Description

The TSV639x series of dual and quad operational amplifiers (op amps) offers low voltage operation and rail-to-rail input and output.

For applications configured with gain, the TSV639x series offers an excellent speed/power consumption ratio, 2.4 MHz gain bandwidth product while consuming only 60 µA at 5 V. The devices also feature an ultra-low input bias current and have a shutdown mode (TSV6393, TSV6395).

These features make the TSV639x family ideal for sensor interfaces, battery supplied and portable applications, as well as active filtering.

Features

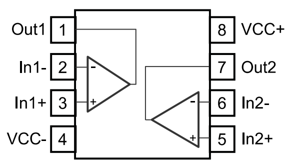
- Rail-to-rail input and output
- Low-power consumption: 60 µA typ at 5 V
- Low supply voltage: 1.5 V - 5.5 V
- Gain bandwidth product: 2.4 MHz typ, stable for gain equal or above -3 or 4
- Low-power shutdown mode: 5 nA typ
- Low offset voltage: 800 µV max (A version)
- Low input bias current: 1 pA typ
- EMI hardened operational amplifiers
- High tolerance to ESD: 4 kV HBM
- Extended temperature range: -40 °C to 125 °C

Applications

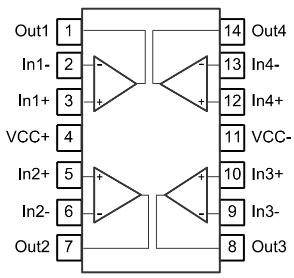
- Battery-powered applications
- Portable devices
- Signal conditioning
- Active filtering
- Medical instrumentation

Package pin connections

Figure 1: Pin connections for each package (top view)



TSV6392IDT/AIDT
SOP-8



TSV6394IPT/AIPT
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Absolute maximum ratings and operating conditions

Table 2: Absolute maximum ratings (AMR)

Symbol	Parameter		Value	Unit
V_{CC}	Supply voltage [(1)]		6	V
V_{id}	Differential input voltage [(2)]		$\pm V_{CC}$	
V_{in}	Input voltage [(3)]		$(V_{CC}^-) - 0.2$ to $(V_{CC}^+) + 0.2$	
I_{in}	Input current [(4)]		10	mA
$\overline{SHDN}$	Shutdown voltage [(3)]		$(V_{CC}^-) - 0.2$ to $(V_{CC}^+) + 0.2$	V
T_{stg}	Storage temperature		-65 to 150	°C
T_j	Maximum junction temperature		150	
R_{thja}	Thermal resistance junction to ambient [(5)(6)]	SOP-8	125	°C/W
		TSSOP14	100	
ESD	HBM: human body model [(7)]		4	kV
	MM: machine model [(8)]		300	V
	CDM: charged device model [(9)]		1.5	kV
	Latch-up immunity		200	mA

Notes:

(1) All voltage values, except the differential voltage are with respect to the network ground terminal.

(2) Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.

(3) V_{CC} - V_{in} must not exceed 6 V, V_{in} must not exceed 6 V.

(4) The input current must be limited by a resistor in-series with the inputs.

(5) R_{th} are typical values.

(6) Short-circuits can cause excessive heating and destructive dissipation.

(7) Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.

(8) Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω), done for all couples of pin combinations with other pins floating.

(9) Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

Table 3: Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	1.5 to 5.5	V
V_{icm}	Common-mode input voltage range	$(V_{CC}^-) - 0.1$ to $(V_{CC}^+) + 0.1$	
T_{oper}	Operating free-air temperature range	-40 to 125	°C

Electrical characteristics

Table 4: Electrical characteristics at VCC+ = 1.8 V with VCC- = 0 V, Vicm = VCC/2, Tamb = 25 °C, and RL connected to VCC/2 (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
		DC performance				
V_{io}	Offset voltage	TSV639x			3	mV
		TSV639xA			0.8	
		$T_{min} < T_{op} < T_{max}$, TSV639x			4.5	
		$T_{min} < T_{op} < T_{max}$, TSV639xA			2	
DV_{io}	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current, $V_{out} = V_{CC}/2$			1	10 (1)	pA
		$T_{min} < T_{op} < T_{max}$		1	100	
I_{ib}	Input bias current, $V_{out} = V_{CC}/2$			1	10 (1)	
		$T_{min} < T_{op} < T_{max}$		1	100	
CMR	Common mode rejection ratio 20 log ($\Delta V_{ic}/\Delta V_{io}$)	0 V to 1.8 V, V_{out} = 0.9 V	53	74		dB
		$T_{min} < T_{op} < T_{max}$	51			
A_{vd}	Large signal voltage gain	R_L= 10 kΩ, V_{out} = 0.5 V to 1.3 V	85	95		
		$T_{min} < T_{op} < T_{max}$	80			
V_{OH}	High-level output voltage, $V_{OH} = V_{CC} - V_{out}$	R_L = 10 kΩ		5	35	mV
		R_L = 10 kΩ, $T_{min} < T_{op} < T_{max}$			50	
V_{OL}	Low-level output voltage	R_L = 10 kΩ		4	35	
		R_L = 10 kΩ, $T_{min} < T_{op} < T_{max}$			50	
I_{out}	I_{sink}	V_o = 1.8 V	6	12		mA
		$T_{min} < T_{op} < T_{max}$	4			
	I_{source}	V_o = 0 V	6	10		
		$T_{min} < T_{op} < T_{max}$	4			
I_{CC}	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$	40	50	60	µA
		$T_{min} < T_{op} < T_{max}$			62	
		AC performance				
GBP	Gain bandwidth product	R_L = 10 kΩ, C_L = 100 pF		2		MHz
Gain	Minimum gain for stability	Phase margin = 60 °, R_f = 10 kΩ, R_L = 10 kΩ, C_L = 20 pF		4		V/V
				-3		
SR	Slew rate	R_L = 10 kΩ, C_L = 100 pF, V_{out} = 0.5 V to 1.3 V		0.7		V/µs
e_n	Equivalent input noise voltage	f = 1 kHz		60		nV/√Hz
		f = 10 kHz		33		

Table 5: Shutdown characteristics VCC = 1.8 V

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
I_{CC}	Supply current in shutdown mode (all operators)	$\overline{SHDN} = V_{CC}^-$		2.5	50	nA
		$T_{min} < T_{op} < 85$ °C			200	nA
		$T_{min} < T_{op} < 125$ °C			1.5	µA
t_{on}	Amplifier turn-on time	$R_L = 2$ kΩ, $V_{out} = (V_{CC}^-)$ to $(V_{CC}^-) + 0.2$ V		200		ns
t_{off}	Amplifier turn-off time	$R_L = 2$ kΩ, $V_{out} = (V_{CC}^+) - 0.5$ V to $(V_{CC}^+) - 0.7$ V		20		ns
V_{IH}	$\overline{SHDN}$ logic high		1.35			V
V_{IL}	$\overline{SHDN}$ logic low				0.6	V
I_{IH}	$\overline{SHDN}$ current high	$\overline{SHDN} = V_{CC}^+$		10		pA
I_{IL}	$\overline{SHDN}$ current low	$\overline{SHDN} = V_{CC}^-$		10		pA
I_{OLeak}	Output leakage in shutdown mode	$\overline{SHDN} = V_{CC}^-$		50		pA
		$T_{min} < T_{op} < 125$ °C		1		nA

Table 6: Electrical characteristics at VCC+ = 3.3 V, VCC- = 0 V, Vicm = VCC/2, Tamb = 25 °C, RL connected to VCC/2 (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Offset voltage	TSV639x			3	mV
		TSV639xA			0.8	
		$T_{min} < T_{op} < T_{max}$, TSV639x			4.5	
		$T_{min} < T_{op} < T_{max}$, TSV639xA			2	
DV_{io}	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current			1	10 (1)	pA
		$T_{min} < T_{op} < T_{max}$		1	100	
I_{ib}	Input bias current			1	10 (1)	
		$T_{min} < T_{op} < T_{max}$		1	100	
CMR	Common mode rejection ratio 20 log ($\Delta V_{ic}/\Delta V_{io}$)	0 V to 3.3 V, V_{out} = 1.65 V	57	79		dB
		$T_{min} < T_{op} < T_{max}$	53			
A_{vd}	Large signal voltage gain	R_L = 10 kΩ, V_{out} = 0.5 V to 2.8 V	88	98		
		$T_{min} < T_{op} < T_{max}$	83			
V_{OH}	High-level output voltage, $V_{OH} = V_{CC} - V_{out}$	R_L = 10 kΩ		6	35	mV
		R_L = 10 kΩ, $T_{mi.} < T_{op} < T_{max}$			50	
V_{OL}	Low-level output voltage	R_L = 10 kΩ		7	35	
		R_L = 10 kΩ, $T_{min} < T_{op} < T_{max}$			50	
I_{out}	I_{sink}	V_o = 3.3 V	23	45		mA
		$T_{min} < T_{op} < T_{max}$	20			
	I_{source}	V_o = 0 V	23	38		
		$T_{min} < T_{op} < T_{max}$	20			
I_{CC}	Supply current (per operator)	No load, V_{out} = 1.75 V	43	55	64	µA
		$T_{min} < T_{op} < T_{max}$			66	
AC performance						
GBP	Gain bandwidth product	R_L = 10 kΩ, C_L = 100 pF		2.2		MHz
Gain	Minimum gain for stability	Phase margin = 60 °, R_f = 10 kΩ, R_L = 10 kΩ, C_L = 20 pF		4		V/V
				-3		
SR	Slew rate	R_L = 10 kΩ, C_L = 100 pF, V_{out} = 0.5 V to 2.8 V		0.9		V/µs

Table 7: Electrical characteristics at VCC+ = 5 V with VCC- = 0 V, Vicm = VCC/2, Tamb = 25 °C, and RL connected to VCC/2 (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Offset voltages	TSV639x			3	mV
		TSV639xA			0.8	
		$T_{min} < T_{op} < T_{max}$, TSV639x			4.5	
		$T_{min} < T_{op} < T_{max}$, TSV639xA			2	
DV_{io}	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current, $V_{out} = V_{CC}/2$			1	10 (1)	pA
		$T_{min} < T_{op} < T_{max}$		1	100	
I_{ib}	Input bias current, $V_{out} = V_{CC}/2$			1	10 (1)	
		$T_{min} < T_{op} < T_{max}$		1	100	
CMR	Common mode rejection ratio 20 log ($\Delta V_{ic}/\Delta V_{io}$)	0 V to 5 V, V_{out} = 2.5 V	60	80		dB
		$T_{min} < T_{op} < T_{max}$	55			
SVR	Supply voltage rejection ratio 20 log ($\Delta V_{CC}/\Delta V_{io}$)	V_{CC} = 1.8 to 5 V	75	93		
		$T_{min} < T_{op} < T_{max}$	73			
A_{vd}	Large signal voltage gain	R_L = 10 kΩ, V_{out} = 0.5 V to 4.5 V	89	98		
		$T_{min} < T_{op} < T_{max}$	84			
EMIRR	EMI rejection ratio, EMIRR = -20 log ($V_{RFpeak}/\Delta V_{io}$)	V_{RF} = 100 mV_{rms} , f = 400 MHz		61		
		V_{RF} = 100 mV_{rms} , f = 900 MHz		85		
		V_{RF} = 100 mV_{rms} , f = 1800 MHz		92		
		V_{RF} = 100 mV_{rms} , f = 2400 MHz		83		
V_{OH}	High-level output voltage, $V_{OH} = V_{CC} - V_{out}$	R_L = 10 kΩ		7	35	mV
		R_L = 10 kΩ, $T_{min} < T_{op} < T_{max}$			50	
V_{OL}	Low-level output voltage	R_L = 10 kΩ		6	35	
		R_L = 10 kΩ, $T_{min} < T_{op} < T_{max}$			50	
I_{out}	I_{sink}	V_o = 5 V	40	65		mA
		$T_{min} < T_{op} < T_{max}$	35			
	I_{source}	V_o = 0 V	40	72		
		$T_{min} < T_{op} < T_{max}$	35			
I_{CC}	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$	50	60	69	µA
		$T_{min} < T_{op} < T_{max}$			72	
AC performance						
GBP	Gain bandwidth product	R_L = 10 kΩ, C_L = 100 pF		2.4		MHz
Gain	Minimum gain for stability	Phase margin = 60 °, R_f = 10 kΩ, R_L = 10 kΩ, C_L = 20 pF,		4		V/V
				-3		
SR	Slew rate	R_L = 10 kΩ, C_L = 100 pF		1.1		V/µs

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
e_n	Equivalent input noise voltage	f = 1 kHz		60		nV/√Hz
		f = 10 kHz		33		
THD+N	Total harmonic distortion + noise	V_{CC} = 5 V, f_{in} = 1 kHz, A_{CL} = -10, R_L = 100 kΩ, V_{icm} = V_{CC}/2, BW = 22 kHz, V_{out} = 1 V_{rms}		0.015		%

Table 8: Shutdown characteristics at VCC = 5 V

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
I_{CC}	Supply current in shutdown mode (all operators)	$\overline{SHDN}$ = V_{CC}^-		5	50	nA
		T_{min} < T_{op} < 85 °C			200	
		T_{min} < T_{op} < 125 °C			1.5	µA
t_{on}	Amplifier turn-on time	R_L = 2 kΩ, V_{out} = (V_{CC}^-) V to (V_{CC}^-) + 0.2 V		200		ns
t_{off}	Amplifier turn-off time	R_L = 2 kΩ, V_{out} = (V_{CC}^+) - 0.5 V to (V_{CC}^+) - 0.7 V		20		
V_{IH}	$\overline{SHDN}$ logic high		2			V
V_{IL}	$\overline{SHDN}$ logic low				0.8	V
I_{IH}	$\overline{SHDN}$ current high	$\overline{SHDN}$ = V_{CC}^+		10		pA
I_{IL}	$\overline{SHDN}$ current low	$\overline{SHDN}$ = V_{CC}^-		10		
I_{OLeak}	Output leakage in shutdown mode	$\overline{SHDN}$ = V_{CC}^-		50		
		T_{min} < T_{op} < 125 °C		1		nA

Electrical characteristic curves

Figure 2: Supply current vs. supply voltage at Vicm = VCC/2

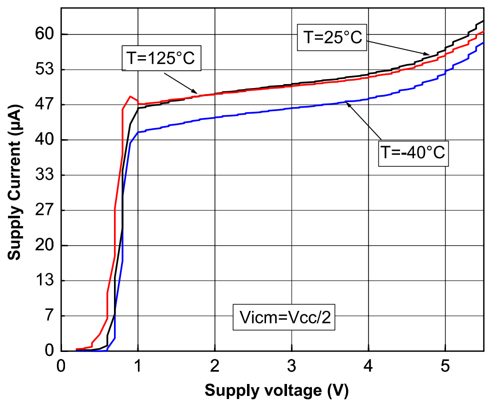


Figure 3: Output current vs. output voltage at VCC = 1.5 V

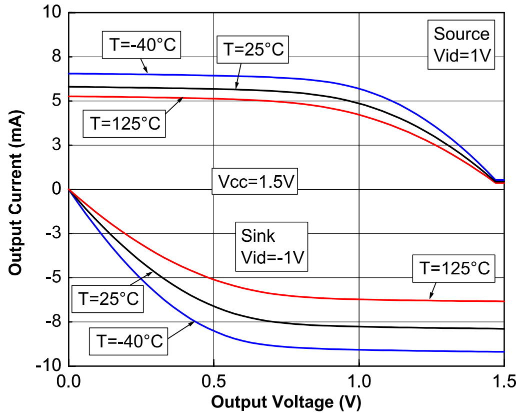


Figure 4: Output current vs. output voltage at VCC = 5 V

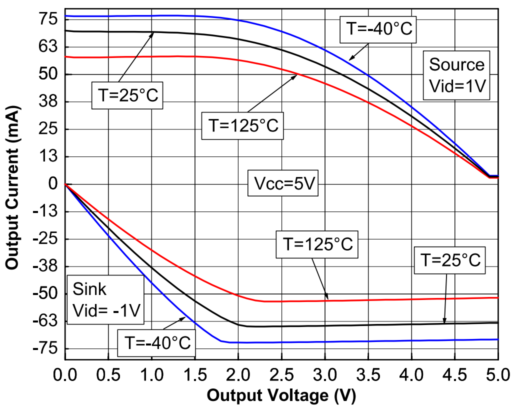


Figure 5: Closed loop response for gain = -10, at VCC = 1.5 V and VCC = 5 V

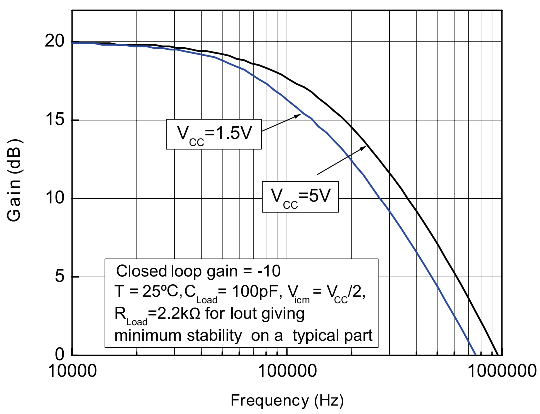


Figure 6: Closed loop response for gain = -3 at VCC = 1.5 V

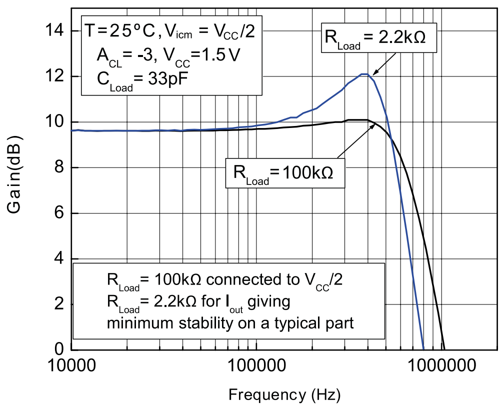


Figure 7: Closed loop response for gain = -3 at VCC = 5 V

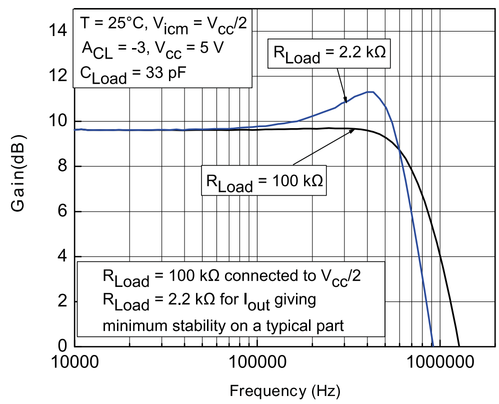


Figure 8: Positive slew rate vs. supply voltage in closed loop

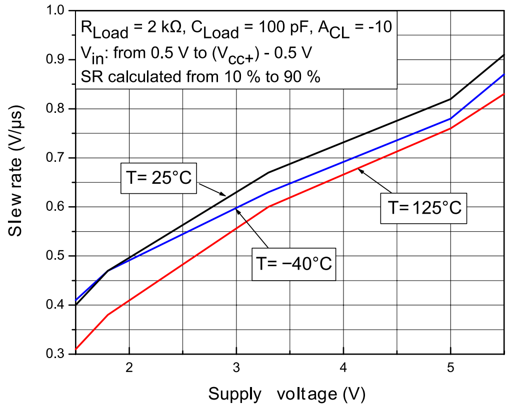


Figure 9: Negative slew rate vs. supply voltage in closed loop

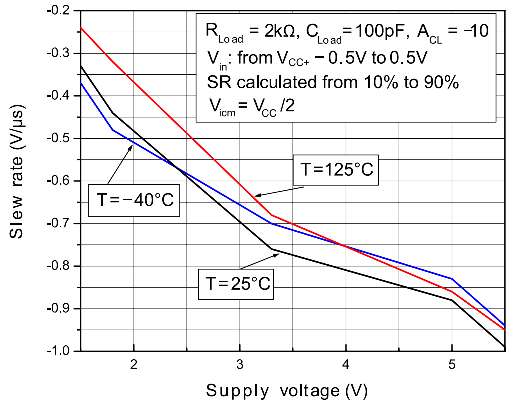


Figure 10: Slew rate vs. supply voltage in open loop

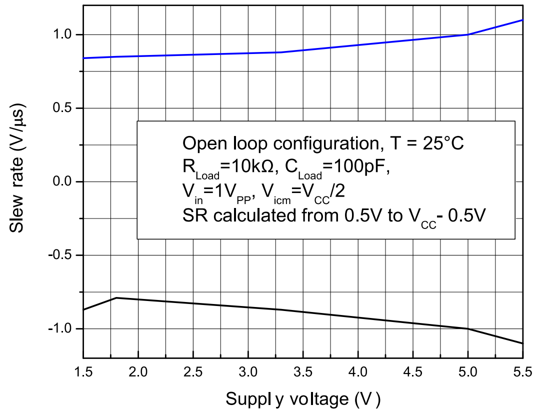


Figure 11: Slew rate timing in open loop

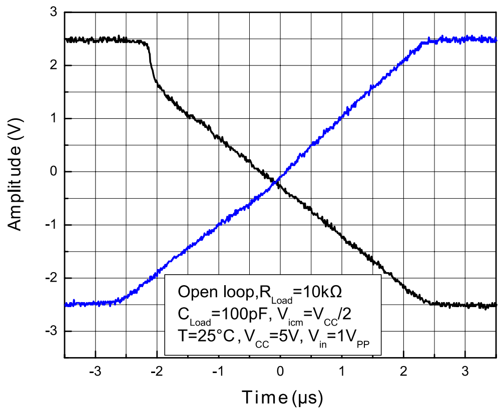


Figure 12: Slew rate timing in closed loop

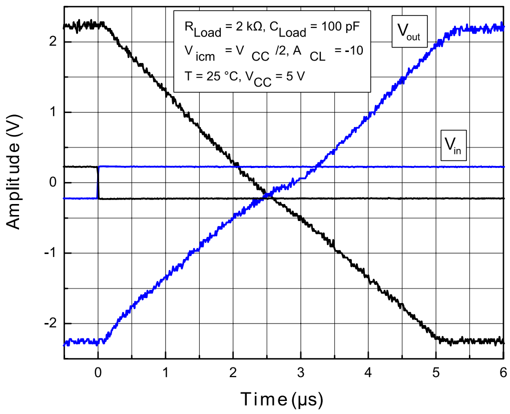


Figure 13: Noise vs. frequency

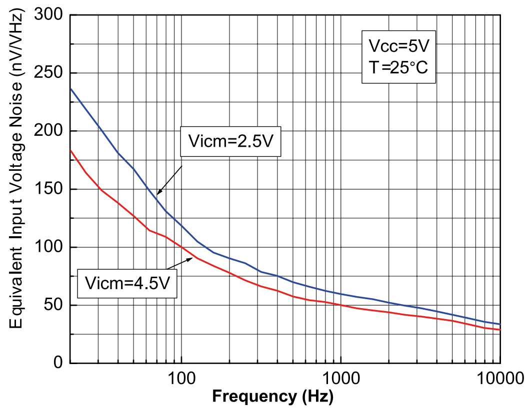


Figure 14: Distortion and noise vs. output voltage at VCC = 1.8 V

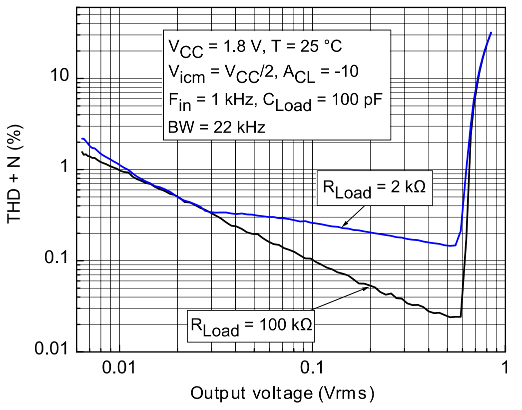


Figure 15: Distortion and noise vs. frequency at VCC = 1.8 V

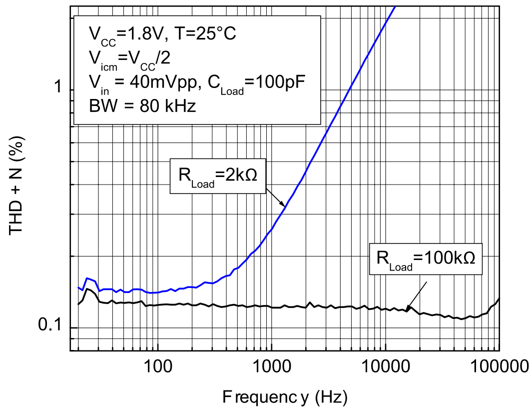


Figure 16: Distortion and noise vs. output voltage at VCC = 5 V

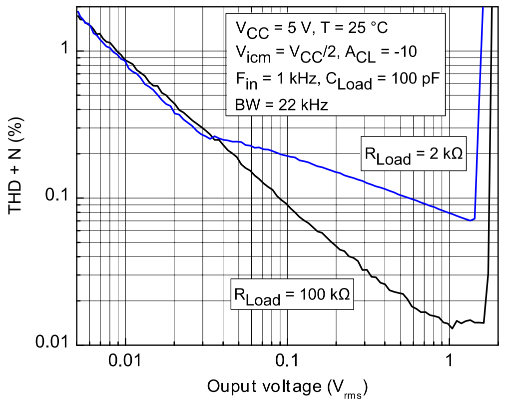


Figure 17: Distortion and noise vs. frequency at VCC = 5 V

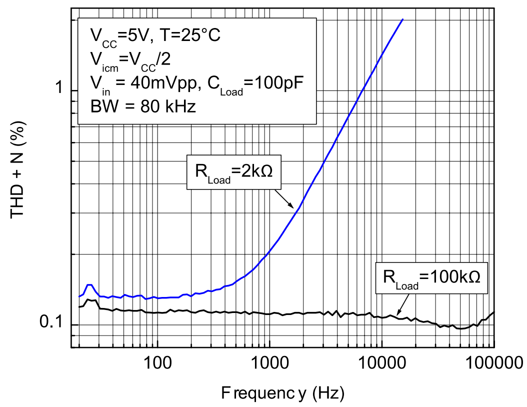


Figure 18: EMIRR vs. frequency at VCC = 5 V, T = 25 °C

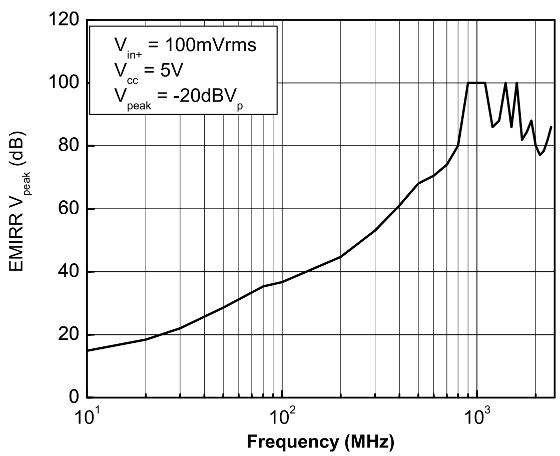


Figure 19: Input offset voltage vs input common-mode at VCC = 1.5 V

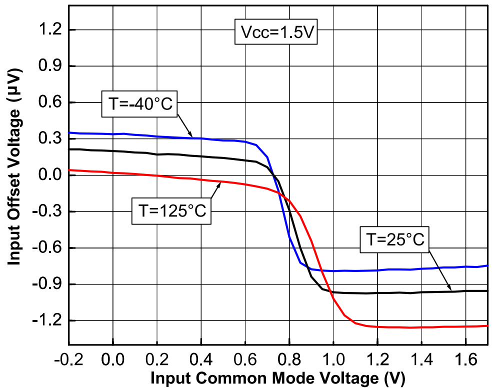


Figure 20: Input offset voltage vs input common-mode at VCC = 5 V

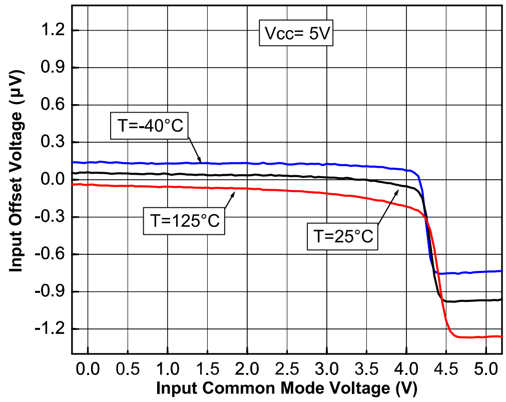


Figure 21: Test configuration for turn-on time (Vout pulled down)

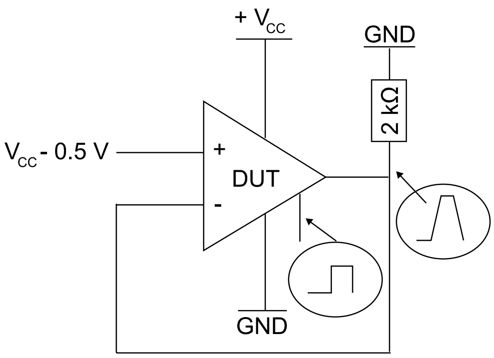


Figure 22: Test configuration for turn-off time (Vout pulled down)

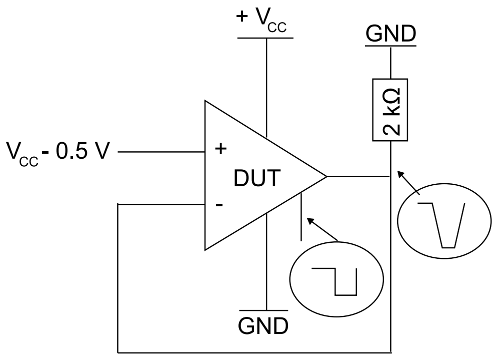


Figure 23: Turn-on time, VCC = 5 V, Vout pulled down, T = 25 °C

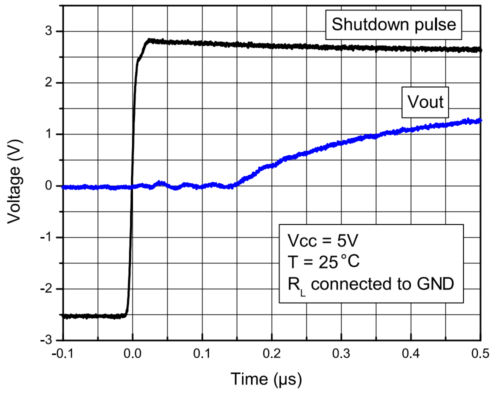
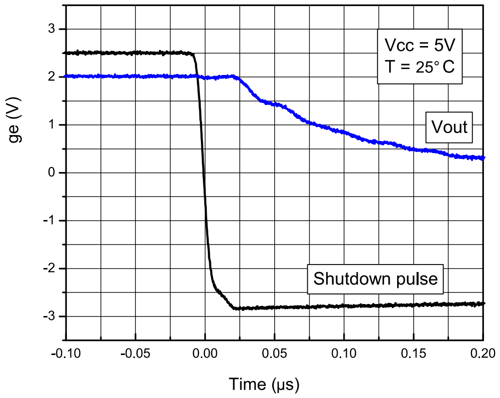


Figure 24: Turn-off time, VCC = 5 V, Vout pulled down, T = 25 °C



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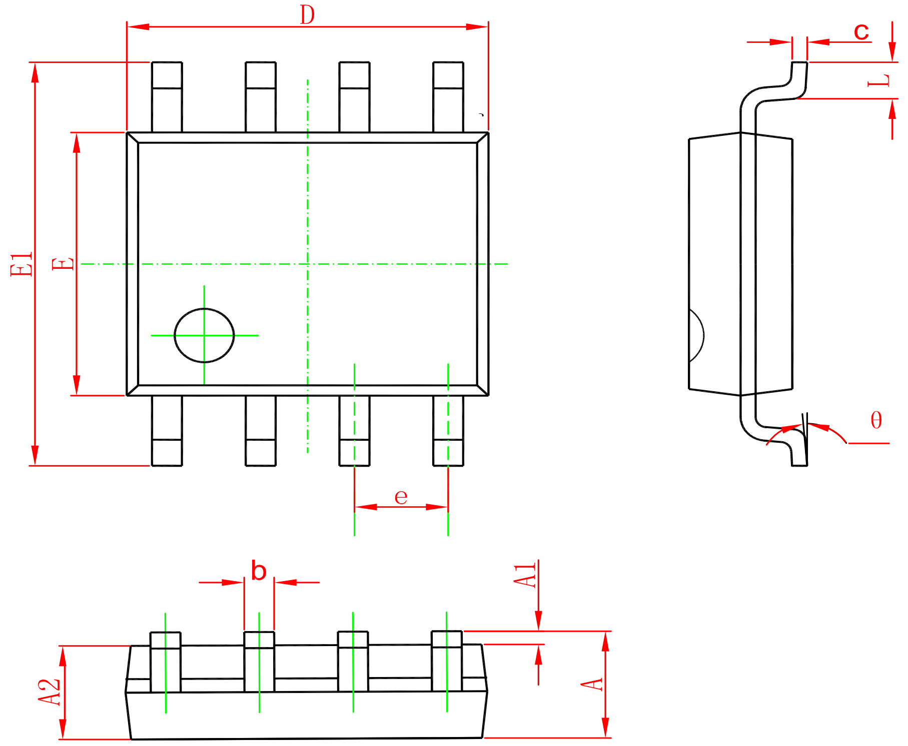
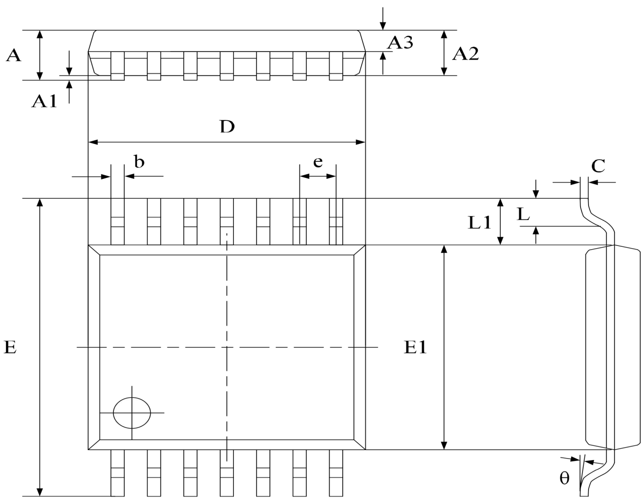


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

TSSOP-14



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	-	1.200	-	0.0472
A1	0.050	0.150	0.002	0.006
A2	0.900	1.050	0.037	0.043
A3	0.390	0.490	0.016	0.020
b	0.200	0.290	0.008	0.012
C	0.130	0.180	0.005	0.007
D	4.860	5.060	0.198	0.207
E	6.200	6.600	0.253	0.269
E1	4.300	4.500	0.176	0.184
e	0.650 typ.		0.0256 typ.	
L1	1.000 ref.		0.0393 ref.	
L	0.450	0.750	0.018	0.031
θ	0°	8°	0°	8°

Ordering information

Order code	Package	Baseqty	Deliverymode	Marking
UMW TSV6392AIDT	SOP-8	2500	Tape and reel	V632AI
UMW TSV6392IDT	SOP-8	2500	Tape and reel	V6392I
UMW TSV6394IPT	TSSOP-14	4000	Tape and reel	TSV6394
UMW TSV6394AIPT	TSSOP-14	4000	Tape and reel	TSV6394