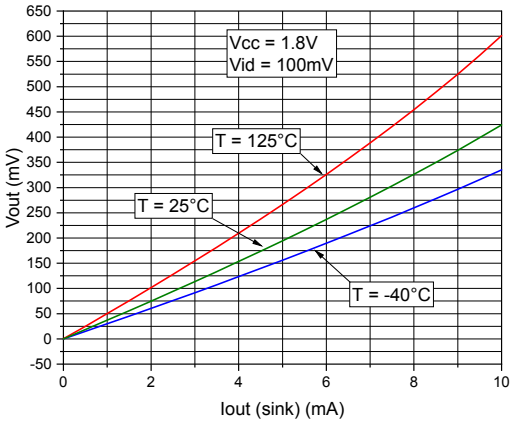


Figure 29. Output drop voltage vs. output sink current at V_{CC} = 3.3 V

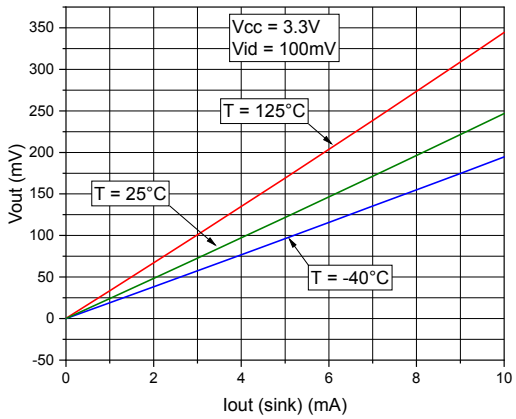


Figure 30. Output drop voltage vs. output sink current at V_{CC} = 5.0 V

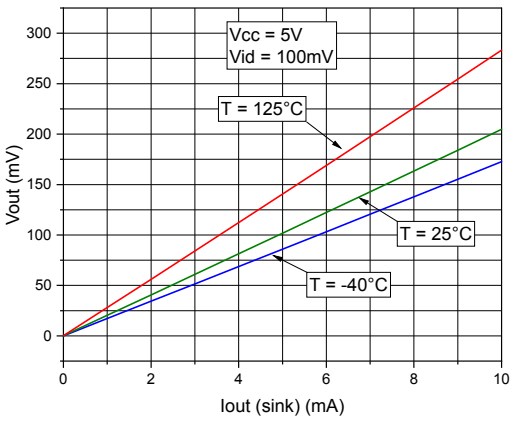


Figure 31. High-level output leakage current vs. output voltage at V_{CC} = 1.8 V

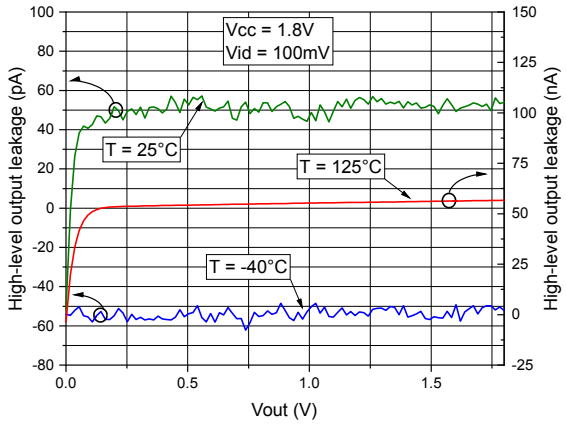


Figure 32. High-level output leakage current vs. output voltage at V_{CC} = 5.0 V

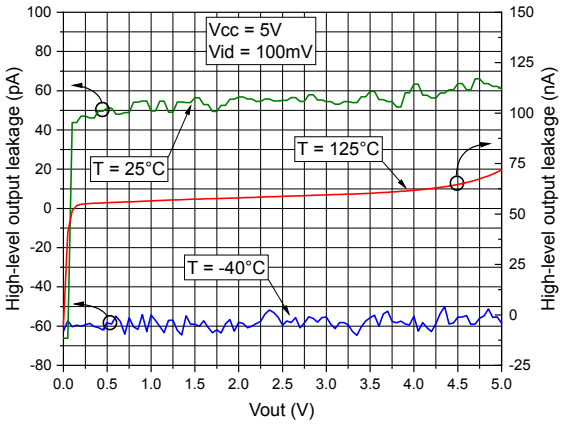


Figure 33. High-to-low propagation delay vs. overdrive at V_{CC} = 1.8 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

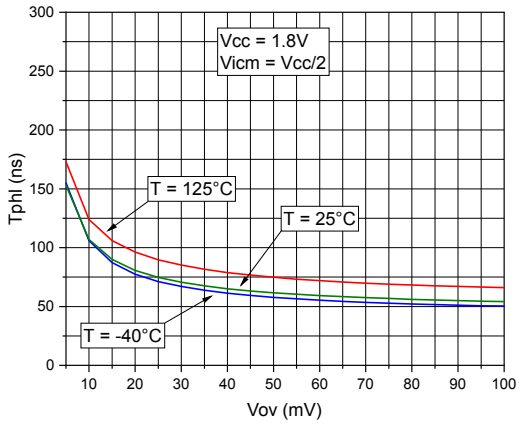


Figure 34. High-to-low propagation delay vs. overdrive at V_{CC} = 3.3 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

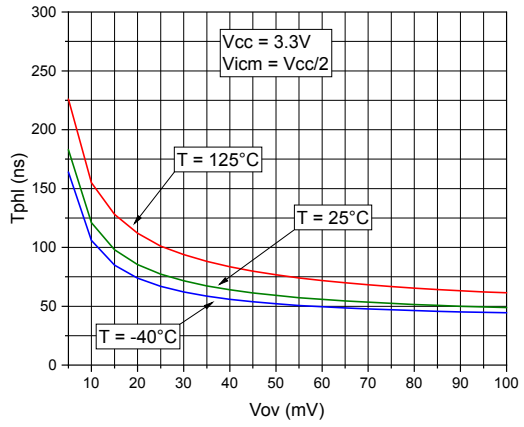


Figure 35. High-to-low propagation delay vs. overdrive at V_{CC} = 5.0 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

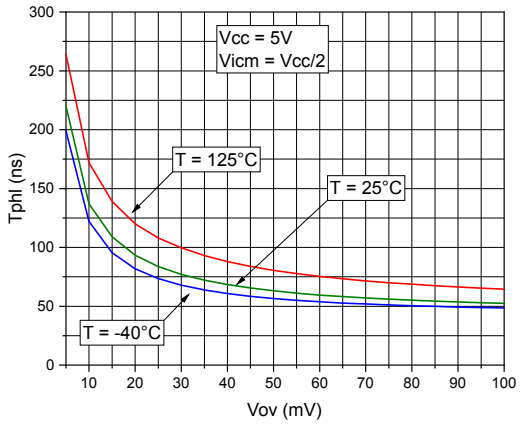


Figure 36. Low-to-high propagation delay vs. overdrive at V_{CC} = 1.8 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

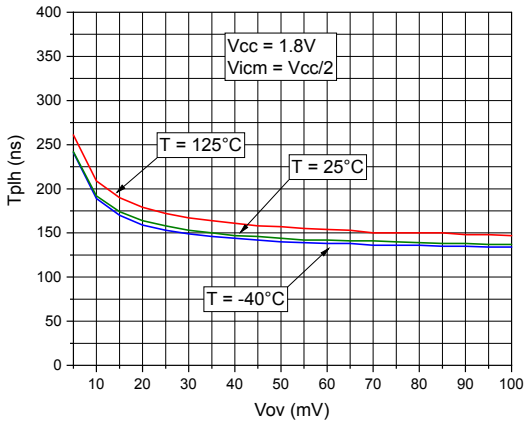


Figure 37. Low-to-high propagation delay vs. overdrive at V_{CC} = 3.3 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

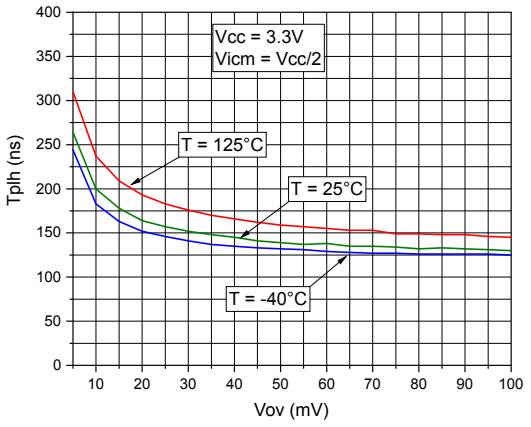


Figure 38. Low-to-high propagation delay vs. overdrive at V_{CC} = 5.0 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

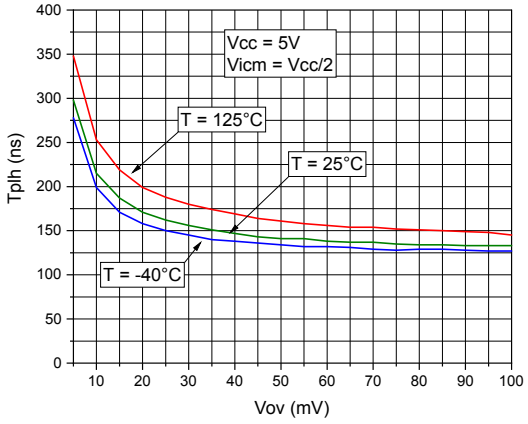


Figure 39. Low-to-high propagation delay vs. input common-mode voltage at V_{CC} = 1.8 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

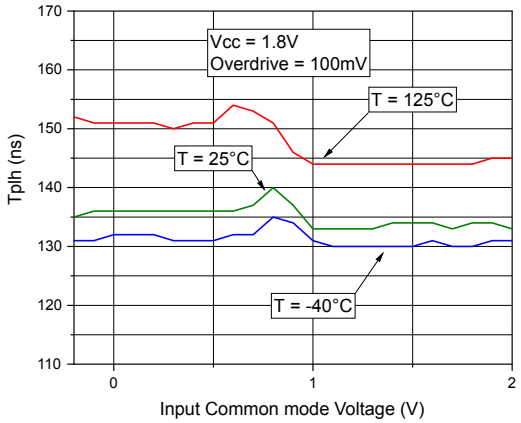


Figure 40. Low-to-high propagation delay vs. input common-mode voltage at V_{CC} = 3.3 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

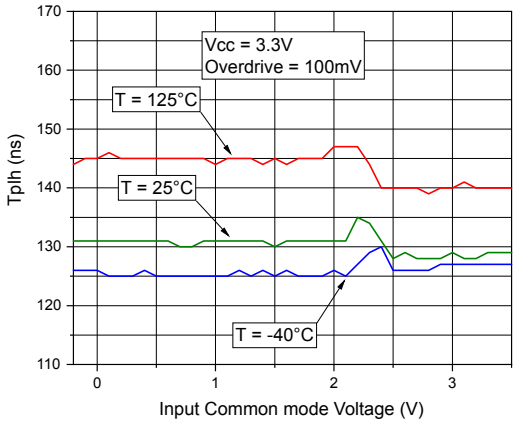


Figure 41. Low-to-high propagation delay vs. input common-mode voltage at V_{CC} = 5.0 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

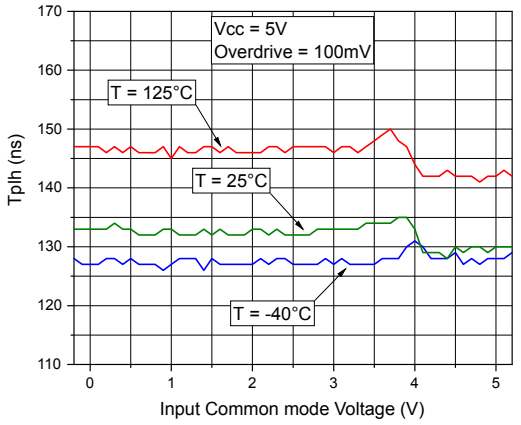


Figure 42. Low-to-high propagation delay vs. supply voltage at V_{icm} = V_{CC}/2, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

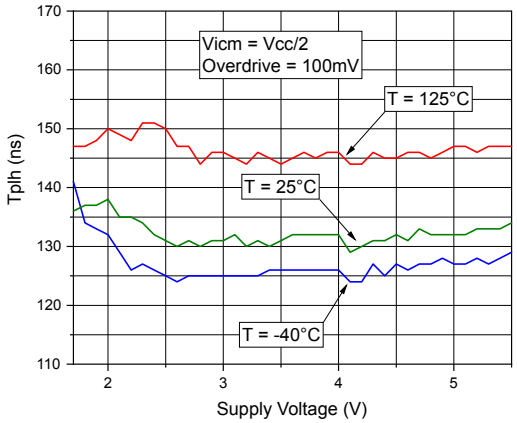


Figure 43. High-to-low propagation delay vs. input common-mode voltage at V_{CC} = 1.8 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

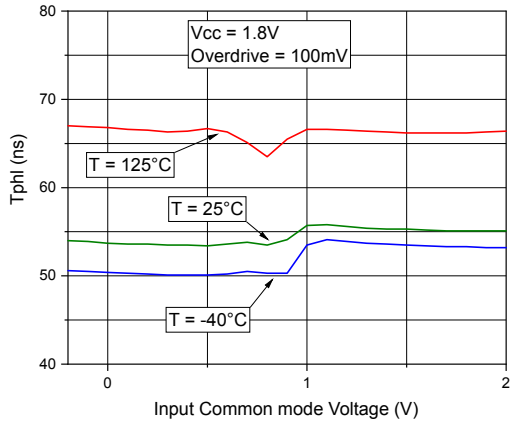


Figure 44. High-to-low propagation delay vs. input common-mode voltage at V_{CC} = 3.3 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

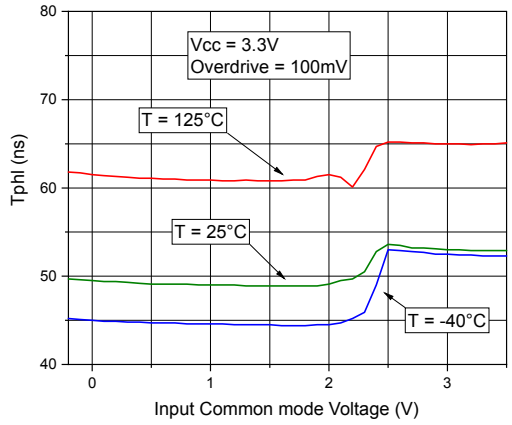


Figure 45. High-to-low propagation delay vs. input common-mode voltage at V_{CC} = 5.0 V, C_L = 15 pF, R_{PU} = 2.5 kΩ, V_{PU} = V_{CC}

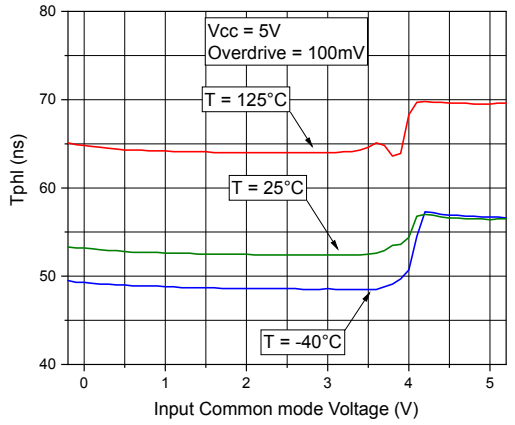
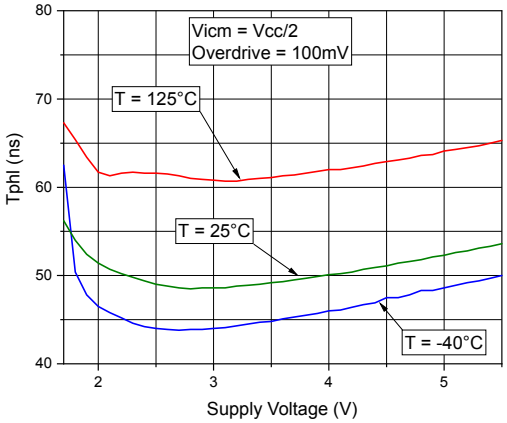


Figure 46. High-to-low propagation delay vs. supply voltage at $V_{icm} = V_{CC}/2$, $C_L = 15$ pF, $R_{PU} = 2.5$ kΩ, $V_{PU} = V_{CC}$

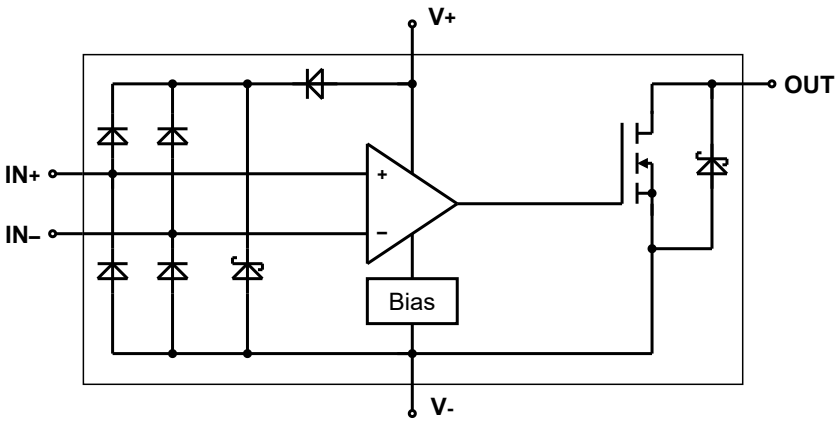


5 Application information

Overview

The TS3121 has an embedded fail-safe architecture. This feature allows power saving by dynamically turning on and off the comparator as needed during operation. Due to the fail-safe design, the input and output pins can stay biased while the power supply is disconnected (V_{CC} = 0 V). The open-drain output stage allows the comparator to be used in level shifting applications, where the output voltage range is independent from the supply.

Figure 47. Functional block diagram



Operating voltages

The TS3121 can operate from 1.7 V to 5.5 V and parameters are fully specified at 1.8 V, 3.3 V, and 5 V. The specifications are guaranteed in the extended temperature range of -40 to +125 °C. The TS3121 features an open-drain output stage that is decoupled from V_{CC}. This allows output voltages from 0 V to 5.5 V, independent of V_{CC}. The rail-to-rail input stage is also decoupled from V_{CC}, allowing the comparator to sustain input common-mode voltages from 0 V to 5.5 V and independent of V_{CC}.

Input offset voltage drift versus temperature

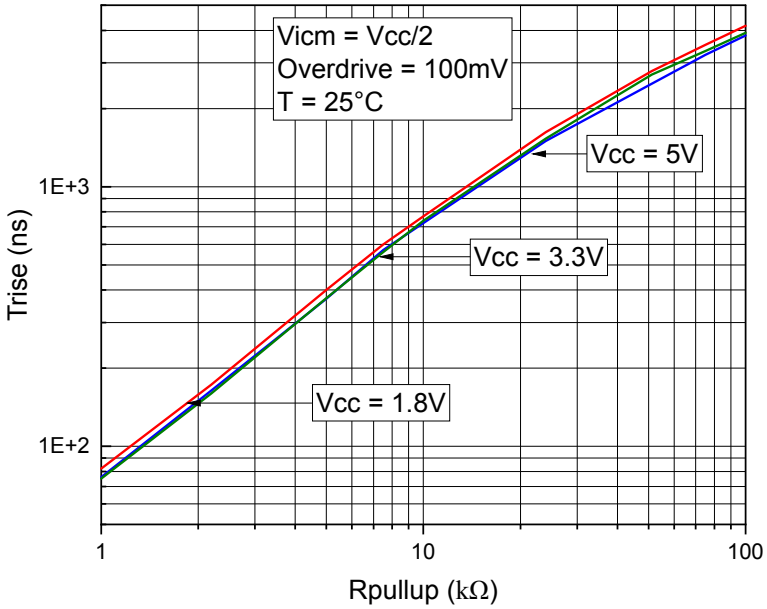
The input voltage drift variation versus temperature is defined as the offset variation related to the offset value measured at 25 °C. The signal chain accuracy at 25 °C can be compensated during the production at the application level. The maximum input voltage drift over the temperature enables the system designer to anticipate the effect of temperature variations.

$$\frac{\Delta V_{io}}{\Delta V} = \max\left|\frac{V_{io}(T) - V_{io}(25°C)}{T - 25°C}\right| \quad (1)$$

Where T = -40 °C and +125 °C. The datasheet maximum value is guaranteed by a measurement on a representative sample size ensuring a Cpk (process capability index) greater than 1.3. The datasheet reports the absolute worst-case value between -40 °C and +125 °C.

Resistor values for high-speed design

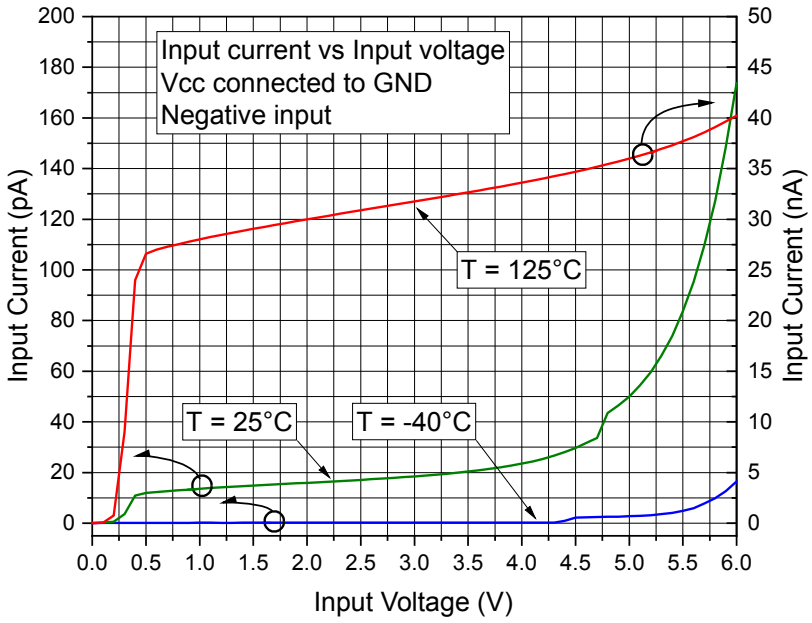
Figure 48. **Rise time vs. pull-up resistor**



Fail-safe characteristic

The TS3121 features a fail-safe characteristic. When the comparator is not powered on (V_{CC} = 0 V), the fail-safe design allows bias voltages on the input and output pins. The following graph shows the characteristic of bias current versus voltage for the input pins when V_{CC} = 0 V.

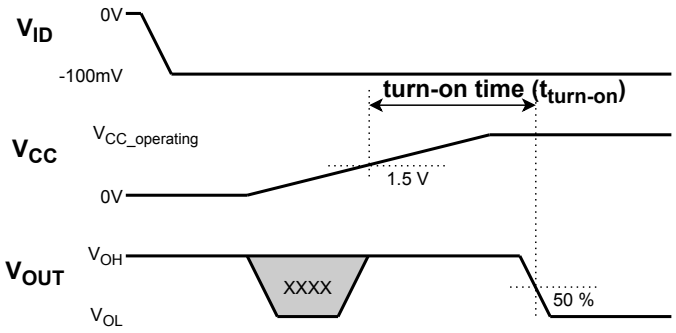
Figure 49. **Fail-safe bias current vs. voltage**



Guaranteed turn-on time

The TS3121 is tested in production for a guaranteed start-up time. Once the supply voltage crosses the minimum value of $V_{CC\_min\_operating}$ = 1.7 V, the output voltage is settled in a stable condition within a maximum delay of $t_{turn\text{-}on}$ = 15 µs. For low power applications, the supply voltage of the TS3121 can be disconnected when the device is not in use. During shutdown (V_{CC} = 0 V), because of its fail-safe structure, the input and output pins can stay biased. In applications with switched Vcc, care should be taken to keep the Vcc ramp-up below 0.5 V/µs to prevent false triggering of the integrated ESD protection circuit.

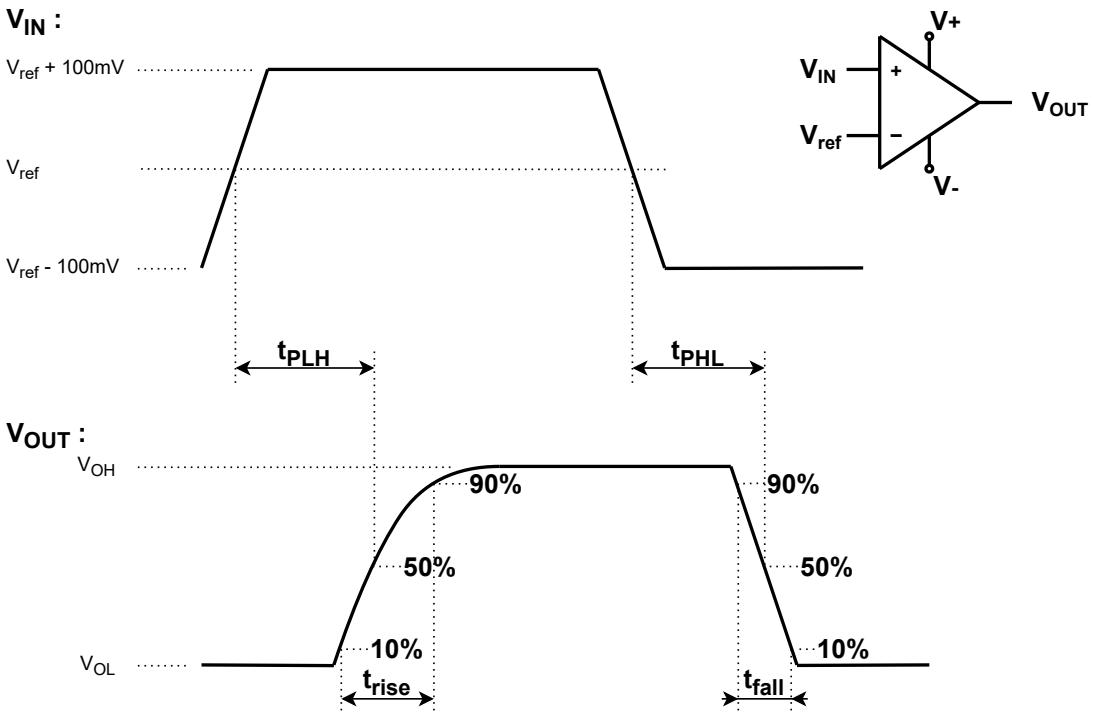
Figure 50. Turn-on timing diagram



Propagation delay

There is a delay between when the input crosses the reference voltage and the output responds. This is called the propagation delay. Propagation delay can be different between high-to-low and low-to-high input transitions. This is shown as t_{PLH} and t_{PHL} in Figure 51 and is measured from the mid-point of the input to the midpoint of the output. Note that for open-drain comparators, the output rise time t_{rise} and t_{PLH} strongly depend on the pull-up circuit connected to the output pin.

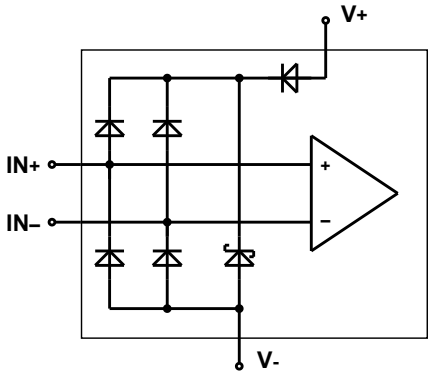
Figure 51. Propagation delay



Input stage

The input stage has a fail-safe architecture, effectively allowing bias voltages higher than V_{CC}. This is especially useful if the comparator is disconnected from the power supply (V_{CC} = 0 V). Care must be taken when V_{IN} exceeds V_{CC}. Keep slew rates below 0.5 V/µs to prevent false triggering of the ESD clamp.

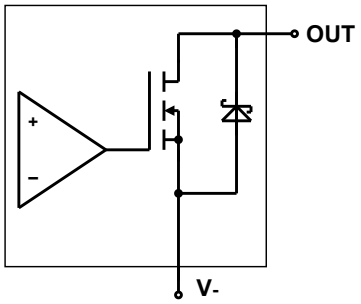
Figure 52. Input stage



Output stage

With a dedicated ESD clamp in the open-drain output stage, voltage levels higher than V_{CC} can be applied to the comparator output. The TS3121 can thus be used for level shifter applications where the output voltage is independent of the comparator supply voltage.

Figure 53. Output stage



PCB layout recommendations

Particular attention must be paid to the layout of the PCB tracks connected to the comparator, load, and power supply. The power and ground traces are critical as they must provide adequate energy and grounding for all circuits. The best practice is to use short and wide PCB traces to minimize voltage drops and parasitic inductance. In addition to minimizing parasitic impedance over the entire surface, a multi-via technique that connects the bottom and top layer ground planes together in many locations is often used. The copper traces that connect the output pins to the load and supply pins should be as wide as possible to minimize trace impedance.

Decoupling capacitor

To ensure op amp full functionality, it is recommended to place two decoupling capacitors of 100 nF and 10 nF as close as possible to the comparator supply pins. A good decoupling helps to reduce electromagnetic interference impact.

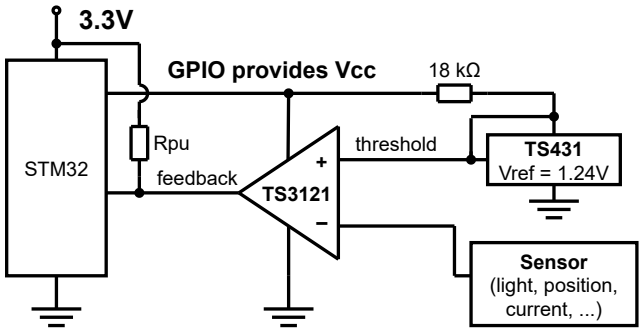
6 Typical applications

Low-power signal conditioning

The TS3121 is a key circuit element for signal conditioning with fast response time in a low-power environment. It was designed for regular turning on and off of the supply line. For this reason the TS3121 comes with fail-safe input and output pins that allow the presence of voltage when the comparator is not supplied (V_{CC} = 0 V).

Figure 54 shows a typical sensor conditioning application. The sensor signal can come from various sources, for example: light, position, current, or temperature monitoring. The supply for the reference voltage TS431 and for the comparator are provided by the GPIO pin of a microcontroller which is activated during 100 µs every 100 ms. This duty cycle effectively divides the overall power consumption by a factor of thousand from typically 60 µA to only 60 nA and hence considerably below the consumption of a low-power comparator. The pull-up resistor is connected to the supply of the microcontroller. In the displayed application the feedback signal is HIGH for V_{CC} = 0 V or for a sensor signal inferior to the reference voltage. The feedback signal is LOW when the sensor signal is higher than the reference voltage and after a maximum delay of $t_{turn-on}$ = 15 µs from the moment where V_{CC} passes V_{CC-min}. An embedded hysteresis of 1 mV prevents the comparator from instable toggling during the transition phase when the sensor voltage and reference voltage are equivalent (V_{diff} = V_{io}).

Figure 54. Typical application schematic



7 Package information

To meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions, and product status are available at: www.st.com. ECOPACK is an ST trademark.

7.1 SC70-5 (or SOT323-5) package information

Figure 55. SC70-5 (or SOT323-5) package outline

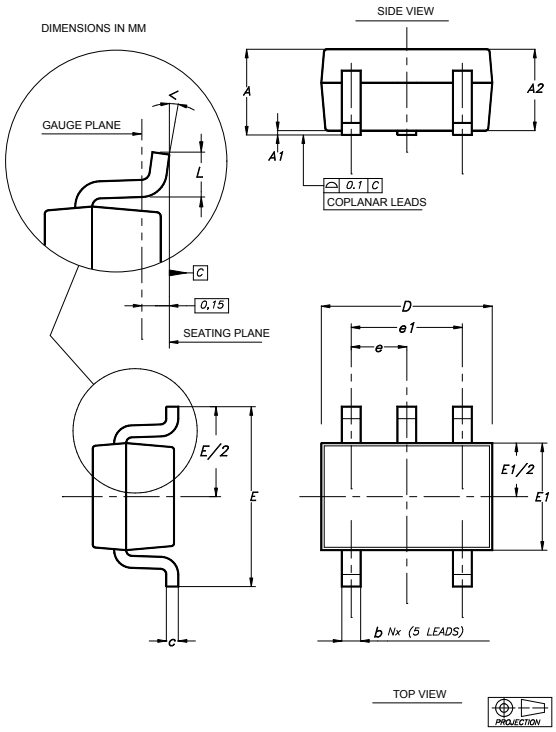


Table 7. SC70-5 (or SOT323-5) package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.80		1.10	0.032		0.043
A1			0.10			0.004
A2	0.80	0.90	1.00	0.032	0.035	0.039
b	0.15		0.30	0.006		0.012
c	0.10		0.22	0.004		0.009
D	1.80	2.00	2.20	0.071	0.079	0.087
E	1.80	2.10	2.40	0.071	0.083	0.094
E1	1.15	1.25	1.35	0.045	0.049	0.053
e		0.65			0.025	
e1		1.30			0.051	
L	0.26	0.36	0.46	0.010	0.014	0.018
<	0°		8°	0°		8°

7.2 SOT23-5 package information

Figure 56. **SOT23-5 package outline**

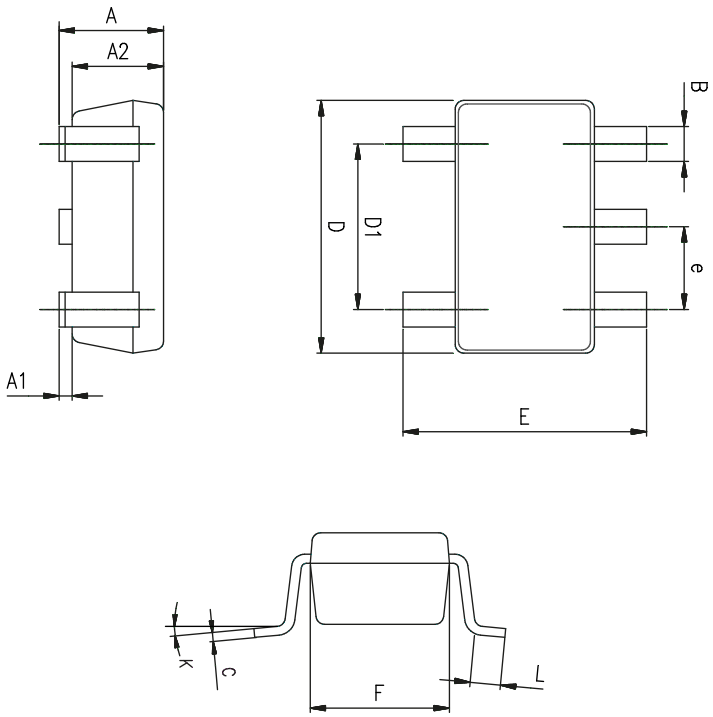


Table 8. **SOT23-5 mechanical data**

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90	1.20	1.45	0.035	0.047	0.057
A1			0.15			0.006
A2	0.90	1.05	1.30	0.035	0.041	0.051
B	0.35	0.40	0.50	0.014	0.016	0.020
C	0.09	0.15	0.20	0.004	0.006	0.008
D	2.80	2.90	3.00	0.110	0.114	0.118
D1		1.90			0.075	
e		0.95			0.037	
E	2.60	2.80	3.00	0.102	0.110	0.118
F	1.50	1.60	1.75	0.059	0.063	0.069
L	0.10	0.35	0.60	0.004	0.014	0.024
K	0 degrees		10 degrees	0 degrees		10 degrees

8 Ordering information

Table 9. Order code

Order code	Package	Packaging	Marking
TS3121ICT	SC70-5	Tape and reel	K5T
TS3121AICT			K5U
TS3121IYCT (1)			K5V
TS3121AIYCT (1)			K5W
TS3121ILT	SOT23-5		K5T
TS3121AILT			K5U
TS3121IYLT (1)			K5V
TS3121AIYLT (1)			K5W

1. *Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q002 or equivalent.*

Revision history

Table 10. **Document revision history**

Date	Revision	Changes
31-Jul-2024	1	Initial release.
14-Nov-2024	2	Updated description on the cover page.

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