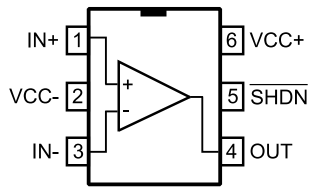
Micropower (60 µA), wide bandwidth (2.4 MHz) CMOS operational amplifiers

Description

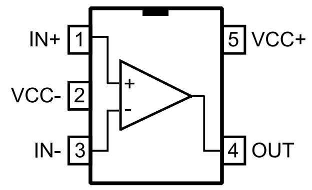
The TSV6390, TSV6391, and their "A" versions are single operational amplifiers (op amps) offering low voltage, low power operation, and rail-to-rail input and output.

With a very low input bias current and low offset voltage (500 µV maximum for the A version), the TSV6390 and TSV6391 are ideal for applications requiring precision. The devices can operate at power supplies ranging from 1.5 to 5.5 V, and are therefore ideal for battery-powered devices, extending battery life.

When used with a gain (above -3 or 4), these products feature an excellent speed/power consumption ratio, offering a 2.4 MHz gain bandwidth product while consuming only 60 µA at a 5 V supply voltage.



TSV6390ICT/ILT
SC70-6/SOT23-6



TSV6391ICT/ILT
SC70-5/SOT23-5

Features

- Low offset voltage: 500 µV max (A version)
- Low power consumption: 60 µA typ at 5 V
- Low supply voltage: 1.5 V – 5.5 V
- Gain bandwidth product: 2.4 MHz typical
- Stable in gain configuration (-3 or 4)
- Low power shutdown mode: 5 nA typical
- High output current: 63 mA at V_{CC} = 5 V
- Low input bias current: 1 pA typical
- Rail-to-rail input and output
- Extended temperature range: -40 °C to 125 °C
- 4 kV human body model

Applications

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

Absolute maximum ratings and operating conditions

Table 1: 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)	SC70-6	232	°C/W
		SOT23-6	240	
		SC70-5	205	
		SOT23-5	250	
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 network ground terminal.

(2)The differential voltage is 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)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 2: 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 3: 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	TSV6390 and TSV6391			3	mV
		TSV6390A and TSV6391A			0.5	
		$T_{min} < T_{op} < T_{max}$, TSV6390 and TSV6391			4.5	
		$T_{min} < T_{op} < T_{max}$, TSV6390A and TSV6391A			2	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current, $V_{out} = V_{CC}/2$ (1)			1	10	pA
		$T_{min} < T_{op} < T_{max}$		1	100	
I_{ib}	Input bias current, ($V_{out} = V_{CC}/2$) (1)			1	10	
		$T_{min} < T_{op} < T_{max}$		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	R_L = 10 kΩ		5	35	mV
		$T_{min} < T_{op} < T_{max}$			50	
V_{OL}	Low-level output voltage	R_L = 10 kΩ		4	35	
		$T_{min} < T_{op} < T_{max}$			50	
I_{out}	I_{sink}	V_{out} = 1.8 V	6	12		mA
		$T_{min} < T_{op} < T_{max}$	4			
	I_{source}	V_{out} = 0 V	6	10		
		$T_{min} < T_{op} < T_{max}$	4			
I_{CC}	Supply current, $\overline{SHDN} = V_{CC}$	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 4: Shutdown characteristics VCC = 1.8 V (TSV6390)

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		300		ns
t_{off}	Amplifier turn-off time	R_L = 2 kΩ, Vout = (V_{CC+}) - 0.5 V to (V_{CC+}) - 0.7 V		20		ns
V_{IH}	$\overline{SHDN}$ logic high		1.3			V
V_{IL}	$\overline{SHDN}$ logic low				0.5	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
		$T_{min} < T_{op} < T_{max}$		1		nA

Table 5: 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	TSV6390 and TSV6391			3	mV
		TSV6390A and TSV6391A			0.5	
		$T_{min} < T_{op} < T_{max}$, TSV6390 and TSV6391			4.5	
		$T_{min} < T_{op} < T_{max}$, TSV6390A and TSV6391A			2	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current (1)			1	10	pA
		$T_{min} < T_{op} < T_{max}$		1	100	
I_{ib}	Input bias current (1)			1	10	
		$T_{min} < T_{op} < T_{max}$		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	R_L = 10 kΩ		6	35	mV
		$T_{min.} < T_{op} < T_{max}$			50	
V_{OL}	Low-level output voltage	R_L = 10 kΩ		7	35	
		$T_{min} < T_{op} < T_{max}$			50	
I_{out}	I_{sink}	V_{out} = 3.3 V	23	45		mA
		$T_{min} < T_{op} < T_{max}$	20	42		
	I_{source}	V_{out} = 0 V	23	38		
		$T_{min} < T_{op} < T_{max}$	20			
I_{CC}	Supply current, $\overline{SHDN} = V_{CC}$	No load, $V_{out} = V_{CC}/2$	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
e_n	Equivalent input noise voltage	f = 1 kHz		65		nV/√Hz

Table 6: 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 voltage	TSV6390 and TSV6391			3	mV
		TSV6390A and TSV6391A			0.5	
		$T_{min} < T_{op} < T_{max}$, TSV6390 and TSV6391			4.5	
		$T_{min} < T_{op} < T_{max}$, TSV6390A and TSV6391A			2	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current, $V_{out} = V_{CC}/2$ (1)			1	10	pA
		$T_{min} < T_{op} < T_{max}$		1	100	
I_{ib}	Input bias current, $V_{out} = V_{CC}/2$ (1)			1	10	
		$T_{min} < T_{op} < T_{max}$		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			
V_{OH}	High-level output voltage	R_L = 10 kΩ		7	35	mV
		$T_{min} < T_{op} < T_{max}$			50	
V_{OL}	Low-level output voltage	R_L = 10 kΩ		6	35	
		$T_{min} < T_{op} < T_{max}$			50	
I_{out}	I_{sink}	V_{out} = 5 V	40	65		mA
		$T_{min} < T_{op} < T_{max}$	35			
	I_{source}	V_{out} = 0 V	40	72		
		$T_{min} < T_{op} < T_{max}$	35			
I_{CC}	Supply current, $\overline{SHDN} = V_{CC}$	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
e_n	Equivalent input noise voltage	f = 1 kHz		60		nV/√Hz
		f = 10 kHz		33		
THD+N	Total harmonic distortion + noise	Av = -10, f_{in} = 1 kHz, R = 100 kΩ, V_{icm} = Vcc/2, V_{in} = 40 mVpp		0.11		%

Table 7: Shutdown characteristics VCC = 5 V (TSV6390)

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	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		300		ns
t_{off}	Amplifier turn-off time	$R_L = 2$ kΩ, Vout = $(V_{CC+}) - 0.5$ V to $(V_{CC+}) - 0.7$ V		30		ns
V_{IH}	$\overline{SHDN}$ logic high		4.5			V
V_{IL}	$\overline{SHDN}$ logic low				0.5	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
		$T_{min} < T_{op} < T_{max}$		1		nA

Electrical characteristics curves

Figure 1: Supply current vs. supply voltage at Vicm = VCC/2

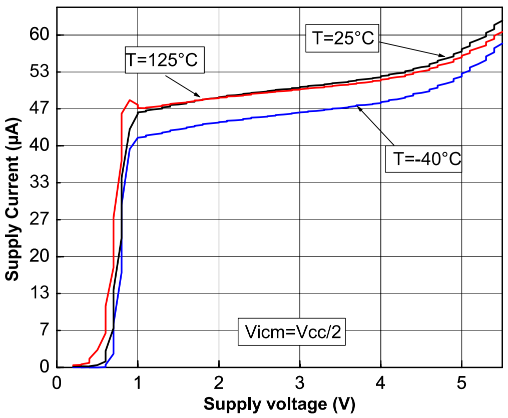


Figure 2: Output current vs. output voltage at VCC = 1.5 V

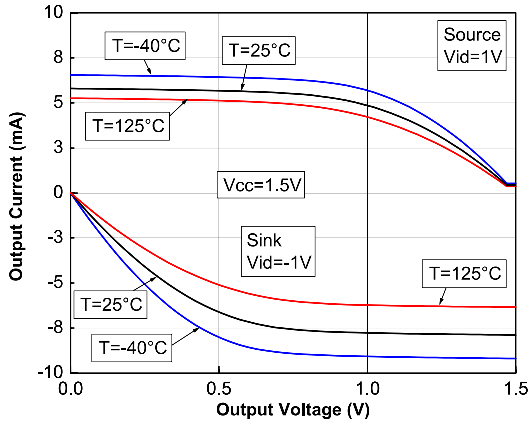


Figure 3: Output current vs. output voltage at VCC = 5 V

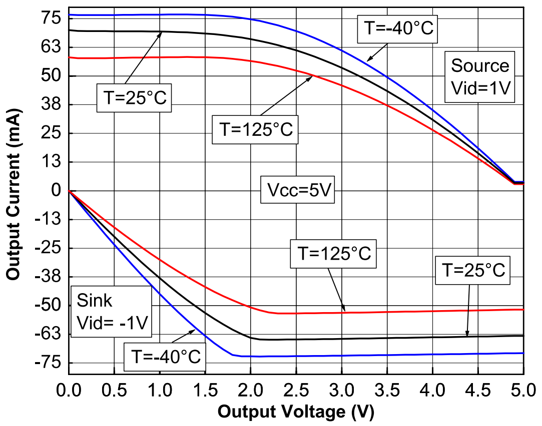


Figure 4: Peaking at closed loop gain = -10

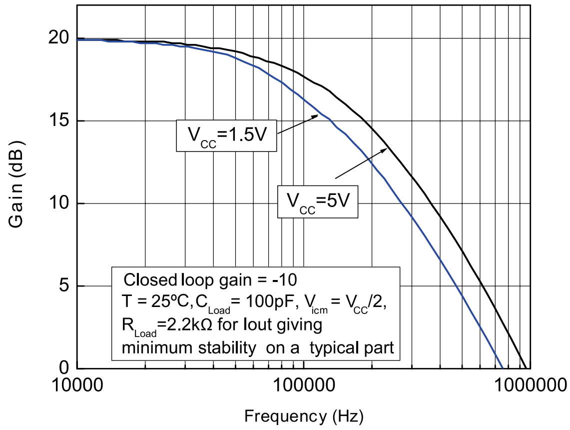


Figure 5: Peaking at closed loop gain = -3 at VCC = 1.5 V

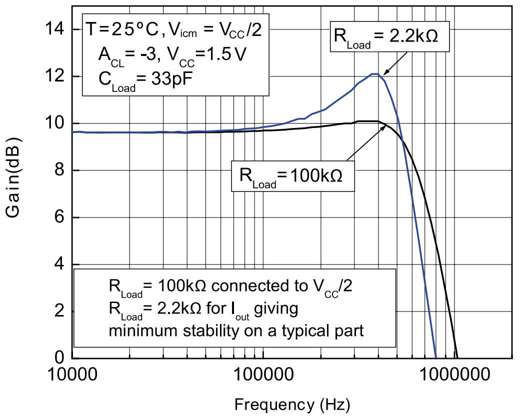


Figure 6: Peaking at closed loop gain = -3 at VCC = 5 V

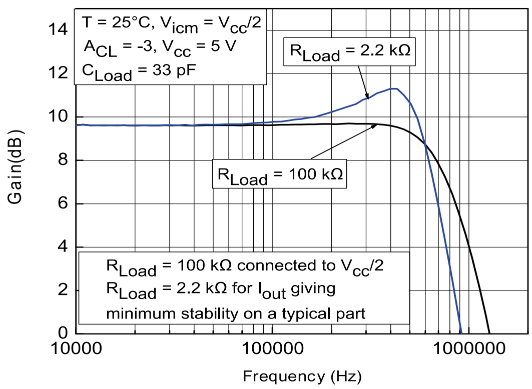


Figure 7: Positive slew rate vs. supply voltage

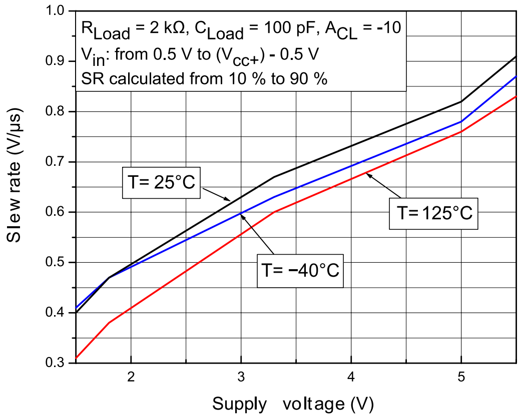


Figure 8: Negative slew rate vs. supply voltage

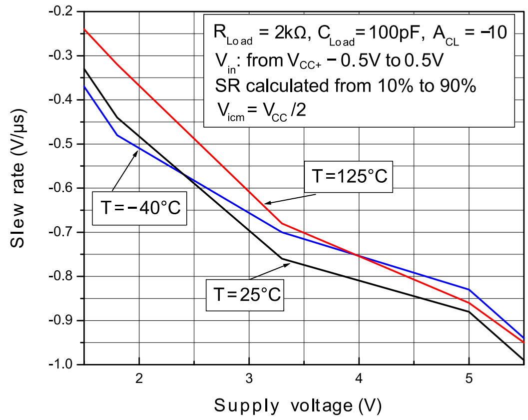


Figure 9: Distortion + noise vs. output voltage at VCC = 1.8 V

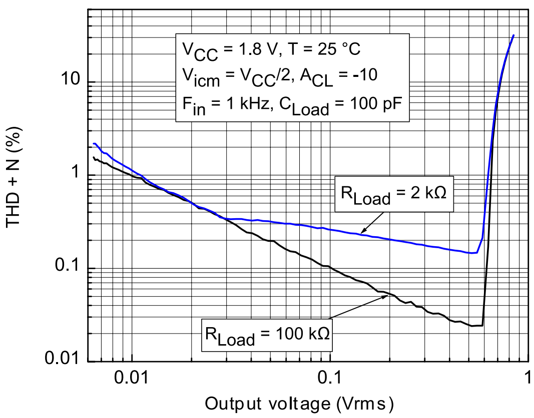


Figure 10: Distortion + noise vs. output voltage at VCC = 5 V

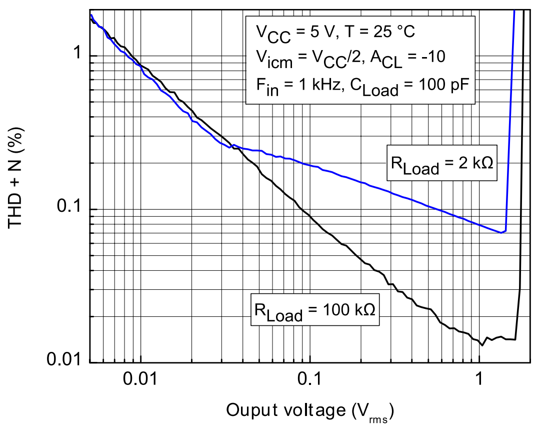


Figure 11: Slew rate timing

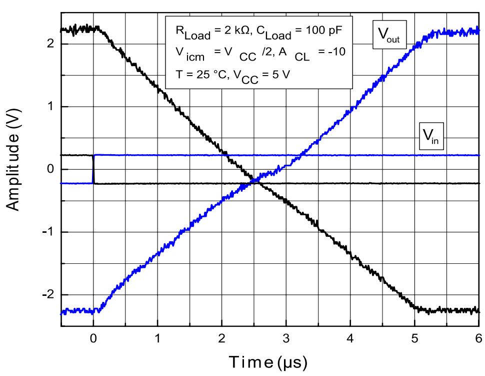


Figure 12: Noise vs. frequency at VCC = 5 V

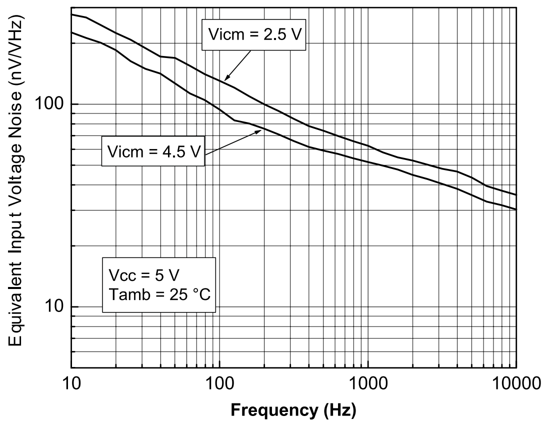


Figure 13: Input offset voltage vs input common-mode at VCC = 1.5 V

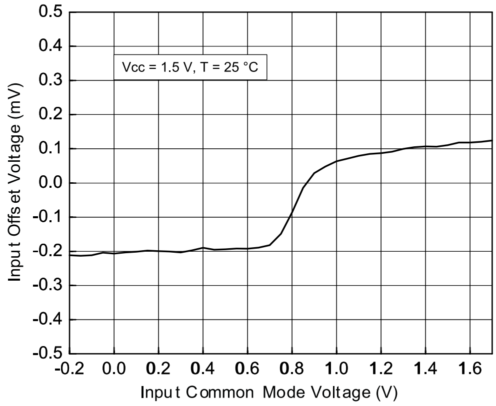


Figure 14: Input offset voltage vs input common-mode at VCC = 5 V

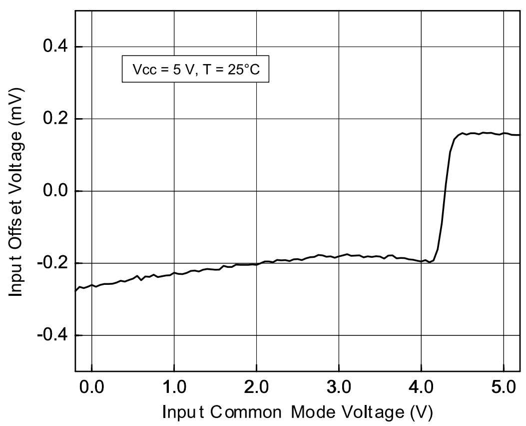


Figure 15: Test configuration for turn-on time (Vout pulled down)

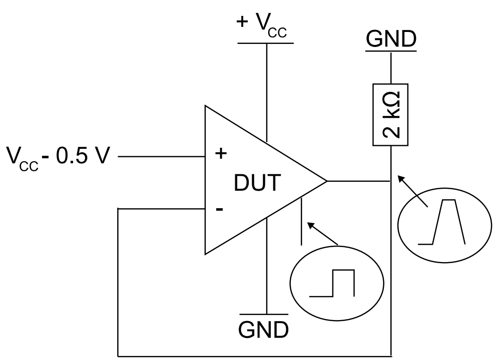


Figure 16: Test configuration for turn-off time (Vout pulled down)

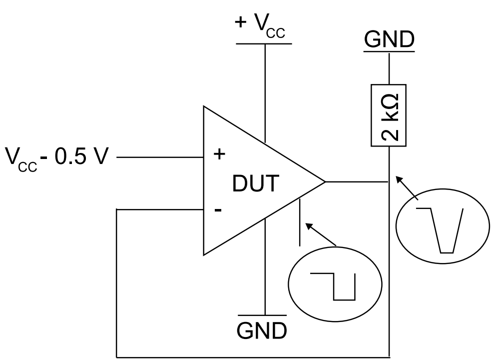


Figure 17: Turn-on time, VCC = 5 V, Vout pulled down, T = 25 °C

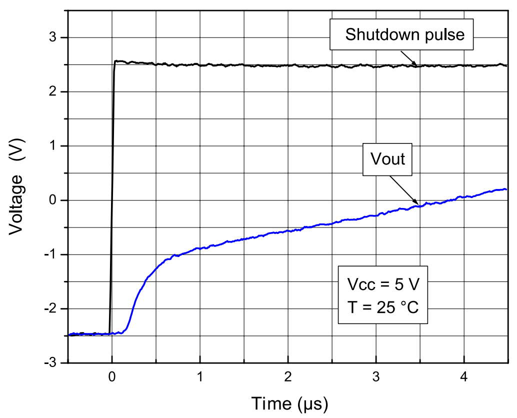
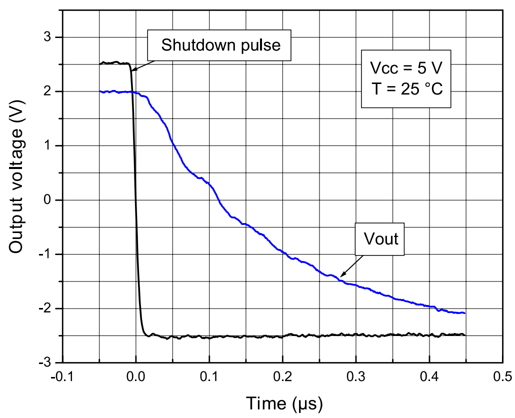
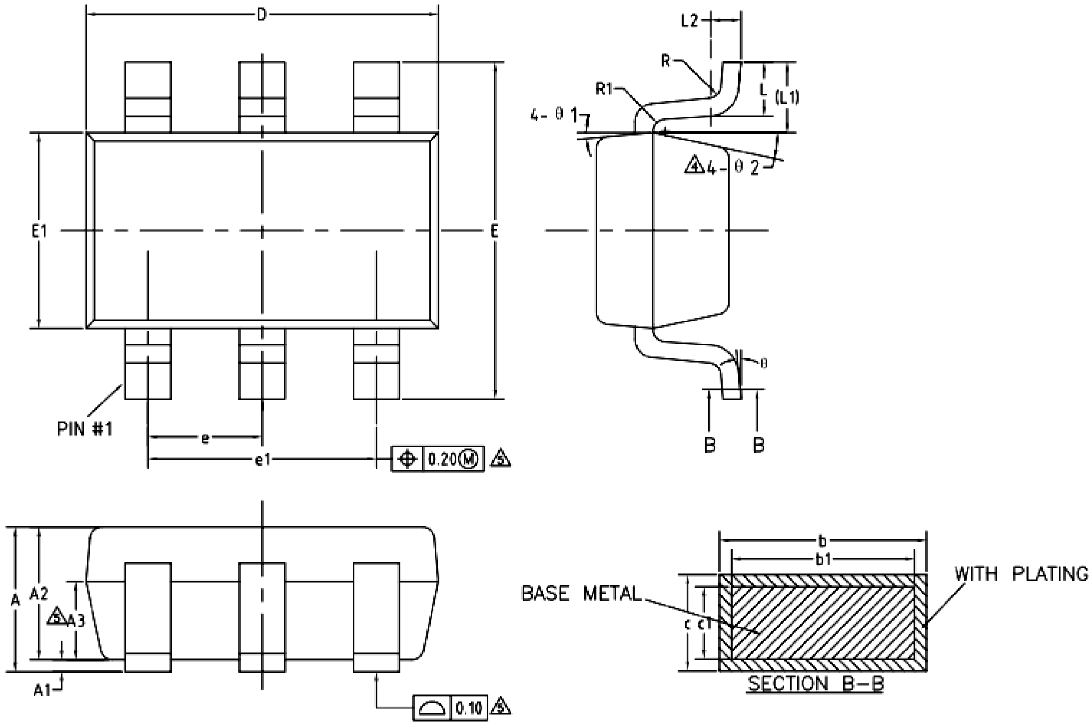


Figure 18: Turn-off time, VCC = 5 V, Vout pulled down, T = 25 °C



Package Dimension

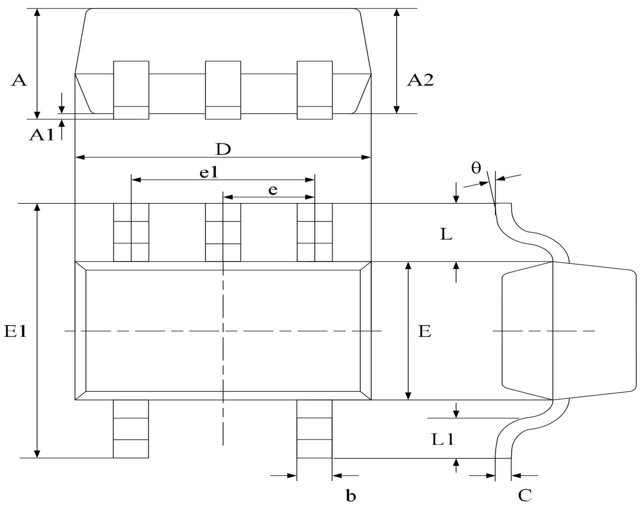
SOT23-6



COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

	SYMBOL	MIN	NOM	MAX
	A	–	–	1.25
	A1	0	–	0.15
	A2	1.00	1.10	1.20
	A3	0.60	0.65	0.70
	b	0.36	–	0.50
	b1	0.36	0.38	0.45
	c	0.14	–	0.20
	c1	0.14	0.15	0.16
	D	2.826	2.926	3.026
	E	2.60	2.80	3.00
	E1	1.526	1.626	1.726
△4	e	0.90	0.95	1.00
△4	e1	1.80	1.90	2.00
	L	0.35	0.45	0.60
	L1	0.59REF		
	L2	0.25BSC		
△3	R	0.10	–	–
△3	R1	0.10	–	0.20
	θ	0°	–	8°
	θ1	3°	5°	7°
△4	θ2	6°	–	14°

SC70-5（SOT353）



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.800	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.800	0.900	0.035	0.039
b	0.150	0.350	0.006	0.014
C	0.080	0.150	0.003	0.006
D	1.8500	2.150	0.079	0.087
E	1.100	1.400	0.045	0.053
E1	1.950	2.200	0.085	0.096
e	0.850 typ.		0.026 typ.	
e1	1.200	1.400	0.047	0.055
L	0.42 ref.		0.021 ref.	
L1	0.260	0.460	0.010	0.018
θ	0°	8°	0°	8°

Ordering information

Order code	Package	Baseqty	Deliverymode	Marking
UMW TSV6391ICT	SC70-5	3000	Tape and reel	K41 U
UMW TSV6391AICT	SC70-5	3000	Tape and reel	K20 U
UMW TSV6390ILT	SOT23-6	3000	Tape and reel	K19 U
UMW TSV6390AILT	SOT23-6	3000	Tape and reel	K42 U