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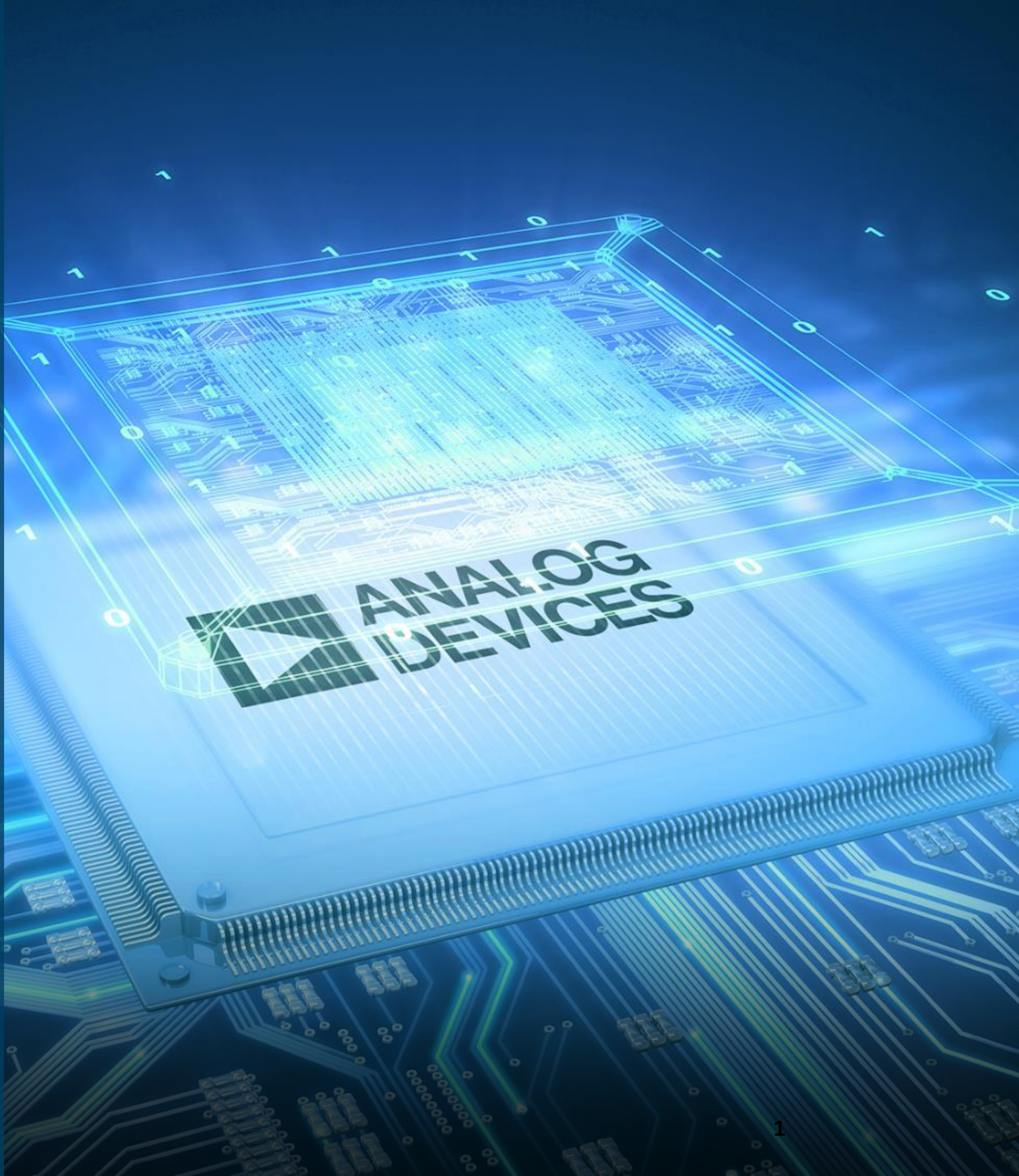
Counting Electrons: Making Ultra-high Sensitivity Femtoamp Measurements

VICKY WONG

Applications Engineer

Precision Measurement and Conditioning



04/27/2017

Agenda

- Solving Customers' Problems:
  - What is the problem out there?
  - How do we solve it?
- Design Techniques
  - How to select components?
  - What are the noise sources?
- Measurement Challenges
  - Tips and Considerations
- Ultra High Sensitivity Femtoampere Measurement Platform
- Photoelectric Demo

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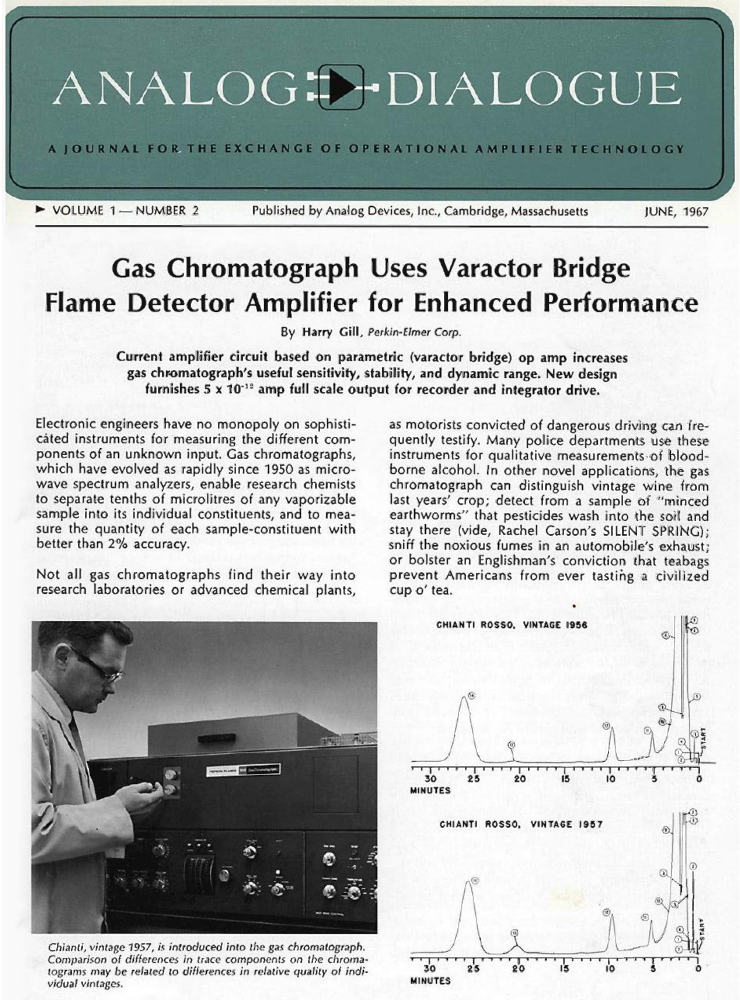
Solving Customers' Problems

WHAT IS THE PROBLEM OUT THERE AND HOW DO WE SOLVE IT?

Keeping up with Evolving Needs



ANALOG DIALOGUE

A JOURNAL FOR THE EXCHANGE OF OPERATIONAL AMPLIFIER TECHNOLOGY

► VOLUME 1 — NUMBER 2 Published by Analog Devices, Inc., Cambridge, Massachusetts JUNE, 1967

Gas Chromatograph Uses Varactor Bridge Flame Detector Amplifier for Enhanced Performance

By Harry Gill, *Perkin-Elmer Corp.*

Current amplifier circuit based on parametric (varactor bridge) op amp increases gas chromatograph's useful sensitivity, stability, and dynamic range. New design furnishes 5×10^{-12} amp full scale output for recorder and integrator drive.

Electronic engineers have no monopoly on sophisticated instruments for measuring the different components of an unknown input. Gas chromatographs, which have evolved as rapidly since 1950 as microwave spectrum analyzers, enable research chemists to separate tenths of microlitres of any vaporizable sample into its individual constituents, and to measure the quantity of each sample-constituent with better than 2% accuracy.

Not all gas chromatographs find their way into research laboratories or advanced chemical plants, as motorists convicted of dangerous driving can frequently testify. Many police departments use these instruments for qualitative measurements of blood-borne alcohol. In other novel applications, the gas chromatograph can distinguish vintage wine from last years' crop; detect from a sample of "minced earthworms" that pesticides wash into the soil and stay there (vide, Rachel Carson's SILENT SPRING); sniff the noxious fumes in an automobile's exhaust; or bolster an Englishman's conviction that teabags prevent Americans from ever tasting a civilized cup o' tea.

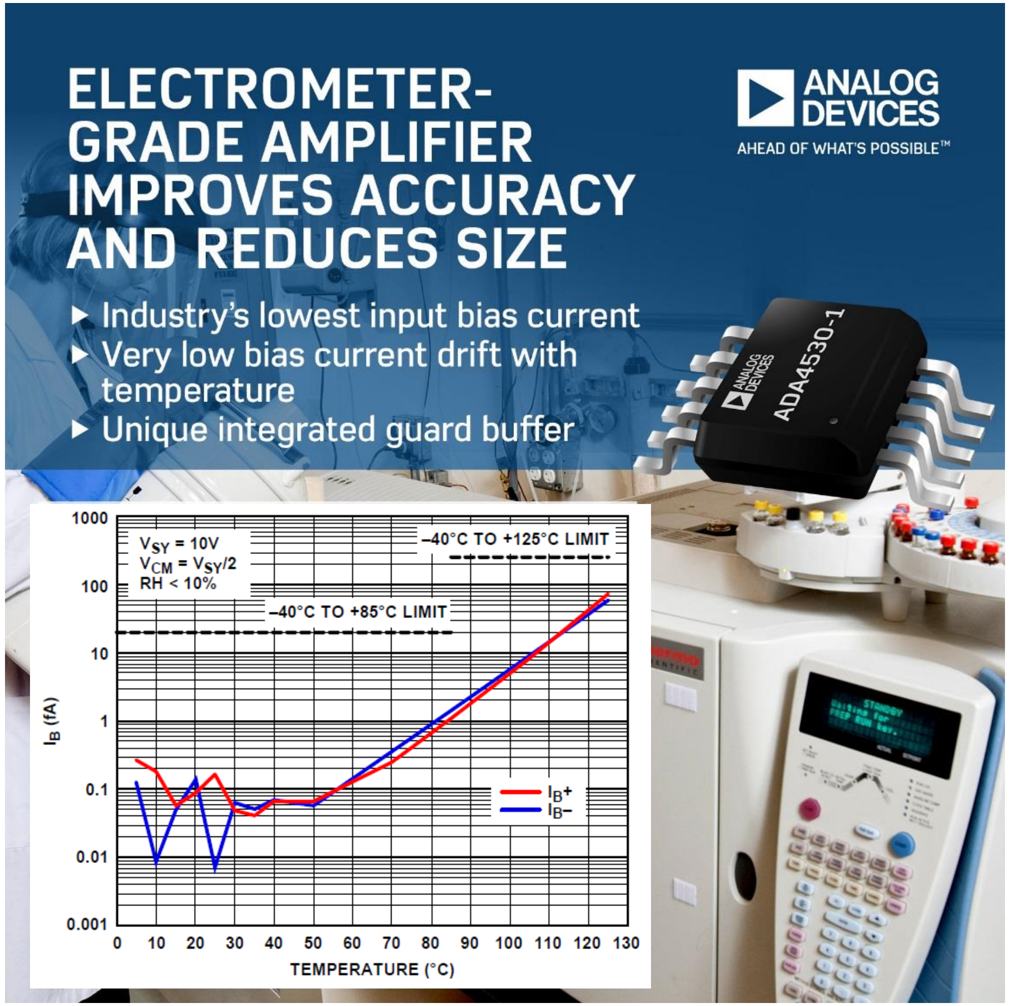
CHIANTI ROSSO, VINTAGE 1956

30 25 20 15 10 5 0
MINUTES
START

CHIANTI ROSSO, VINTAGE 1957

30 25 20 15 10 5 0
MINUTES
START

Chianti, vintage 1957, is introduced into the gas chromatograph. Comparison of differences in trace components on the chromatograms may be related to differences in relative quality of individual vintages.



Measurement Instruments Require Increasing Sensitivity

Instrumentation Applications

- Chemical Analysis
- Environmental Metrology
- Process Monitoring

Analytical Measurement / Example Systems with Ultra High Sensitivity Measurements

Analytical Measurement	Example Systems with Ultra High Sensitivity Measurements	
Separation	HP Liquid Chromatography LP Liquid Chromatography Gas Chromatography	Ion Chromatography Flash Chromatography
Mass Spectrometry	Single Quadrupole Tandem Quadrupole	Time of Flight FT Mass Spectrometry
Spectroscopy	UV/Vis IR, Near IR Raman Polarimetry and Refractrometry Color Measurement Nuclear Magnetics Resonance	Fluorescence and Luminescence Absorption X-Ray Fluorescence X-Ray Diffraction Inductively Coupled Plasma Elemental Analyzers
Surface Science	Electron Microscopy Optical Microscopy Surface Analysis	Scanning Probe Microscopy Confocal Microscopy
Material Characterization	Particle Characterization Viscometry and Rheometry Calorimeters	Thermal Analysis Petroleum Analyzers
Electrochemistry	Potentiostats Electrometers Source Measure Units EC Sensors	

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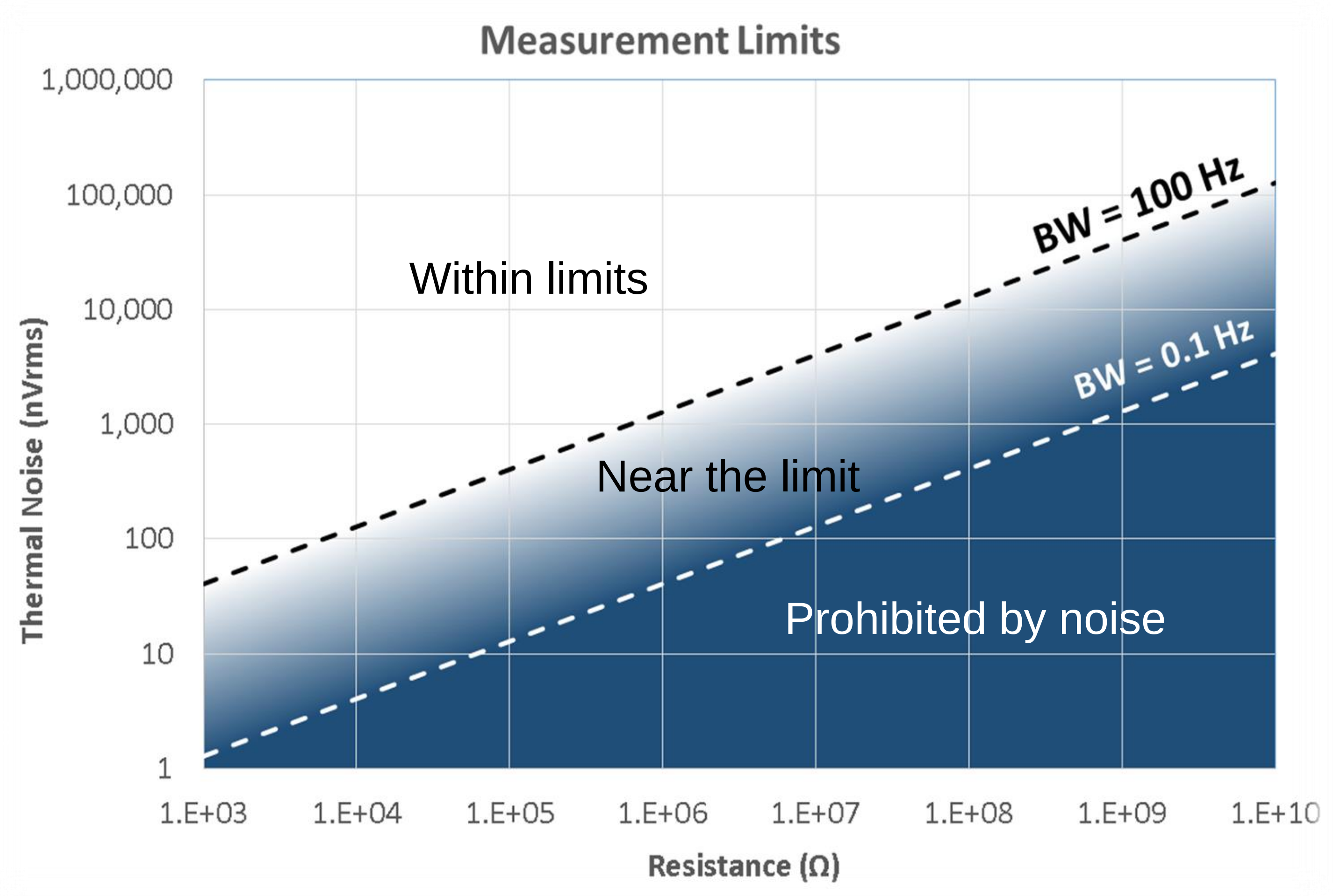
Limits of Detection

- The measure a signal, the measurement level must be above the noise
- Low-level measurements require us to go close to the shaded area
- Special considerations are required to achieve precise and accurate results
- Electrometers are used for low current measurements



The Electrometer

- Definition: an electrical instrument for measuring electric charge or electrical potential difference with low leakage current
- Voltmeter, Ammeter, Ohmmeter, Coulombmeter function
  - Very high input impedance
    (typically above 100TΩ or as high as 10PΩ)
  - Very low input offset current
    (less than 50fA or as low as 50aA)
  - Employs transimpedance amplifier
    for current measurements

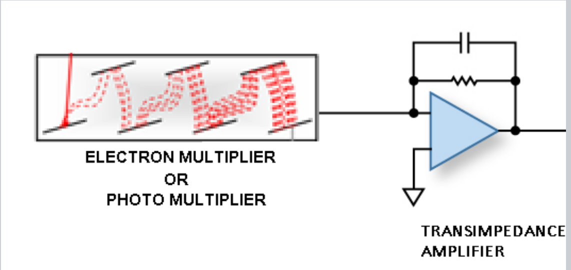
The Prefixes Used with SI Units

Prefix	Symbol	Meaning	Scientific Notation
exa-	E	1,000,000,000,000,000,000	10^{18}
peta-	P	1,000,000,000,000,000	10^{15}
tera-	T	1,000,000,000,000	10^{12}
giga-	G	1,000,000,000	10^{9}
mega-	M	1,000,000	10^{6}
kilo-	k	1,000	10^{3}
hecto-	h	100	10^{2}
deka-	da	10	10^{1}
—	—	1	10^{0}
deci-	d	0.1	10^{-1}
centi-	c	0.01	10^{-2}
milli-	m	0.001	10^{-3}
micro-	μ	0.000 001	10^{-6}
nano-	n	0.000 000 001	10^{-9}
pico-	p	0.000 000 000 001	10^{-12}
femto-	f	0.000 000 000 000 001	10^{-15}
atto-	a	0.000 000 000 000 000 001	10^{-18}

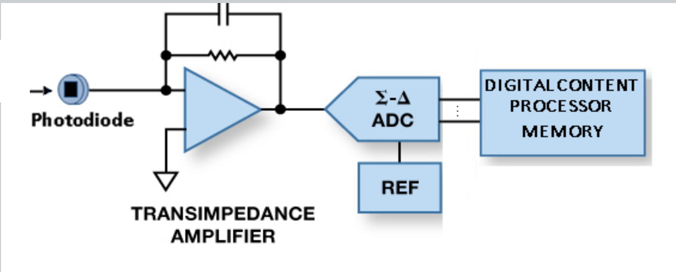
High Sensitivity Detectors Require Precision Signal Chains to Enable Lowest Detection Levels

Photon/Electron Detectors: Current Output

Electron or Photon Multiplier

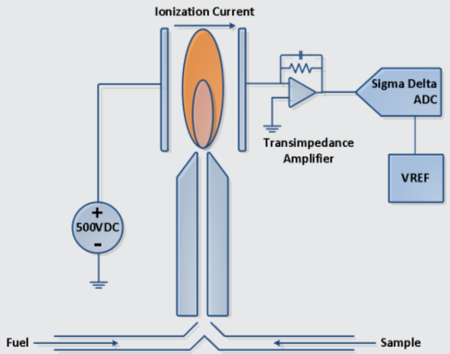


Photodiode

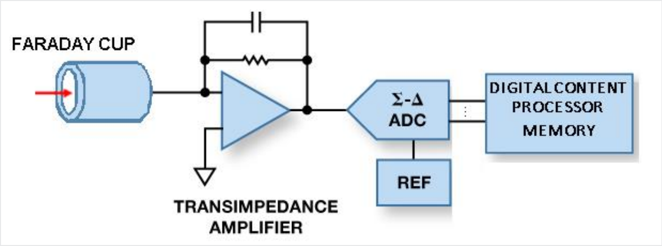


Ion Detectors: Charge Output

Flame Ionization Detector



Faraday Cup



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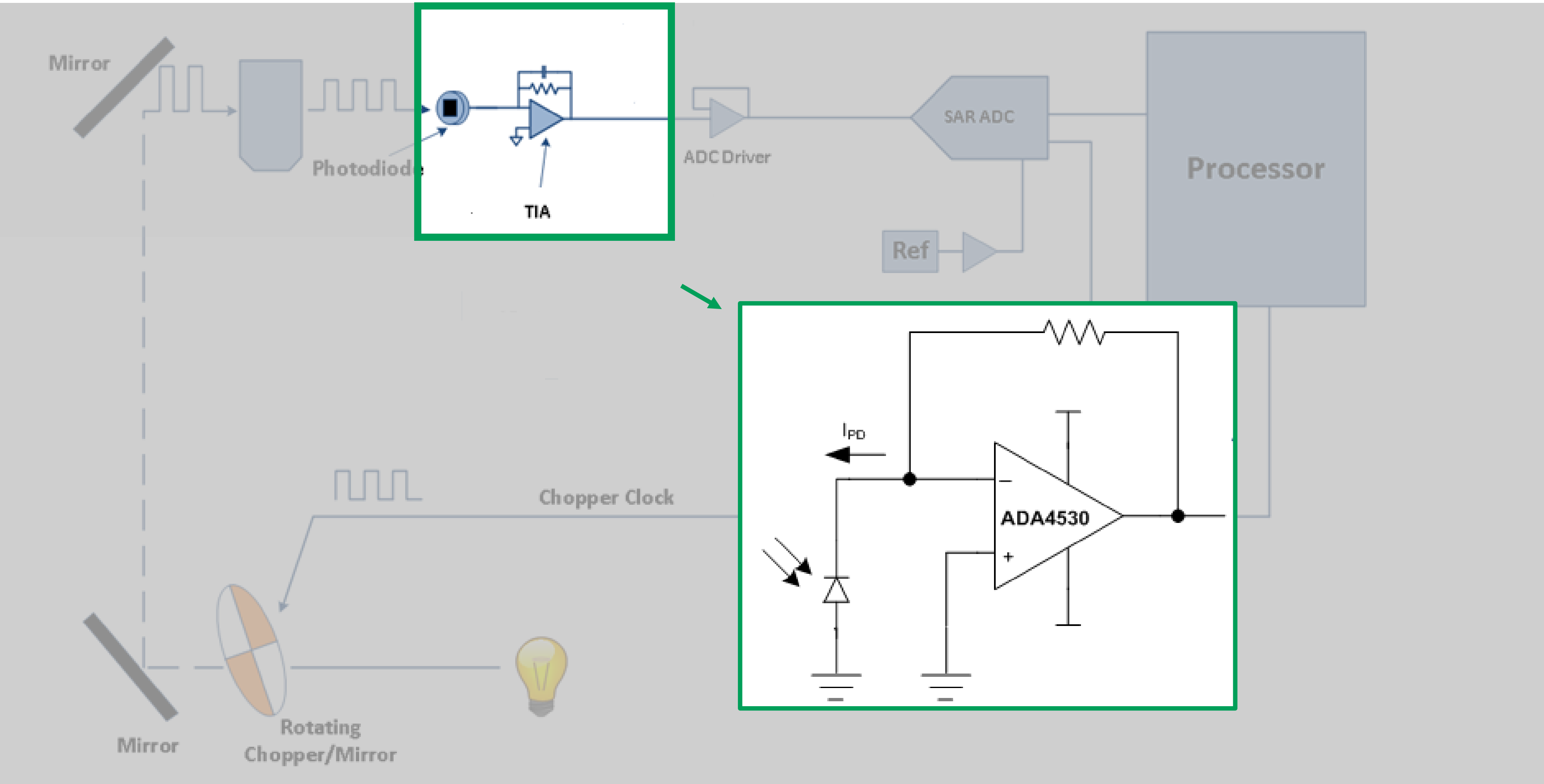
Spectroscopy Example

Spectroscopy: study of interaction of matter and radiated energy
"What is it?" "How much is there?"



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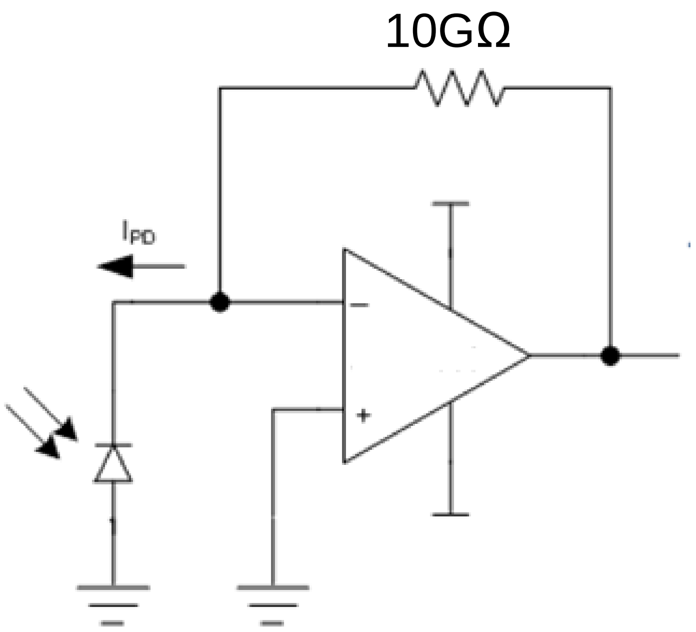
The need for an electrometer-grade amplifier

- Sensor:
  - Photodiode (light → I)
- Op Amp:
  - Transimpedance Amp (TIA) circuit (I → V)
- Signal:
  - Desired output = 10V
  - Full-scale current = 1nA
  - R_F = 10GΩ
- Temperature:
  - 15C to 35C



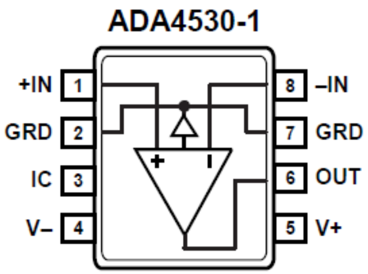
Amp	$I_{BIAS\ MAX}$ @ 25C	Vos max @ 25C	TCVos	Error for 1nA Full Scale
ADA4622	10 pA	800 uV	15 uV/C	1.01 %
AD549	100 fA	500 uV	15 uV/C	0.018 %
ADA4530	20 fA	40 uV	0.5 uV/C	0.0025 %

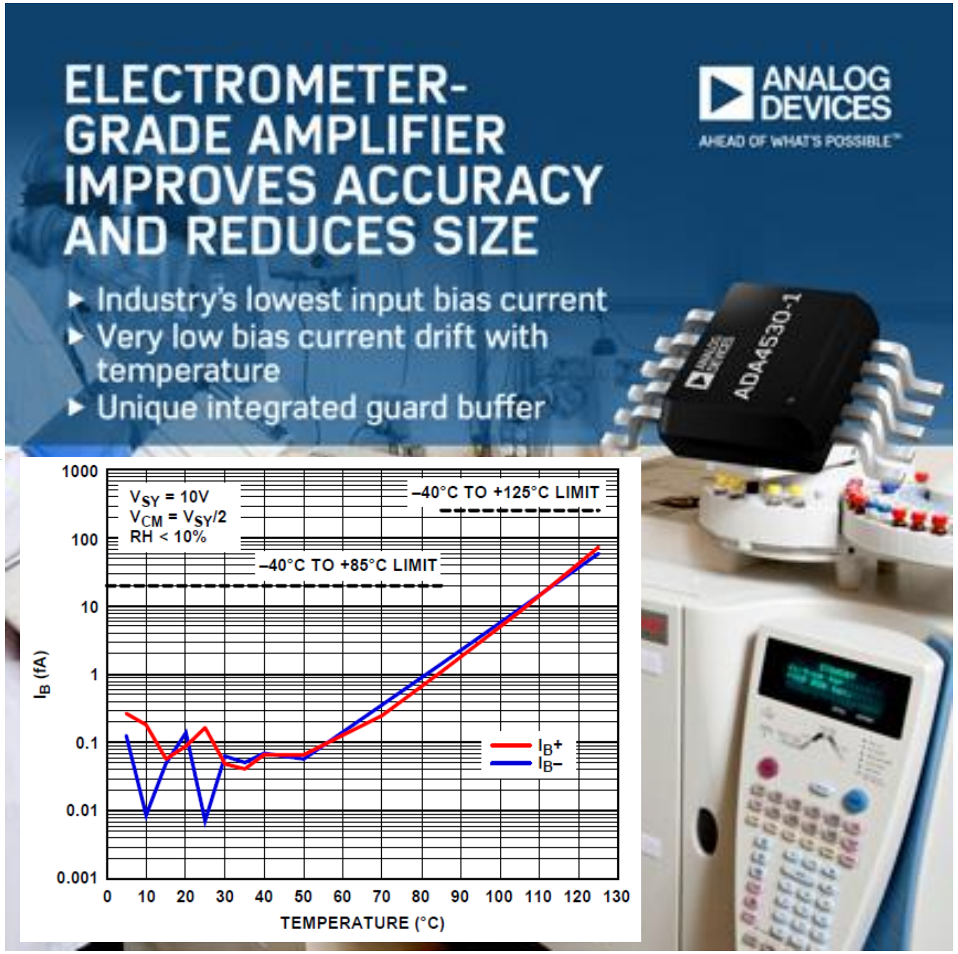
ADA4530-1: Not your typical amplifier!

Key Benefits

- ▶ Ultra Low Input Bias Current Electrometer-Grade Amplifier
- ▶ New level of sensitivity!
  - 0.1fA typ IB at 25C
  - 20fA max IB from 25C to 85C
  - 250fA max IB at 125C
  - Low offset drift of 0.5uV/C max
- ▶ Easy to use
  - Integrated guard buffer
  - Pin out optimized for input pin isolation from power supplies
  - Surface mount package

624 electrons / sec !





45x lower input bias current and 10x better DC precision than the leading competitor part

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Beyond Typical Characterization Targeting Low Level Current Measurement

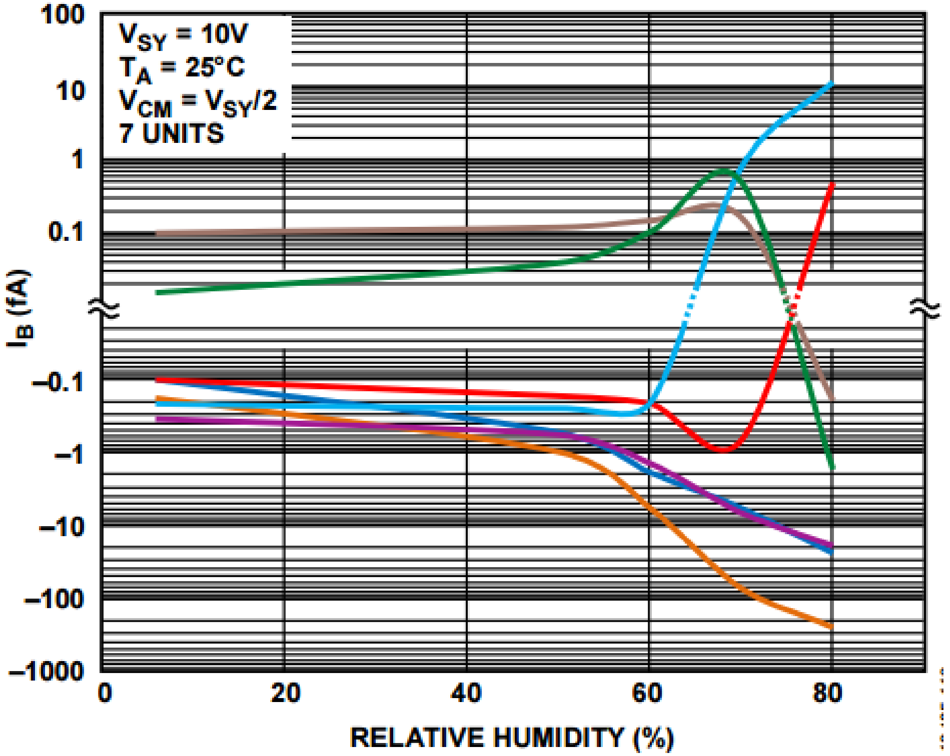

Figure 112. Effective Input Bias Current vs. Relative Humidity

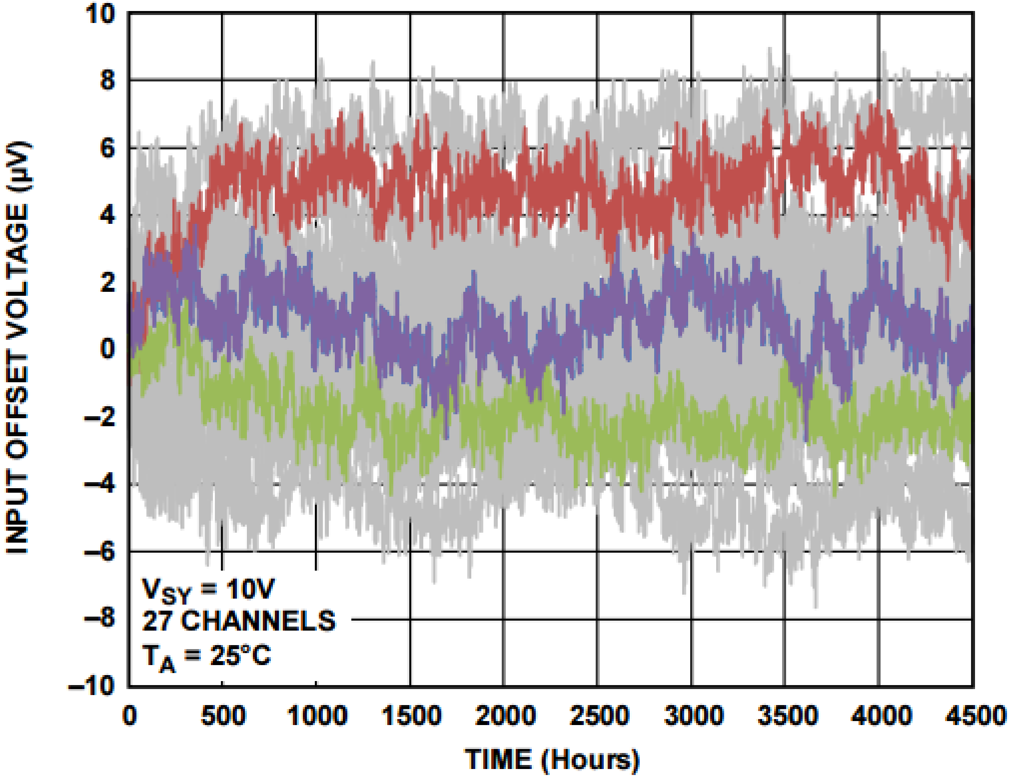

Figure 19. V_{OS} Long-Term Drift

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Design Example

HOW DO I SELECT COMPONENTS AND WHAT ARE THE NOISE SOURCES?

The Implementation Challenges

Surface contamination

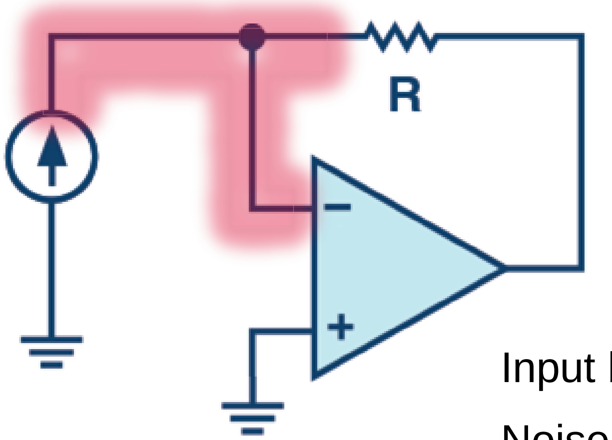
Dielectric absorption

Leakage

Stability

Humidity

Triboelectricity



Radiated noise

RF

Power-line noise

Electrostatic coupling

Input bias current

Noise

Offset drift

Output swing

Compensation

Board Material

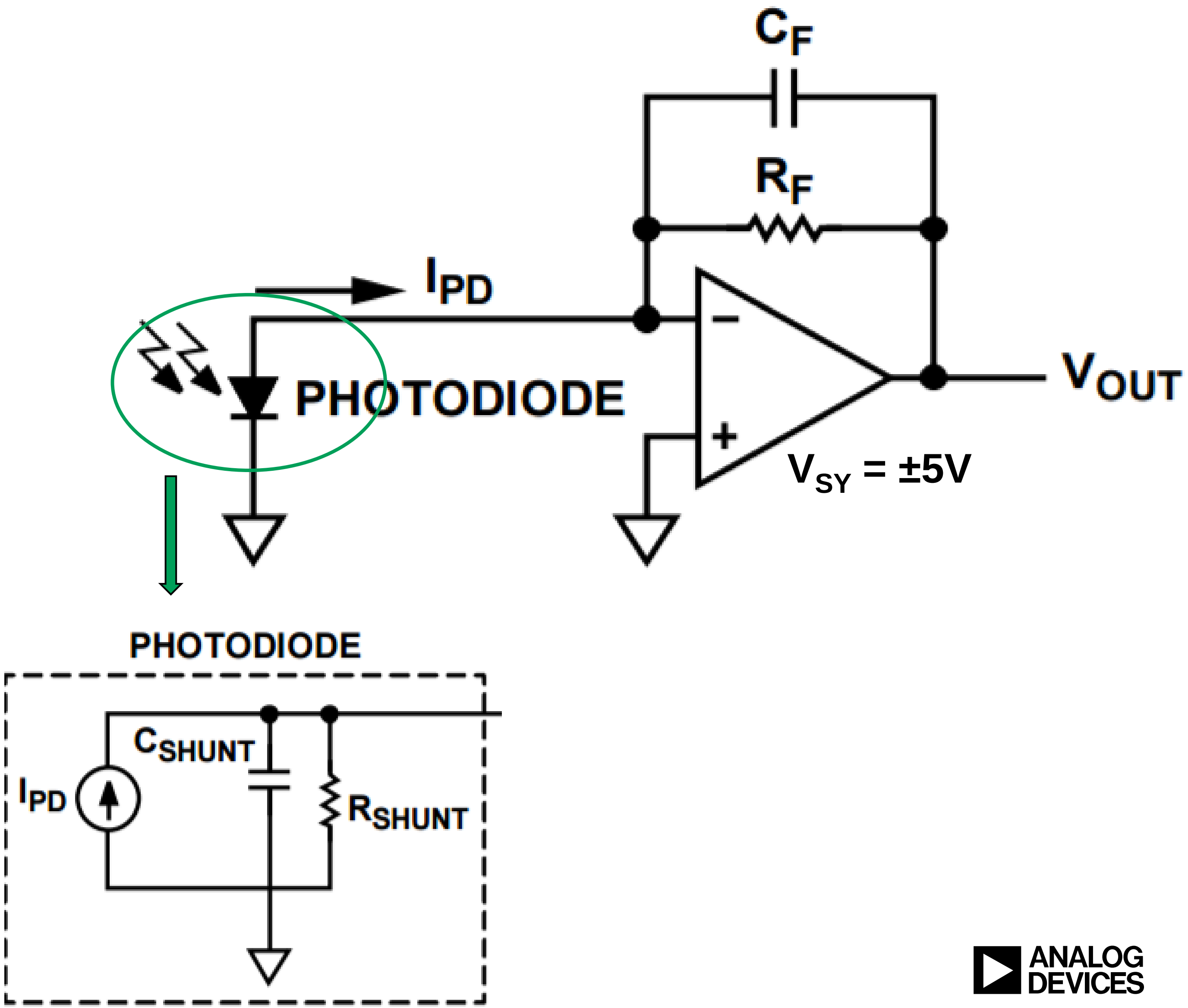
Paste Material

Ground noise

Design Example

Hamamatsu S1226-18BQ

I_{PD} max = 500pA



- R_{SHUNT} = 50 GΩ typ, 5GΩ min
- C_{SHUNT} = 35pF
- Operating temp: -20C to 60C

R_F selection

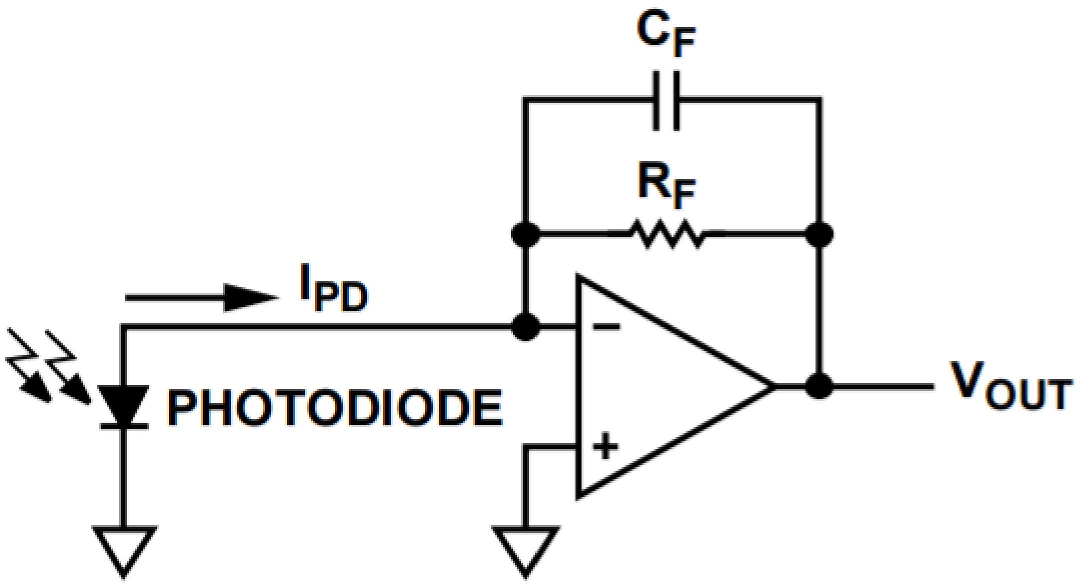
$$RF\ Thermal\ Noise, V_{N,Rf} = \sqrt{4\ \times k\ \times T \times R_F}$$

$$V_{OUT} = I_{PD} \times R_F$$

$$SNR = \frac{V_{OUT}}{V_{N,Rf}}$$

$$SNR\ \alpha\ \sqrt{R_F}$$

SNR improves by $\sqrt{\boldsymbol{R_F}}$



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R_F Selection

Factors that Limit Upper Limit of R_{SHUNT}

- Maximum output swing

$$\boldsymbol{V_{OUT} = I_{PD} \times R_F}$$

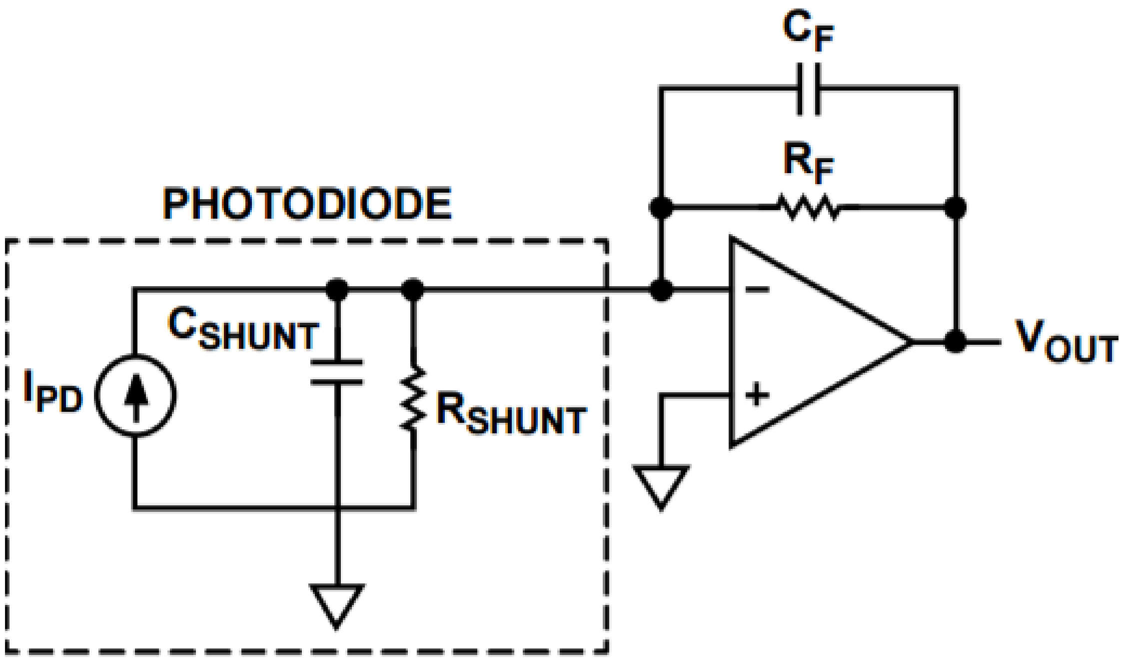
- Signal bandwidth

$$f_{SIGNAL} = \frac{1}{2\pi R_F C_F}$$

- R_{SHUNT}
  - R_{SHUNT} decreases with increasing temperature

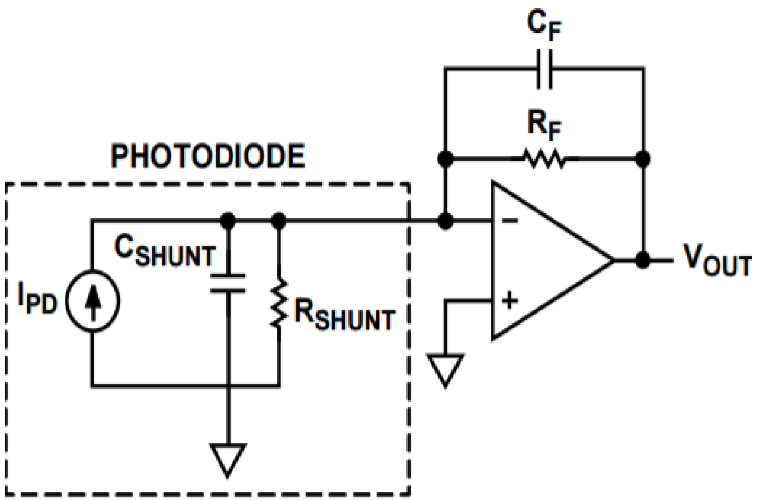
$$\boldsymbol{Noise\ Gain\ @\ DC = 1 + \frac{R_F}{R_{SHUNT}}}$$

- Current Noise
  - Amp current noise > R_F thermal noise



DC Error Budget

Error Source	Equation	ADA4530-1	
		25 C	**60C**
R_{SHUNT}		5 GΩ	442 MΩ
V_{OS}		40 uV	40 uV + 18 uV
Noise Gain	$1+\frac{R_F}{R_{SHUNT}}$	3	23
Vos Error RTO	$V_{OS} \times Noise\ Gain$	120 uV	1.3 mV
I_B		20 fA	20 fA
I_B Error RTO	$I_B \times R_F$	200 uV	200 uV
Total Error RTO		320 uV	1.5 mV
Total Error RTI		**32 fA**	**150 fA**



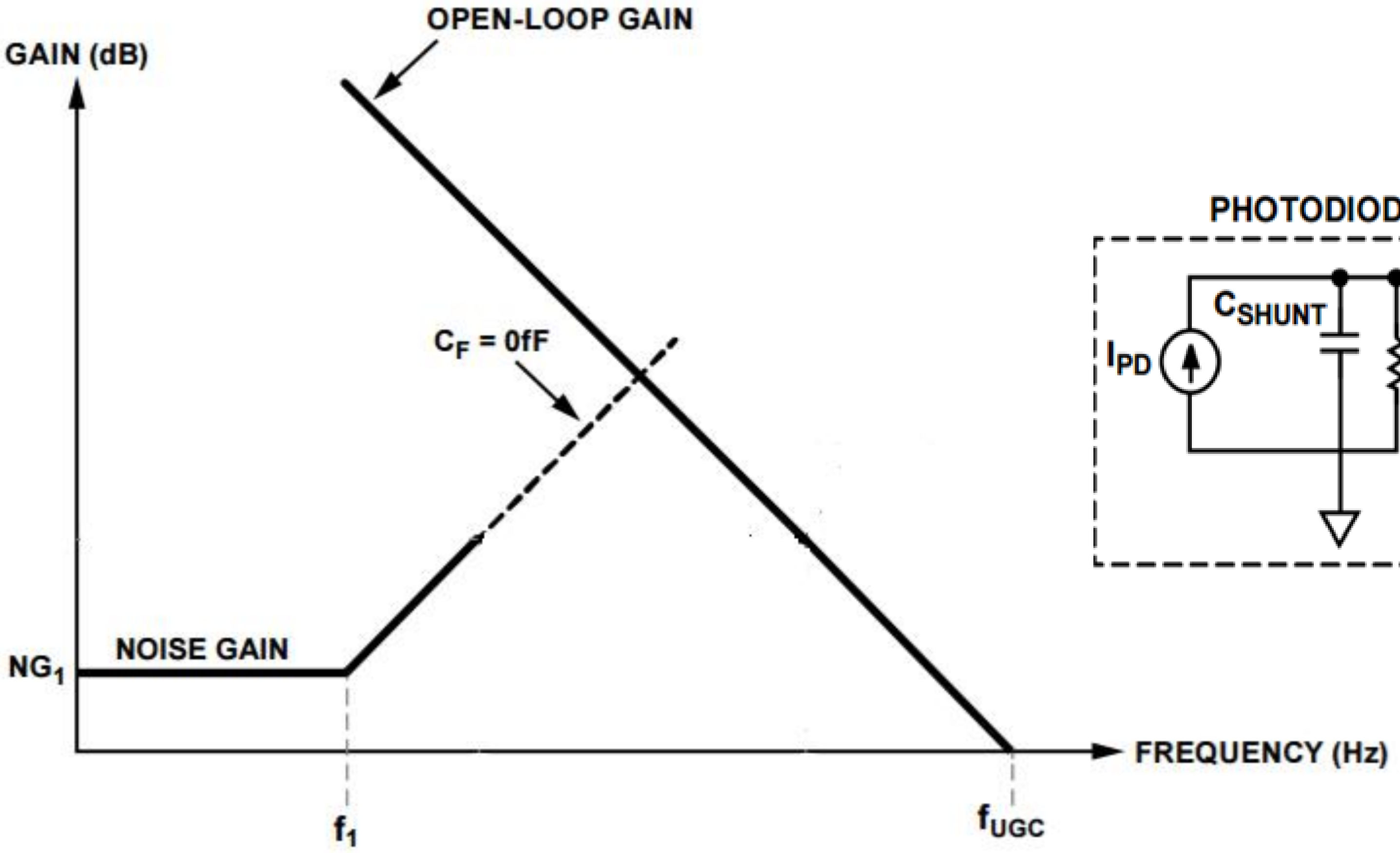
RTO: Referred to Output
RTI: Referred to Input

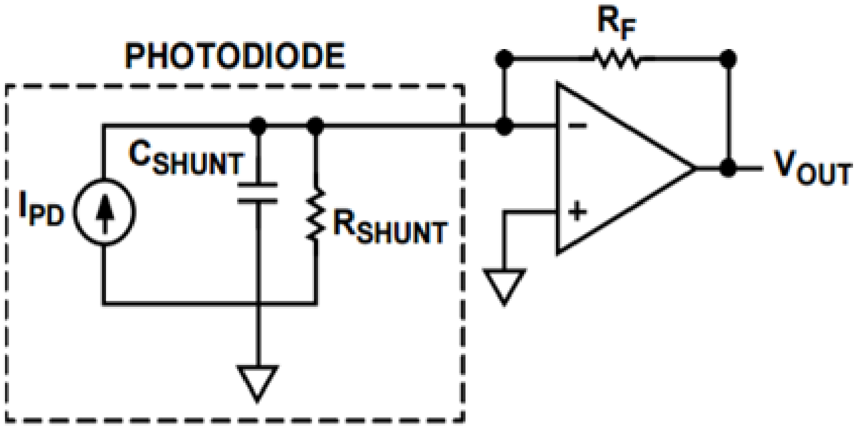
DC Error Budget

Error Source	Equation	ADA4530-1		Comp A	
		25 C	60C	25 C	60C
R_{SHUNT}		5 GΩ	442 MΩ	5 GΩ	442 MΩ
V_{OS}		40 uV	40 uV + 18 uV	150 uV	150 uV + 140 uV
Noise Gain	$1 + \frac{R_F}{R_{SHUNT}}$	3	23	3	23
Vos Error RTO	$V_{OS} \times Noise\ Gain$	120 uV	1.3 mV	450 uV	6.8 mV
I_B		20 fA	20 fA	20 fA	220 fA
I_B Error RTO	$I_B \times R_F$	200 uV	200 uV	200 uV	2.2 mV
Total Error RTO		320 uV	1.5 mV	320 uV	9 mV
Total Error RTI		**32 fA**	**150 fA**	**65 fA**	**900 fA**

RTO: Referred to Output
RTI: Referred to Input

AC Performance





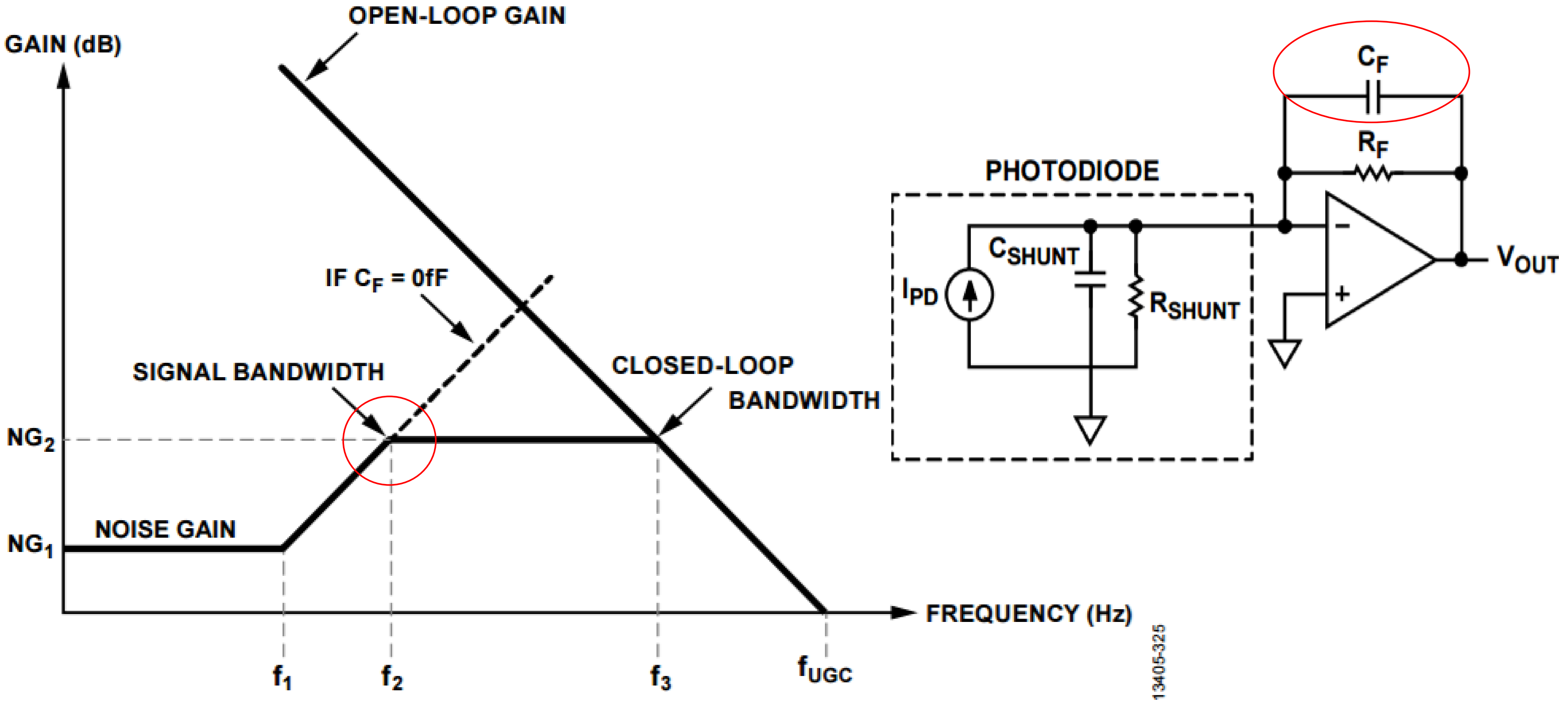
$$NG_1 = 1 + \frac{RF}{R_{SHUNT}}$$

$$f_1 = \frac{1}{\frac{R_F R_{SHUNT}}{R_F + R_{SHUNT}}\left(C_F + C_{SHUNT}\right)}$$

AC Performance

$$NG_2 = 1 + \frac{C_{SHUNT}}{C_F}$$

$$NG_1 = 1 + \frac{RF}{R_{SHUNT}}$$

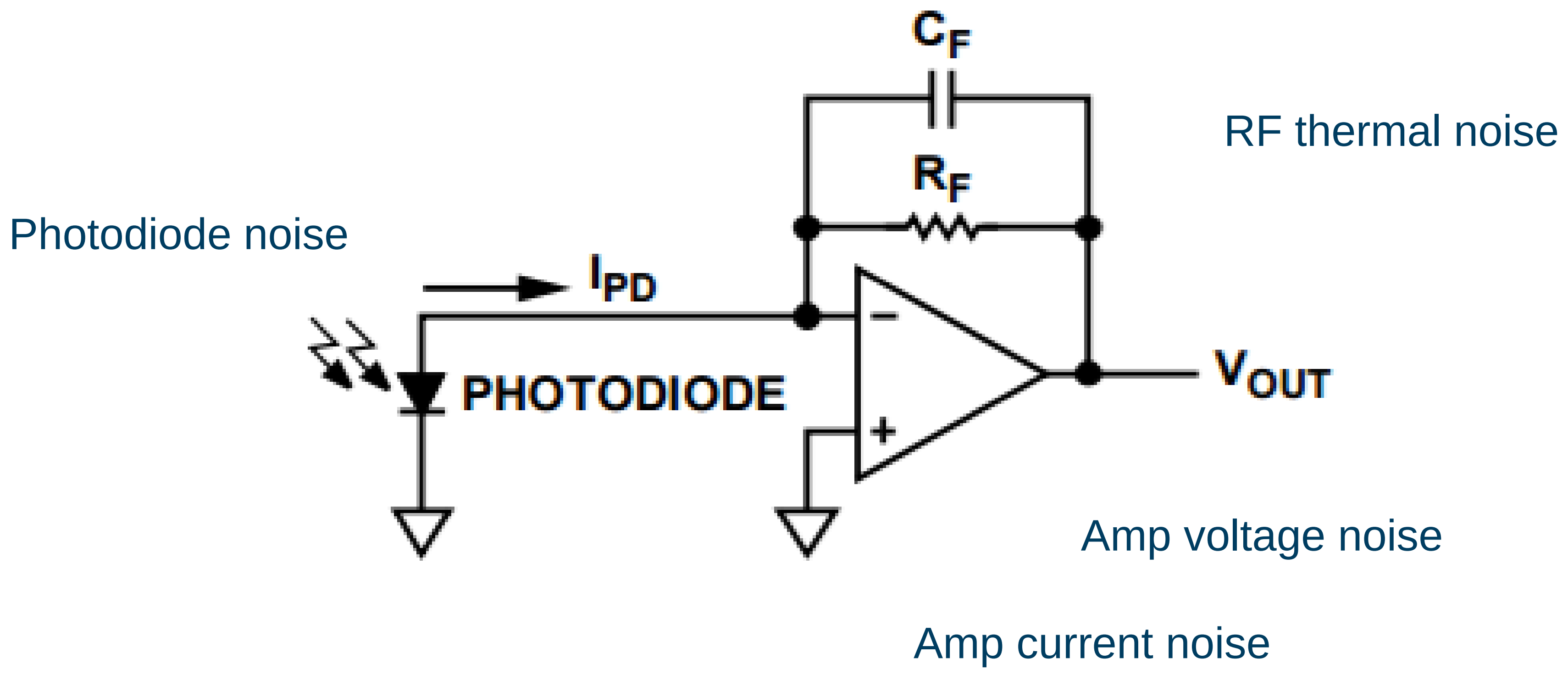


$$f_1 = \frac{1}{\frac{R_F R_{SHUNT}}{R_F + R_{SHUNT}}\left(C_F + C_{SHUNT}\right)}$$

$$f_2 = \frac{1}{R_F C_F}$$

$$f_3 = \frac{f_{UGC}}{\left(1 + \frac{C_{SHUNT}}{C_F}\right)}$$

Noise sources



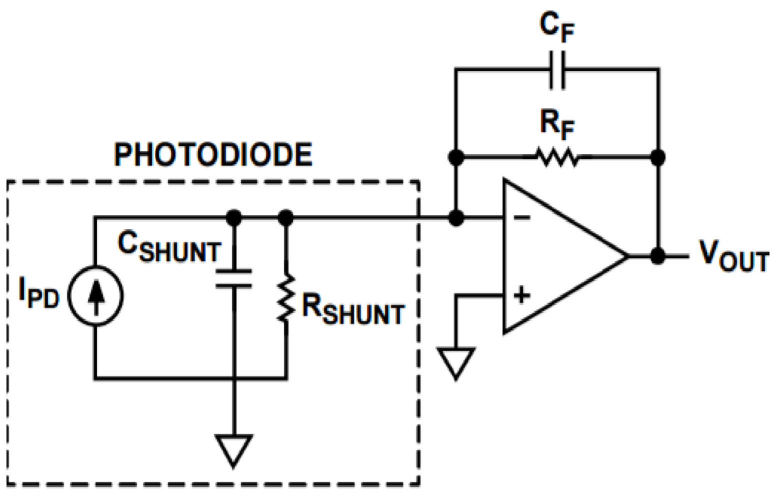
Low Frequency Noise

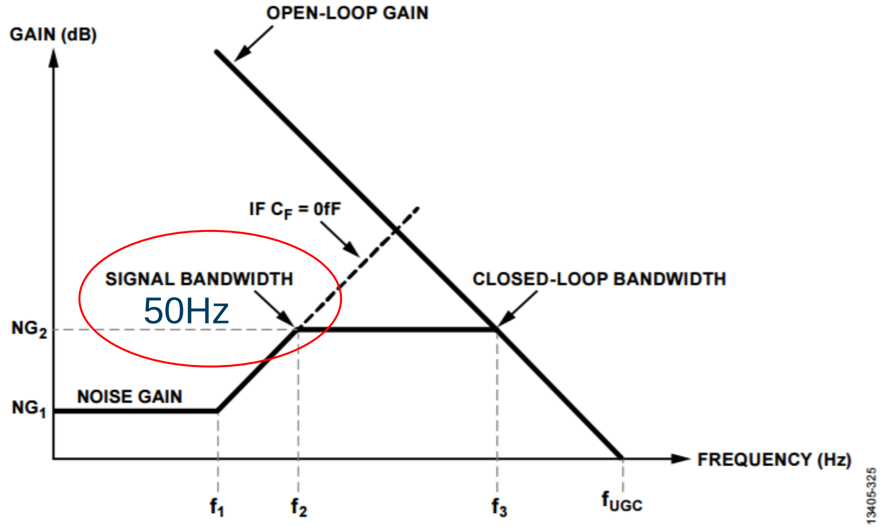
Noise Source	RTO Noise Equation	Noise BW	RTO Noise @ 25C	RTO Noise @ 60C
R_F	$\sqrt{4\,k\,TR_F}$	$\frac{\pi}{2} f_2$	12.8 uV/rtHz	13.5uV/rtHz
R_{SHUNT} (Photodiode)	$\frac{R_F}{R_{SHUNT}} \sqrt{4\,k\,TR_{SHUNT}}$	$\frac{\pi}{2} f_2$	18 uV/rtHz	64uV/rtHz
Amp Current Noise	$I_N\,R_F$	$\frac{\pi}{2} f_2$	700 nV/rtHz	2.4 uV/rtHz
Total LF Noise (NSD)			22 uV/rtHz	66 uV/rtHz
Total LF Noise (RMS)			195 uVrms	585 uVrms

Notes:

$$f_2 = \frac{1}{R_F C_F} = 50\text{Hz}$$

* NSD: Noise Spectral Density



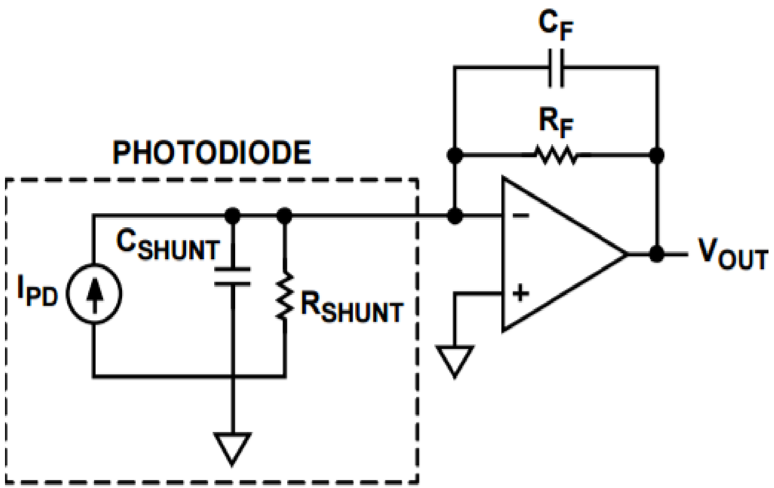


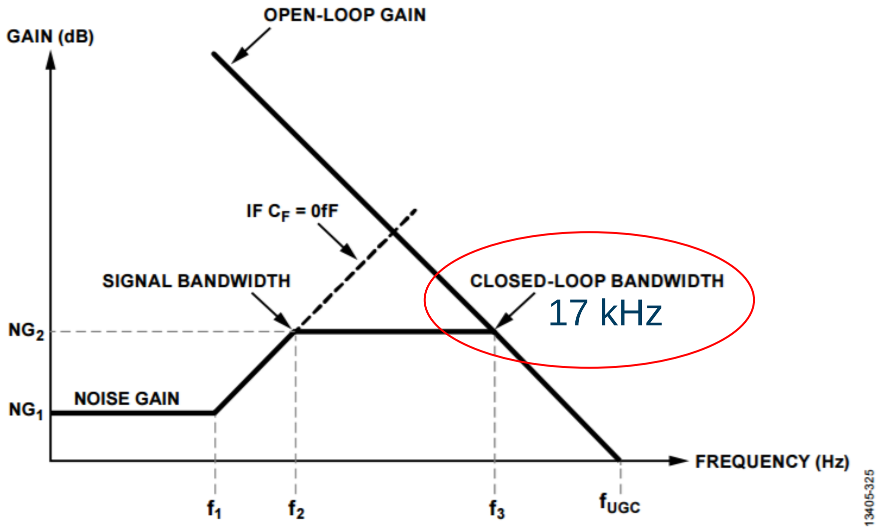
High Frequency Noise

Noise Source	RTO Noise Equation	Noise BW	RTO Noise @ 25C	RTO Noise @ 60C
Amp Voltage Noise	$V_N \times (1 + \frac{C_{SHUNT}}{C_F})$	$\frac{\pi}{2} f_3$	1.6 uV/rtHz	1.7 uV/rtHz
Total HF Noise			271 uVrms	286 uVrms

Notes:

$$f_3 = \frac{f_{UGC}}{\left(1 + \frac{C_{SHUNT}}{C_F}\right)} = 17 \text{ kHz}$$





Noise Summary

Noise Source	RTO Noise Equation	Noise BW	RTO Noise @ 25C	RTO Noise @ 60C
R_F	$\sqrt{4\,k\,TR_F}$	$\frac{\pi}{2}\,f_2$	12.8 uV/rtHz	13.5uV/rtHz
R_{SHUNT} (Photodiode)	$\frac{R_F}{R_{SHUNT}}\sqrt{4\,k\,TR_{SHUNT}}$	$\frac{\pi}{2}\,f_2$	18 uV/rtHz	64uV/rtHz
Amp Current Noise	$I_N\,R_F$	$\frac{\pi}{2}\,f_2$	700 nV/rtHz	2.4 uV/rtHz
Amp Voltage Noise	$V_N \times (1 + \frac{C_{SHUNT}}{C_F})$	$\frac{\pi}{2}\,f_3$	1.6 uV/rtHz	1.7 uV/rtHz
Total LF Noise (RMS)			195 uVrms	585 uVrms
Total HF Noise (due to V_N)			271 uVrms	286 uVrms

Notes:
f_2 = signal BW = 50Hz
f_3 = closed loop BW = 17 kHz

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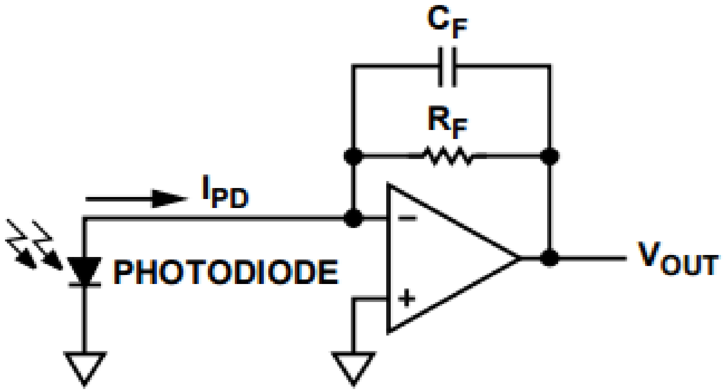
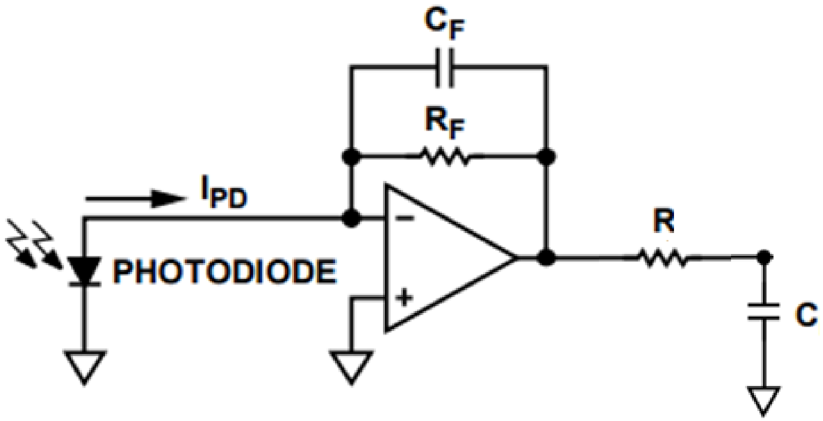
Signal-to-Noise Ratio

	Without post LPF	With post LPF
LF Noise	195 µVrms	195 µVrms
HF Noise	271 µVrms	46 µVrms
Total Noise	333 µVrms	200 µVrms
SNR	89.5 dB	94 dB



Without LPF



With LPF

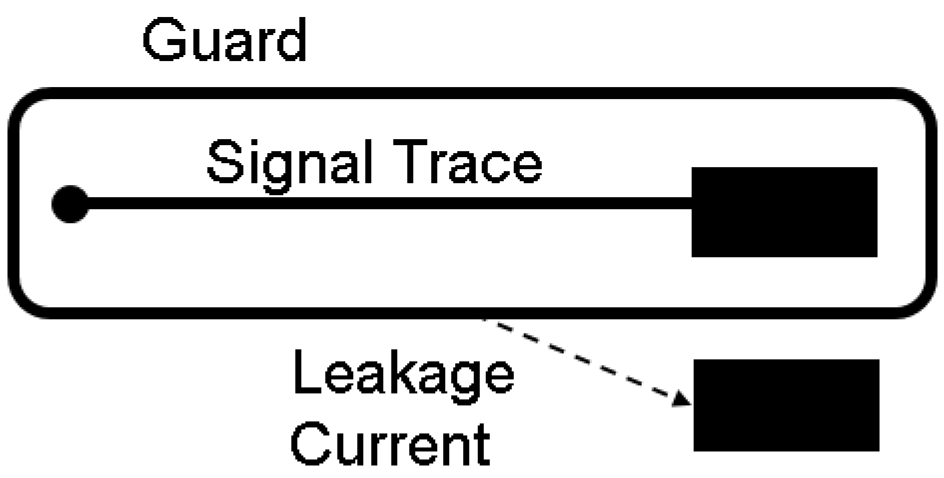
F_{FILTER} = 500Hz

Measurement Challenges

TIPS AND CONSIDERATION

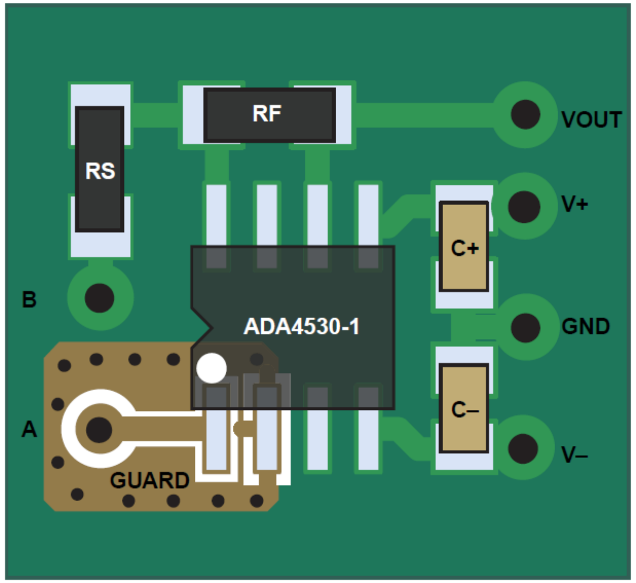
Guarding

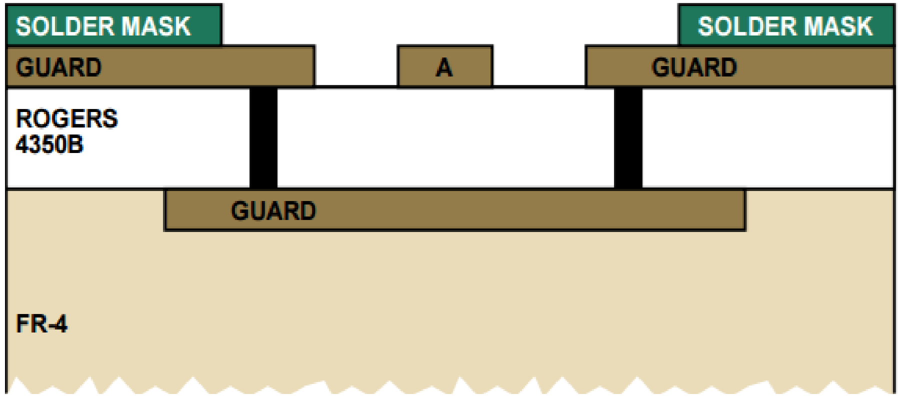
- Surround insulation of high impedance node with another conductor that is driven to the guard voltage (at or close to the high impedance node potential)
- Better layout yields better performance over time and environmental conditions

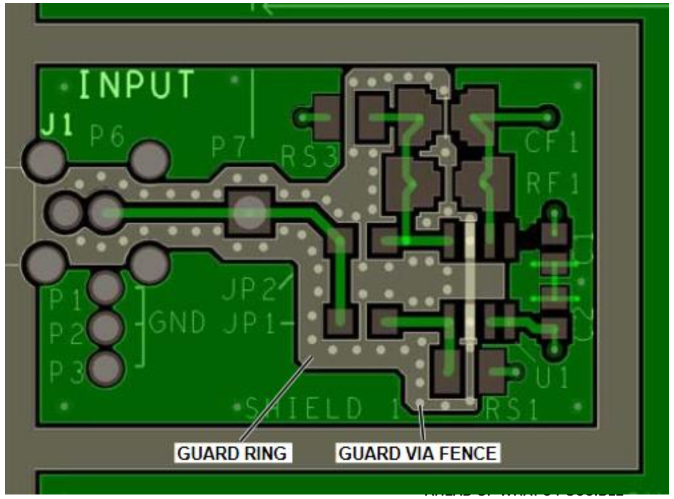


Guarding

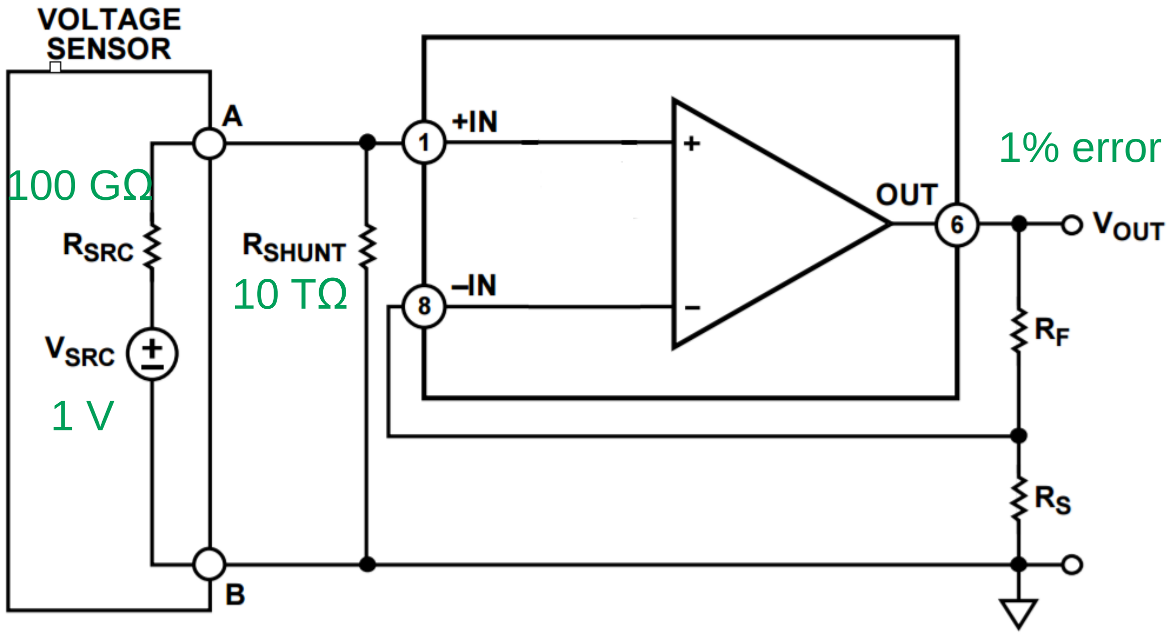
- Guard rings
  - Guard surface leakage
  - Remove solder mask / silkscreen on guard rings/traces
    - Avoid moisture absorption
  - Needs to be driven by an amplifier at the same potential as the input (e.g. a buffer)
- Guard plane
  - Guards through the bulk of PCB
- Via fence
  - Guards lateral leakage paths

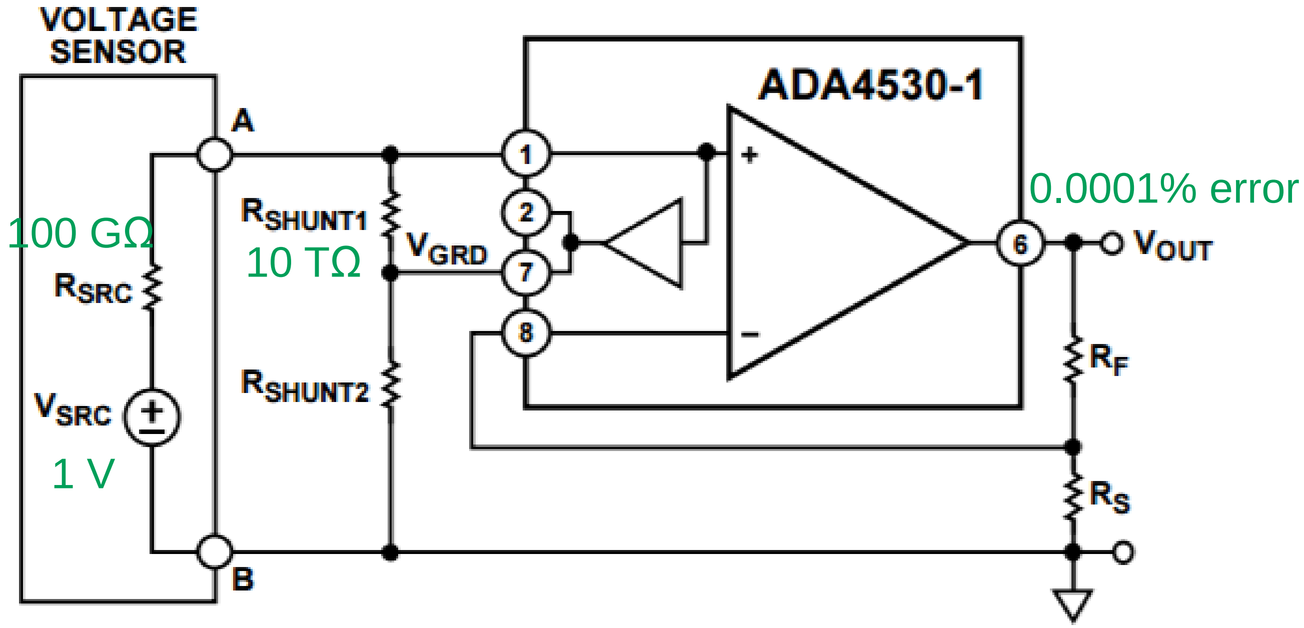






Example of guarding

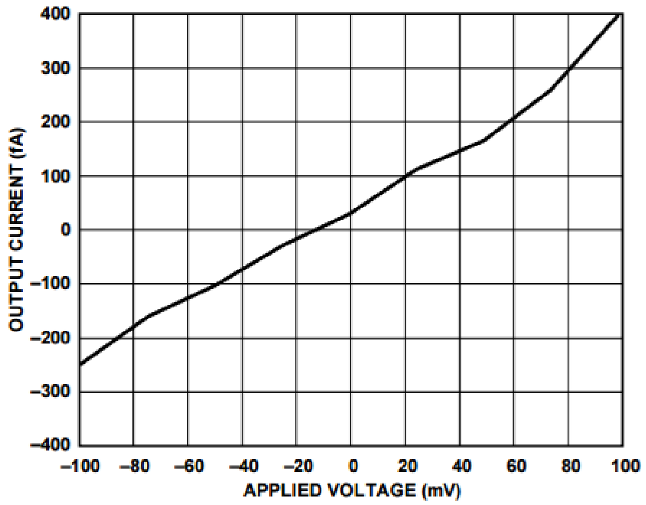




Contamination

Contamination Sources Act as Weak Battery

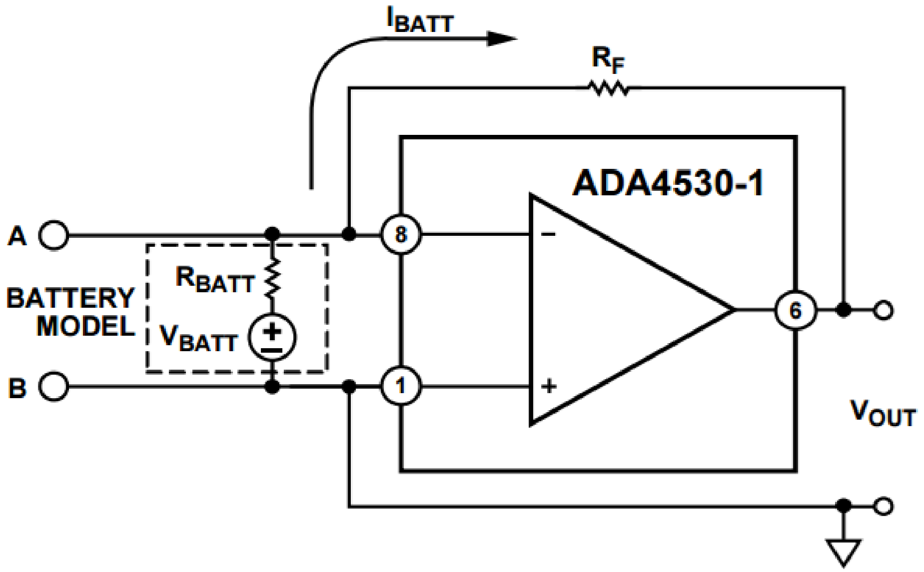
- Solder flux residue
- Dust and other particulate accumulation
- Dirt
- Body Oils
- Saline moisture



Current to Voltage Response of RMA Contaminated Insulation

V_{BATT} = 15mV

R_{BATT} = 300 GΩ



Cleaning and handling is as important as the circuit design itself!

Contamination

- Washing/cleaning is recommended after assembly
- Moisture reduces insulation properties of PCB and cables
  - Choose appropriate materials and perform measurements in controlled environments
  - Bake after wash to eliminate moisture absorption

Material	Moisture Absorption (%)
Hi Pref FR-4	0.50
Nearly pure PTFE	0.02

Source: Rogers Corp.

- NO No-clean solder paste

Table 7. Recommended Cleaning Procedures for Different Solder Paste Material

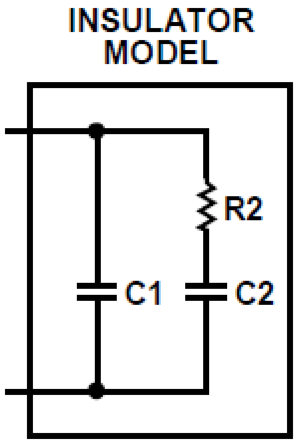
Solder Paste Type	Solder Paste Part Number	Recommended Cleaning Procedure[1]
RMA	AIM RMA258-15R	15 min clean time in an ultrasonic cleaner with fresh IPA, followed by 1.5 hours of bake time at 125°C
Water Soluble	SAC305 Shenmao	1.5 hours clean time in an ultrasonic cleaner with fresh IPA, followed by 1.5 hours of bake time at 125°C
No Clean	SAC 305 AMTECH LF4300	3 hours clean time in an ultrasonic cleaner with fresh IPA, followed by 3 hours of bake time at 125°C

[1] Bake time was not optimized and was set equal to the cleaning time.

- UG-865 for an effective cleaning procedure

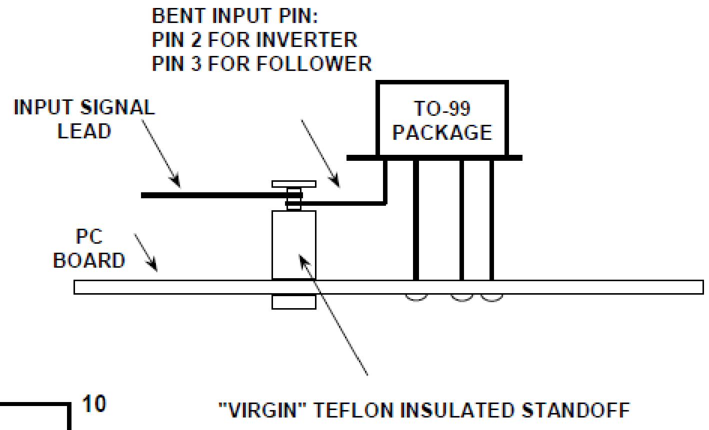
Dielectric Absorption

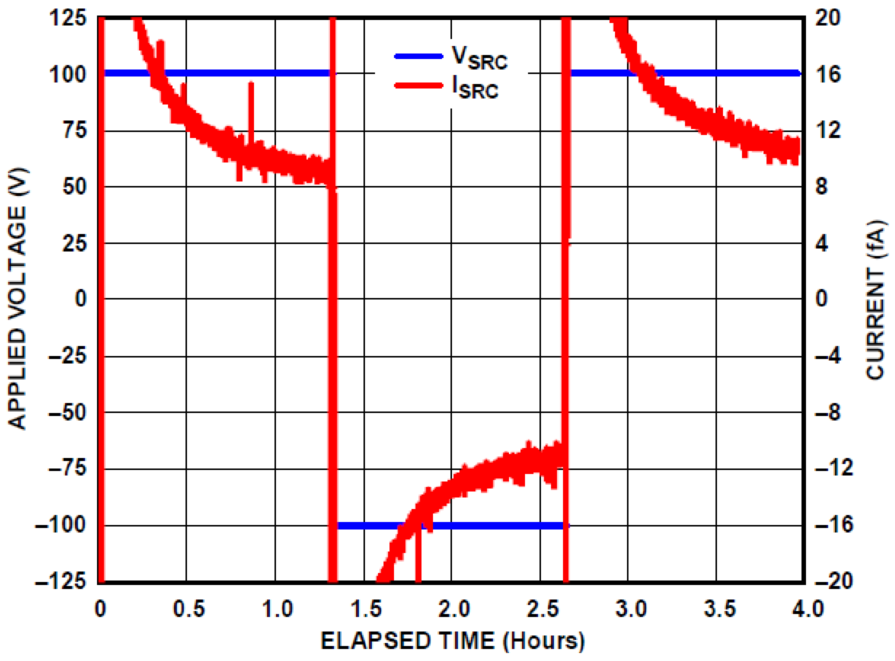
- Dielectric Relaxation / Soakage
- Delay in polarization of dielectric molecules in response to an electric field
- Commonly observed in
  - Capacitors
  - Multilayer PCBs
- Often modeled as an RC in parallel with the “ideal” capacitor
- Dominates settling time in electrometer circuits



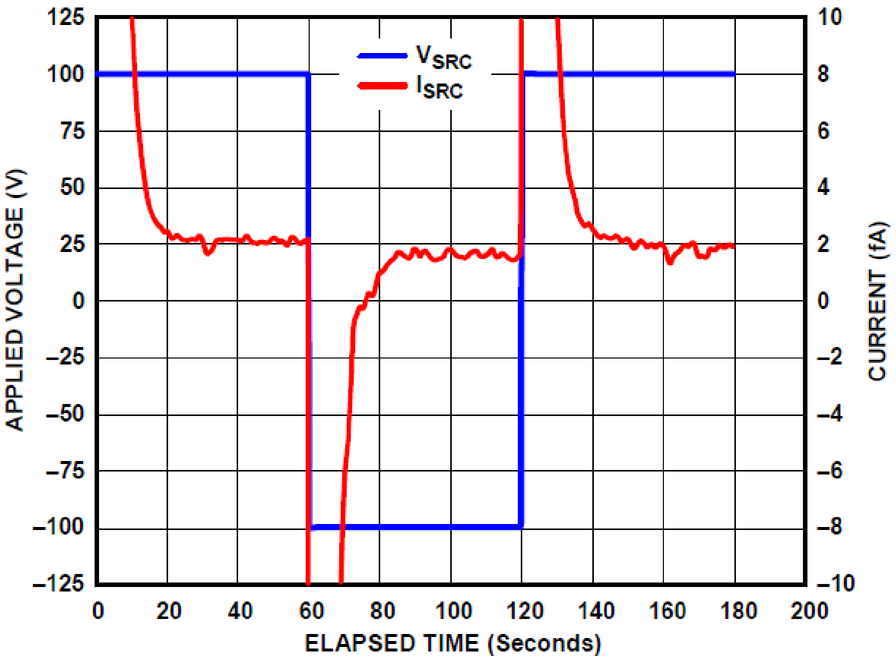
Dealing with Dielectric Absorption in PCBs

- PTFE, Rogers 4350B





Glass epoxy (FR-4)



Rogers 4350B

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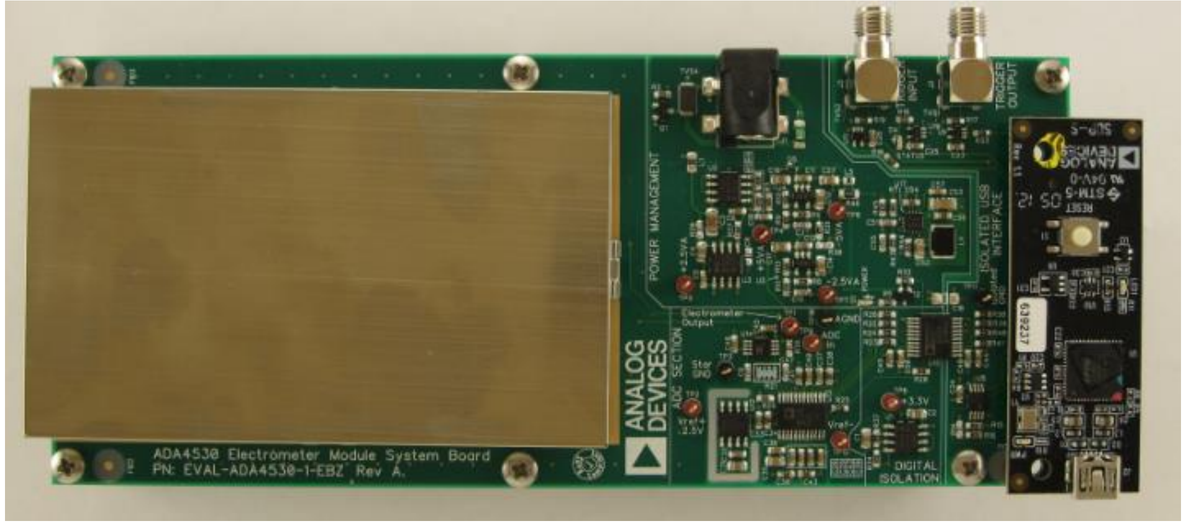
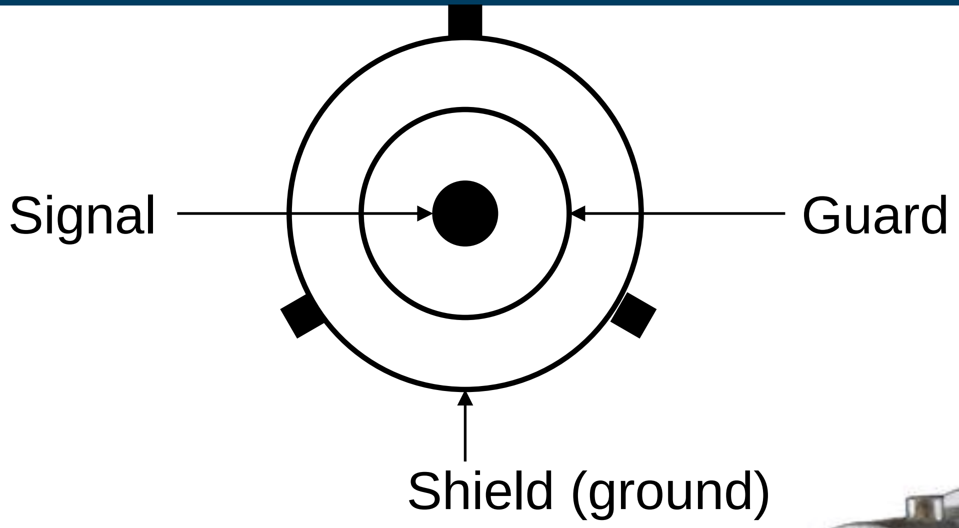
Shielding

- Shields help keep stray fields away from sensitive nodes
- Shields should be grounded when exposed to operators for safety



Cabling and connectors

- Best: Use triax
  - Has an extra inner conductor to guard signal
- BNC, SMA and coaxial cables are OK as long as there is very little potential difference between center conductor and shield
  - Cost effective
  - Some RF materials (PTFE) have good low-leakage, low DA properties
- Cable tie down to reduce triboelectric effects



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Summary

- Design of low-level current measurement hardware requires attention to many details!

Problem	Source	Solution
PCB leakage	Moisture and contamination	Dust covers/shielding
	Solder flux contamination	Avoid no-clean solder paste; wash and bake
Dielectric absorption	Charge trapped in dielectrics	Use PTFE / Rogers 4350B dielectric material
Cable leakage	Poor quality insulation between conductors	Use PTFE-insulated cables or triax cables/connectors
Extrinsic Noise	E/M fields, Powerline interference	Shielding and guarding
	Mechanical vibrations, triboelectricity	Cable tie-downs

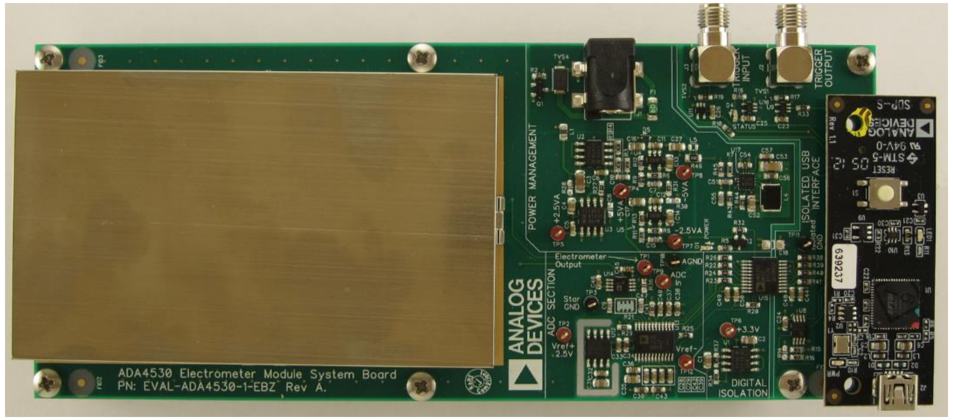
- A femtoammeter measurement platform solves many problems and enables quick prototyping

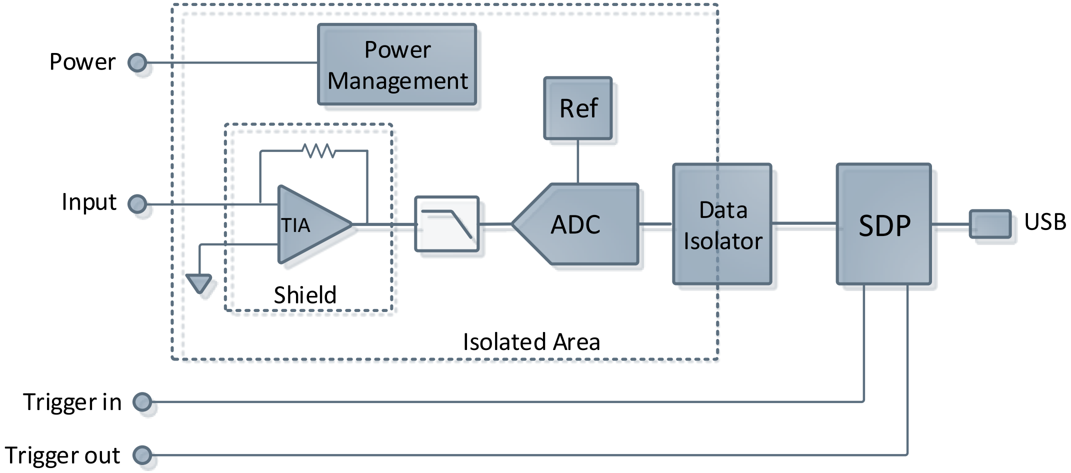
Femtoampere Measurement Platform

MAKING IT EASY FOR DESIGN-INS

Ultra High Sensitivity Femtoammeter Module

- Development module for sensors with low-level current output
  - Direct interface to sensors like photodiodes, faraday cups through SMA connector
- Features
  - **<10fA sensitivity** with 10GΩ transimpedance
    - 500pA measurement range
    - Shielding
    - Isolation with **ADuM3151**
  - Femtoampere input bias op amp
    - **ADA4530-1**
  - 24-bit resolution ADC
    - **AD7172-2**
  - USB interface to PC via SDP
  - Simple power supply: 9VDC input
    - **ADP7118, ADP2442, ADP7182**
  - Measurement synchronization
    - Trigger in/out signals





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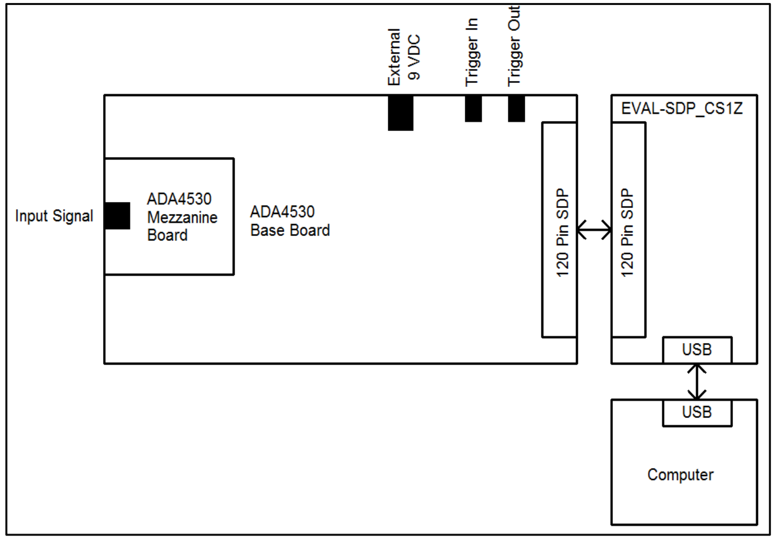
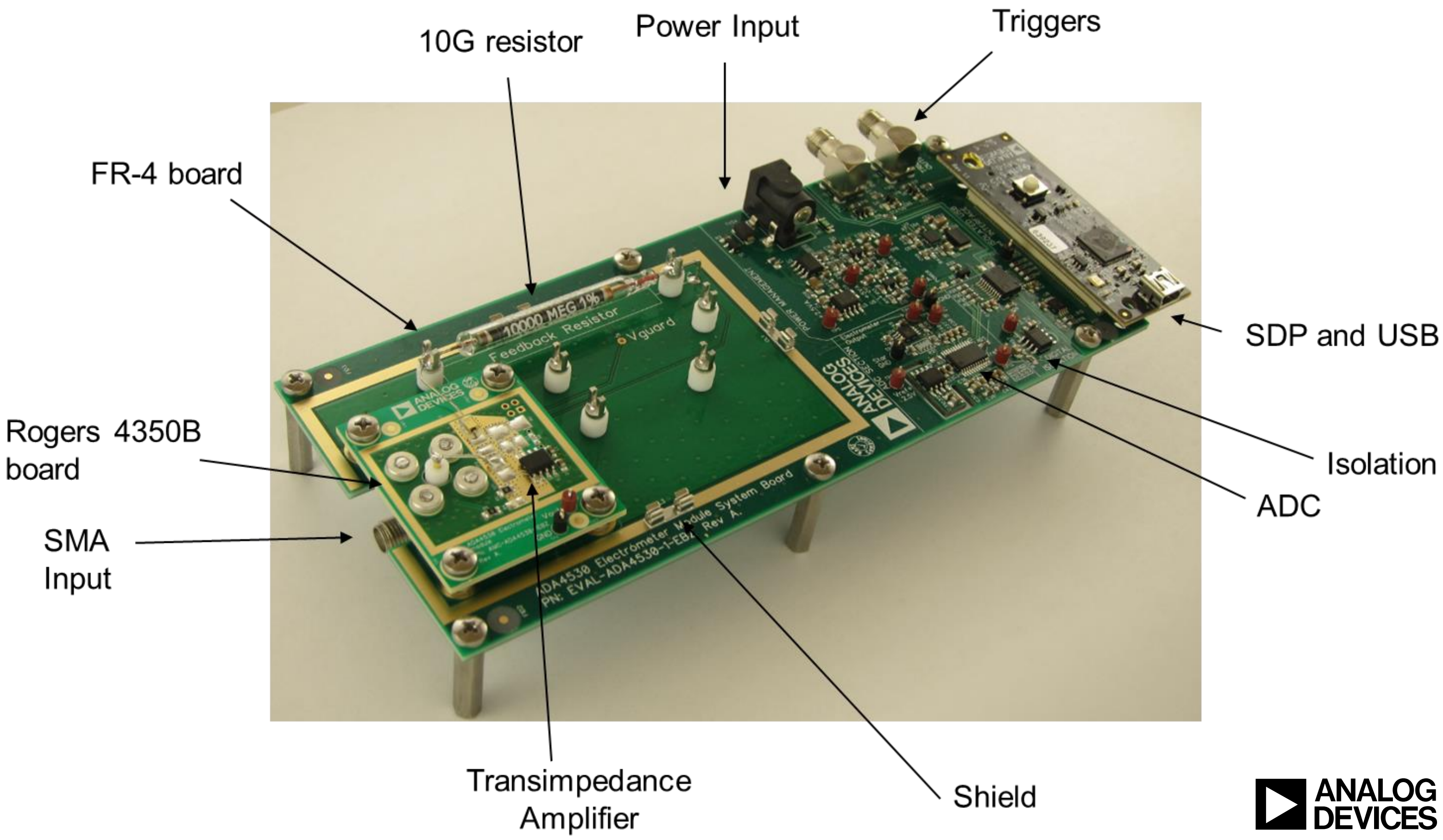
Ultra High Sensitivity Femtoammeter Module

- Allows user to directly connect sensor to the board in their own application environment
- Designed for real-world applications





CN-0407: Ultra High Sensitivity Femtoampere Measurement Platform

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Circuit Note
CN-0407

Circuits from the Lab® Reference Designs

Circuits from the Lab® reference designs are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit www.analog.com/CN0407.

Devices Connected/Referenced	
ADA4530-1	Femtoampere Input Bias Current Electrometer Amplifier
AD7172-2	Low Power, 24-Bit, 31.25 kSPS, Sigma-Delta ADC with True Rail-to-Rail Buffers
ADR4525	Ultralow Noise, High Accuracy, Voltage Reference
ADP2442	36 V, 1 A, Synchronous, Step-Down, DC-to-DC Regulator with External Clock Synchronization
ADG1419	2.1 Ω On Resistance, ±15 V/+12 V/±5 V, *i*CMOS SPDT Switch
ADP7118	20 V, 200 mA, Low Noise, CMOS LDO Linear Regulator
ADP7182	−28 V, −200 mA, Low Noise, Linear Regulator
ADuM3151	3.75 kV, 7-Channel, SPIsolator Digital Isolators for SPI

Ultrahigh Sensitivity Femtoampere Measurement Platform

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

- CN-0407 Circuit Evaluation Board (EVAL-CN0407-SDPZ), Consists of Two Boards
  - Low Leakage Mezzanine Board (EVAL-CN0407-1-SDPZ)
  - Data Acquisition Board (EVAL-CN0407-2-SDPZ)
- System Demonstration Platform (EVAL-SDP-CS1Z)

Design and Integration Files

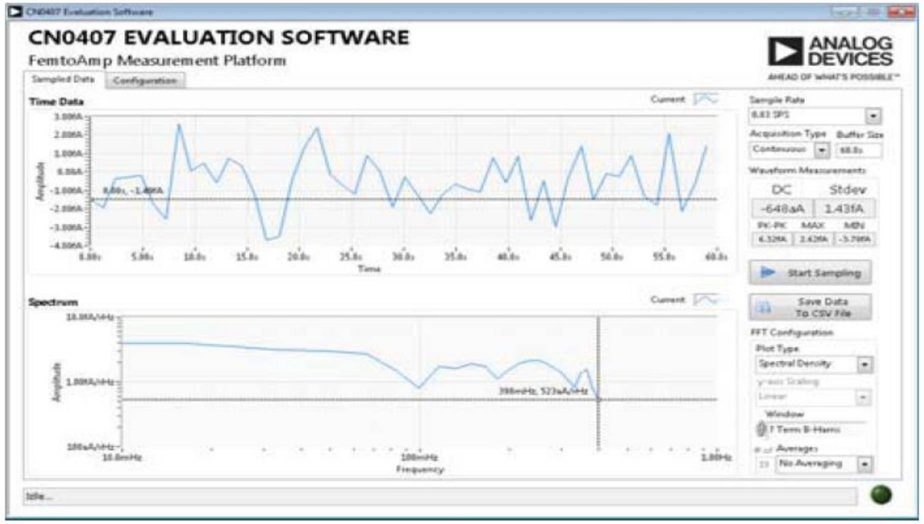
- Schematics, Layout Files, Bill of Materials

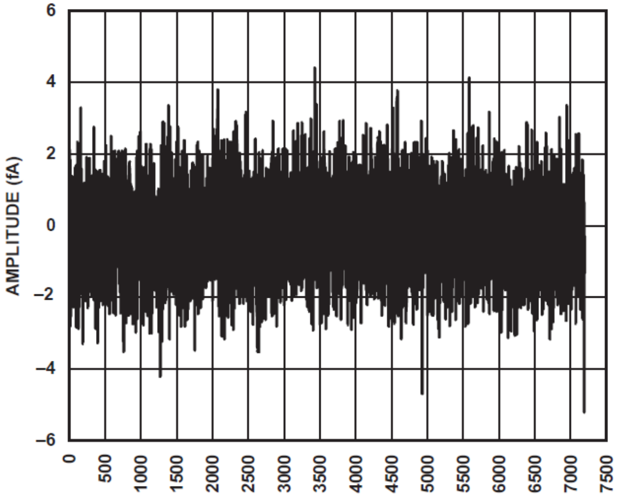
CIRCUIT FUNCTION AND BENEFITS

The system functional diagram in Figure 1 is a precision analog front end for measurement of current down to the femtoampere range. This industry-leading solution is ideal for chemical analyzers and laboratory grade instrument where an ultrahigh sensitivity analog front end is required for signal conditioning current output sensors such as photodiodes, photomultiplier tubes, and Faraday cups. Applications that can use this solution include mass spectrometry, chromatography, and coulometry.

The EVAL-CN0407-SDPZ provides a reference design for real-world application by partitioning the system into a low-leakage mezzanine board and a data acquisition board. The input signal conditioning is implemented with the ADA4530-1 on the mezzanine board. The ADA4530-1 is an electrometer-grade amplifier with ultralow input bias current of 20 fA maximum at 85°C. A guard buffer is integrated on the chip to isolate the input pins from leakage to the printed circuit board (PCB). The default amplifier configuration is in the transimpedance mode with a 10 GΩ glass resistor and a metal shield that prevents leakage current from entering any of the high impedance paths on the board. In addition, the mezzanine board includes unpopulated resistor and capacitor pads to allow prototyping with surface-mount feedback resistors as well as other input configurations.

The data acquisition board uses an AD7172-2 24-bit Σ-Δ analog-to-digital-converter (ADC) and is powered from a single 9 V dc supply. The on-board supply generates all necessary voltages required to power both boards. The board connects to a PC via the SDP-S board (EVAL-SDP-CS1Z) and uses digital isolation to prevent noise from the USB bus or ground loops from degrading low current measurements.





Board Noise (sampled data with an open input at 0.83sps for 120min)

www.analog.com/CN0407

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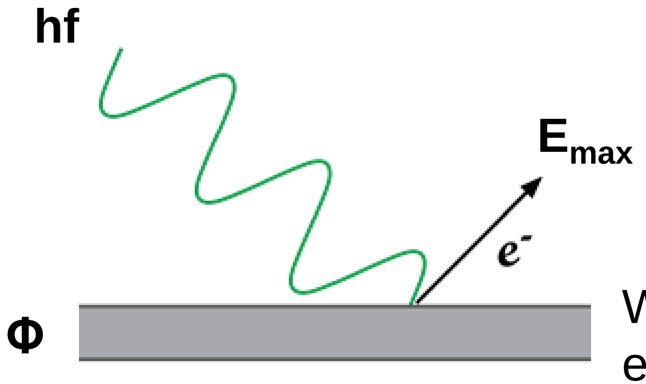
The Photoelectric Effect Demo

AS A LOW LEAKAGE MEASUREMENT CASE STUDY

Photoelectric Effect

- Emission of electrons when light is shone onto a photoemissive material



$$E_{max} = hf - \Phi$$

Work function, Φ : min energy required to eject an electron from the surface of the material

- Sensor:
  - Phototube (vacuum tube with an anode and a cathode)
  - Cesium Antimony
  - What is the work function of the phototube?

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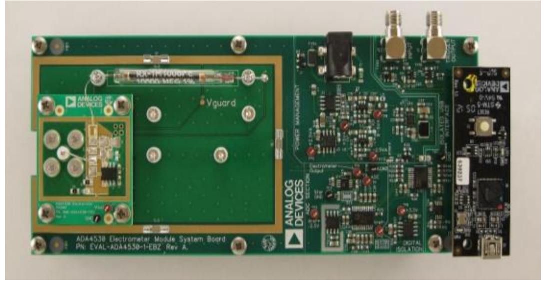
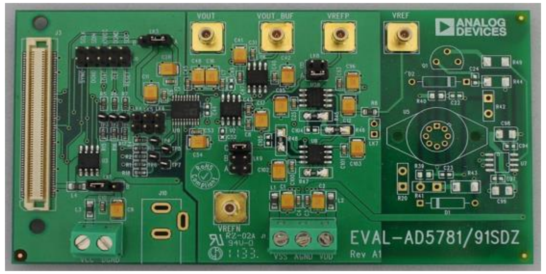
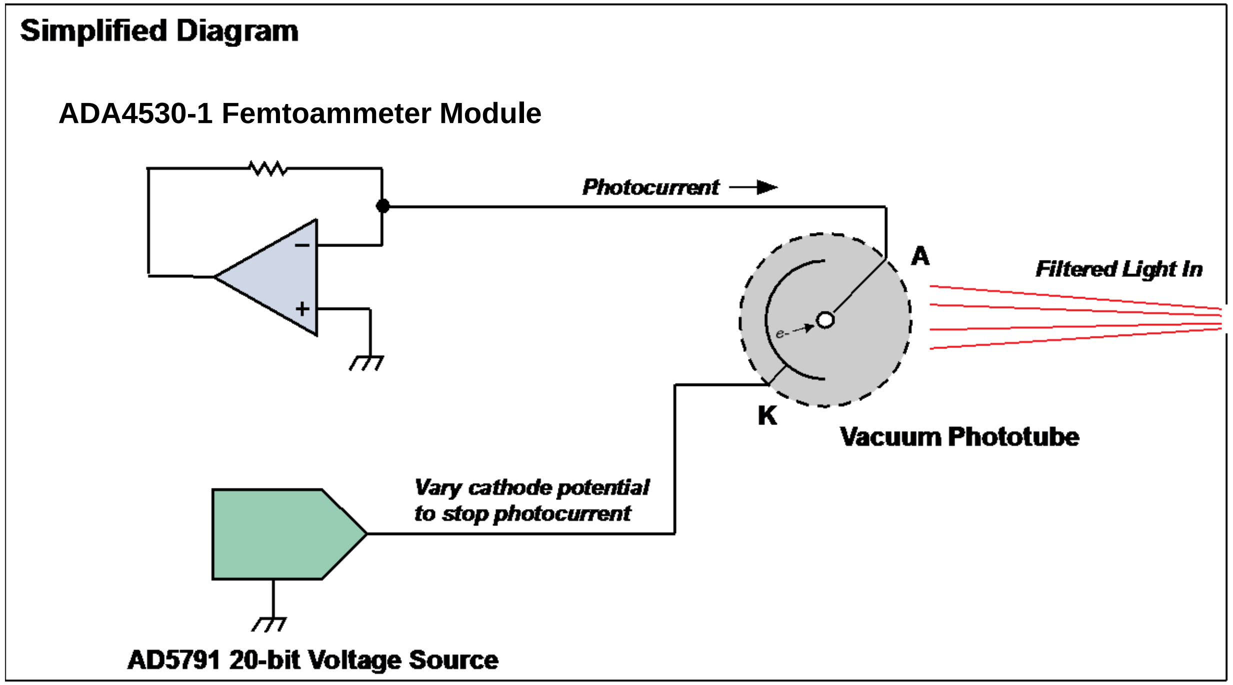
Demo: Using ADA4530-1 to Accurately Measure Current down to 0 fA







- Use a phototube with Cesium Antimony material
- Provide a light source
- Measure the photocurrent
- Apply a voltage (stopping potential) opposing the electron flow to measure kinetic energy
- Calculate work function $E_{max} = q \times V_{STOP} = hf - \Phi$

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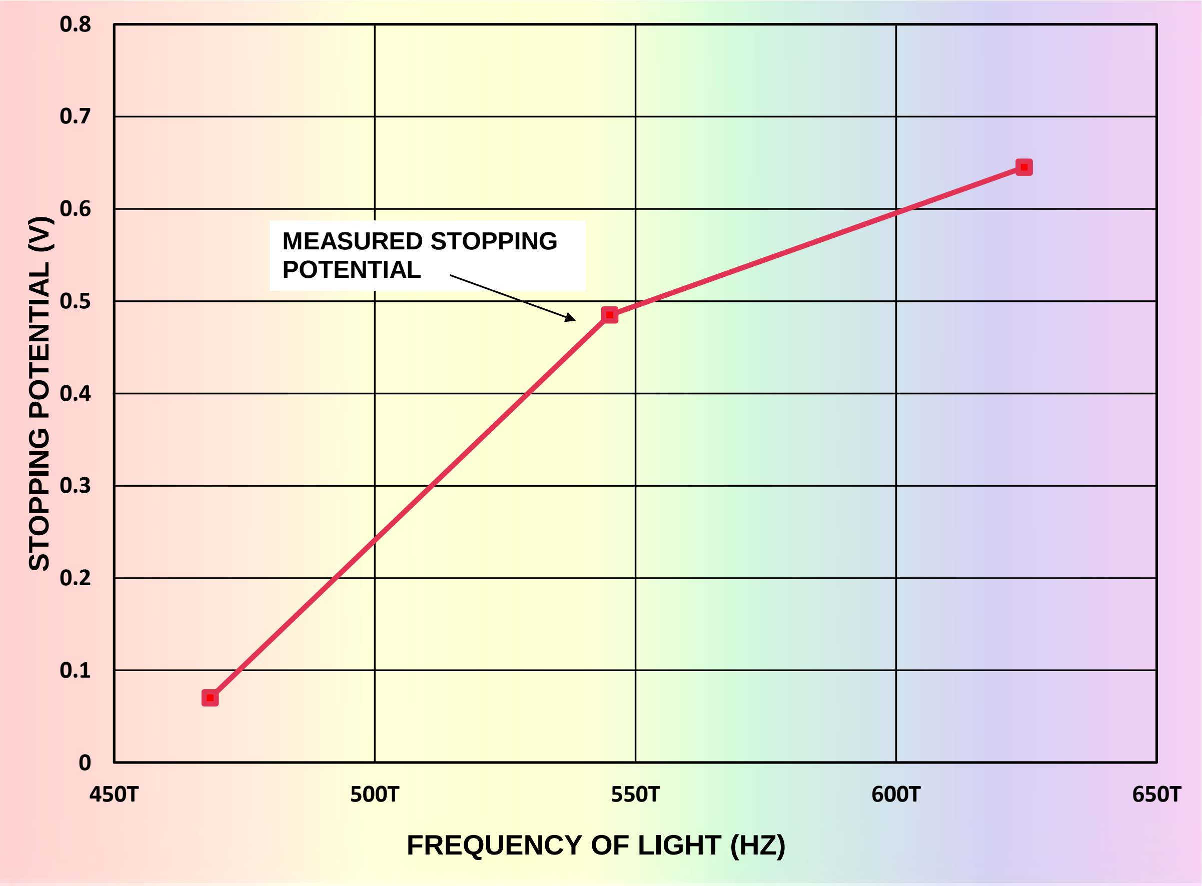
Demo Measurement Results



- The stopping potential varies with light frequency as expected
- Work function, Φ, measured to be 1.86eV

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Conclusion / Takeaways

Things we learned

- It is important to minimize output error and maximize SNR to achieve high sensitivity current measurements.
  - Minimizing output error demands a high precision amplifier with low IB and drift.
  - Maximizing SNR requires careful selection of gain component.
- Design of low-level current measurement hardware requires attention to unique considerations.
  - Board leakage, contamination, moisture, dielectric absorption, cabling, etc. can contribute to significant measurement errors.
  - Best practices with guarding, shielding, cleaning/handling, appropriate board/solder material and cabling mitigate the errors.
- ADI's ultra high sensitivity femtoampere measurement platform provides out of the box direct connection to sensors in your application environment.

Useful links

- ADA4530-1 front end electrometer (http://www.analog.com/media/en/technical-documentation/data-sheets/ADA4530-1.pdf)
- CN-0407: Ultrahigh Sensitivity Femtoampere Measurement Platform (www.analog.com/CN0407)
- User Guide: UG-865 (http://www.analog.com/media/en/technical-documentation/user-guides/ADA4530-1R-EBZ_UG-865.pdf)
- App Note: AN1373 (http://www.analog.com/media/en/technical-documentation/application-notes/AN-1373.pdf)

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