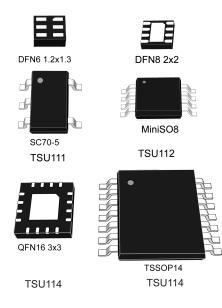


Datasheet

Nanopower (900 nA), high accuracy (150 µV) 5 V CMOS operational amplifier



Features

- Sub-micro ampere current consumption: Icc = 900 nA typ. at 25 °C
- Low offset voltage: 150 μ V max. at 25 °C, 235 μ V max. over full temperature range (-40 to 85 °C)
- Low noise over 0.1 to 10 Hz bandwidth: 3.6 μVpp
- Low supply voltage: 1.5 V to 5.5 V
- · Rail-to-rail input and output
- Gain bandwidth product: 11.5 kHz typ.
- Low input bias current: 10 pA max. at 25 °C
- High tolerance to ESD: 4 kV HBM
- More than 25 years of typical equivalent lifetime supplied by a 220 mA.h CR2032 coin type Lithium battery
- · High accuracy without calibration
- · Tolerance to power supply transient drops

Applications

- Gas sensors: CO, O₂, and H₂S
- Alarms: PIR sensors
- Signal conditioning for energy harvesting and wearable products
- Ultra long-life battery-powered applications
- Battery current sensing
- Active RFID tags

Product status link

TSU111, TSU112, TSU114

Related prod	ucts
See TSU101, TSU102, and TSU104	for further power savings
See TSZ121, TSZ122, TSZ124	for increased accuracy

Description

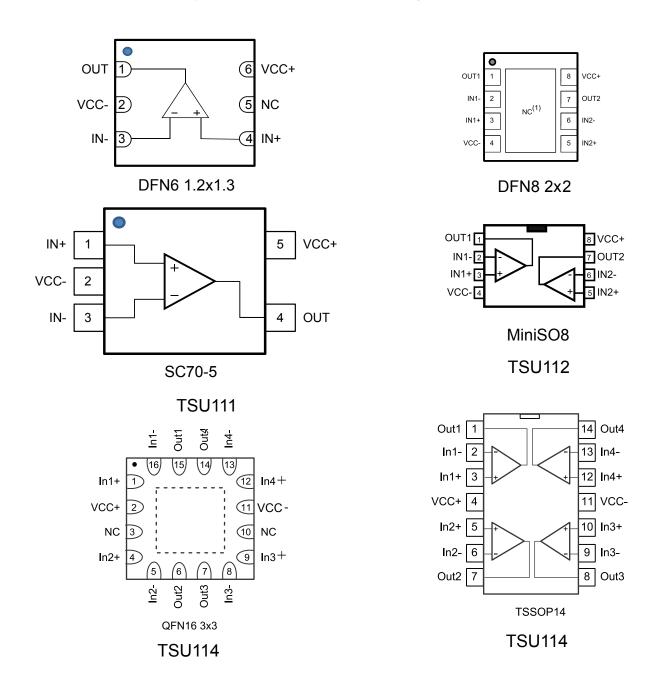
The TSU111, TSU112 and the TSU114 operational amplifiers (op-amp) offer an ultra low-power consumption per channel of 900 nA typical and 1.2 μ A maximum when supplied by 3.3 V. Combined with a supply voltage range of 1.5 V to 5.5 V, these features allow the TSU11x to be efficiently supplied by a coin type Lithium battery or a regulated voltage in low-power applications.

The high accuracy of 150 μ V max. and 11.5 kHz gain bandwidth make the TSU11x ideal for sensor signal conditioning, battery supplied, and portable applications.



1 Package pin connections

Figure 2. Pin connections for each package (top view)



1. The exposed pad of the DFN8 2x2 can be connected to V_{CC} or left floating.

DS11846 - Rev 6 page 2/35



2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings (AMR)

Symbol	Parameter	Value	Unit	
V _{CC}	Supply voltage (1)	6		
V _{id}	Differential input voltage (2)		±V _{CC}	V
V _{in}	Input voltage (3)		(V _{CC} ₋) - 0.2 to (V _{CC} ₊) + 0.2	
l _{in}	Input current (4)		10	mA
T _{stg}	Storage temperature		-65 to 150	90
Tj	Maximum junction temperature	150	— °C	
		DFN6 1.2x1.3	232	
		SC70-5	205	
D.	The second second second (5) (6)	DFN8 2x2	57	°C/W
R _{thja}	Thermal resistance junction-to-ambient (5) (6)	MiniSO8	190	C/VV
		QFN16 3x3	45	
		100		
	HBM: human body model (7)		4000	V
ESD	CDM: charged device model (8)		1500	V
	Latch-up immunity (9)		200	mA

- 1. All voltage values, except the differential voltage are with respect to the 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} (V_{CC-}) 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. Related to ESDA/JEDEC JS-001 Apr. 2010.
- 8. Related to JEDEC JESD22-C101-E Dec. 2009.
- 9. Related to JEDEC JESD78C Sep. 2010.

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	V
T _{oper}	Operating free-air temperature range	-40 to 85	°C

DS11846 - Rev 6 page 3/35



3 Electrical characteristics

Table 3. Electrical characteristics at (V $_{CC}$ +) = 1.8 V with (V $_{CC}$ -) = 0 V, V $_{icm}$ = V $_{CC}$ /2, T $_{amb}$ = 25 °C, and R $_{L}$ = 1 M Ω connected to V $_{CC}$ /2 (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
		DC performance				
	land to ffeet wells and	T = 25 °C			150	
V_{io}	Input offset voltage	-40 °C < T< 85 °C			235	μV
ΔV _{io} /ΔΤ	Input offset voltage drift	-40 °C < T< 85 °C			1.4	μV/°C
	(1)	T = 25 °C		1	10	
l _{io}	Input offset current (1)	-40 °C < T< 85 °C			50	
1	land him a sum of (1)	T = 25 °C		1	10	pA
I _{ib}	Input bias current (1)	-40 °C < T< 85 °C			50	
	Common mode rejection ratio,	T = 25 °C	76	107		
CMR	20 log ($\Delta V_{icm}/\Delta V_{io}$), $V_{icm} = 0$ to 1.8 V	-40 °C < T< 85 °C	71			dB
		R _L = 100 kΩ, T = 25 °C	95	120		
A _{vd} Large signal voltage gain, $V_{out} = 0.2 \text{ V to } (V_{CC+}) - 0.2 \text{ V}$		R _L = 100 kΩ, -40 °C < T< 85 °C	90			
VoH (drop from Voc+)	R _L = 10 kΩ, T = 25 °C		10	25		
	High-level output voltage, (drop from V _{CC} +)	$R_L = 10 \text{ k}\Omega$			40	
		-40 °C < T< 85 °C			40	mV
		R_L = 10 k Ω , T = 25°C		8	25	IIIV
V_{OL}	Low-level output voltage	R _L = 10 kΩ, -40 °C < T< 85 °C			40	
	Output aink aurrant	T = 25 °C	2.8	5		
	Output sink current, $V_{out} = V_{CC}$, $V_{ID} = -200 \text{ mV}$	-40 °C < T< 85 °C	1.5	5		
l _{out}	Output source current,	T = 25 °C	2	4		mA
	$V_{out} = 0 \text{ V},$ $V_{ID} = 200 \text{ mV}$	-40 °C < T< 85 °C	1.5			
	Supply current (per channel), no load,	T = 25 °C		900	1200	
I _{CC}	$V_{\text{out}} = V_{\text{CC}}/2$	-40 °C < T< 85 °C			1480	nA
		AC performance			'	
GBP	Gain bandwidth product			10		1.11
Fu	Unity gain frequency	$R_1 = 1 M\Omega, C_1 = 60 pF$		8		kHz
Фт	Phase margin	KL = 1 W122, CL = 60 PF		60		degree
G _m	Gain margin			10		dB

DS11846 - Rev 6 page 4/35



Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
SR	Slew rate (10 % to 90 %)	$R_L = 1 M\Omega$, $C_L = 60 pF$,		2.5		V/ms
SK	Siew rate (10 % to 90 %)	$V_{out} = 0.3 \text{ V to } (V_{CC+}) - 0.3 \text{ V}$		2.5		V/IIIS
e _n	Equivalent input noise voltage	f = 100 Hz		220		nV/√Hz
∫e _n	Low-frequency, peak-to-peak input noise	Bandwidth: f = 0.1 to 10 Hz		3.8		μV _{pp}
t _{rec}	Overload recovery time	100 mV from rail in comparator, R_L = 100 kΩ,		325		μs
		V _{ID} = ±1 V, -40 °C < T< 85 °C				

^{1.} Guaranteed by design

Table 4. Electrical characteristics at (V $_{CC}$ +) = 3.3 V with (V $_{CC}$ -) = 0 V, V $_{icm}$ = V $_{CC}$ /2, T $_{amb}$ = 25 °C, and R $_{L}$ = 1 M Ω connected to V $_{CC}$ /2 (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
		DC performance				
V _{io}	Input offset voltage	T = 25 °C			150	μV
v io	input onset voltage	-40 °C < T< 85 °C			235	μν
ΔV _{io} /ΔΤ	Input offset voltage drift	-40 °C < T< 85 °C			1.4	μV/°C
I.	Inner de affect as support (1)	T = 25 °C		1	10	
l _{io}	Input offset current (1)	-40 °C < T< 85 °C			50	
1	Leaved bine assument (1)	T = 25 °C		1	10	pА
l _{ib}	Input bias current (1)	-40 °C < T< 85 °C			50	
CMD	Common mode rejection ratio,	T = 25 °C	81	110		
CMR	20 log ($\Delta V_{icm}/\Delta V_{io}$), $V_{icm} = 0$ to 3.3 V	-40 °C < T< 85 °C	76			
^	Large signal voltage gain, V _{out} = 0.2 V to	R_L = 100 k Ω , T = 25 °C	105	130	dB	
A _{vd}	(V _{CC+}) - 0.2 V	R_L = 100 k Ω , -40 °C < T< 85 °C	105			
.,		R _L = 10 kΩ, T = 25 °C		10	25	
V _{OH}	High-level output voltage, (drop from V _{CC} +)	R _L = 10 kΩ, -40 °C < T< 85 °C			40	
		R _L = 10 kΩ, T = 25°C		7	25	mV
V _{OL}	Low-level output voltage	R _L = 10 kΩ, -40 °C < T< 85 °C			40	
		T = 25 °C	12	22		
	Output sink current, V _{out} = V _{CC} , V _{ID} = -200 mV	-40 °C < T< 85 °C	6			
l _{out}	Outside source and Market Mark	T = 25 °C	9	18		mA
	Output source current, V _{out} = 0 V, V _{ID} = 200 mV	-40 °C < T< 85 °C	5			
	Supply current (per channel), no load,	T = 25 °C		900	1200	^
Icc	$V_{out} = V_{CC}/2$	-40 °C < T< 85 °C			1480	nA
		AC performance	'			
GBP	Gain bandwidth product			11		ld le
Fu	Unity gain frequency	$R_L = 1 M\Omega$, $C_L = 60 pF$		10		kHz
Фт	Phase margin			60		degrees
G _m	Gain margin			7		dB

DS11846 - Rev 6 page 5/35



Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
SR	Slew rate (10 % to 90 %)	$R_L = 1 M\Omega$, $C_L = 60 pF$,		2.5		V/ms
JK	Siew fate (10 % to 90 %)	$V_{\text{out}} = 0.3 \text{ V to } (V_{\text{CC+}}) - 0.3 \text{ V}$				V/IIIS
e _n	Equivalent input noise voltage	f = 100 Hz		220		nV/√Hz
ſen	Low-frequency, peak-to-peak input noise Bandwidth: f = 0.1 to 10 Hz			3.7		μV _{pp}
t _{rec}	Overload recovery time	100 mV from rail in comparator, R _L = 100 k Ω , V _{ID} = ±1 V, -40 °C < T< 85 °C		630		μs

^{1.} Guaranteed by design

Table 5. Electrical characteristics at (V $_{CC}$ +) = 5 V with (V $_{CC}$ -) = 0 V, V $_{icm}$ = V $_{CC}$ /2, T $_{amb}$ = 25 °C, and R $_{L}$ = 1 M Ω connected to V $_{CC}$ /2 (unless otherwise specified)

Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
	DC peri	ormance				
V	land the office to traditions	T = 25 °C			150	/
V_{io}	Input offset voltage	-40 °C < T< 85 °C			235	μV
ΔV _{io} /ΔΤ	Input offset voltage drift	-40 °C < T< 85 °C			1.4	μV/°C
		T = 25 °C		1	10	
l _{io}	Input offset current (1)	-40 °C < T< 85 °C			50	~ Λ
	Local Advisor and (1)	T = 25 °C		1	10	pA
l _{ib}	Input bias current (1)	-40 °C < T< 85 °C			50	
	Common mode rejection ratio, 20 log (ΔV _{icm} /ΔV _{io}), V _{icm}	T = 25 °C	90	121		
CMR	= 0 to 3.9 V	-40 °C < T< 85 °C	90			
CIVIR	Common mode rejection ratio, 20 log (ΔV _{icm} /ΔV _{io}), V _{icm}	T = 25 °C	85	112		
	= 0 to 5 V	-40 °C < T< 85 °C	80			I.D.
SVR	Supply voltage rejection ratio, V _{CC} = 1.5 to 5.5 V,	T = 25 °C	92	116		dB
SVK	V _{icm} = 0 V	-40 °C < T< 85 °C	84			
^	Lorge signal voltage gain V = 0.2 V to (V) 0.2 V	R _L = 100 kΩ, T = 25 °C	105	135		
A_{vd}	Large signal voltage gain, V _{out} = 0.2 V to (V _{CC+}) - 0.2 V	R_L = 100 k Ω , -40 °C < T< 85 °C	101			
.,		R _L = 10 kΩ, T = 25 °C		10	25	
V _{OH}	High-level output voltage, (drop from V _{CC} +)	R _L = 10 kΩ, -40 °C < T< 85 °C			40	
		R _L = 10 kΩ, T = 25°C		7	25	mV
V_{OL}	Low-level output voltage	R _L = 10 kΩ, -40 °C < T< 85 °C			40	
		T = 25 °C	30	45		
	Output sink current, V _{out} = V _{CC} , V _{ID} = -200 mV	-40 °C < T< 85 °C	15			
l _{out}	0.1.1	T = 25 °C	25	41		mA
	Output source current, V _{out} = 0 V, V _{ID} = 200 mV	-40 °C < T< 85 °C	18			
	0	T = 25 °C		950	1350	
I _{CC}	Supply current (per channel), no load, V _{out} = V _{CC} /2	-40 °C < T< 85 °C			1620	nA
	AC perf	ormance				

DS11846 - Rev 6 page 6/35



Symbol	Parameter	Conditions		Тур.	Max.	Unit	
GBP	Gain bandwidth product			11.5		kHz	
Fu	Unity gain frequency	D = 1 MO C = 60 pF		10		KIIZ	
Φ _m	Phase margin	$R_L = 1 M\Omega$, $C_L = 60 pF$		60		degrees	
G _m	Gain margin			7		dB	
SR	Slew rate (10 % to 90 %)	R_L = 1 M Ω , C_L = 60 pF, V_{out} = 0.3 V to (V_{CC} $_+$) - 0.3 V		2.7		V/ms	
e _n	Equivalent input noise voltage	f = 100 Hz		200		nV/√Hz	
ſen	Low-frequency, peak-to-peak input noise	Bandwidth: f = 0.1 to 10 Hz		3.6		μV _{pp}	
t _{rec}	Overload recovery time	100 mV from rail in comparator, $R_L = 100 \text{ k}\Omega, V_{ID} = \pm 1 \text{ V},$ $-40 \text{ °C} < T < 85 \text{ °C}$		940		μs	
		V _{in} = -10 dBm, f = 400 MHz		54			
ENUDD		V _{in} = -10 dBm, f = 900 MHz		79			
EMIRR	Electromagnetic interference rejection ratio (2)	V _{in} = -10 dBm, f = 1.8 GHz		65 dB		ав	
		V _{in} = -10 dBm, f = 2.4 GHz		65			

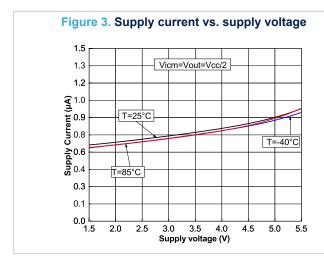
^{1.} Guaranteed by design

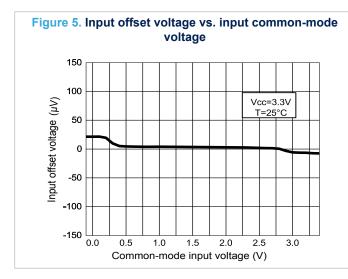
DS11846 - Rev 6 page 7/35

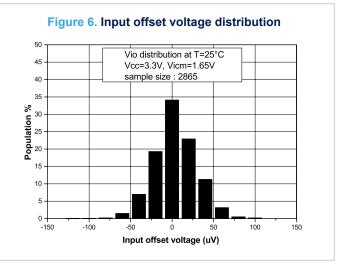
^{2.} Based on evaluations performed only in conductive mode on the TSU111ICT.

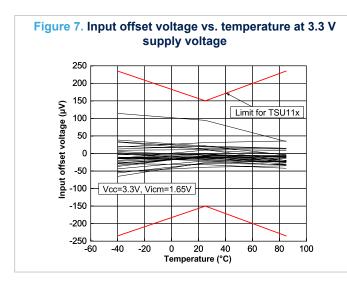


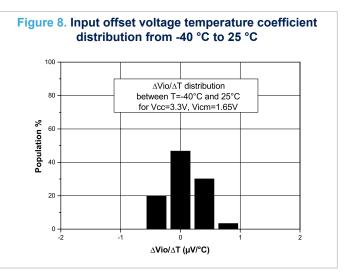
4 Electrical characteristic curves











DS11846 - Rev 6 page 8/35



Figure 9. Input offset voltage temperature coefficient distribution from 25 °C to 85 °C

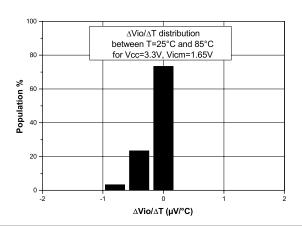


Figure 10. Input bias current vs. temperature at mid V_{ICM}

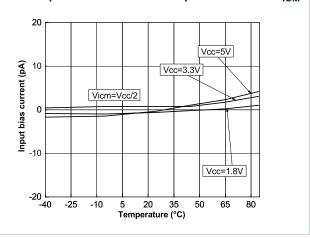


Figure 11. Input bias current vs. temperature at low V_{ICM}

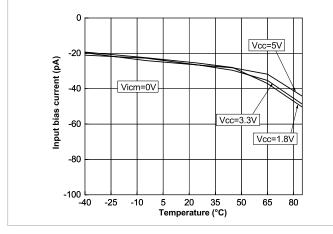


Figure 12. Input bias current vs. temperature at high V_{ICM}

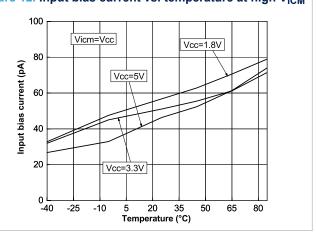


Figure 13. Output characteristics at 1.8 V supply voltage

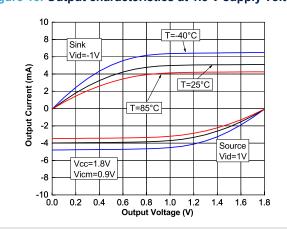
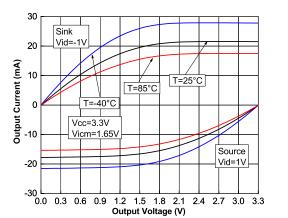


Figure 14. Output characteristics at 3.3 V supply voltage



DS11846 - Rev 6 page 9/35



-30

-40

-50

0.0

0.5

1.0

Figure 15. Output characteristics at 5 V supply voltage 50 Sink 40 Vid=-1\ 30 Output Current (mA) T=85°C 20 T=25°C 10 0 Vcc=5V -10 Vicm=2.5V -20

2.5 3.0 3.5

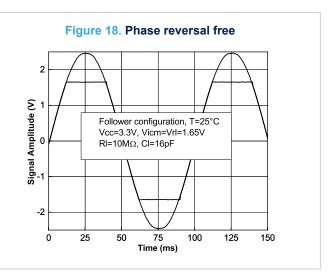
Output Voltage (V)

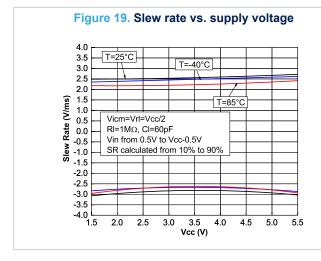
2.0

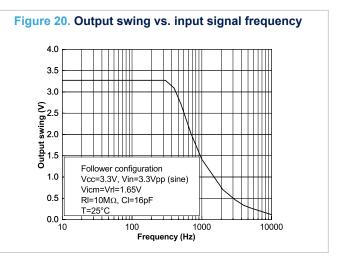
Vid=1V

4.0 4.5

Figure 16. Output saturation with a sinewave on the input 3.300 3.275 Vout 3.250 3.225 €3.200 3.200 3.175 3.150 0.125 0.100 0.075 Follower configuration, T=25°C, Vcc=3.3V Vin from rail to 200mV from rail, f=10Hz RI=100k Ω connected to other rail CI=75pF (+1MΩ scope probe to rail) 0.075 0.050 Vout 0.025 Vin 0.000 L 20 30 5 10 15 25 35 45 40 Time (ms)







DS11846 - Rev 6 page 10/35



Figure 21. Triangulation of a sine wave

3.0
Follower configuration, Vin=3Vpp, f=1kHz

2.5
Panilod Vision (Signature)

Vcc=3.3V, Vicm=Vrl=1.65V
RI=10M\(\Omega\), Cl=16pF, T=25°C

0.0
1
2
Time (ms)

Figure 22. Large signal response at 3.3 V supply voltage

Follower configuration, T=25°C

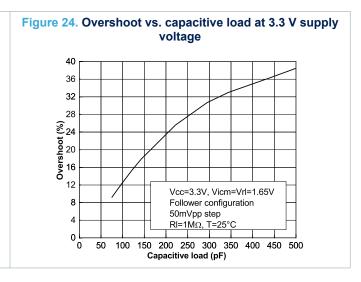
Follower configuration, T=25°C

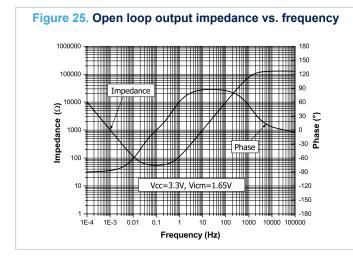
Vcc=3.3V
Vicm=Vrl=1.65V
Rl=10MΩ, Cl=16pF

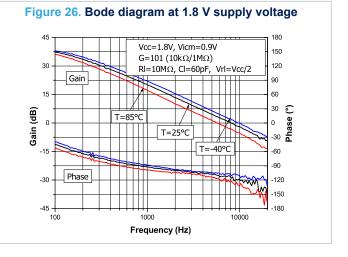
0 1 2 3 4 5 6 7 8 9 10

Time (ms)

Figure 23. Small signal response at 3.3 V supply voltage Follower configuration, T=25°C 30 25 20 Vcc=3.3V Vicm=Vrl=1.65V RI=1M Ω , CI=75pF -20 -25 -30 0.2 0.3 0.5 0.6 0.7 0.4 8.0







DS11846 - Rev 6 page 11/35



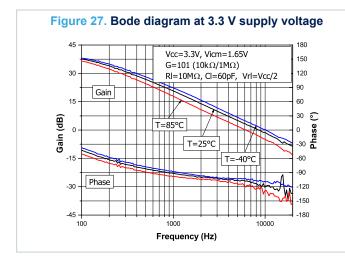


Figure 28. Bode diagram at 5 V supply voltage Vcc=5V, Vicm=2.5V 150 $G=101 (10k\Omega/1M\Omega)$ 120 30 RI=10MΩ, CI=60pF, VrI=Vcc/2 90 Gain 60 T=85°C 30 Phase (°) Gain (dB) 0 T=25°C -30 T=-40°C -60 -90 Phase -120 -30 -150 100 1000 10000 Frequency (Hz)

Figure 29. Gain bandwidth product vs. input commonmode voltage 10 9 8 6 GBP (kHz) Vcc=3.3V, Vout=1.65V 5 Vrl=1.65V RI=10M Ω , CI=60pF T=25°C 3 Simulated at 20dB 2 0.0 1.5 2.0 Vicm (V) 0.5 1.0 2.5 3.0

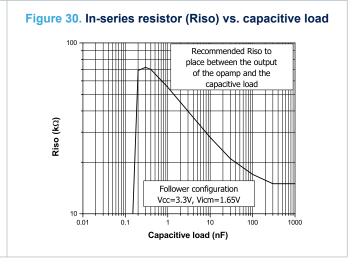
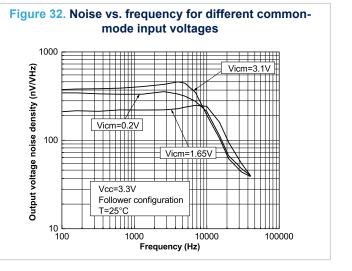


Figure 31. Noise vs. frequency for different power supply voltages 1000 Output voltage noise density (nV/VHz) Vcc=1.8V 100 Vcc=5V E Vcc=3.3V Vicm=Vcc/2 Follower configuration T=25°C 10 L 1000 10000 100000 Frequency (Hz)



DS11846 - Rev 6 page 12/35



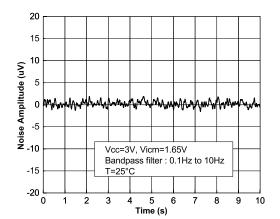


Figure 33. Noise amplitude on a 0.1 Hz to 10 Hz frequency range

DS11846 - Rev 6 page 13/35



Application information

5.1 Nanopower applications

The TSU11x can operate from 1.5 V to 5.5 V. The parameters are fully specified at 1.8 V, 3.3 V, and 5 V supply voltages and are very stable in the full V_{CC} range. Additionally, the main specifications are guaranteed on the industrial temperature range from -40 to 85 °C. The estimated lifetime of the TSU11x exceeds 25 years if supplied by a CR2032 battery (see Figure 34. CR2032 battery).



Figure 34. CR2032 battery

5.1.1 Schematic optimization aiming for nanopower

To benefit from the full performance of the TSU11x, the impedances must be maximized so that current consumption is not lost where it is not required.

For example, an aluminum electrolytic capacitance can have significantly high leakage. This leakage may be greater than the current consumption of the op-amp. For this reason, ceramic type capacitors are preferred. For the same reason, big resistor values should be used in the feedback loop. However, there are two main limitations to be considered when choosing a resistor.

- Noise generated: a 100 kΩ resistor generates 40 nV/√Hz, a bigger resistor value generates even more noise.
- Leakage on the PCB: leakage can be generated by moisture. This can be improved by using a specific coating process on the PCB.

DS11846 - Rev 6 page 14/35



5.1.2 PCB layout considerations

For correct operation, it is advised to add 10 nF decoupling capacitors as close as possible to the power supply pins.

Minimizing the leakage from sensitive high impedance nodes on the inputs of the TSU11x can be performed with a guarding technique. The technique consists of surrounding high impedance tracks by a low impedance track (the ring). The ring is at the same electrical potential as the high impedance node.

Therefore, even if some parasitic impedance exists between the tracks, no leakage current can flow through them as they are at the same potential (see Figure 35. Guarding on the PCB).

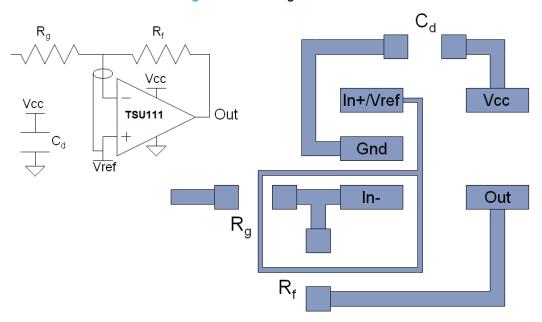


Figure 35. Guarding on the PCB

5.2 Rail-to-rail input

The TSU11x is built with two complementary PMOS and NMOS input differential pairs. Thus, the device has a rail-to-rail input, and the input common mode range is extended from (V_{CC-}) - 0.1 V to (V_{CC+}) + 0.1 V.

The TSU11x has been designed to prevent phase reversal behavior.

5.3 Input offset voltage drift overtemperature

The maximum input voltage drift variation overtemperature is defined as the offset variation related to the offset value measured at 25 °C. The operational amplifier is one of the main circuits of the signal conditioning chain, and the amplifier input offset is a major contributor to the chain accuracy. The signal chain accuracy at 25 °C can be compensated during production at application level. The maximum input voltage drift over temperature enables the system designer to anticipate the effect of temperature variations.

The maximum input voltage drift over temperature is computed using Equation 1.

Equation 1

$$\frac{\Delta V_{io}}{\Delta T} = \text{max} \left| \frac{V_{io}(T) - V_{io}(25 \,^{\circ}\text{C})}{T - 25 \,^{\circ}\text{C}} \right|$$

Where T = -40 °C and 85 °C.

The TSU11x datasheet maximum values are guaranteed by measurements on a representative sample size ensuring a C_{pk} (process capability index) greater than 1.3.

DS11846 - Rev 6 page 15/35



5.4 Long term input offset voltage drift

To evaluate product reliability, two types of stress acceleration are used:

- Voltage acceleration, by changing the applied voltage
- Temperature acceleration, by changing the die temperature (below the maximum junction temperature allowed by the technology) with the ambient temperature.

The voltage acceleration has been defined based on JEDEC results, and is defined using Equation 2.

Equation 2

$$A_{FV} = e^{\beta \cdot (V_S - V_U)}$$

Where:

A_{FV} is the voltage acceleration factor

 β is the voltage acceleration constant in 1/V, constant technology parameter (β = 1)

V_S is the stress voltage used for the accelerated test

V_U is the voltage used for the application

The temperature acceleration is driven by the Arrhenius model, and is defined in Equation 3.

Equation 3

$$A_{FT} = e^{\frac{E_a}{k} \cdot \left(\frac{1}{T_U} - \frac{1}{T_S}\right)}$$

Where:

AFT is the temperature acceleration factor

Ea is the activation energy of the technology based on the failure rate

k is the Boltzmann constant (8.6173 x 10^{-5} eV.K⁻¹)

 T_U is the temperature of the die when V_U is used (°K)

 T_S is the temperature of the die under temperature stress (°K)

The final acceleration factor, A_F , is the multiplication of the voltage acceleration factor and the temperature acceleration factor (Equation 4).

Equation 4

$$A_F = A_{FT} \times A_{FV}$$

 A_F is calculated using the temperature and voltage defined in the mission profile of the product. The A_F value can then be used in Equation 5 to calculate the number of months of use equivalent to 1000 hours of reliable stress duration.

Equation 5

Months =
$$A_F \times 1000 \text{ h} \times 12 \text{ months} / (24 \text{ h} \times 365.25 \text{ days})$$

To evaluate the op amp reliability, a follower stress condition is used where V_{CC} is defined as a function of the maximum operating voltage and the absolute maximum rating (as recommended by JEDEC rules).

The V_{io} drift (in μV) of the product after 1000 h of stress is tracked with parameters at different measurement conditions (see Equation 6).

Equation 6

$$V_{CC} = maxV_{op}$$
 with $V_{icm} = V_{CC}/2$

The long term drift parameter (ΔV_{io}), estimating the reliability performance of the product, is obtained using the ratio of the V_{io} (input offset voltage value) drift over the square root of the calculated number of months (Equation 7).

Equation 7

$$\Delta V_{io} = \frac{V_{io} drift}{\sqrt{(month s)}}$$

DS11846 - Rev 6 page 16/35



Where V_{io} drift is the measured drift value in the specified test conditions after 1000 h stress duration.

5.5 Using the TSU11x with sensors

The TSU11x has MOS inputs, thus input bias currents can be guaranteed down to 10 pA maximum at ambient temperature. This is an important parameter when the operational amplifier is used in combination with high impedance sensors.

The TSU11x is perfectly suited for trans-impedance configuration. This configuration allows a current to be converted into a voltage value with a gain set by the user. It is an ideal choice for portable electrochemical gas sensing or photo/UV sensing applications. The TSU11x, using trans-impedance configuration, is able to provide a voltage value based on the physical parameter sensed by the sensor.

5.5.1 Electrochemical gas sensors

The output current of electrochemical gas sensors is generally in the range of tens of nA to hundreds of μ A. As the input bias current of the TSU11x is very low (see Figure 10. Figure 8, Figure 11. Figure 9, and Figure 12. Figure 10) compared to these current values, the TSU11x is well adapted for use with the electrochemical sensors of two or three electrodes. Figure 37. Potentiostat schematic using the TSU111 shows a potentiostat (electronic hardware required to control a three electrode cell) schematic using the TSU11x. In such a configuration, the devices minimize leakage in the reference electrode compared to the current being measured on the working electrode.

Another great advantage of TSU11x versus the competition is its low noise for low frequencies (3.6 μ Vpp over 0.1 to 10 Hz), and low input offset voltage of 150 μ V max. These improved parameters for the same power consumption allow a better accuracy.

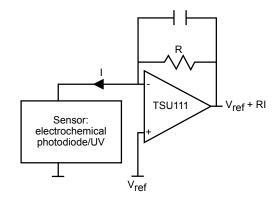
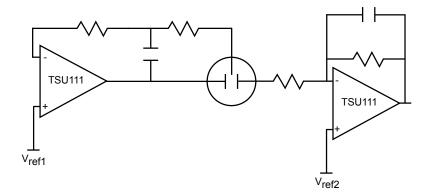


Figure 36. Trans-impedance amplifier schematic

Figure 37. Potentiostat schematic using the TSU111



DS11846 - Rev 6 page 17/35



5.6 Fast desaturation

When the TSU11x goes into saturation mode, it takes a short period of time to recover, typically 630 µs. When recovering after saturation, the TSU11x does not exhibit any voltage peaks that could generate issues (such as false alarms) in the application (see Figure 16. Figure 14).

We can observe that this circuit still exhibits good gain even close to the rails i.e. A_{vd} greater than 105 dB for V_{cc} = 3.3 V with V_{out} varying from 200 mV up to a supply voltage minus 200 mV. With a trans-impedance schematic, a voltage reference can be used to keep the signal away from the supply rails.

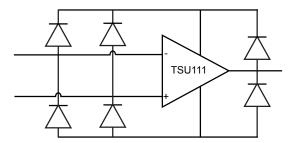
5.7 Using the TSU11x in comparator mode

The TSU11x can be used as a comparator. In this case, the output stage of the device always operates in saturation mode. In addition, Figure 4. Figure 3 shows that the current consumption is not higher and even decreases smoothly close to the rails. The TSU11x is obviously an operational amplifier and is therefore optimized for use in linear mode. We recommend using the TS88 series of nanopower comparators if the primary function is to perform a signal comparison only.

5.8 ESD structure of the TSU11x

The TSU11x is protected against electrostatic discharge (ESD) with dedicated diodes (see Figure 38. ESD structure). These diodes must be considered at application level especially when signals applied on the input pins go beyond the power supply rails (V_{CC+}) or (V_{CC-}).

Figure 38. ESD structure



Current through the diodes must be limited to a maximum of 10 mA as stated in Table 1. Absolute maximum ratings (AMR). A serial resistor on the inputs can be used to limit this current.

5.9 EMI robustness of nanopower devices

Nanopower devices exhibit higher impedance nodes and consequently they are more sensitive to EMI. To improve the natural robustness of the TSU11x device, we recommend to add three capacitors of around 22 pF each between the two inputs, and between each input and ground. These capacitors lower the impedance of the input at high frequencies and therefore reduce the impact of the radiation.

DS11846 - Rev 6 page 18/35



6 Package information

In order 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.

DS11846 - Rev 6 page 19/35



6.1 SC70-5 (or SOT323-5) package information (TSU111)

SIDE VIEW

SIDE VIEW

A1

A2

GAUGE PLANE

A2

GOT IC

COPLANAR LEADS

D

No. (5 LEADS)

TOP VIEW

Figure 39. SC70-5 (or SOT323-5) package outline

Table 6. SC70-5 (or SOT323-5) package mechanical data

			Din	nensions		
Ref.		Millimeters		Inches		
	Min.	Тур.	Max.	Min.	Тур.	Max.
А	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
С	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
е		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°

DS11846 - Rev 6 page 20/35

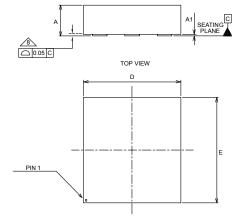


DFN6 1.2x1.3 package information (TSU111) 6.2

PIN#1 ID

Figure 40. DFN6 1.2x1.3 package outline

BOTTOM VIEW



SIDE VIEW

Table 7. DFN6 1.2x1.3 mechanical data

	Dimensions						
Ref		Millimeters			Inches		
	Min.	Тур.	Max.	Min.	Тур.	Max.	
A	0.31	0.38	0.40	0.012	0.015	0.016	
A1	0.00	0.02	0.05	0.000	0.001	0.002	
b	0.15	0.18	0.25	0.006	0.007	0.010	
С		0.05			0.002		
D		1.20			0.047		
E		1.30			0.051		
е		0.40			0.016		
L	0.475	0.525	0.575	0.019	0.021	0.023	
L3	0.375	0.425	0.475	0.015	0.017	0.019	

DS11846 - Rev 6 page 21/35



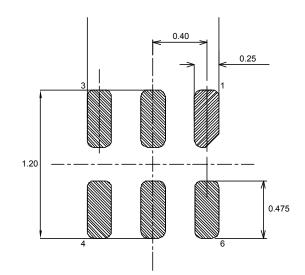


Figure 41. DFN6 1.2x1.3 recommended footprint

Table 8. DFN6 1.2x1.3 recommended footprint data

Dimensions						
Ref.	Millimeters	Inches				
A	4.00	0.158				
В	4.00	0.156				
С	0.50	0.020				
D	0.30	0.012				
Е	1.00	0.039				
F	0.70	0.028				
G	0.66	0.026				

DS11846 - Rev 6 page 22/35



6.3 MiniSO8 package information (TSU112)

PIN 1 IDENTIFICATION

PIN 1 IDENTIFICATION

PIN 1 IDENTIFICATION

PLANE

C

GAUGE PLANE

L1

L2

K

Figure 42. MiniSO8 package outline

Table 9. MiniSO8 mechanical data

Dim.	Millim	neters		Inches		
	Min.	Тур.	Max.	Min.	Тур.	Max.
Α			1.1			0.043
A1	0		0.15	0		0.006
A2	0.75	0.85	0.95	0.03	0.033	0.037
b	0.22		0.4	0.009		0.016
С	0.08		0.23	0.003		0.009
D	2.8	3	3.2	0.11	0.118	0.126
E	4.65	4.9	5.15	0.183	0.193	0.203
E1	2.8	3	3.1	0.11	0.118	0.122
е		0.65			0.026	
L	0.4	0.6	0.8	0.016	0.024	0.031
L1		0.95			0.037	
L2		0.25			0.01	
k	0°		8°	0°		8°
ccc			0.1			0.004

DS11846 - Rev 6 page 23/35



6.4 DFN8 2x2 package information (TSU112)

Figure 43. DFN8 2x2 package outline

Table 10. DFN8 2x2 package mechanical data

	Dimensions						
Ref.	Millimeters				Inches		
	Min.	Тур.	Max.	Min.	Тур.	Max.	
Α	0.51	0.55	0.60	0.020	0.022	0.024	
A1			0.05			0.002	
A3		0.15			0.006		
b	0.18	0.25	0.30	0.007	0.010	0.012	
D	1.85	2.00	2.15	0.073	0.079	0.085	
D2	1.45	1.60	1.70	0.057	0.063	0.067	
E	1.85	2.00	2.15	0.073	0.079	0.085	
E2	0.75	0.90	1.00	0.030	0.035	0.039	
е		0.50			0.020		
L	0.225	0.325	0.425	0.009	0.013	0.017	
ddd			0.08			0.003	

DS11846 - Rev 6 page 24/35



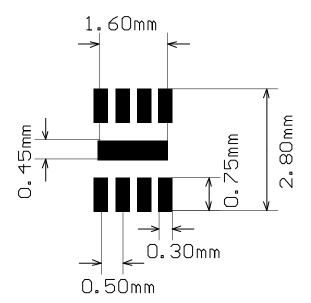


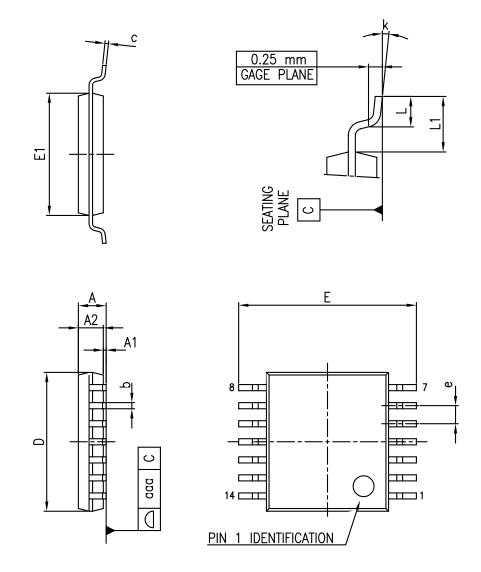
Figure 44. DFN8 2x2 recommended footprint

DS11846 - Rev 6 page 25/35



6.5 TSSOP14 package information (TSU114)

Figure 45. TSSOP14 package outline



DS11846 - Rev 6 page 26/35



Table 11. TSSOP14 mechanical data

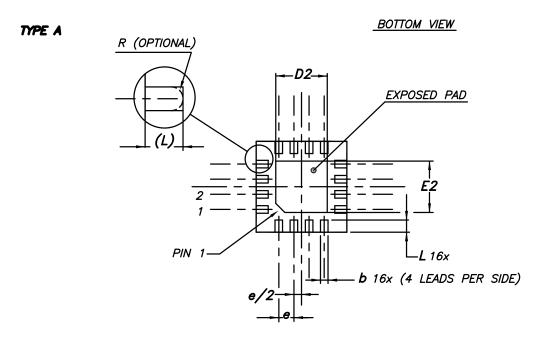
Symbol	mm			
Syllibol	Min.	Тур.	Max.	
Α			1.20	
A1	0.05		0.15	
A2	0.80	1.00	1.05	
b	0.19		0.30	
С	0.09		0.20	
D	4.90	5.00	5.10	
E	6.20	6.40	6.60	
E1	4.30	4.40	4.50	
е		0.65		
L	0.45	0.60	0.75	
L1		1.00		
k	0		8	
aaa			0.10	

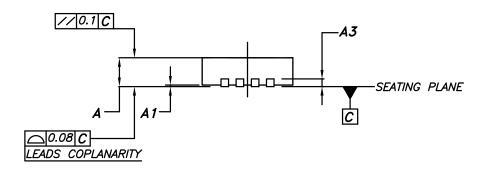
DS11846 - Rev 6 page 27/35

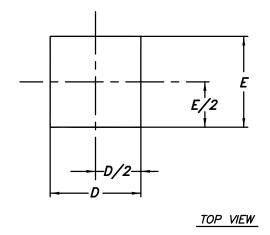


6.6 QFN16 (3x3x0.9) package information (TSU114)

Figure 46. QFN16 (3x3x0.9) package outline







DS11846 - Rev 6 page 28/35



Cumbal	mm				
Symbol	Min.	Тур.	Max.		
A	0.80	0.90	1		
A1	0		0.05		
A3		0.20			
b	0.18		0.30		
D	2.90	3.00	3.10		
D2	1.50		1.80		
Е	2.90	3.00	3.10		
E2	1.50		1.80		
е		0.50			
L ⁽¹⁾	0.30		0.50		

Table 12. QFN16 (3x3x0.9) mechanical data

^{1.} The value of "L" a JEDEC norm is min. 0.35 – max. 0.45

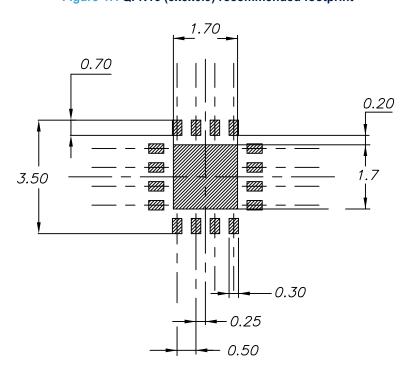


Figure 47. QFN16 (3x3x0.9) recommended footprint

DS11846 - Rev 6 page 29/35



7 Ordering information

Table 13. Order code

Order code	Temperature range	Package ⁽¹⁾	Marking
TSU111IQ1T		DFN6 1.2x1.3	K8
TSU111ICT	40 %0 42 05 %0	SC70-5	No No
TSU112IQ2T		DFN8 2x2	V27
TSU112IST	-40 °C to 85 °C	MiniSO8	K37
TSU114IPT		TSSOP14	TSU114IPT
TSU114IQ4T		QFN16 3x3x0.9	K164

^{1.} All devices are delivered in tape and reel packing.

DS11846 - Rev 6 page 30/35



Revision history

Table 14. Document revision history

Date	Revision	Changes
17-Oct-2016	1	Initial release
		Features: added "rail-to-rail input and output".
	2	Description: updated the maximum ultra low-power consumption of TSU111 op-amp.
14-Nov-2016		Applications: updated
		Table 5: added EMIRR typ. values
		Added Section 5.9: "EMI robustness of nanopower devices".
04-Dec-2017	3	Added the part number TSU112 and the relative package information MiniSO8 and DFN8 2x2.
08-May-2018	4	Updated Section 3 Electrical characteristics.
21-Jan-2019	5	Added the part number TSU114, therefore the document has been updated accordingly.
06 Fab 2010	6	Updated Section 3 Electrical characteristics.
06-Feb-2019	6	Added Figure 5. Input offset voltage vs. input common-mode voltage.

DS11846 - Rev 6 page 31/35





Contents

1	Pac	kage pii	age pin connections					
2	Abs	olute m	Plute maximum ratings and operating conditions3					
3	Elec	trical characteristics						
4	Elec	trical c	trical characteristic curves					
5	Арр	oplication information						
	5.1	Nanop	power applications					
		5.1.1	Schematic optimization aiming at nanopower	14				
		5.1.2	PCB layout considerations	15				
	5.2	Rail-to	o-rail input					
	5.3	Input o	offset voltage drift overtemperature					
	5.4	Long t	term input offset voltage drift	16				
	5.5	Using	the TSU11x with sensors					
		5.5.1	Electrochemical gas sensors	17				
	5.6	Fast d	desaturation					
	5.7	Using	the TSU11x in comparator mode					
	5.8	ESD s	structure of the TSU11x	18				
	5.9	EMI ro	obustness of nanopower devices					
6	Pac	kage inf	formation	19				
	6.1	SC70-	-5 (or SOT323-5) package information (TSU111)	20				
	6.2	DFN6	1.2x1.3 package information (TSU111)	20				
	6.3	MiniS	O8 package information (TSU112)					
	6.4	DFN8	2x2 package information (TSU112)	23				
	6.5	TSSO	P14 package information (TSU114)	25				
	6.6	QFN1	6 (3x3x0.9) package information (TSU114)	27				
7	Ord	ering in	formation	30				
Rev	vision	history	/					

DS11846 - Rev 6 page 32/35



List of tables

Table 1.	Absolute maximum ratings (AMR)
Table 2.	Operating conditions
Table 3.	Electrical characteristics at ($\mathbf{V}_{\mathbf{CC}}$ +) = 1.8 V with ($\mathbf{V}_{\mathbf{CC}}$ -) = 0 V, V_{icm} = $\mathbf{V}_{\mathbf{CC}}$ /2, T_{amb} = 25 °C, and R_L = 1 M Ω connected to $\mathbf{V}_{\mathbf{CC}}$ /2 (unless otherwise specified)
Table 4.	Electrical characteristics at ($\mathbf{V}_{\mathbf{CC}}$ +) = 3.3 V with ($\mathbf{V}_{\mathbf{CC}}$ -) = 0 V, V_{icm} = $\mathbf{V}_{\mathbf{CC}}$ /2, V_{amb} = 25 °C, and $V_{\mathbf{CC}}$ = 1 M $V_{\mathbf{CC}}$ (unless otherwise specified)
Table 5.	Electrical characteristics at (\mathbf{V}_{CC} +) = 5 V with (\mathbf{V}_{CC} -) = 0 V, V_{icm} = \mathbf{V}_{CC} /2, V_{amb} = 25 °C, and V_{CC} = 1 M V_{CC} connected to V_{CC} /2 (unless otherwise specified)
Table 6.	SC70-5 (or SOT323-5) package mechanical data
Table 7.	DFN6 1.2x1.3 mechanical data
Table 8.	DFN6 1.2x1.3 recommended footprint data
Table 9.	MiniSO8 mechanical data
Table 10.	DFN8 2x2 package mechanical data
Table 11.	TSSOP14 mechanical data
Table 12.	QFN16 (3x3x0.9) mechanical data
Table 13.	Order code
Table 14.	Document revision history

DS11846 - Rev 6 page 33/35



List of figures

Figure 2.	Pin connections for each package (top view)	. 2
Figure 3.	Supply current vs. supply voltage	. 8
Figure 4.	Supply current vs. input common-mode voltage	. 8
Figure 5.	Input offset voltage vs. input common-mode voltage	. 8
Figure 6.	Input offset voltage distribution	. 8
Figure 7.	Input offset voltage vs. temperature at 3.3 V supply voltage	. 8
Figure 8.	Input offset voltage temperature coefficient distribution from -40 °C to 25 °C	. 8
Figure 9.	Input offset voltage temperature coefficient distribution from 25 °C to 85 °C	
Figure 10.	Input bias current vs. temperature at mid V _{ICM}	
Figure 11.	Input bias current vs. temperature at low V _{ICM}	
Figure 12.	Input bias current vs. temperature at high V _{ICM}	
Figure 13.	Output characteristics at 1.8 V supply voltage	
Figure 14.	Output characteristics at 3.3 V supply voltage	
Figure 15.	Output characteristics at 5 V supply voltage	
Figure 16.	Output saturation with a sinewave on the input	
Figure 17.	Output saturation with a square wave on the input.	
Figure 18.	Phase reversal free	
Figure 19.	Slew rate vs. supply voltage	
Figure 20.	Output swing vs. input signal frequency	
Figure 21.	Triangulation of a sine wave	
Figure 22.	Large signal response at 3.3 V supply voltage	
Figure 23.	Small signal response at 3.3 V supply voltage	
Figure 24.	Overshoot vs. capacitive load at 3.3 V supply voltage	
Figure 25.	Open loop output impedance vs. frequency	
Figure 26.	Bode diagram at 1.8 V supply voltage	
Figure 27.	Bode diagram at 3.3 V supply voltage	
Figure 28.	Bode diagram at 5 V supply voltage	
Figure 29.	Gain bandwidth product vs. input common-mode voltage	
Figure 30.	In-series resistor (Riso) vs. capacitive load	
Figure 31.	Noise vs. frequency for different power supply voltages	
Figure 32.	Noise vs. frequency for different common-mode input voltages	
Figure 33.	Noise amplitude on a 0.1 Hz to 10 Hz frequency range	
Figure 34.	CR2032 battery	
Figure 35.	Guarding on the PCB	
Figure 36.	Trans-impedance amplifier schematic	
Figure 37.	Potentiostat schematic using the TSU111	
Figure 38.	ESD structure.	
Figure 39.	SC70-5 (or SOT323-5) package outline	
Figure 40.	DFN6 1.2x1.3 package outline	
Figure 41.	DFN6 1.2x1.3 recommended footprint	
Figure 42.	MiniSO8 package outline	
Figure 43.	DFN8 2x2 package outline	
Figure 44.	DFN8 2x2 recommended footprint.	
Figure 45.	TSSOP14 package outline	
Figure 46.	QFN16 (3x3x0.9) package outline	
Figure 47.	QFN16 (3x3x0.9) recommended footprint.	
-	, , , , , , , , , , , , , , , , , , , ,	_

DS11846 - Rev 6 page 34/35



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DS11846 - Rev 6 page 35/35