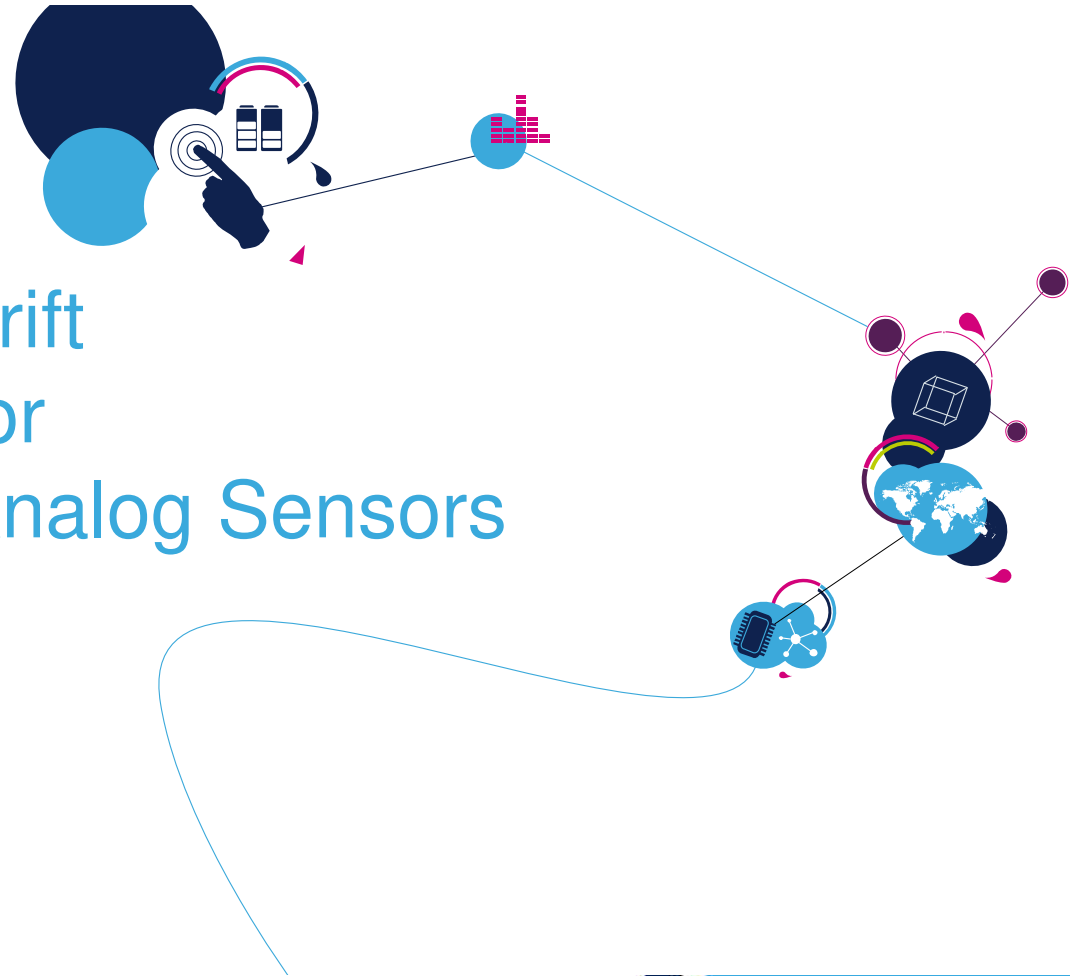


Ultra-low Power, Zero Drift Operational Amplifiers for Industrial and Remote Analog Sensors

Gregory Gosciniak
STMicroelectronics

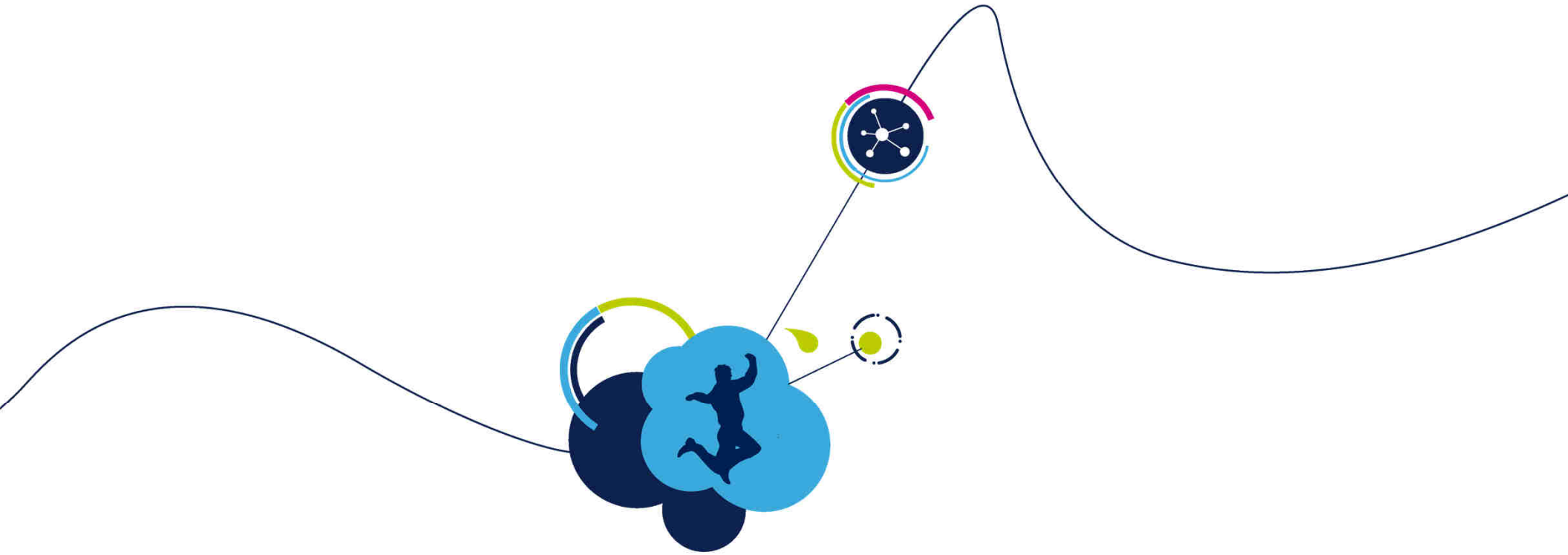


Technology Tour 2019
Schaumburg, IL | April 25



Agenda 2

- Key Op amp parameters for Precision
 - V_{io} - Input offset Voltage
 - CMRR – Common Mode rejection Ratio
 - I_{ib} – Input bias Current
 - Noise
- Analog sensor case study: Gas Sensor
- High performance Op amps in ST

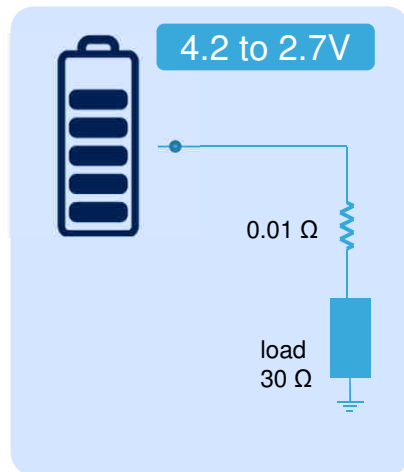


Op amps: V_{io} - input offset voltage

Why op amps and why precision

4

Battery fuel gauging



$0.9 \text{ mV} \leq V1 \text{ max}$
 $\leq 1.4 \text{ mV}$

Very small
signal



Need to
amplify

STM32 power supply:
1.65 to 3.6V

12-bit
ADC

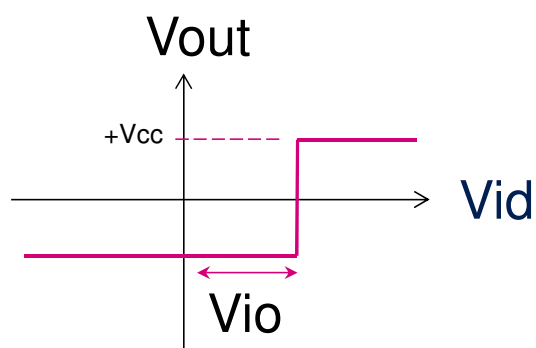
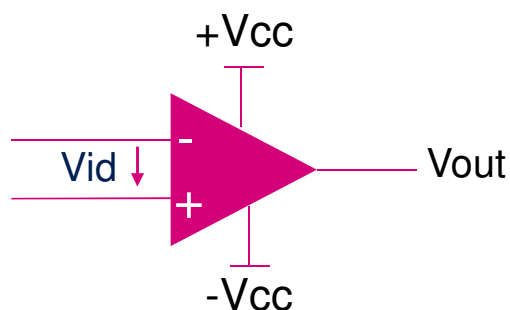


LSB of the ADC
 $= 3.6 \text{ V} / 2^{12}$
 $= 0.88 \text{ mV} !$

Input offset voltage

What is this?

Vio offset



LM324

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage ⁽¹⁾ $T_{amb} = +25^{\circ}C$ LM124-LM224 LM324		2	5 7	mV
	$T_{min} \leq T_{amb} \leq T_{max}$ LM124-LM224 LM324			7 9	

TS507

V_{io}	Input offset voltage ⁽²⁾	$V_{icm} = 0$ to $3.8V$, $T = 25^{\circ}C$ TS507C full temperature range TS507I full temperature range		25	100 250 400	μV
		$V_{icm} = 0V$ to $5V$, $T = 25^{\circ}C$ TS507C full temperature range TS507I full temperature range			450 550 750	

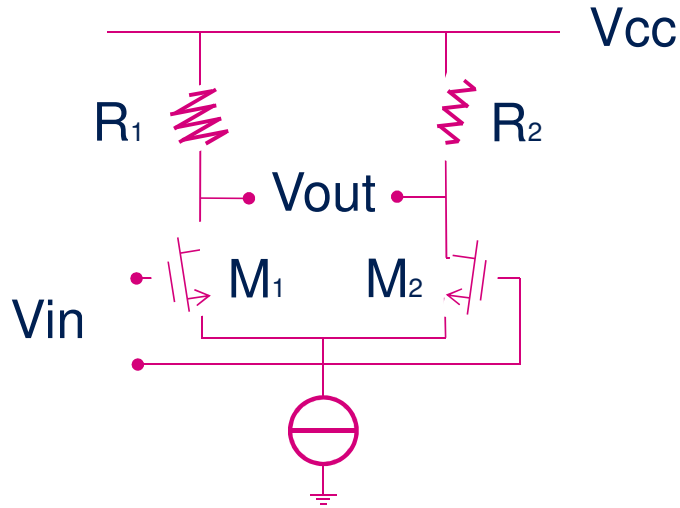
TSZ121 (Very high accuracy)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Input offset voltage	$T = 25^{\circ}C$		1	5	μV
		$-40^{\circ}C < T < 125^{\circ}C$			8	
$\Delta V_{io}/\Delta T$	Input offset voltage drift ⁽¹⁾	$-40^{\circ}C < T < 125^{\circ}C$		10	30	nV/ $^{\circ}C$

Input offset voltage

Where does it comes from?

Differential input



Component mismatch
 $R1 \neq R2, M1 \neq M2 \Rightarrow$ **offset**

For CMOS technology

$$V_{os} = \Delta V_{th} + \frac{V_{GS} - V_T}{2} \left(\frac{\Delta R}{R} + \frac{\Delta k'}{k'} + \frac{\Delta W/L}{W/L} \right)$$

ΔV_{th} linked to the substrate doping.
 Second term linked to the MOS size.

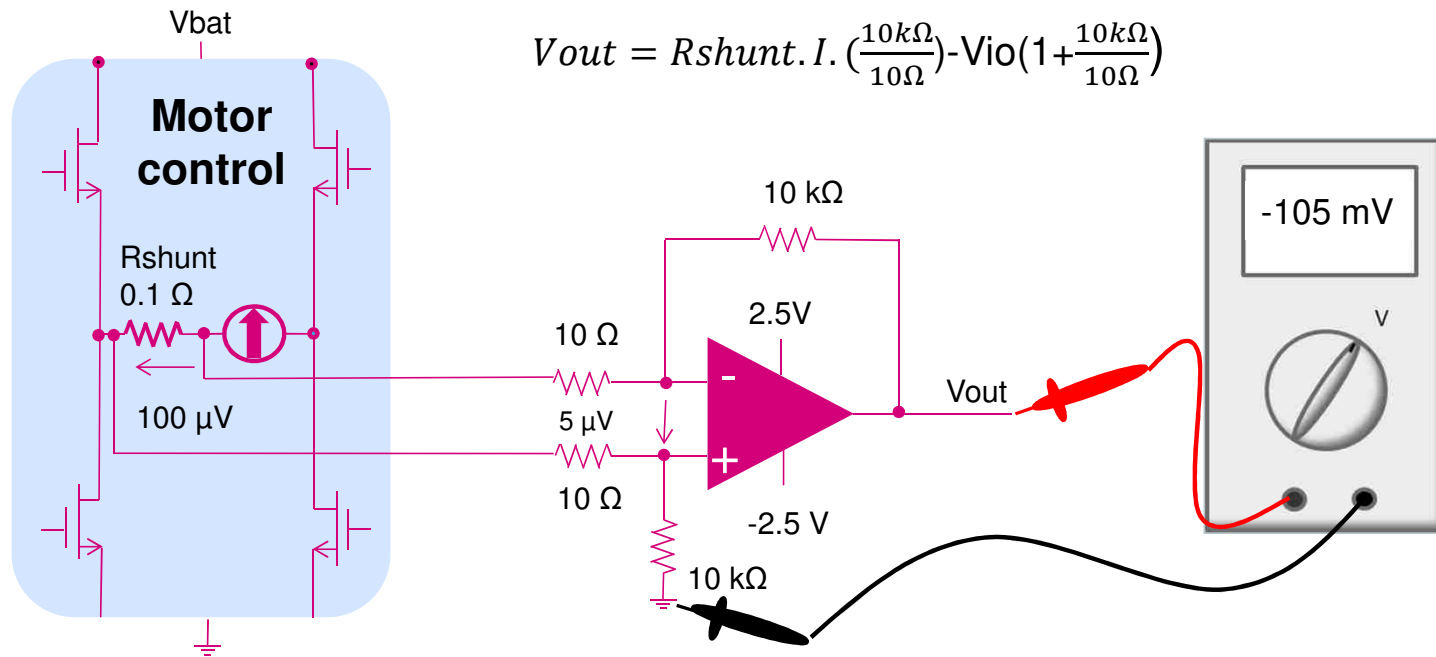
Mismatch is mainly due to:

- Doping variations
- Lithographic errors
- Packaging & local stress

Impact of V_{IO} on a real application

Current sensing for motor control

7



$I = 1 \text{ mA}$

TSZ121
 $V_{IO} = 5 \text{ μV}$

5% error on speed information
rotation information is correct

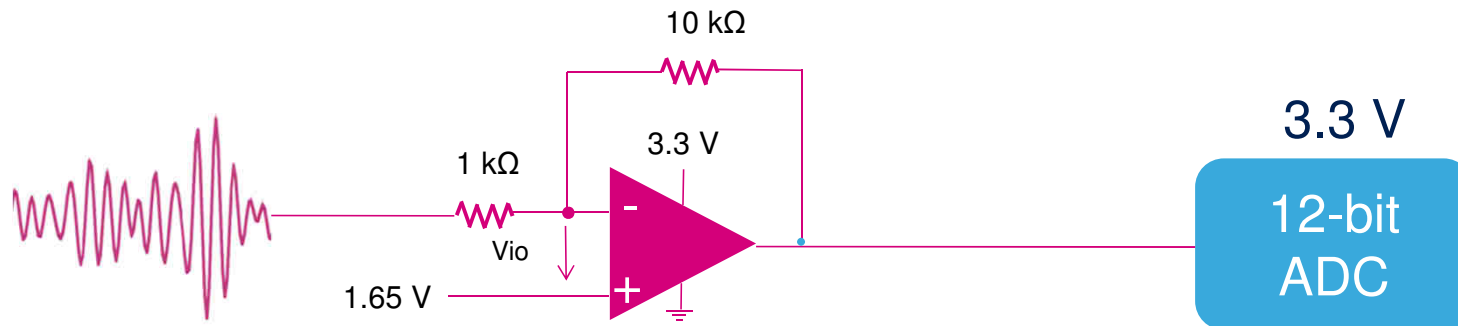
Summary of V_{IO} impact on motor control applications

8

Opamp	Offset @ 25°C	V_{OUT} for a current $I = 1 \text{ mA}$	Comment
Ideal	0 μV	100 mV	Theoretical measurement in a perfect world!
TS507	+100 μV	-100 μV	Speed of the motor is incorrect. Information about the motor rotation is incorrect.
	-100 μV	200 mV	100% error on motor speed. Information about the motor rotation is correct.
TSZ121	+5 μV	95 mV	5% error on the motor speed. Information about the motor rotation is correct.
	-5 μV	-105 mV	5% error on the motor speed. Information about motor rotation is correct.

The real cost of V_{IO} !

9



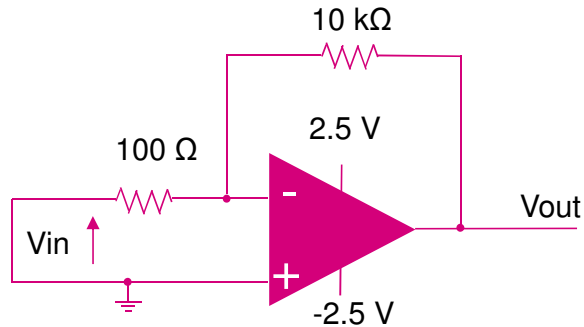
The LSB of the ADC is $3.3 \text{ V}/2^{12} = 805 \text{ } \mu\text{V}$

The input signal is amplified by -10, and the V_{IO} by 11

	Maximum V_{IO}	Maximum offset at ADC	Equivalent effective ADC
TSZ121	5 μV	55 μV	~12 bits
TS507	100 μV	1.1 mV	~11 bits
TS512A	500 μV	5.5 mV	~9 bits
TS512	2.5 mV	27.5 mV	~7 bits

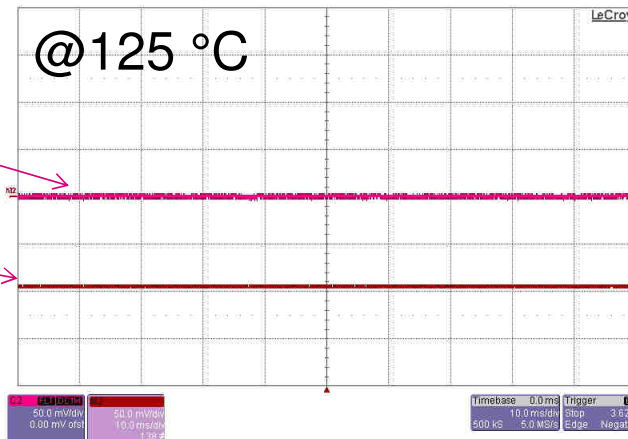
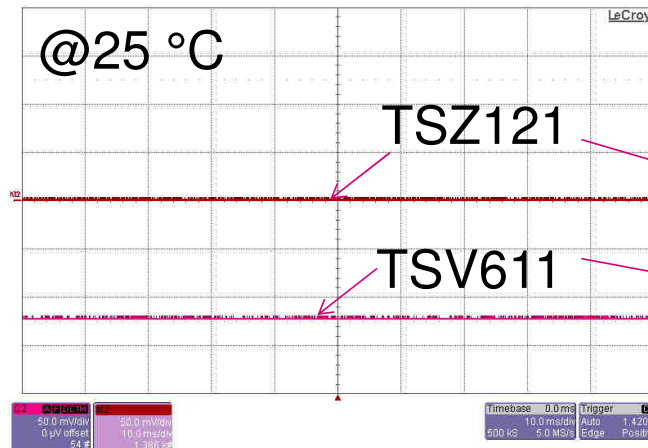
$\Delta V_{io}/\Delta T$ and calibration

10

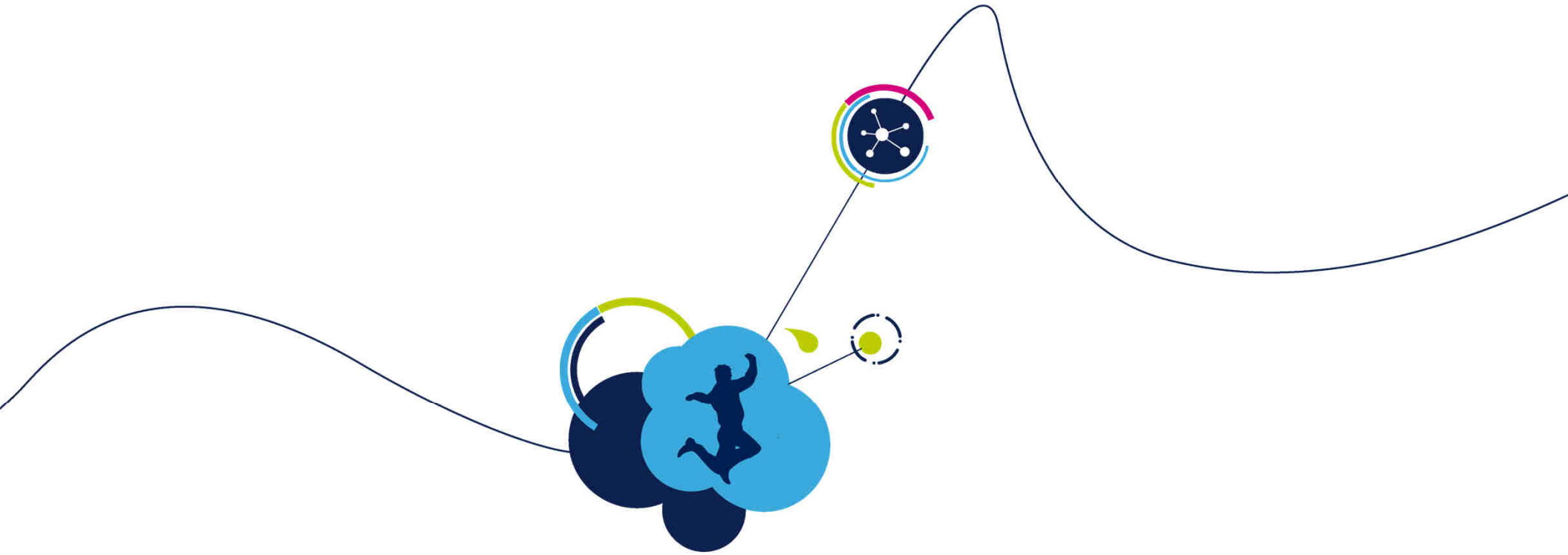


$$V_{out} = V_{in} \left(\frac{-10\text{ k}\Omega}{100\Omega} \right) \pm V_{io} \left(1 + \frac{10\text{ k}\Omega}{100\Omega} \right) \quad (1)$$

$$V_{out} = V_{in} \left(\frac{-10\text{ k}\Omega}{100\Omega} \right) \pm \left(V_{io} \pm dT \left(\frac{\Delta V_{io}}{\Delta T} \right) \right) \left(1 + \frac{10\text{ k}\Omega}{100\Omega} \right) \quad (2)$$



	V_{io} @ 25°C max	$\Delta v_{io}/\Delta t$ max
TSZ121	$5\ \mu\text{V}$	$30\text{ nV}/^{\circ}\text{C}$
TSV611	4 mV	$10\ \mu\text{V}/^{\circ}\text{C}$

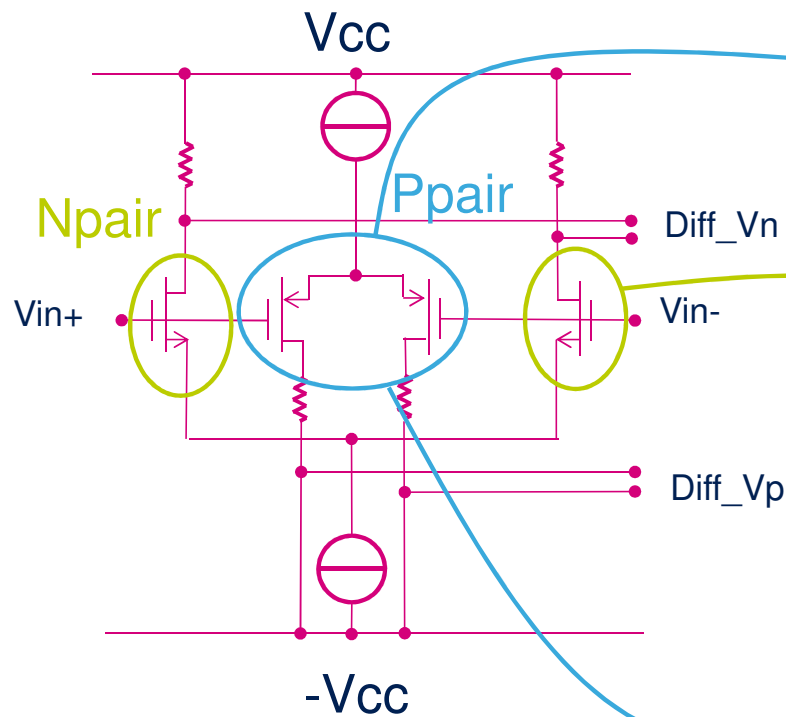


Op amps: CMRR – Common mode rejection ratio

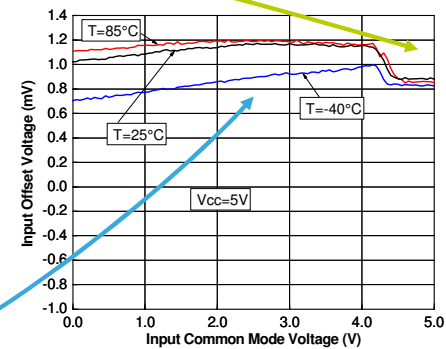
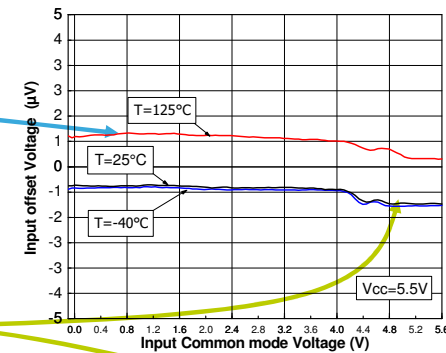
Common mode rejection ratio

12

Input stage of a CMOS op amp



TSZ121



TSV611

Impact of CMRR on a battery monitoring

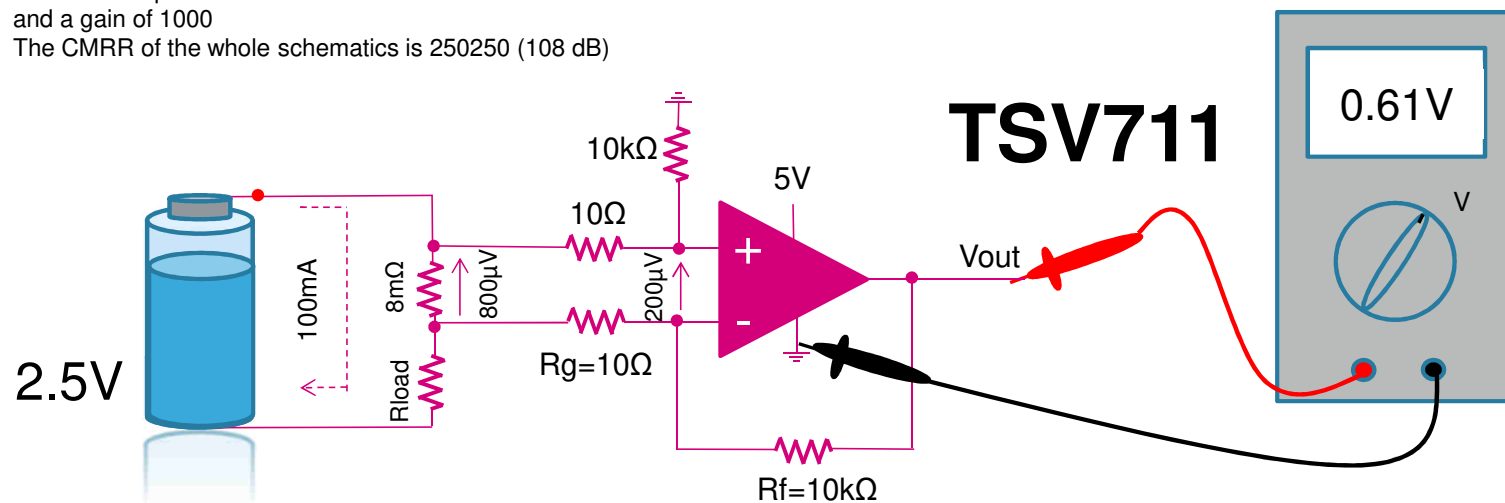
High-side current sensing

12

$$CMRR_{res} = \frac{1 + \frac{R_f}{R_g}}{4\epsilon}$$

$$V_{out} = 0.8 - \left(1 + \frac{R_f}{R_g}\right) \cdot V_{io} \pm \frac{v_{bat}}{CMRR_{res}} \left(\frac{R_f}{R_g}\right) \pm \frac{v_{icm} - v_{cc}/2}{CMRR_{op}} \left(1 + \frac{R_f}{R_g}\right)$$

With $\epsilon=0.1\%$ precision resistance
and a gain of 1000
The CMRR of the whole schematics is 250250 (108 dB)



TSV711	Impact on Vout	Error %
Vio	0.2V	25%
CMRRres @4.2V (108dB)	16.8mV	2.1%
CMRRop @4.2V (74dB)	340mV	42.5%
CMRRres @2.5V (108dB)	10mV	1.2%
CMRRop @2.5V (74dB)	0mV	0%

Impact of CMRR on a battery monitoring

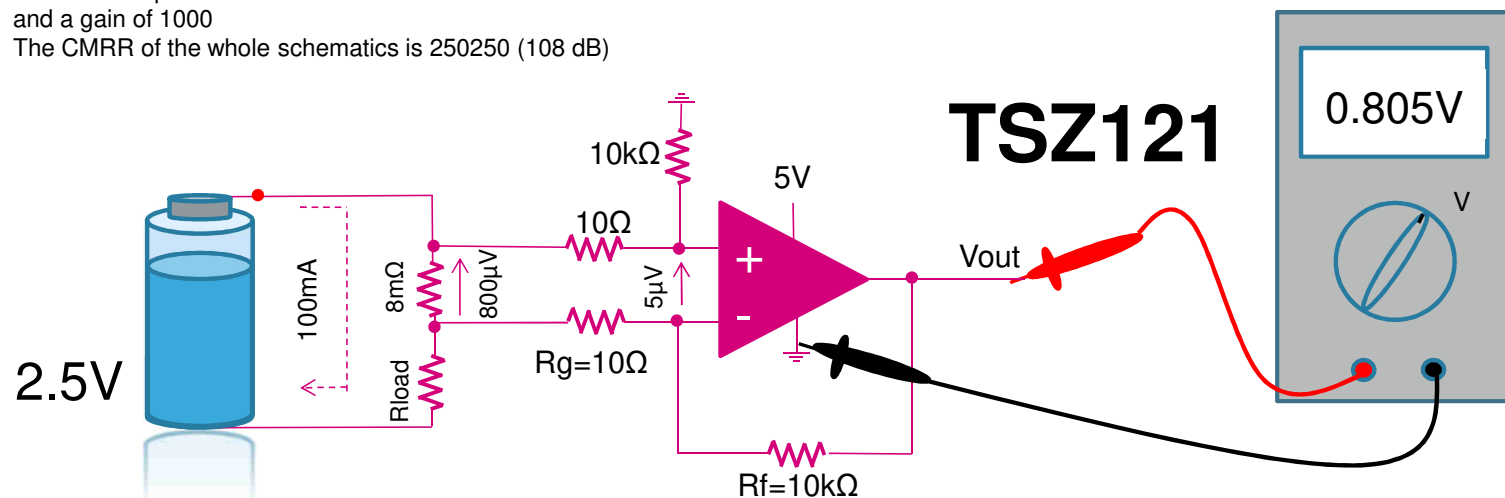
High-side current sensing

13

$$CMRR_{res} = \frac{1 + \frac{R_f}{R_g}}{4\epsilon}$$

$$V_{out} = 0.8 - \left(1 + \frac{R_f}{R_g}\right) \cdot V_{io} \pm \frac{v_{bat}}{CMRR_{res}} \left(\frac{R_f}{R_g}\right) \pm \frac{v_{icm} - v_{cc}/2}{CMRR_{op}} \left(1 + \frac{R_f}{R_g}\right)$$

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CMRRop @4.2V (74dB)	340mV	42.5%
CMRRres @2.5V (108dB)	10mV	1.2%
CMRRop @2.5V (74dB)	0mV	0%

TSZ121	Impact on Vout	Error %
Vio	0.005V	0.5%
CMRRres @4.2V (108dB)	16.8mV	2.1%
CMRRop @4.2V (115dB)	3mV	0.4%
CMRRres @2.5V (108dB)	10mV	1.2%
CMRRop @2.5V (115dB)	0mV	0%

V_{IO} , CMRR, PSRR and A_{VD}

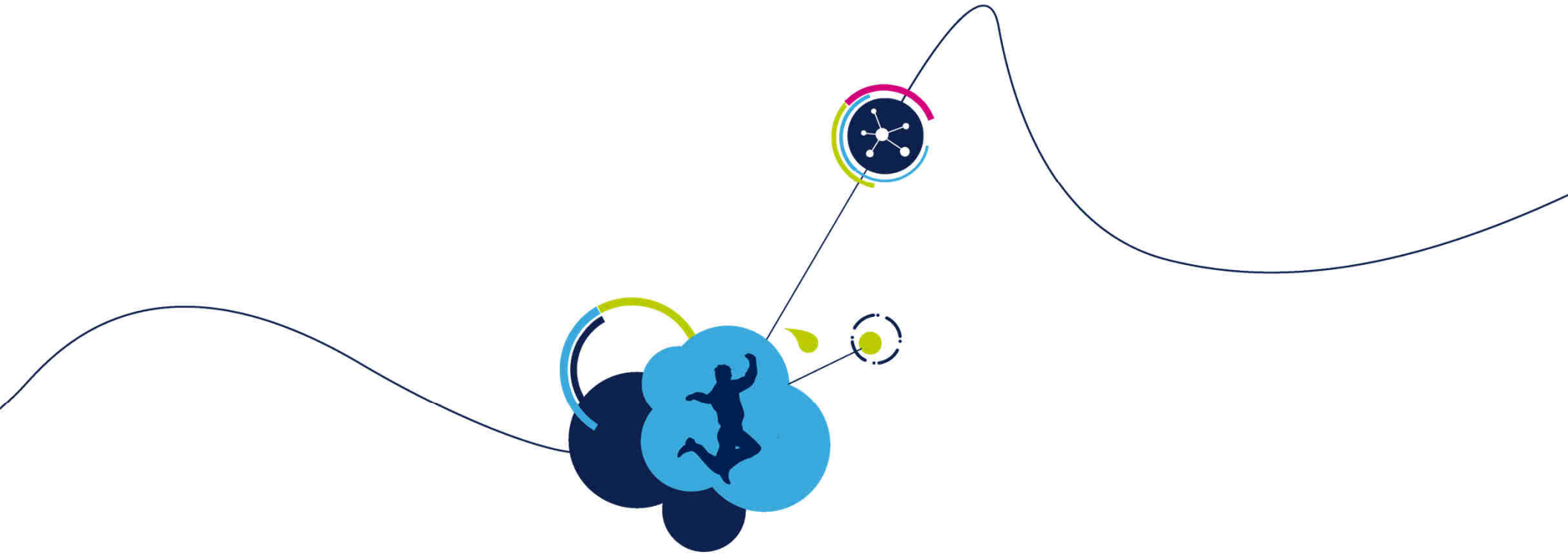
15

$$V_{id} = V_{io} + \frac{\partial V_{id}}{\partial V_{out}} \Delta V_{out} + \frac{\partial V_{id}}{\partial V_{icm}} \Delta V_{icm} + \frac{\partial V_{id}}{\partial V_{cc}} \Delta V_{cc} + \frac{\partial V_{id}}{\partial T} \Delta T(1)$$

Diagram illustrating the equation for V_{id} with annotations:

- V_{io} : Input offset
- $\frac{\partial V_{id}}{\partial V_{out}} \Delta V_{out}$: A_{VD}
- $\frac{\partial V_{id}}{\partial V_{icm}} \Delta V_{icm}$: CMRR
- $\frac{\partial V_{id}}{\partial V_{cc}} \Delta V_{cc}$: PSRR
- $\frac{\partial V_{id}}{\partial T} \Delta T(1)$: Input offset drift

We define: $A_{vd} = -20 \log\left(\left|\frac{\partial V_{id}}{\partial V_{out}}\right|\right)$, $CMRR = -20 \log\left(\left|\frac{\partial V_{id}}{\partial V_{icm}}\right|\right)$, $SVR = -20 \log\left(\left|\frac{\partial V_{id}}{\partial V_{cc}}\right|\right)$ and $DV_{io} = \left|\frac{\partial V_{id}}{\partial T}\right|$



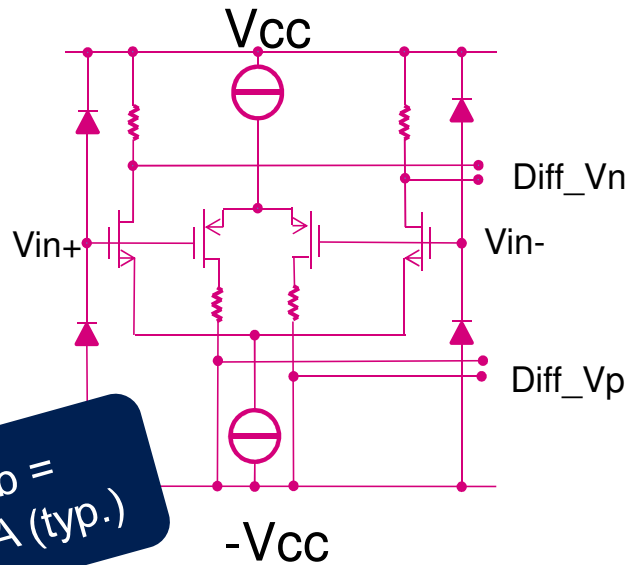
Op amps: lib – Input bias current

Input bias current

17

CMOS

No gate current, only diode leakage

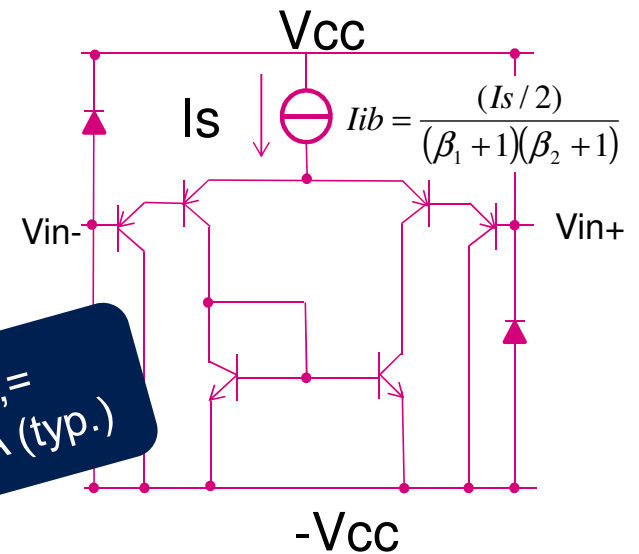


$I_{ib} = 1 \text{ pA (typ.)}$

$$I_{ib} = \left| \frac{I_{ibn} + I_{ibp}}{2} \right|$$

BIPOLAR

Current in/out (NPN/PNP) in the base



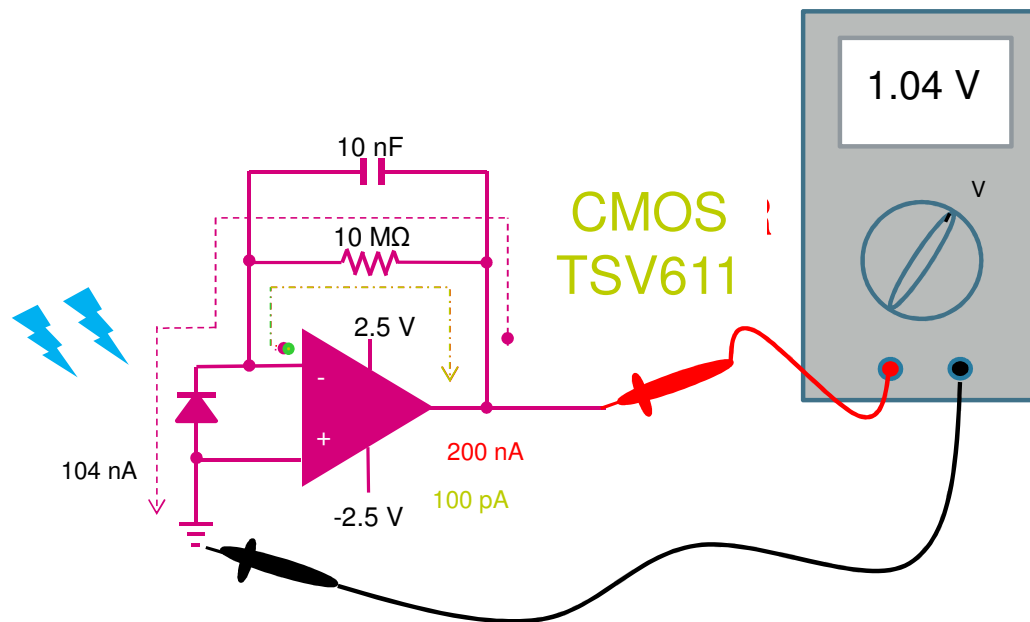
$I_{ib} = 20 \text{ nA (typ.)}$

$$I_{ib} = \frac{(I_s / 2)}{(\beta_1 + 1)(\beta_2 + 1)}$$

UV sensor application

18

UV source Index 4

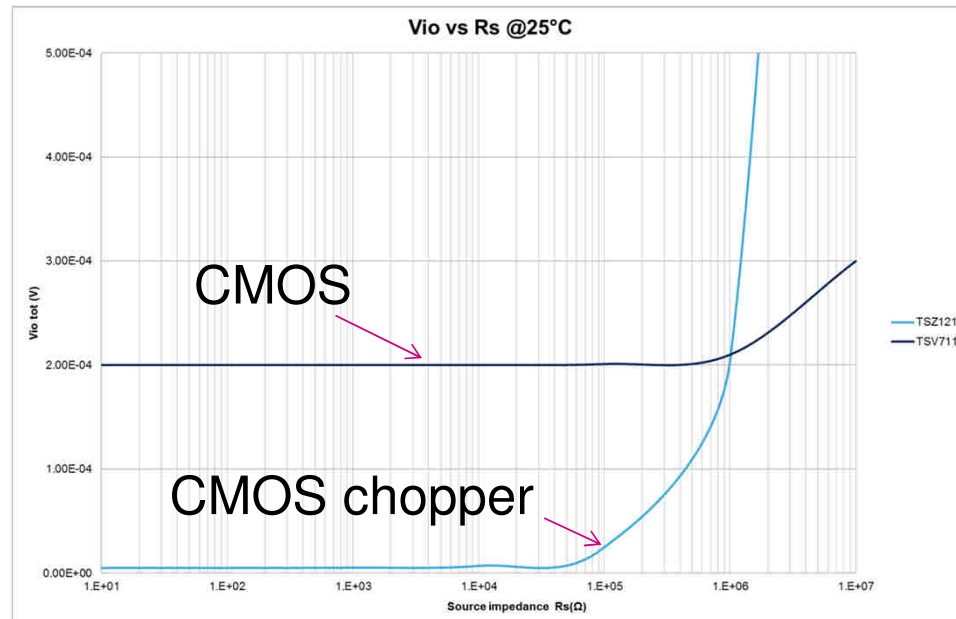
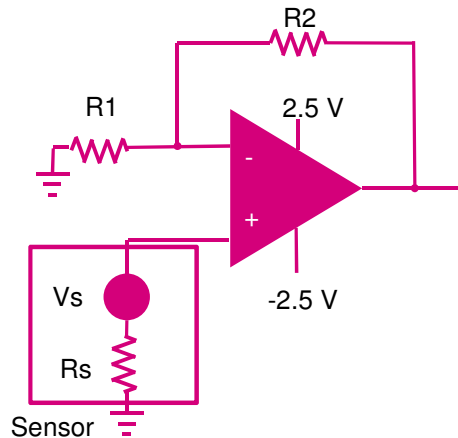


UV table translation for the UV sensor and Gain of 10M

UV1	UV2	UV3	UV4	UV5	UV6	UV7
0.26 V	0.52 V	0.78 V	1.04 V	1.3 V	1.56 V	1.82 V

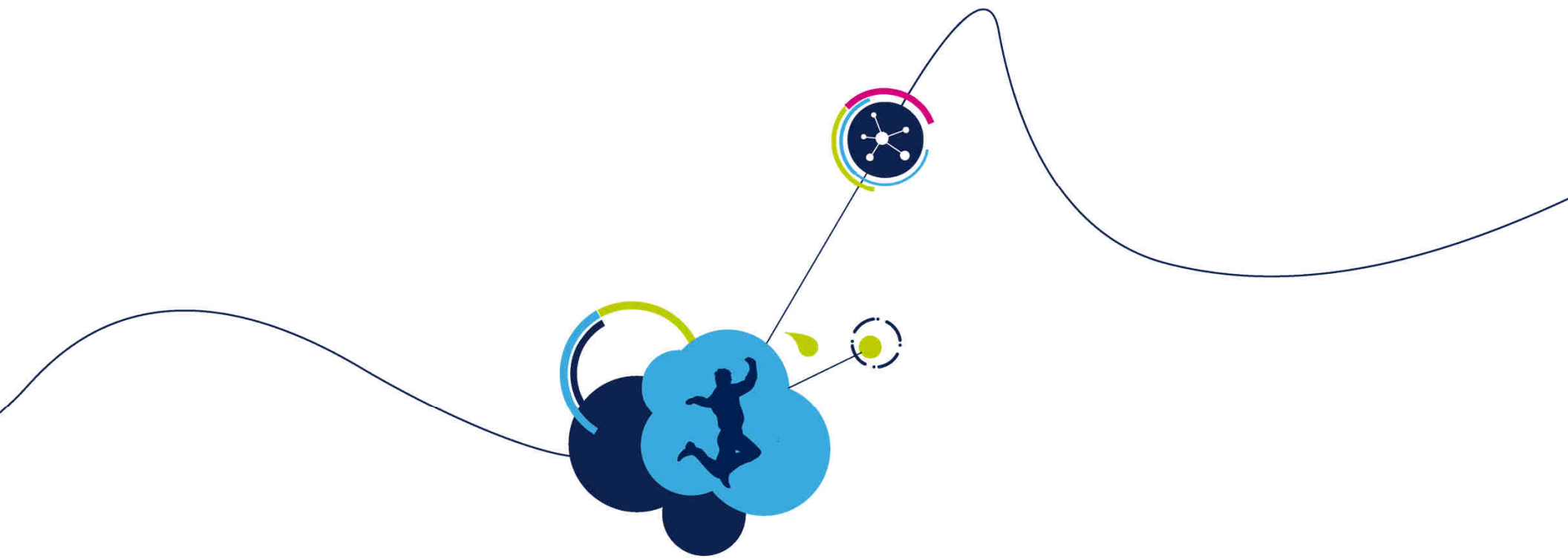
Is the TSZ121 chopper always a good choice?

19



$$V_{io\ tot} = V_{io} + R_s \cdot I_n \quad (1)$$

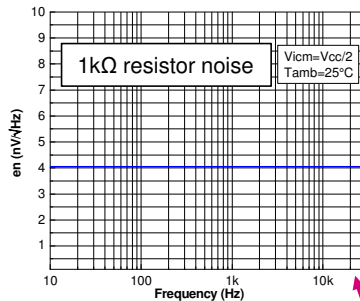
$$R_s > \frac{V_{io}}{I_n} \quad (2)$$



Opamps: Noise

Noise sources of an op amp

21



Resistors generate a white noise with a spectral density of:

$$e_n = \sqrt{4kTR} \quad \text{VHz}^{-\frac{1}{2}}$$

Where

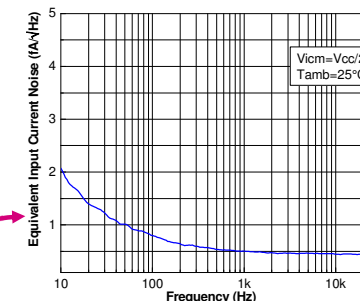
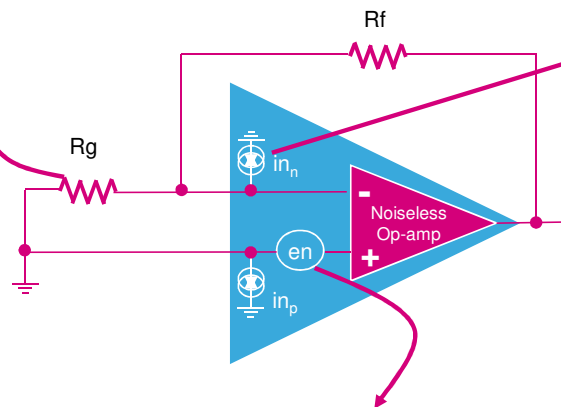
$$k = 1.38 \cdot 10^{-23} \text{ JK}^{-1}$$

(Boltzmann's constant)

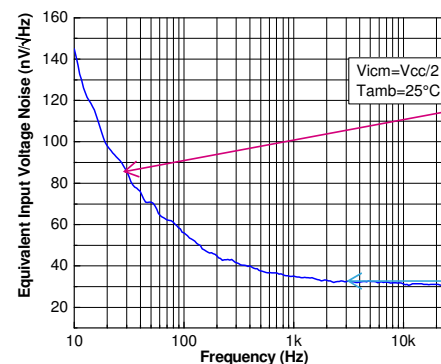
$$T = T(^{\circ}\text{C}) + 273.15$$

(Temperature in Kelvin)

There are 5 sources of noise



For CMOS input op amps, input noise current is extremely low (0.5fA/√Hz) and generally does not affect design



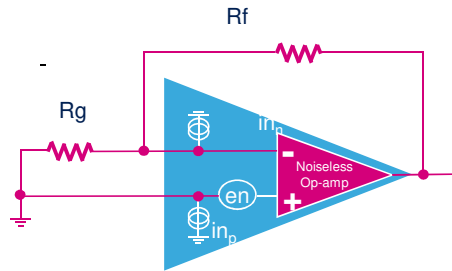
$\frac{1}{f}$ noise (flicker noise)

$$e_{nf}(f) = \sqrt{\frac{enf(1\text{Hz})}{f}} \text{ V}/\sqrt{\text{Hz}}$$

White noise
 $e_n \text{ V}/\sqrt{\text{Hz}}$

Contribution of each source of noise

22

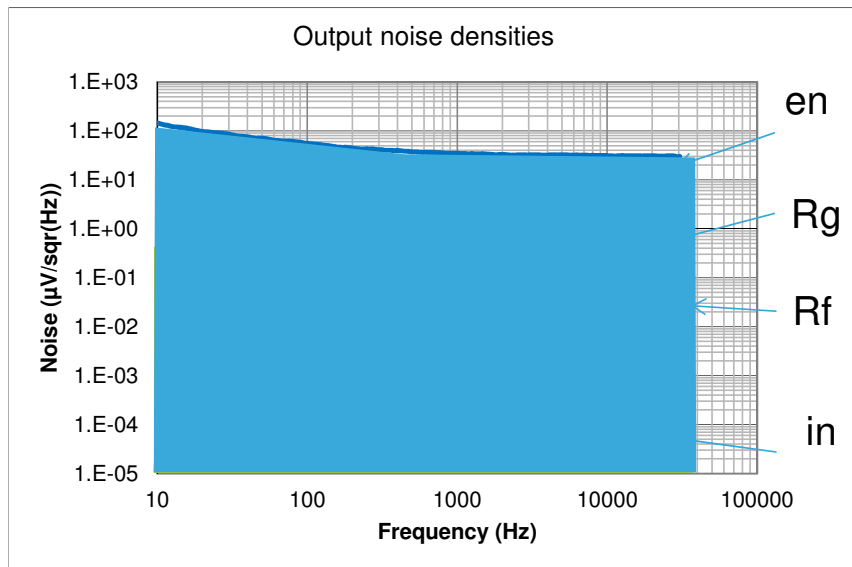
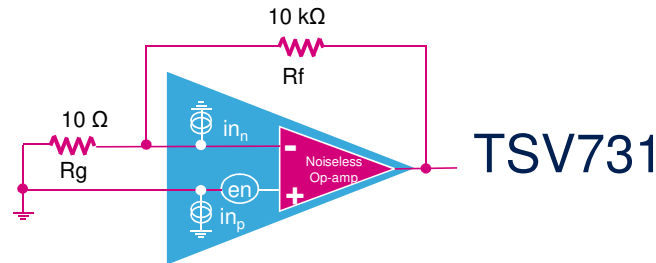


$$V_{out_{rms}} = \sqrt{\int_{fL}^{fH} \left[e_n^2 \left(1 + \frac{R_f}{R_g} \right)^2 + R_f^2 I_{nn}^2 + 4kTR_g \left(\frac{R_f}{R_g} \right)^2 + 4kTR_f \right] df}$$

Noise source	Spectral density noise referred to the output	RMS noise value over a given bandwidth referred to the output
e_n	$e_n \cdot \left(1 + \frac{R_f}{R_g} \right)$	$\left(1 + \frac{R_f}{R_g} \right) \cdot \sqrt{e_n^2 (FH - FL)}$ if white noise $\left(1 + \frac{R_f}{R_g} \right) \cdot \sqrt{e_n^2 (1\text{Hz}) \cdot \ln\left(\frac{FH}{FL}\right)}$ if 1/f noise
I_{nn}	$I_{nn} \cdot R_f$	$R_f \cdot \sqrt{I_{nn}^2 (FH - FL)}$ if white noise
R_g	$\frac{R_f}{R_g} \cdot \sqrt{4 \cdot k \cdot T \cdot R_g}$	$\frac{R_f}{R_g} \cdot \sqrt{4 \cdot k \cdot T \cdot R_g \cdot (FH - FL)}$
R_f	$\sqrt{4 \cdot k \cdot T \cdot R_f}$	$\sqrt{4 \cdot k \cdot T \cdot R_f \cdot (FH - FL)}$

Contribution of each source of noise

23

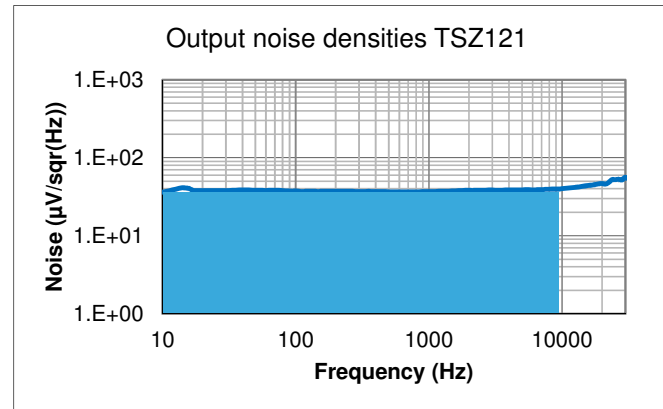
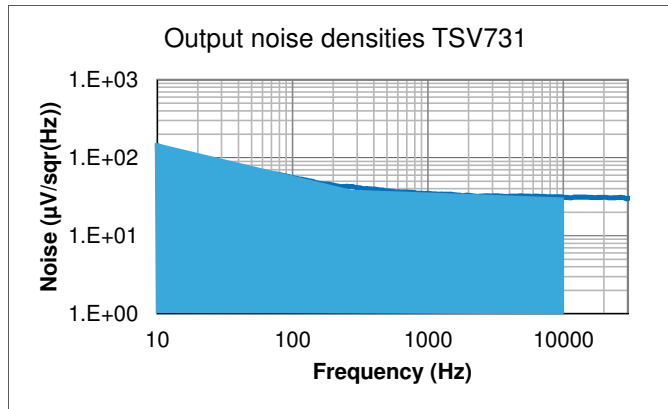
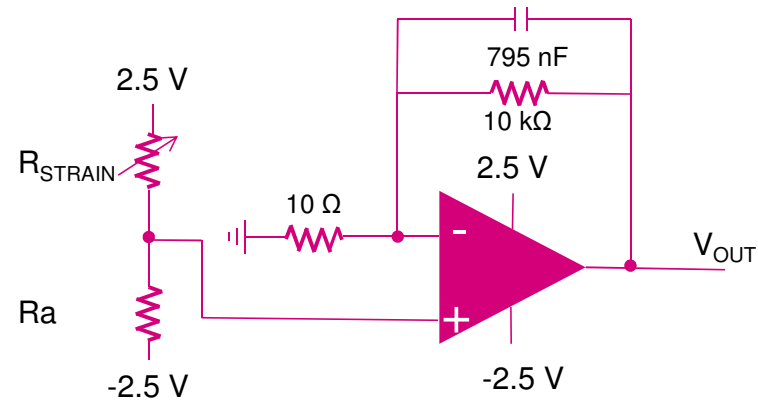


Noise voltage contribution to the output BW = 30 kHz		
Noise Source		en V_{RMS}
OPAMP	en	$5.37 \cdot 10^{-3}$
	In	$8.66 \cdot 10^{-9}$
THERMAL	Rf	$2.2 \cdot 10^{-6}$
	Rg	$70.5 \cdot 10^{-6}$

$$V_{\text{outRms}} = \sqrt{en^2 + In^2 + Rf^2 + Rg^2}$$

Impact of noise in a application

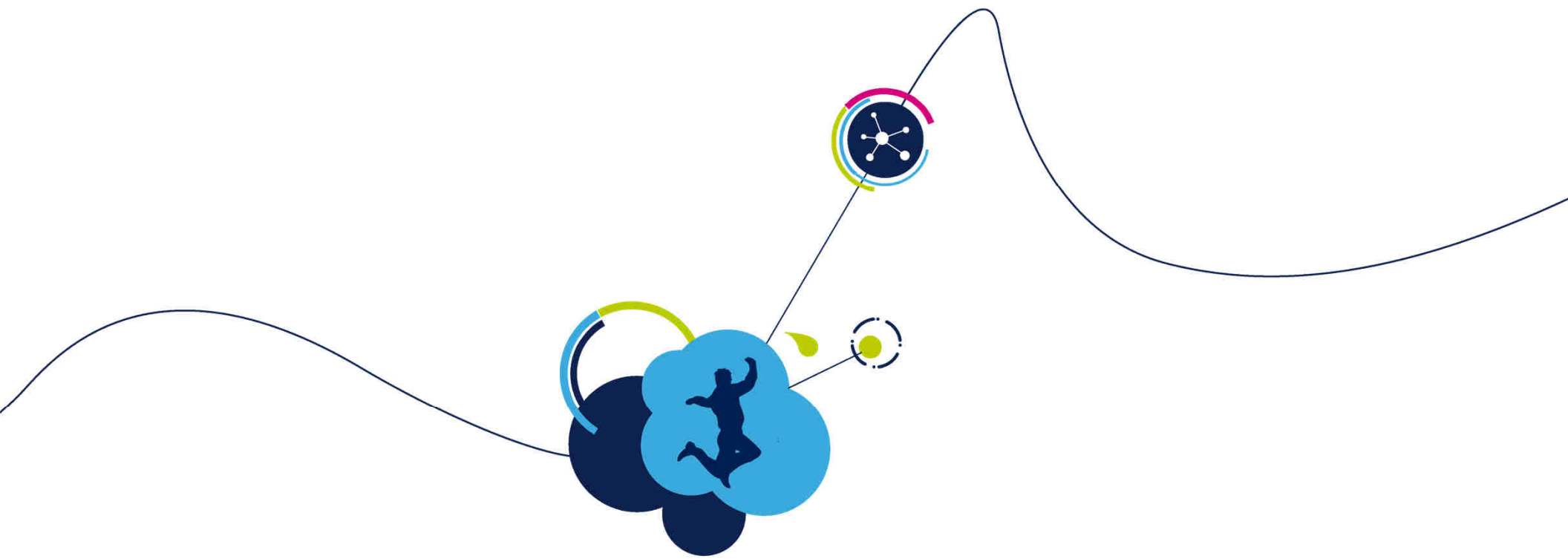
24



Bandwidth 20 Hz

$$\text{en_Vout}_{\text{Rms}} = 0.69 \text{ mV}_{\text{Rms}}$$

$$\text{en_Vout}_{\text{Rms}} = 0.16 \text{ mV}_{\text{Rms}}$$



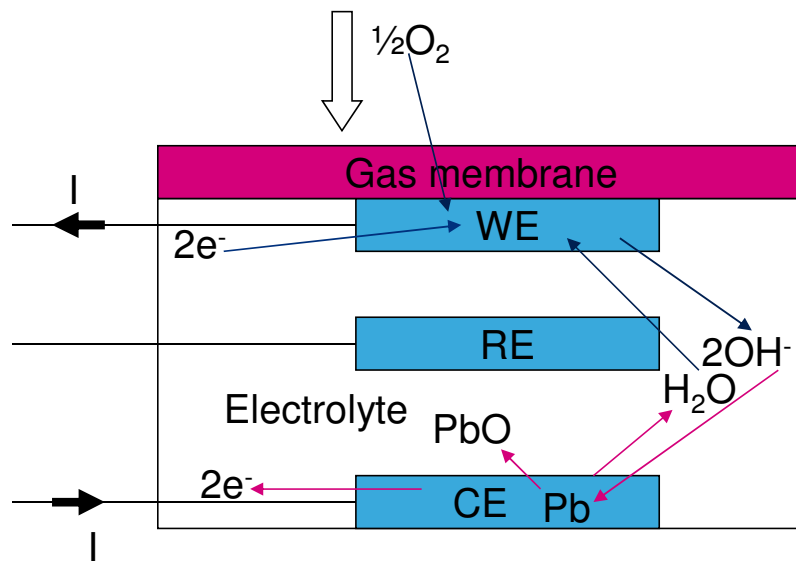
Use case study: Gas sensor

What is an electrochemical sensor

26

- Different technologies of sensors

- Electrochemical (amperometric) : Low consumption and linear output
- Other types of technologies : Metal Oxide Semiconductor, Non Dispersive Infra Red

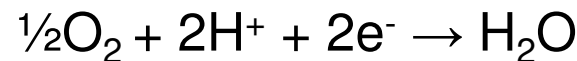


Oxygen sensor

Oxidation on Working Electrode (WE)



Reduction on Counter Electrode (CE)

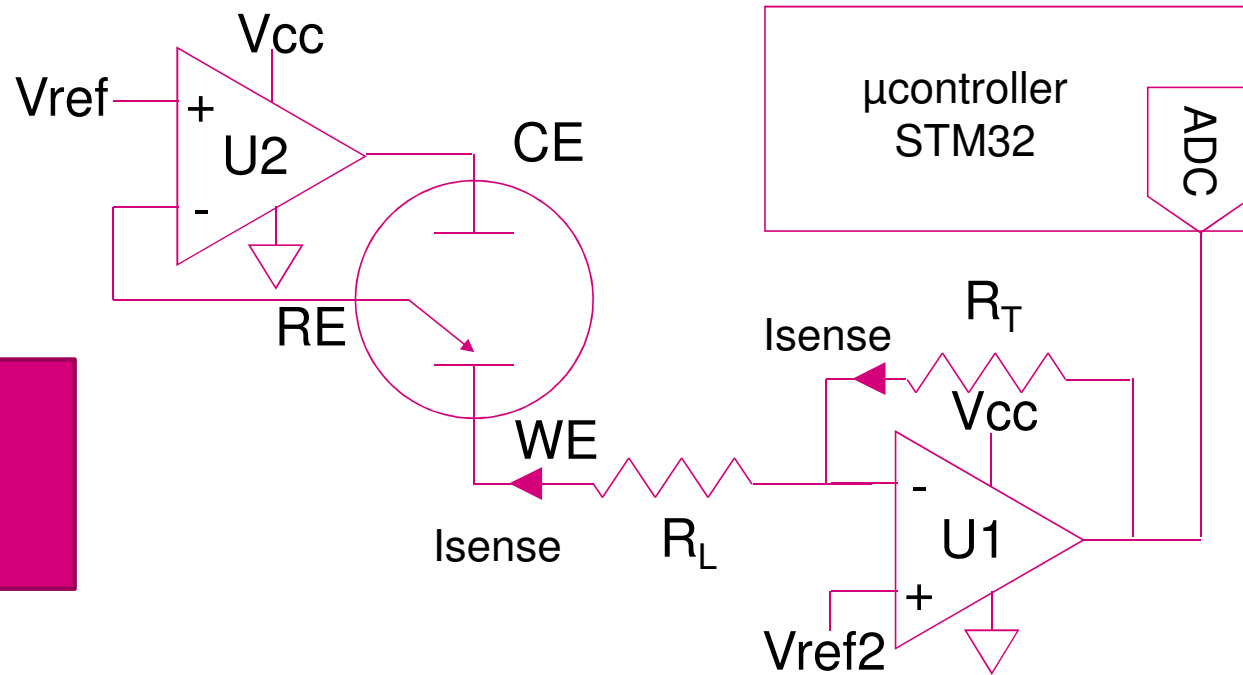


Reference Electrode (RE)



3 electrodes sensors : Potentiostat

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U1/U2 :

- TSU112,
- TSU102,
- TSV712

Need for ST op-amps !

-Bias the sensor

U2 : RE set to V_{ref} without driving current

-Convert the current into voltage (to drive the ADC)

U1 : $V_{out} = V_{ref2} + R_T \cdot I_{sense}$

Sensor Characteristics

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- Polarity
 - For sensors such as CO, H₂S, SO₂, NO the current enters into the working electrode (oxidation)
 - For O₂, NO₂, Cl₂ the current gets out of the working electrode (reduction)
- Bias
 - Most of the sensors including CO need to be biased with the same voltage on the working and reference electrodes
 - Some may require a positive or negative bias (NO, O₂)
- Sensitivity
 - Generally some tens of nA/ppm for toxic gases
 - Up to some 100uA for O₂ sensor in air (20.9%)
- Rload
 - Recommended load to be seen by the sensor (generally in the range 10Ω~100Ω)

Op amp key parameters

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- Small currents means CMOS device
- Rail to rail op-amps preferred especially for low voltages and sensors that require a biasing different than 0V
- Low consumption (battery powered applications)
- Small package

TSU101/TSU102/TSU104
600nA / channel

CMOS
Low Power
Rail to Rail
SC70-5 / DFN8 2x2

TSZ121/TSZ122/TSZ124
Vio 5uV max

TSU111/TSU112/TSU114
900nA / channel, Vio 150uV max

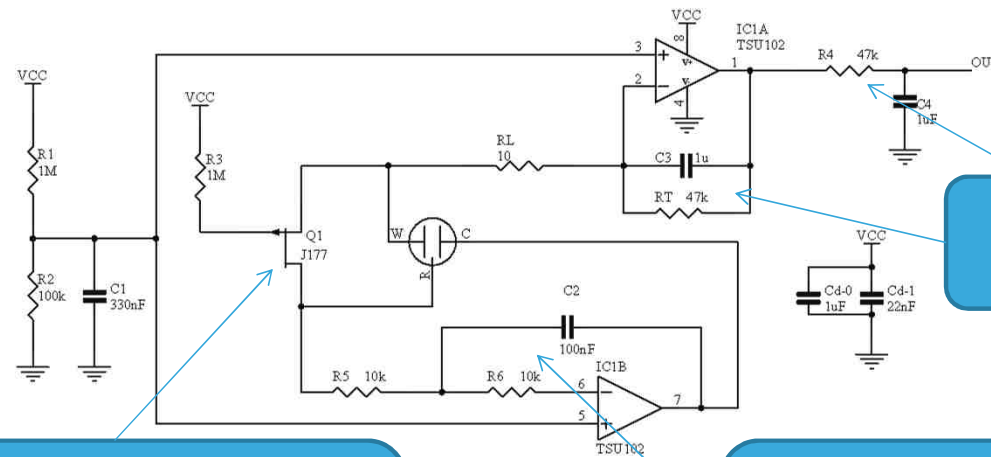
TSV711/TSV712/TSV714
9uA / channel, Vio 200uV max

From sensor specification to application

30

Sensitivity	10 ... 30 nA/ppm
Standard Range	0 – 1000 ppm

For $V_{CC}=3.3V$, $V_{icm}=300mV$ (to keep room from saturation)
Maximum output voltage $0.3+47000*30e-9*1000=1.71V$ (room for over-range)
1ppm means between 0.47mV and 1.4mV on the output (1 LSB of a 12 bit ADC is 0.8mV)



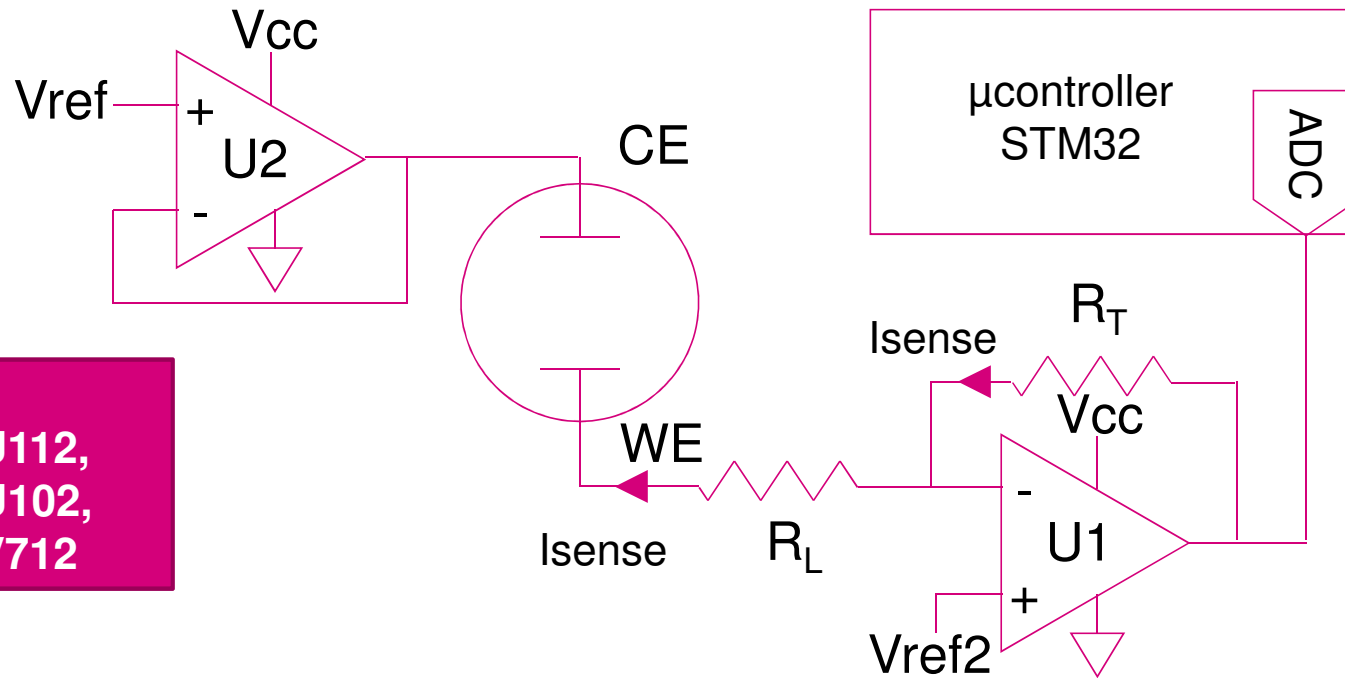
3.4Hz low
pass filter

PJFET to keep the
sensor biased during
power off

Optional
compensation
network

2 electrodes sensors : Transimpedance

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U1/U2 :

- TSU112,
- TSU102,
- TSV712

Two electrodes sensors have no RE
This schematics bias CE at V_{ref} , WE at V_{ref2} ,
and the output reading is $V_{ref2} + R_T \cdot I_{sense}$

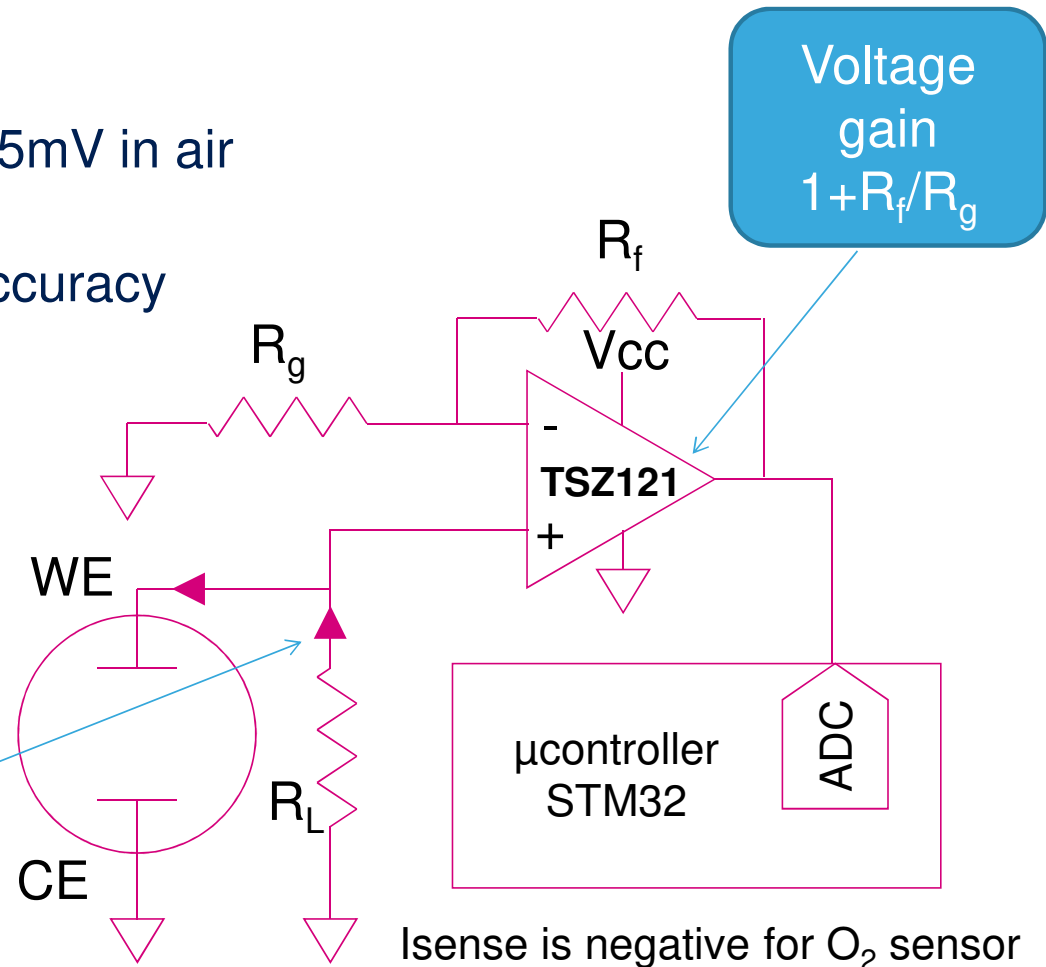
2 electrodes sensors : Galvanic

32

- I to V conversion done by R_L (100Ω)
- Small signal to amplify $\sim 350\mu A \times 100\Omega = 35mV$ in air
- Op-amp used in voltage gain need for accuracy

TSZ121
High precision
amplifier
5uV max
30nV/°C max
29uA typ

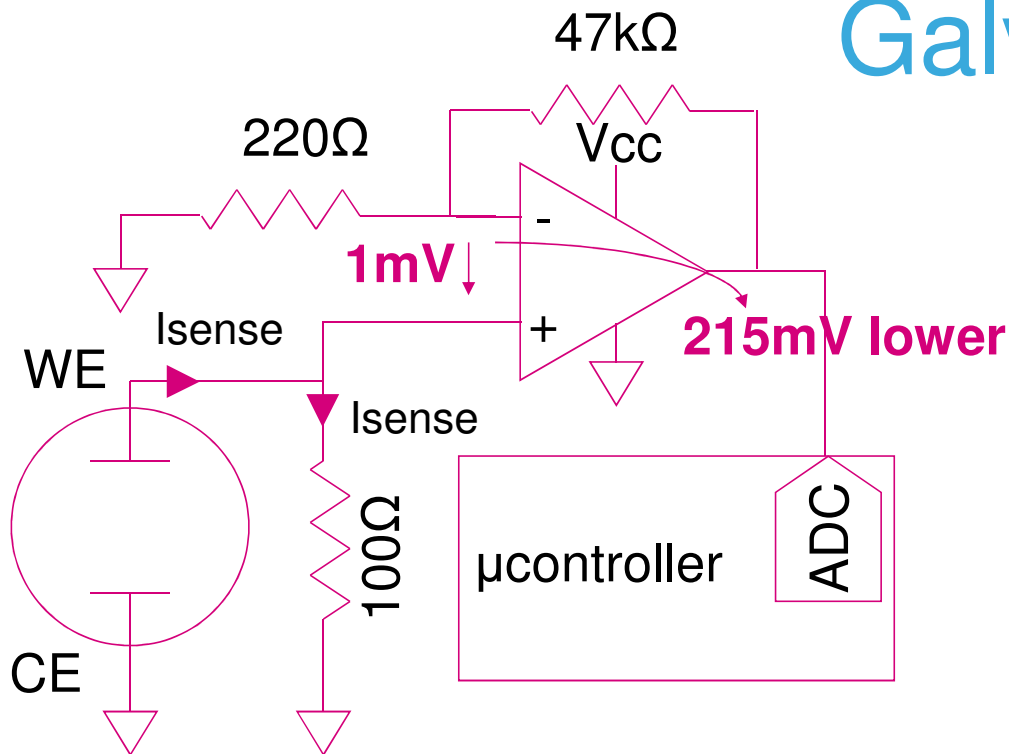
I to V
conversion
 $I \cdot R_L$



Isense is negative for O_2 sensor

Galvanic sensor - Vio

25



O_2 sensor specification
Output Signal | $0.10 \pm 0.02\text{mA}$ in air

Recommended Load
Resistor | 100Ω

This sensor we have outputs $90.8\mu\text{A}$ in air*
Voltage to amplify : 9.08mV

In air* output voltage should be
 $9.08\text{mV} \times (1 + 47/0.22) = 1.95\text{V}$
(*air means $[O_2] = 20.9\%$)

	Output voltage	Vio	[O2] equivalent
TSZ121	1.95V	5uV max	20.9%
Standard micro-power device	1.74V	1mV	18.6%

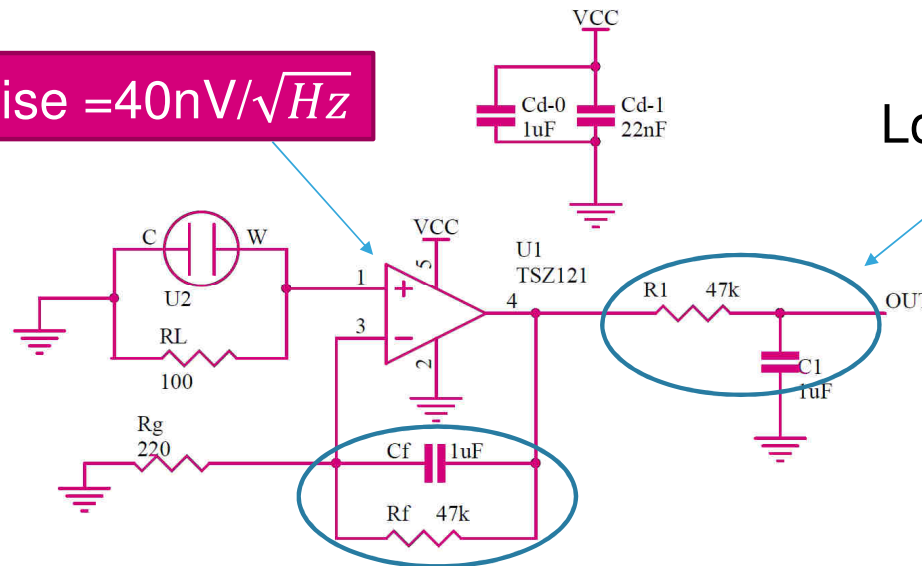
The input offset voltage can cause a significant offset
(alarm would ring in air for second device!)

Galvanic configuration filtering

34

TSZ121 noise = $40\text{nV}/\sqrt{\text{Hz}}$

Low pass filter = 3.4Hz



$$en_{RMS} = e_0 * Gain * \sqrt{1.2 * fc}$$

$$en_{RMS} = \frac{40\text{nV}}{\sqrt{\text{Hz}}} * 214 * \sqrt{1.2 * 3.4\text{Hz}} = 17.3\mu\text{V}_{RMS}$$

Take away

35



Electrochemical sensors need
High performance Opamps
Different Opamp solutions depending on Sensors &
Application constraints.

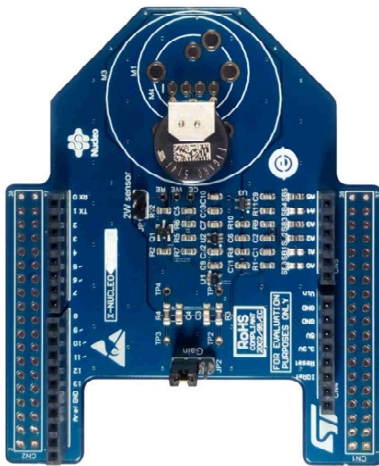
Products	Features (all specifications given at 3.3 V)
TSU111	Ultra low consumption: 900 nA typ
TSU112	Low low noise: 3.7 μ Vpp from 0.1 Hz to 10 Hz
TSU114	Good precision: 150 μ V max
TSU101	Ultra low consumption: 600 nA typ
TSU102	Battery life extension
TSU104	
TSV711	Good compromise between consumption and precision
TSV712	Icc: 9 μ A typ
TSV714	Vio: 200 μ V max
TSZ121	Excellent precision: Vio 5 μ V max
TSZ122	Ultra low noise: 0.8 μ Vpp from 0.1 Hz to 10 Hz
TSZ124	Ideal for galvanic use



Electrochemical gas sensor evaluation pack

2 videos released in February 2018

Order code : **P-NUCLEO-IKA02A1**



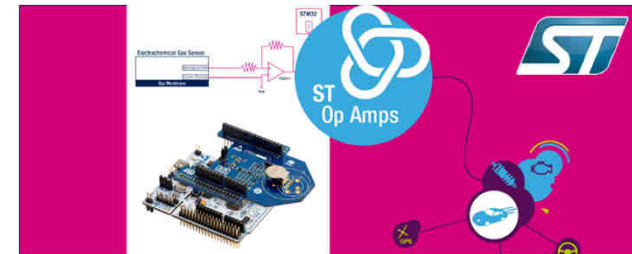
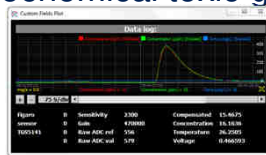
Board

- 2 x TSU111 nano-power op amps
- Are used for signal conditioning
- Are ideal for electrochemical sensing thanks to high precision and low power consumption



Getting Started with P-NUCLEO-IKA02A1

- STM32 Nucleo pack for electrochemical toxic gas sensing



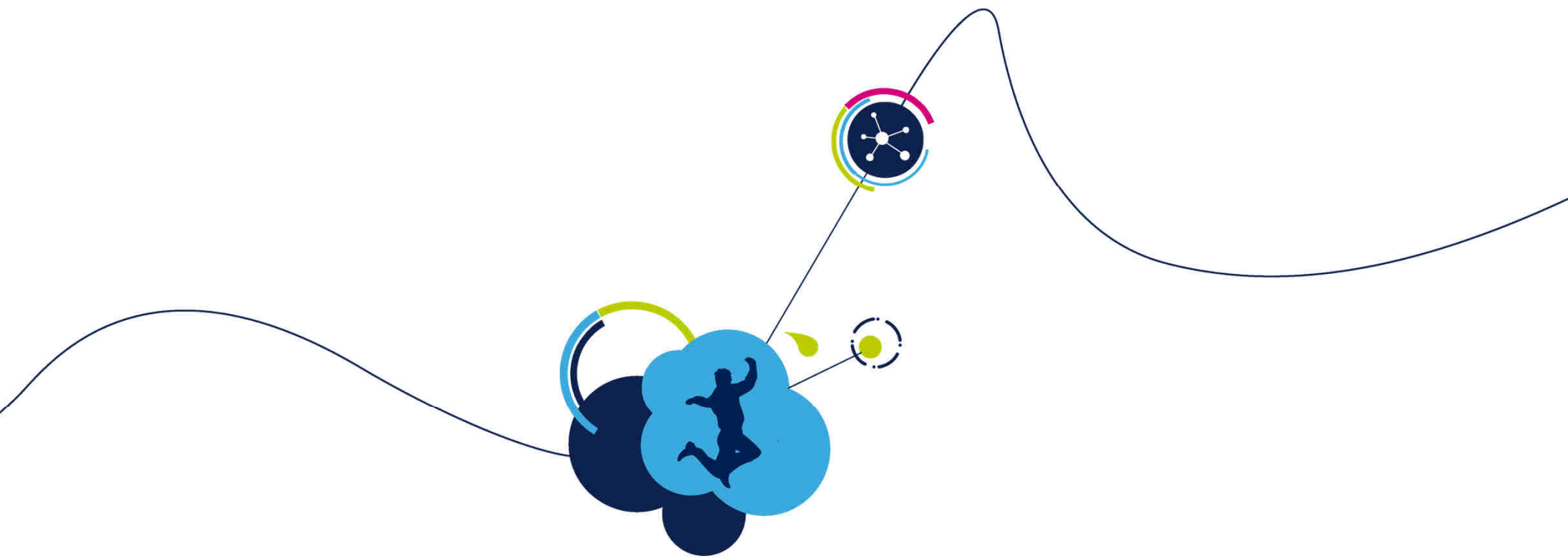
Product overview

Wireless Home CO detector

Wireless CO detector demo

- Based on **TSU111** Op Amps and **S2-LP** sub-1GHz RF transceiver and Figaro TGS5141 CO sensor





High Performance Op amps in ST

General Purpose Analog

The best choice for longevity,
robustness and power efficiency



- 40 year experience in the analog
- 5 Billion units manufactured per year (100 units/s)
- 5 400 commercial parts
- Worldwide Customer Base
- Large Technology portfolio From Analog to Mixed Signal
- High reliability products 0.05ppm for Automotive Grade, 1ppm for Standard Grade

From Standard to High performance

1980

2019

I_{cc} (LM358)

1.2mA max @25°C

power savings

*supply current enhanced by *1400*



I_{cc} (TSU101)

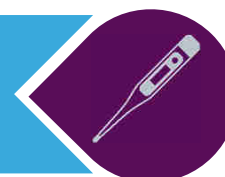
850nA max @25°C

V_{io} (LM358)

7mV max @25°C

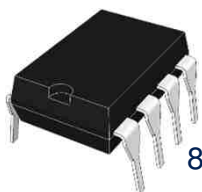
accuracy

*input offset enhanced by *1400*



V_{io} (TSZ121)

5μV max @25°C

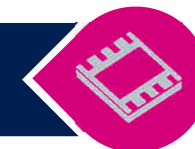


DIP8

8.8mm*6.4mm*4mm

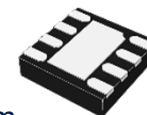
space saving

*volume enhanced by *100*



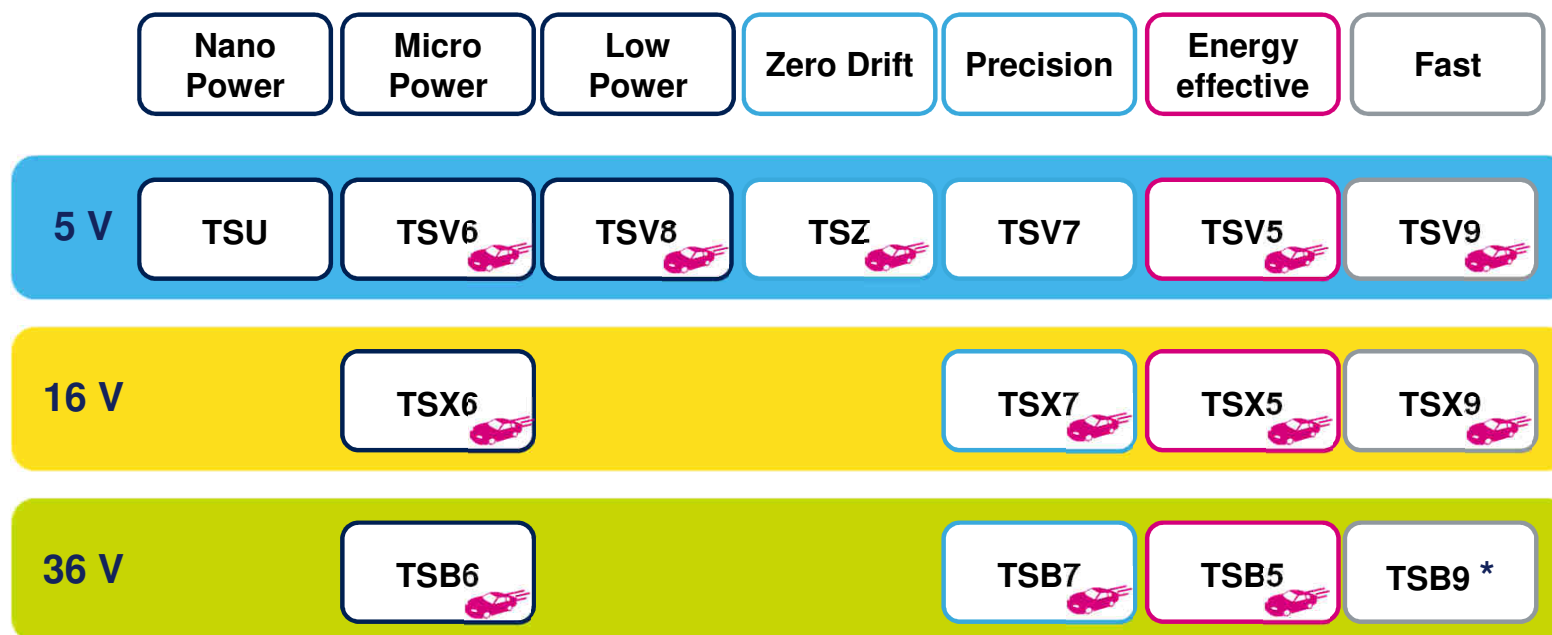
DFN8

2mm*2mm*0.55mm



High Performance Op Amps

40



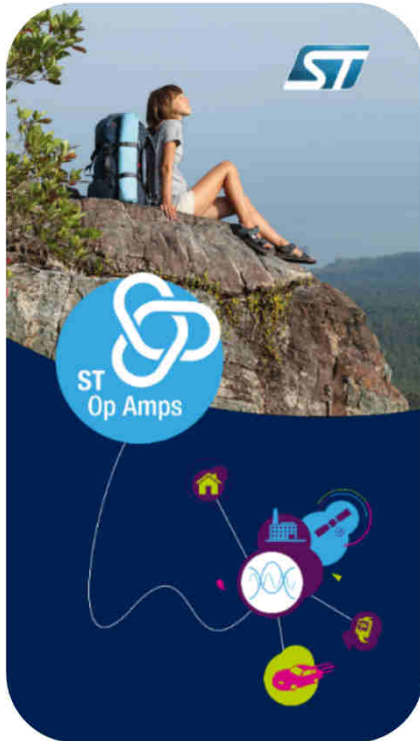
 AECQ-100

* In development



High Precision & Nanopower Op Amps

41



TSZ12 Series
Zero Drift
CMOS Amplifier

- Very low offset $5\mu\text{V}$ max
- Very low drift in Temperature $30\text{nV}/^\circ\text{C}$

TSZ181-182
Zero Drift & Speed
Amplifier

- Very low offset $25\mu\text{V}$ max
- Very low drift in Temperature $0.1\mu\text{V}/^\circ\text{C}$
- Excellent Speed/power ratio $3\text{MHz}/1\text{mA}$

TSU111-112
Nanopower Amplifiers
Zero Drift

- 900nA current Consumption
- Only $150\mu\text{V}$ max input offset Voltage
- Operating from 1.5V

TSU10x Series
Nanopower Amplifiers

- 580nA current consumption
- Operating from 1.5V

Smoke detector
CO detector
PIR detector
Power metering
Measurement tools
Active filtering
Signal conditioning
ECG, glucose meter,
Blood pressure sensor



Smart
Home



Smart
Industry



Analog sensors for smart building

Analog Sensor	Circuit topology	Low power	High Accuracy	Wide band	App note
UV sensor Ambient light	Transimpedance amplifier	TSU401		TSV631	AN4451
Smoke detector	Transimpedance amplifier	TSV6292		TSV522	
CO detector	Potential, Transimpedance ampl or 1 to V converter	TSU402	TSZ122	TSV732	AN4348
PIR detector	AC coupled filters with window comparator	TSU404			AN4368
Temperature sensing (RTD)	Current source + non-inverting amplifier or instrumentation amplifier	TSV714	TSZ124		



[Next category >>](#)

Analog sensors for wearables and health

Analog Sensor	Circuit topology	Low power	High Accuracy	Wide band	App note
Gesture recognition (EMG - electromyography)	Instrumentation amplifier (small signal)		TSZ124		
Heart rate (2point ECG)	Instrumentation amplifier (small signal)		TSZ124		
Heart rate + O ₂ Pulse oximetry	Transimpedance amplifier	TSU402			AN4451
Glucose meter	Reference + 2x transimpedance	TSV612	TSV712		
Blood pressure (piezo resistive)	Instrumentation amplifier (Wheatstone bridge)	TSV714	TSZ124		



[Next category >>](#)

Analog sensors for automotive

Analog Sensor	Circuit topology	Low power	High Accuracy	Wide band	App note
Rain detector Light sensor (Photodiode)	Transimpedance amplifier	TSV631 IVLT		TSV522 IVST	AN4451
Temperature sensing (Thermocouple)	Instrumentation amplifier (small signal)	TSX712 IVST	TSZ124 IVPT		
Steering angle (resolver)	Resolver	TSX564 IVPT		TSX922 IVDT	
NO _x / NH ₃ sensor	Potential, Transimpedance ampl or 1 to V converter			TSV912 HYDT	
O ₂ Sensor	Potential, Transimpedance ampl or 1 to V converter	TSV522 IVST		TSV912 HYDT	



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[Next category >>](#)

Analog sensors for Industry 4.0

Analog Sensor	Circuit topology	Low power	High Accuracy	Wide band	App note
4-20mA current loop	Current driver + differential amplifier	TSB611	TSX711	TSB572	
Contactless temperature (Thermopile)	(Buffer + Instrumentation amplifier + adder) or inverting amplifier	TSZ124			
Transmissive / reflective sensors	Transimpedance amplifier	TSU101		TSV911	AN4451
Pressure	Instrumentation amplifier (Wheatstone bridge)	TSV714	TSZ124	TSX712	
Force / pressure (strain gauge)	Instrumentation amplifier (Wheatstone bridge)	TSV714	TSZ124	TSX712	



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ST Op amps Mobile product selector

Select the best
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among our

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Download the latest mobile version

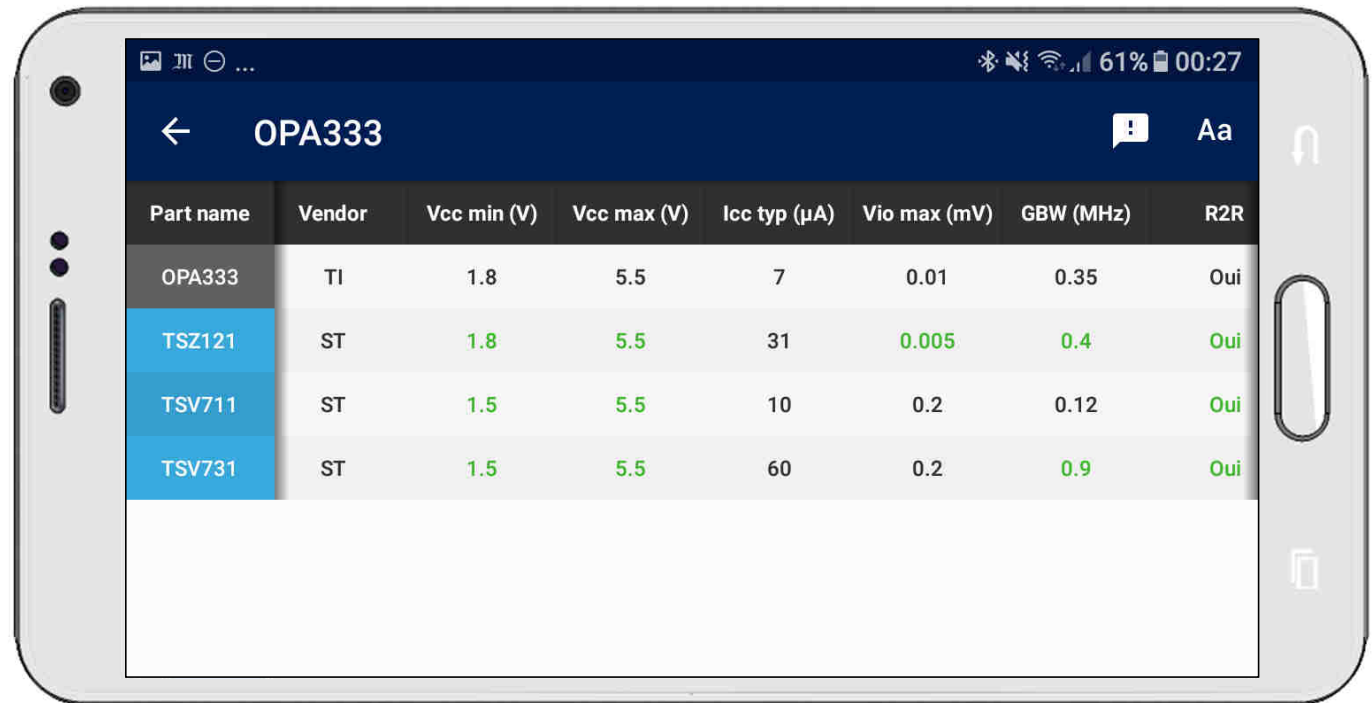


TSZ121 versus OPA333



Cross-reference
proposed by ST
Op amps mobile
application

Parameters in
green are better
or equivalent



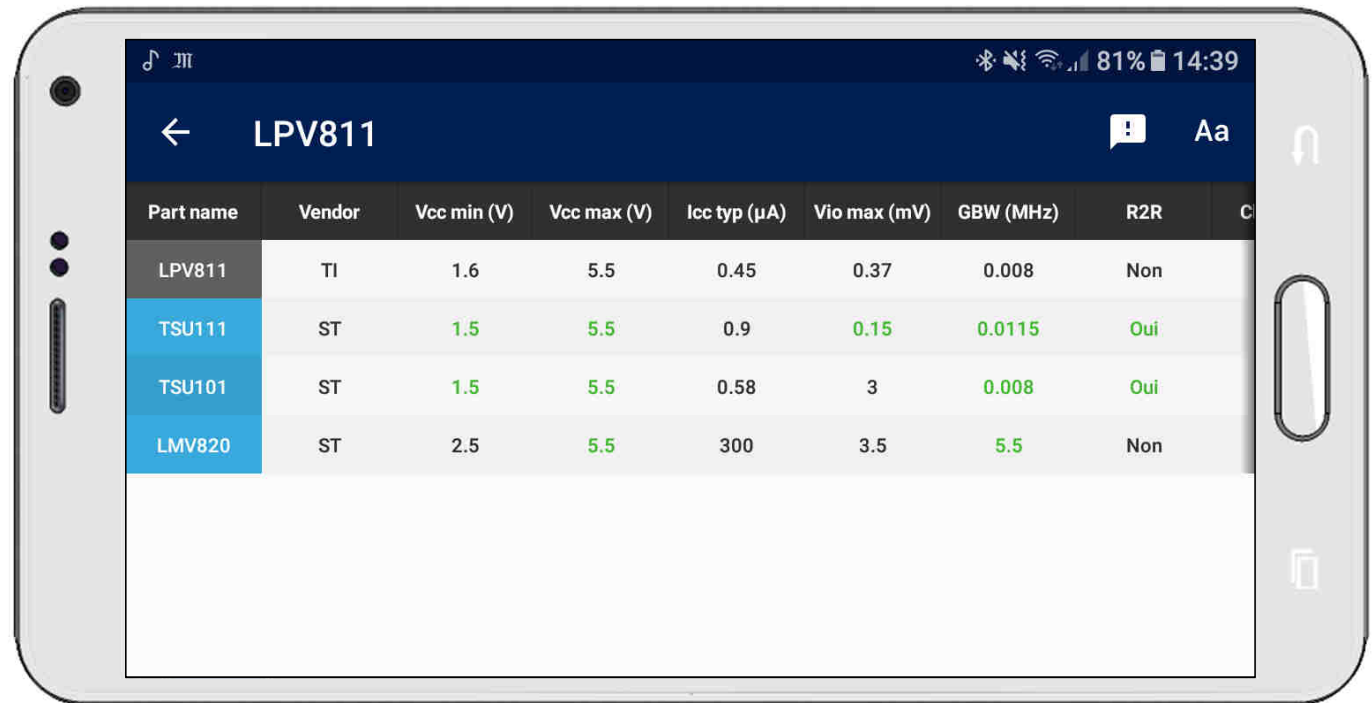
OPA333							
Part name	Vendor	Vcc min (V)	Vcc max (V)	Icc typ (µA)	Vio max (mV)	GBW (MHz)	R2R
OPA333	TI	1.8	5.5	7	0.01	0.35	Oui
TSZ121	ST	1.8	5.5	31	0.005	0.4	Oui
TSV711	ST	1.5	5.5	10	0.2	0.12	Oui
TSV731	ST	1.5	5.5	60	0.2	0.9	Oui

TSU111 versus LPV811



Cross-reference
proposed by ST
Op amps mobile
application

Parameters in
green are better
or equivalent



The image shows a smartphone screen displaying a cross-reference table for the LPV811 op-amp. The table lists alternative parts from ST, with parameters highlighted in green to indicate better or equivalent performance.

Part name	Vendor	Vcc min (V)	Vcc max (V)	Icc typ (µA)	Vio max (mV)	GBW (MHz)	R2R	C
LPV811	TI	1.6	5.5	0.45	0.37	0.008	Non	
TSU111	ST	1.5	5.5	0.9	0.15	0.0115	Oui	
TSU101	ST	1.5	5.5	0.58	3	0.008	Oui	
LMV820	ST	2.5	5.5	300	3.5	5.5	Non	

Thank You

For more information, please visit www.st.com/opamp

