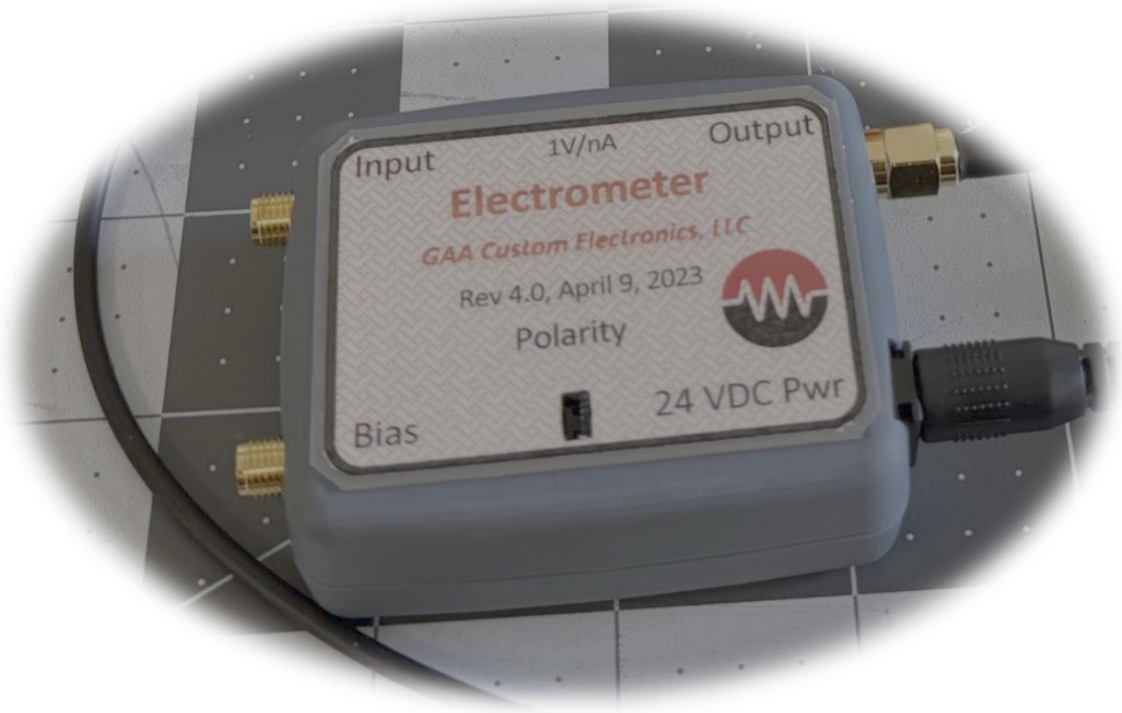


# Electrometer, 4.0

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Background:

An electrometer is an instrument meticulously crafted to measure incredibly minuscule currents. The electrometer design presented in this document employs an operational amplifier with exceptionally low bias current, enabling measurements as low as a pico-ampere (10<sup>-12</sup> amps). This electrometer was derived from a similar design published by Brian Clower's group at Washington State University (1).

The electrometer electronics is housed on a compact 2.3" x 1.75" PC board, designed to fit snugly within a small plastic enclosure. It features SMA connectors for the amplifier input and output, and power is supplied by a compact 24VDC wall supply. The schematic, PC board layout, and parts list are all included in this document.

The heart of this circuit lies in the Analog Devices AD8627 op-amp (IC1). This precision JFET input amplifier boasts an exceptionally low bias current of 250 fA and a low noise level of 17.5 nV per root Hz, making it an ideal choice for this specific application.

The input current to be measured flows into the amplifier through resistor R1, this resistor provides protection to the input amplifier. The output of IC1 is adjusted until the current that flows through R4 equals and cancels the input current being measured. R4 determines the current gain of this stage of the circuit. The resistor R4 can be very large due to the low bias current requirements of IC1, in this case 100M. IC2A is a buffer that has a gain of 1 or -1 allowing inversion of the signal. Jumper JP1 allows the user to select the polarity that can be useful when detecting with a unipolar digitizer. The final stage of amplification is provided by IC2B, this stage provides a gain of 10 and allows bandwidth control (C3) that can be set to the applications needs.

This electrometer can be used to measure DC currents or pulses of current. When making DC current measurements the output of the amplifier can be connected to a multi-meter to display the output voltage. This will provide a measure system with a sensitivity of 1mV per pA of input current. When making pulse current measurements use an oscilloscope to visualize the waveform.

This electrometer has a Bias input that allows you to apply a DC bias voltage on the electrometer input. The Bias input range is +/-5V, the bias voltage applied will appear of the electrometer input and can be used to help accelerate ions to the detector. The bias voltage is subtracted from the output voltage that you monitor.

**You must install the polarity jumper to use this offset feature.**

Electrometer specifications:

- Power source: 24VDC
- Power current: 10mA
- Sensitivity: 1mV per pA

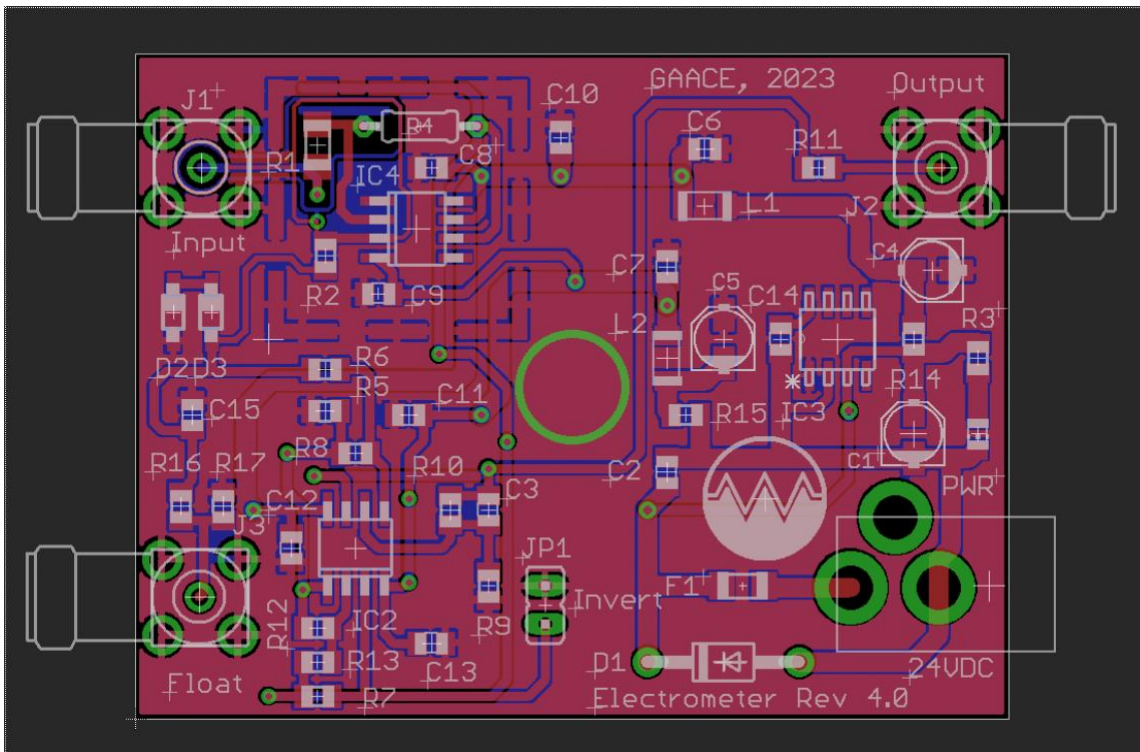
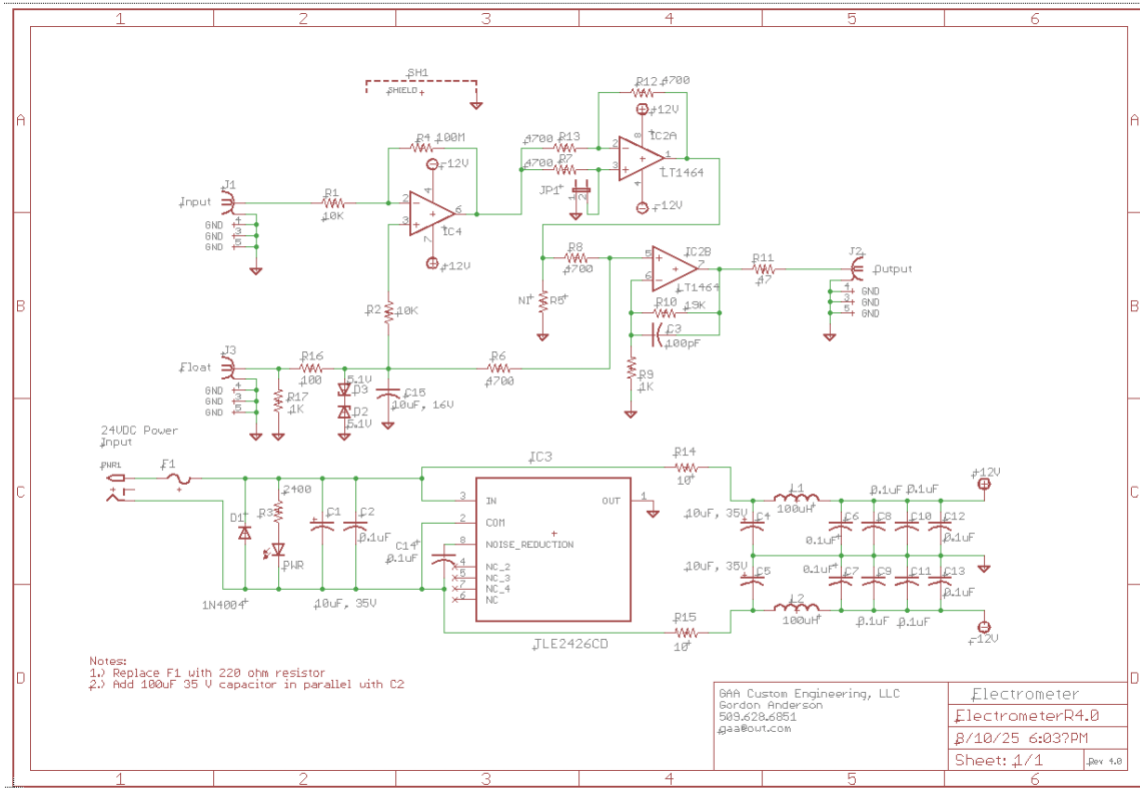
- Rise time: 6 $\mu$ s
- Noise with input open: 22mVp-p, 2.8mV rms
- Dynamic range: +/-5V
- **Output polarity jumper, must be installed when Bias input is used**
- Bias input range +/-5V

Power is provided by a 24VDC wall supply, IC3 is a rail-splitter generating the +/-12 volts used to power the amplifiers. The power supply voltage is filtered to reduce power source noise. The wall supply is isolated so the electrometer circuit does not have an earth ground reference, this allows the user to float the electrometer if needed.

The electrometer pulse response is shown below. This test was done by applying a 8.93mV pulse through a 10pF capacitor into the electrometer. In this case  $8.93 \times 10^{-14}$  coulombs of charge was deposited into the electrometer, or 557,000 electrons.

Based on the noise performance of this electrometer and using averaging during data collection, pulse detection of as low as few hundred electrons is possible.





Electrometer, Rev 4.0												
Qty-1	Part References	Value	Package	Vendor Part Num	VID	Mfg Part Num	Description	Cost	Order Num	Num Ordered	Stock	XREF
3	C1, C4, C5	10uF, 35V	PANASONIC_B	565-2115-1-ND	DK	EMVA350ADA100MD55G	CAP ALUM 10UF 20% 35V SMD	\$0.19	76409859.xlsx	100	98	REF1452
1	C15	10uF, 16V	C0805	1276-2447-2-ND	DK	CL21B104KCC5PNC	CAP CER 0.1UF 100V X7R 0805	\$0.05	79569593.xlsx	40012000	1000	REF485
10	C2, C6, C7, C8, C9, C10, C11, C12, C13, C14	0.1uF	C0805	1276-2447-2-ND	DK	CL21B104KCC5PNC	CAP CER 0.1UF 100V X7R 0805	\$0.05	79569593.xlsx	40012000	1000	REF485
1	C3	100pF	C0805	399-1122-1-ND	DK	C0805C10J5GAC7800	CAP CER 100PF 50V CGO/NPO 0805	\$0.03	70958607.xlsx	100	1000	REF1084
1	D1	1N4004	DO41-10	1N4004G05-ND	DK	1N4004G	DIODE GEN PURP 400V 1A DO41	\$0.13	80575504.xlsx	265	*	REF1119
2	D2, D3	5.1V	SOD123N	MMSZ4689-TPMSCT-ND	DK	MMSZ4689-TP	DIODE ZENER 5.1V 500MW SOD123	\$0.29	NoOrderID.xlsx	175	6	REF1807
1	F1	R1206	R1206	507-1805-1-ND	DK	02C0075AF2E	PTC RESET FUSE 16V 750MA 1206	\$0.19	79541286.xlsx	350	*	REF116
1	H2	LT1464	S008	LT1464CS8-ND	DK	LT1464CS8	IC OPAMP JFET 2 CIRCUIT 8SO	\$10.09	72181805.xlsx	5	5	REF1234
1	H3	TLE2426CD	SOIC127P600X175-8N	296-26774-1-ND	DK	TLE2426CDR	IC VREF GND REF ADJ 1% RSOIC	\$1.86	79905709.xlsx	45	0	REF328
1	H4	AD8627	S008	AD8627ARZ-REEL7CT-ND	DK	AD8627ARZ-REEL7	IC OPAMP JFET 1 CIRCUIT 8SOIC	\$5.37	82246622.xlsx	10	*	REF1824
3	J1, J2, J3	BU-SMA-H	BU-SMA-H	931-1361-ND	DK	PCB-SMAFRA-HT	CONN SMA JACK R/A 50OHM PCB	\$3.41	NoOrderID.xlsx	94	18	REF327
1	JP1		JP1	S1211EC-02-ND	DK	PRPC025FAN-RC	CONN HEADER VERT 2POS 2.54MM	\$0.08	70958607.xlsx	15	*	REF1103
2	L1, L2	100uH	L3216C	490-6589-1-ND	DK	LQH31CN101K03L	FIXED IND 100UH 80MA 15.6OHM SMD	\$0.49	77650762.xlsx	150	50	REF456
1	PWR		CHP-LED0805	475-1410-1-ND	DK	LG R971-KN-1	LED GREEN DIFFUSED 0805 SMD	\$0.17	74391652.xlsx	50	28	REF625
1	PWR1	2.1MMJACKTHM	PJ-102A	CP-102A-ND	DK	PJ-102A	CONN PWR JACK 2X5.5MM SOLDER	\$0.60	65743868.xlsx	30	*	REF239
1	R1	10K	R1206	P10KECT-ND	DK	ERJ-8GEY103V	RES SMD 10K OHM 5% 1/4W 1206	\$0.01	62359582.xlsx	1,000	998	REF540
1	R10	19K	R0805	P19.1KDACT-ND	DK	ERA-6AEB1912V	RES 19.1K OHM 0.1% 1/8W 0805	\$0.12	78813318.xlsx	250	*	REF1614
1	R11		47 R0805	P47ACT-ND	DK	ERJ-6GEY470V	RES SMD 47 OHM 5% 1/8W 0805	\$0.01	80575504.xlsx	1250	1003	REF322
2	R14, R15		10 R0805	P10.OCCCT-ND	DK	ERJ-6ENF10R0V	RES SMD 10 OHM 1% 1/8W 0805	\$0.03	60561377.xlsx	250	250	REF317
1	R16		100 R0805	P100ACT-ND	DK	ERJ-6GEY101V	RES SMD 100 OHM 5% 1/8W 0805	\$0.10	NoOrderID.xlsx	100	5000	REF1838
1	R2		10K R0805	P10KADTR-ND	DK	ERJ-P0G103V	RES SMD 10K OHM 5% 1/2W 0805	\$0.02	75595754.xlsx	5,000	*	REF1421
1	R3		2400 R0805	P2.4KACT-ND	DK	ERJ-6GEY1242V	RES SMD 2.4K OHM 5% 1/8W 0805	\$0.01	60729303.xlsx	1,000	995	REF334
1	R4		100M 0204/7	A105971CT-ND	DK	RGPO207CH100M	RES 100M OHM 5% 1/4W AXIAL	\$0.51	80575504.xlsx	45	20	REF466
0	R5(DNP)	NI	R0805	Not installed								
5	R6, R7, R8, R12, R13		4700 R0805	P4.7KACT-ND	DK	ERJ-6GEY472V	RES SMD 4.7K OHM 5% 1/8W 0805	\$0.01	62359582.xlsx	1,000	6	REF539
2	R9, R17	1K	R0805	P1.0KCTR-ND	DK	ERJ-6ENF1001V	RES SMD 1K OHM 1% 1/8W 0805	\$0.01	68183122.xlsx	5,000	5000	REF947
1	SH1		SHIELD	SHIELD16.5X16.5	DK	903-1051-1-ND	RF SHIELD 0.65" X 0.65" SOLDER	\$1.69	78813318.xlsx	20	*	REF984

(1) HardwareX Volume 4, October 2018, e00030.  
 Implementation of a flexible, open-source platform for ion mobility spectrometry  
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