UM2982

User manual

How to use the STEVAL-CCA058V1 training kit for operational amplifiers and comparators

Introduction

The STEVAL-CCA058V1 training kit is intended for hands-on training on operational amplifiers and comparator-based analog circuits.

You can use the kit in an academic context for students' training, as well as for professionals' training: junior analog engineers, distributors, and customers. It is also useful for a fast evaluation and prototyping of low frequency op amp-based applications.

The STEVAL-CCA058V1 consists of a configurable board, which features the most widely used op-amp-based schematics and applications, and ST op-amps mounted on DIP adaptors.

It should be used with a set of through passive components (resistors and capacitors), and a set of lab instruments (power supply, function generator, multimeter, and oscilloscope).

The kit allows the trainee to experiment the most common op-amp-based schematics. It also allows learning how to choose the most suited op-amp for a custom application. You can find the detailed documentation on guided experiments at www.st.com.

Figure 1. STEVAL-CCA058A1 evaluation kit - main board

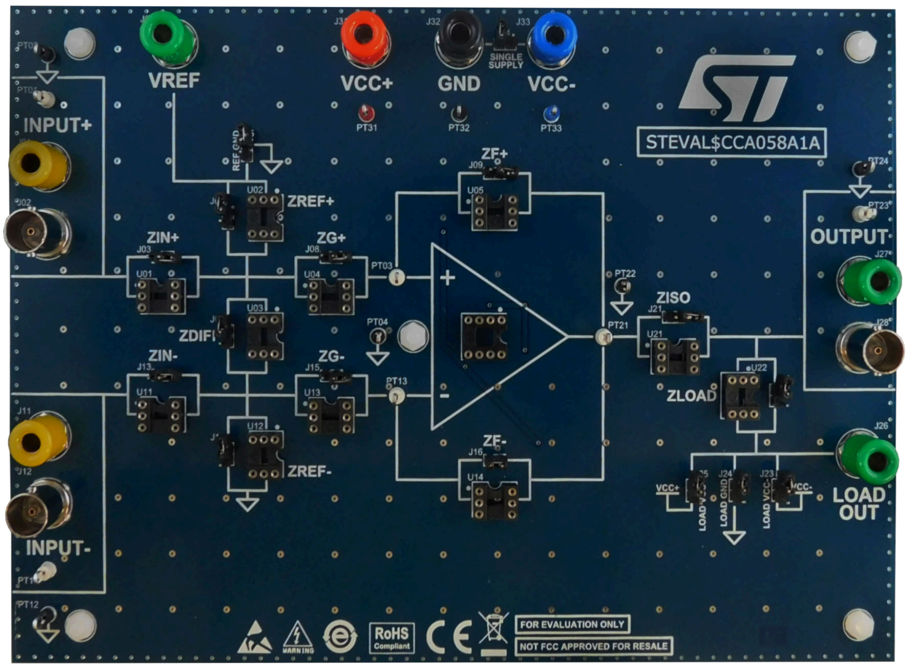
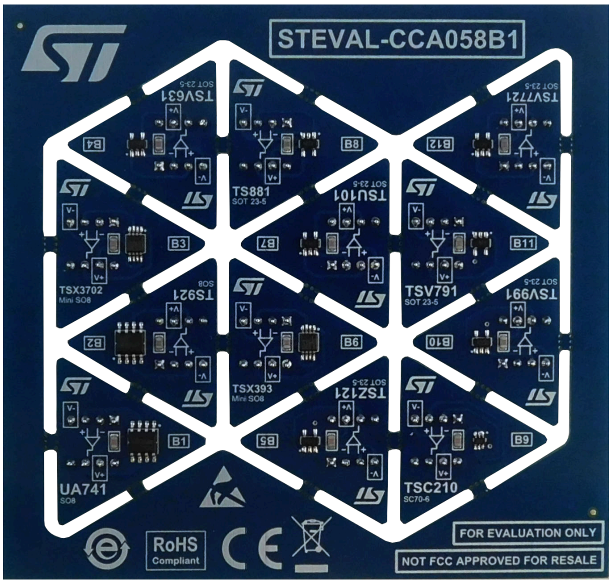


Figure 2. STEVAL-CCA058A1 evaluation kit - op-amp adapter board



1 Getting started

1.1 Safety precautions and protective equipment

Caution: All example applications provided with this kit involve 5 V op-amps and comparators. Thus, voltages over 40 V, that can be harmful for the human body, are not meant to be used with this kit. However, even with low voltage, a fire hazard might occur if the current is not limited. Use a power supply with current limitation and limit the current to 100 mA maximum, which should be sufficient for any of the applications shown here.

Danger: *Even with low voltage, electronic components, such as integrated circuits and electrochemical condensers, might explode if improperly biased. Use safety glasses when the board is biased.*

1.2 Overview

The STEVAL-CCA058V1 is designed to allow fast and easy setup of many op-amp-based basic circuits and applications.

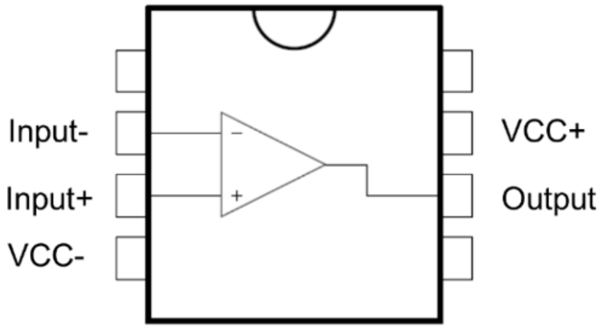
It features:

- Schematics and applications based on operational amplifiers and comparators:
  - Follower, inverter, noninverter
  - Filters
  - Low-side current sensing
  - Photodiode transimpedance amplification
- Low cost to high-performance low-voltage operational amplifiers:
  - Rail-to-rail
  - High bandwidth
  - Low offset
  - High output current
  - Low-power

The kit does not include any electronic component, except decoupling capacitors on the power supply network. You need passive through-hole components, that is, resistors and capacitors, as well as jumpers.

To test the kit, use operational amplifiers and comparators with a single DIP-8 pinout as shown below.

Figure 3. DIP-8 single pinout



A set of commonly used STMicroelectronics preamps and comparators is provided.

1.3 Hardware requirements

To reproduce the experiments described in this document, you need:

- a dual power supply stabilized, preferably with current limitation;
- a function generator;
- a multimeter;
- an oscilloscope or any other waveform acquisition device.

1.4 How to set up an applicative schematic on the board

Step 1. Connect the power supply to the board.

You can choose dual supply (default configuration) or single supply.

Step 1a. For single power supply, short GND and VCC- by adding a jumper on the “J single supply” connector.

You can use a standard laboratory power supply to power the op-amp.

For this supply configuration, a single power supply is sufficient. Its low voltage should be connected either to the VCC- or GND connector.

Important: *When using a current-limitation power supply, limit the current to 30 mA to prevent the destruction of the op-amp, in case the power supply polarity is reversed by mistake.*

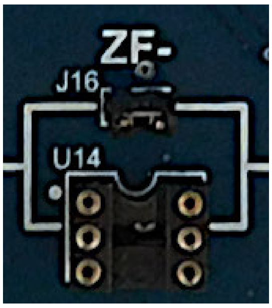
Step 1b. For dual supply mode, use a dual power supply.

Step 2. Configure an application scheme.

You can use both the configuration jumpers and the DIP-6 sockets.

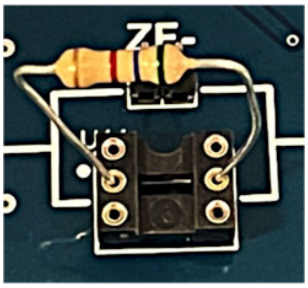
Step 2a. Use the configuration jumpers to short the electrical tracks.

Figure 4. Configuration jumpers



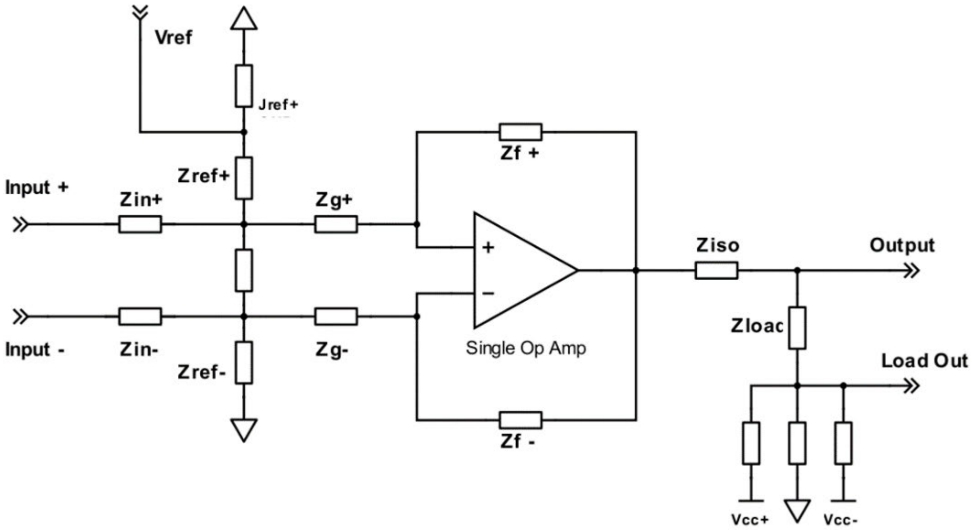
Step 2b. Use the DIP-6 connectors to connect one or several through-hole components in parallel.

Figure 5. DIP-6 connectors



The simplified scheme below shows the available jumpers and connectors.

Figure 6. STEVAL-CCA058V1 main board - simplified scheme



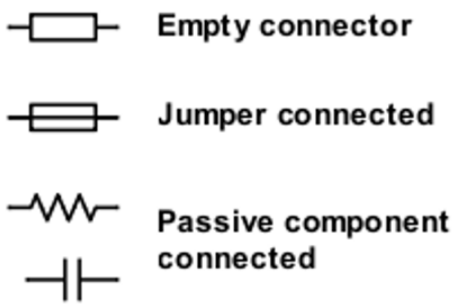
The two-circuit inputs (positive and negative) and the main output have BNC connectors for AC signal and 4 mm jack connectors for DC signal. The V_{REF} input and the load output are intended for DC signal only. They have 4 mm jack connectors only.

Test points for a multimeter or a scope probe are also available for the circuit inputs and outputs, and for the op-amps (circuit internal nodes).

1.4.1 Applicative scheme examples

The following sections show some examples of basic op-amp applications. They illustrate the passive components or jumpers to use, as well as the empty connectors, using the convention shown below.

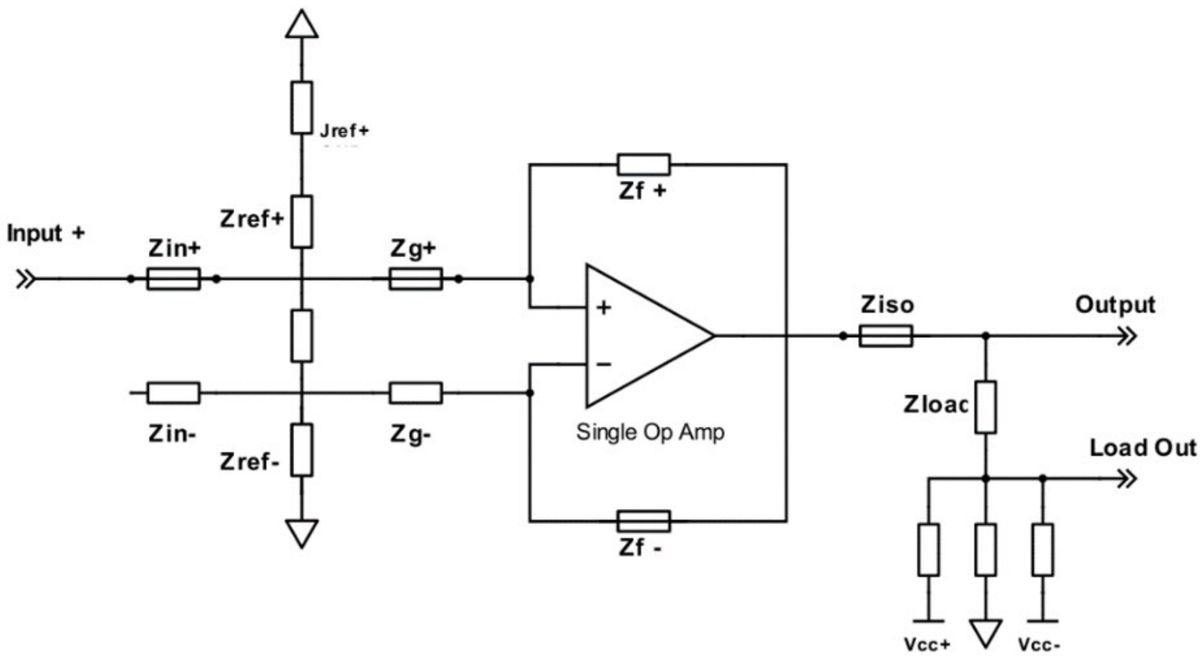
Figure 7. Configuration conventions for the board schematics



1.4.1.1 *Voltage follower*

The op-amp is used in a linear regime. The bias of the output is equal to both positive and negative inputs (with a small difference linked to the op-amp error), provided that the input bias is far from the Vcc+ and Vcc- (or GND in the single supply configuration).

Figure 8. Connection schematic of the voltage follower

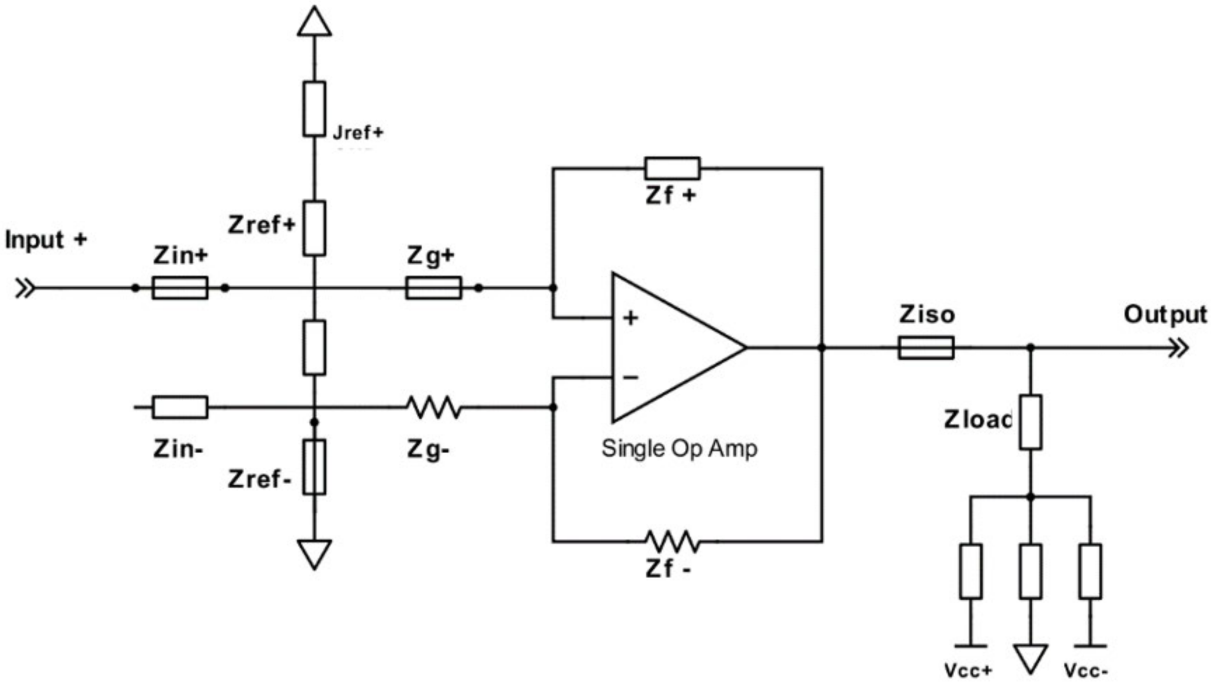


1.4.1.2 *Non-inverting configuration*

The input bias (applied on Input +) is amplified by a factor determined by the Rg- and Rf- resistors connected at Zg- and Zf-.

$$G = 1 + \frac{R_{f-}}{R_{g-}}$$

Figure 9. Connection schematic of the non-inverting configuration

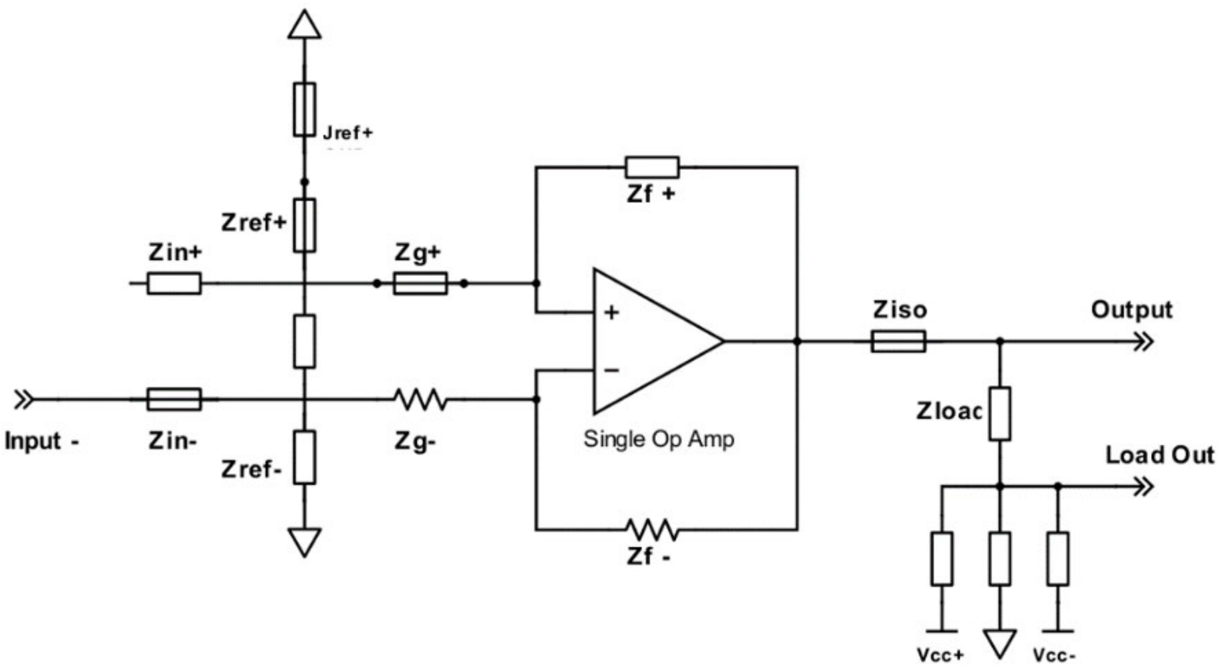


1.4.1.3 Inverting configuration

The input bias (applied on Input -) is amplified by a factor determined by the resistors Rg- and Rz- connected at Zg- and Zf-:

$$G = -\frac{R_{f-}}{R_{g-}}$$

Figure 10. Connection schematic of the inverting configuration



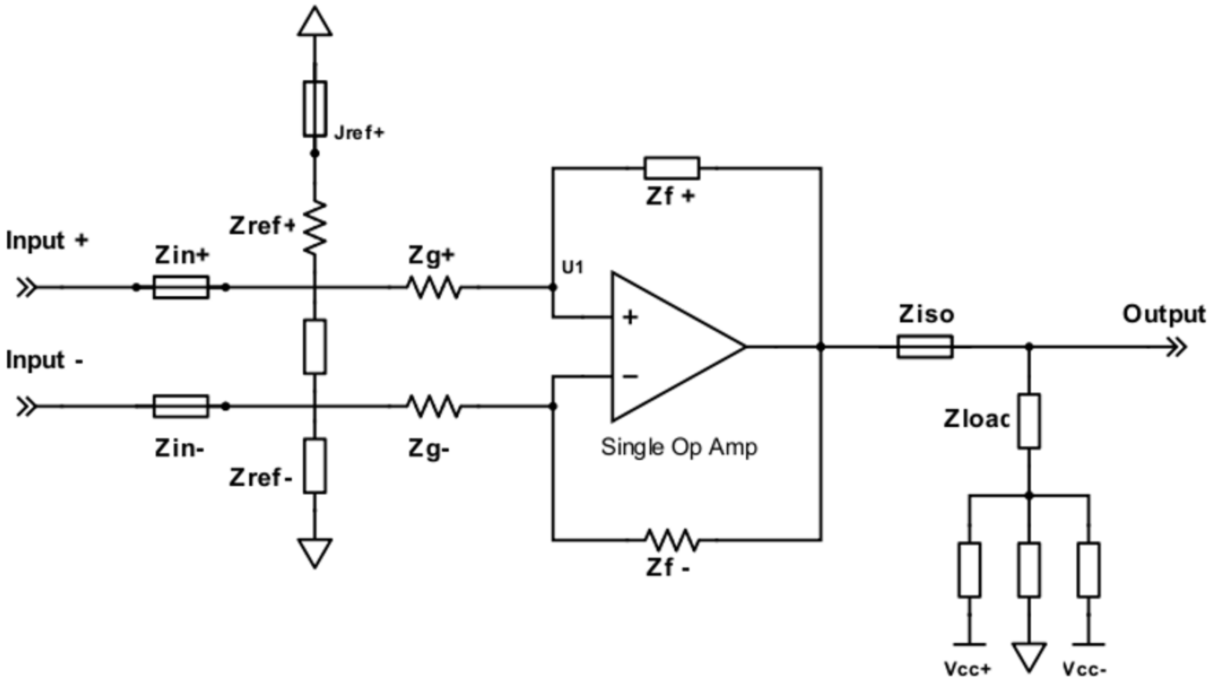
1.4.1.4 Differential amplifier

The differential amplifier schematic has two inputs. It mixes the non-inverting and the inverting configurations.

The bias of the output depends on the voltages on the positive and negative inputs, amplified as in the non-inverting and the inverting configurations.

$$V_{out} = \frac{R_{ref+}}{R_{ref+} + R_{g+}} \cdot \frac{R_{g-} + R_{f-}}{R_{g-}} \cdot V_{Input+} - \frac{R_{f-}}{R_{g-}} \cdot V_{Input-}$$

Figure 11. **Connection schematic of the differential amplifier**



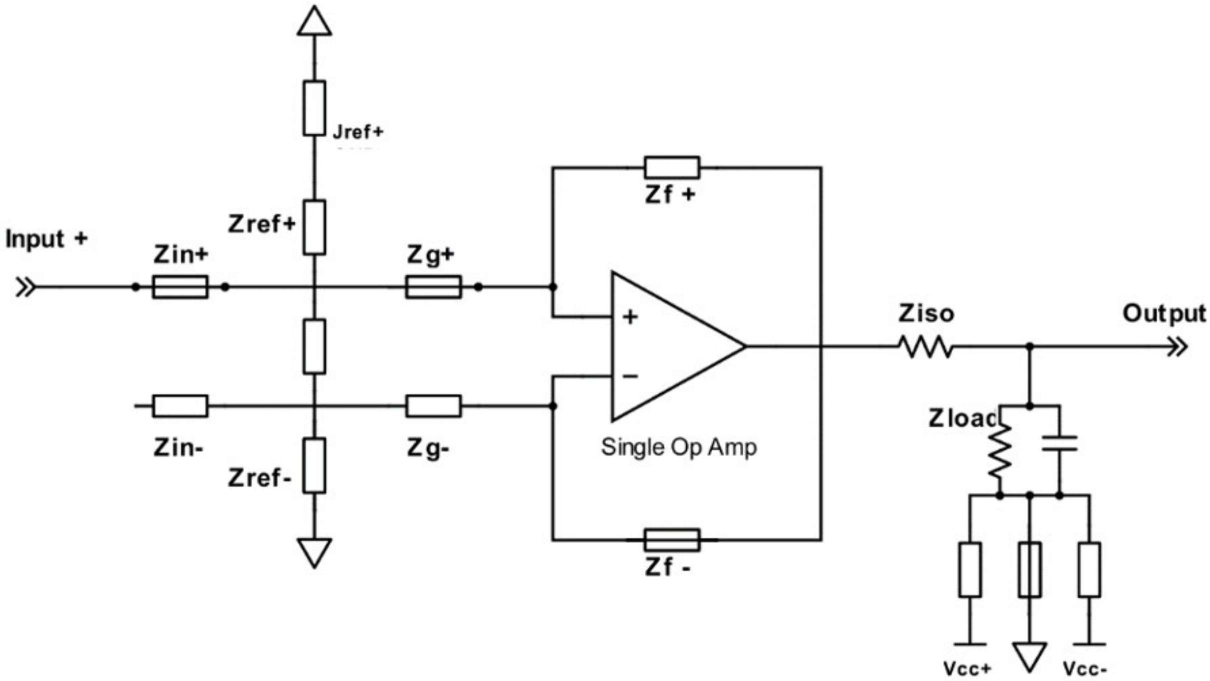
1.4.1.5 Follower with load and Ziso connector

This schematic is the same of the follower mode, but it adds a capacitive and/or resistive load (Zload connector), and an isolation resistor (Ziso connector).

This configuration allows evaluating the stability characteristics of an op-amp.

For further information on the op-amp stability, see AN2653.

Figure 12. **Follower connection schematic with load and Ziso connector**



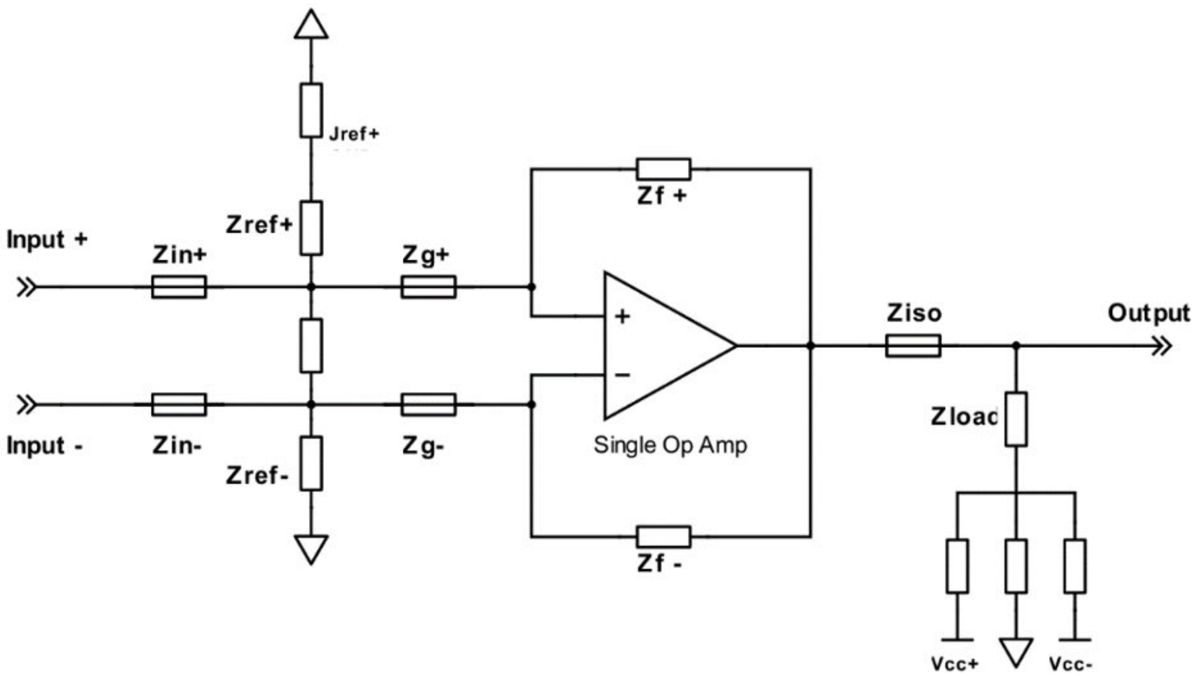
1.4.1.6 *Comparator*

In this configuration, the op-amp is used in a non-linear regime. The output is at high (~Vcc+) if the Vin+>Vin-, or at low (~Vcc- or Gnd in the single supply configuration) if Vin+<Vin-.

Specific op-amps are optimized for this application and referred to as comparators.

For further information on the comparators, see AN4071.

Figure 13. **Comparator connection schematic**



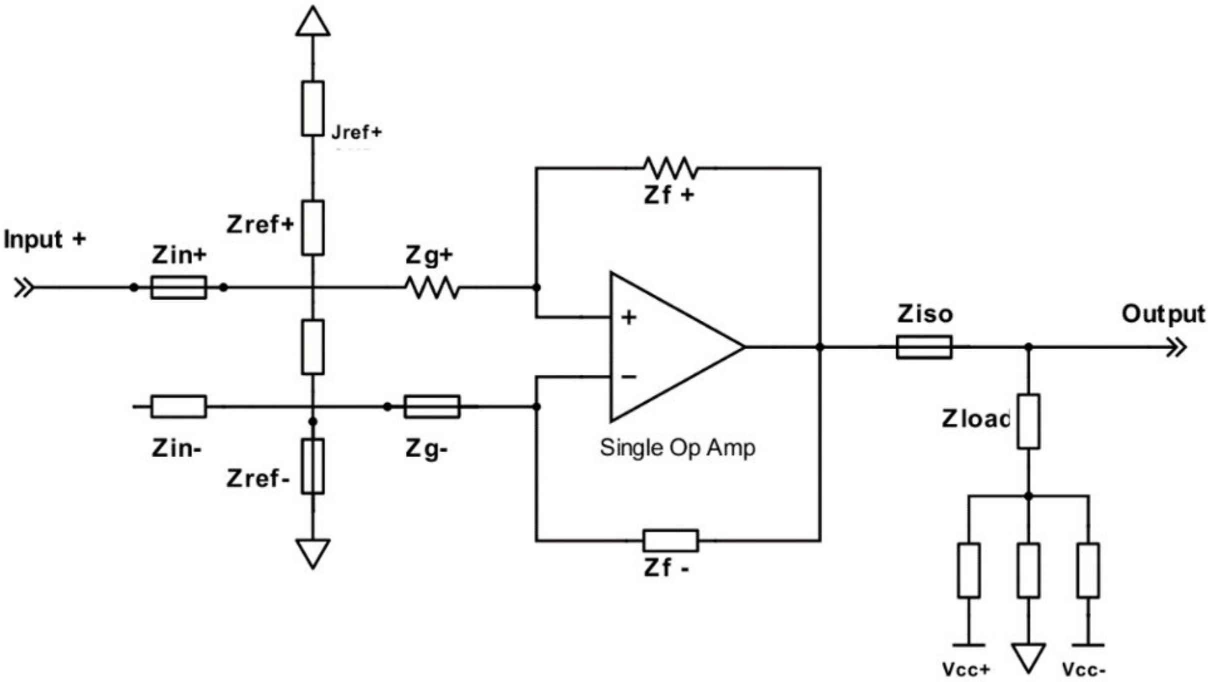
1.4.1.7 *Comparator with hysteresis*

In this schematic, also called Schmitt trigger, the bias of the Input + determines the output state (high or low). However, the bias thresholds at which the output switches from the positive to the negative state (V+) or from the negative to the positive state (V-) are different. The two resistors (Rg+ and Rf+) connected on Zg+ and Zf+ determine these thresholds as follows:

$$V_{+} = \frac{R_{g+}}{R_{g+} + R_{f+}} \cdot V_{cc}$$

$$V_{-} = -\frac{R_{g+}}{R_{g+} + R_{f+}} \cdot V_{cc}$$

Figure 14. **Connection schematic of the comparator with hysteresis**



1.4.1.8 *First order low pass filter*

This schematic acts as a first order low pass filter. The value of the resistor connected to Zin+ and the capacitor connected to Zdiff determine this filter cutoff frequency.

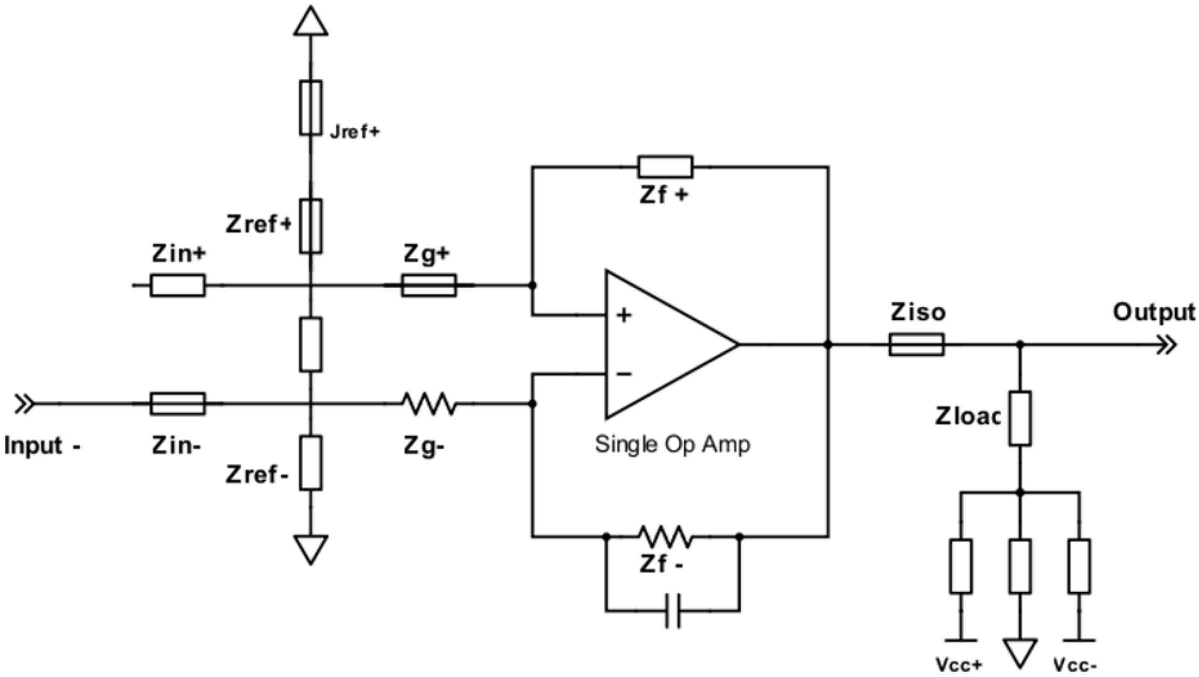
$$f_c = \frac{1}{2\pi R_{Z-} C_{Z-}}$$

This is an inverting circuit. It can have a non-unity gain given by the resistor ratio, similarly to the simple inverting circuit.

$$G = -\frac{R_{f-}}{R_{g-}}$$

Second order Sallen-Key type filters cannot be directly implemented on this board, as they use a more complex feedback network.

Figure 15. **Connection schematic of the low pass filter**



1.4.1.9 High pass filter

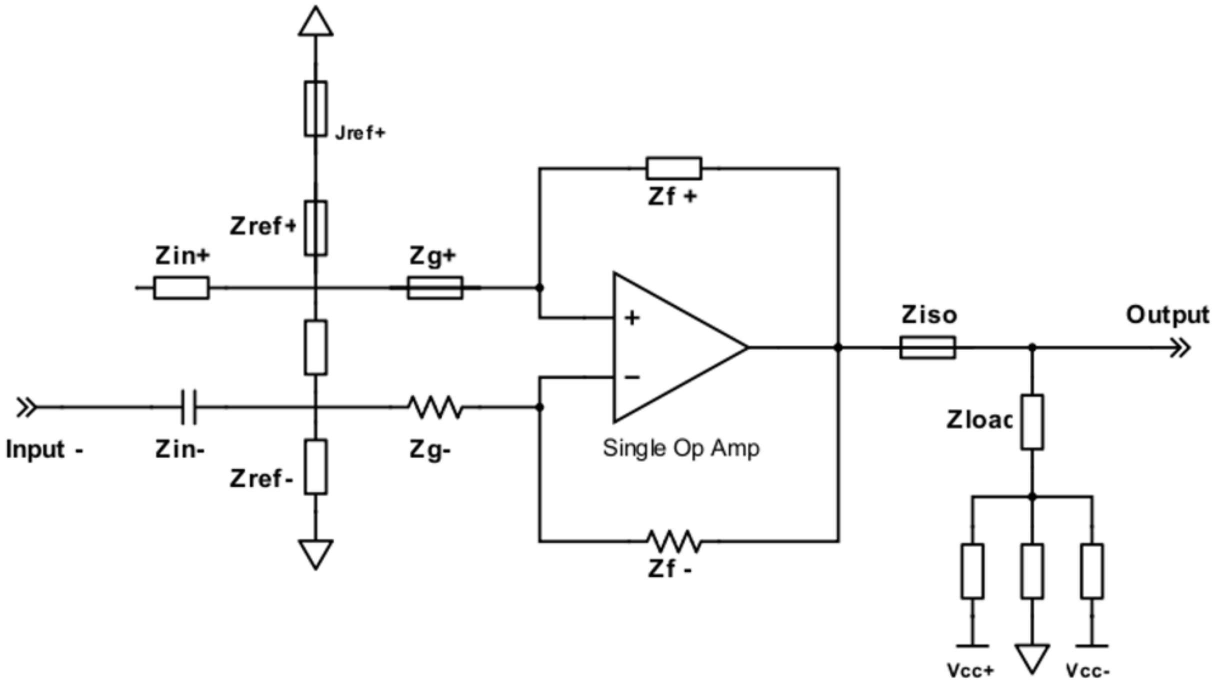
This schematic acts as a high pass filter. The value of the resistor connected to Zg- and the capacitor connected to Zin- determine this filter cutoff frequency.

$$f_c = \frac{1}{2\pi R_{z-} C_{in-}}$$

This is an inverting circuit. It can have a non-unity gain given by the resistor ratio, similarly to the simple inverting circuit.

$$G = -\frac{R_{f-}}{R_{g-}}$$

Figure 16. **Connection schematic of the high pass filter**

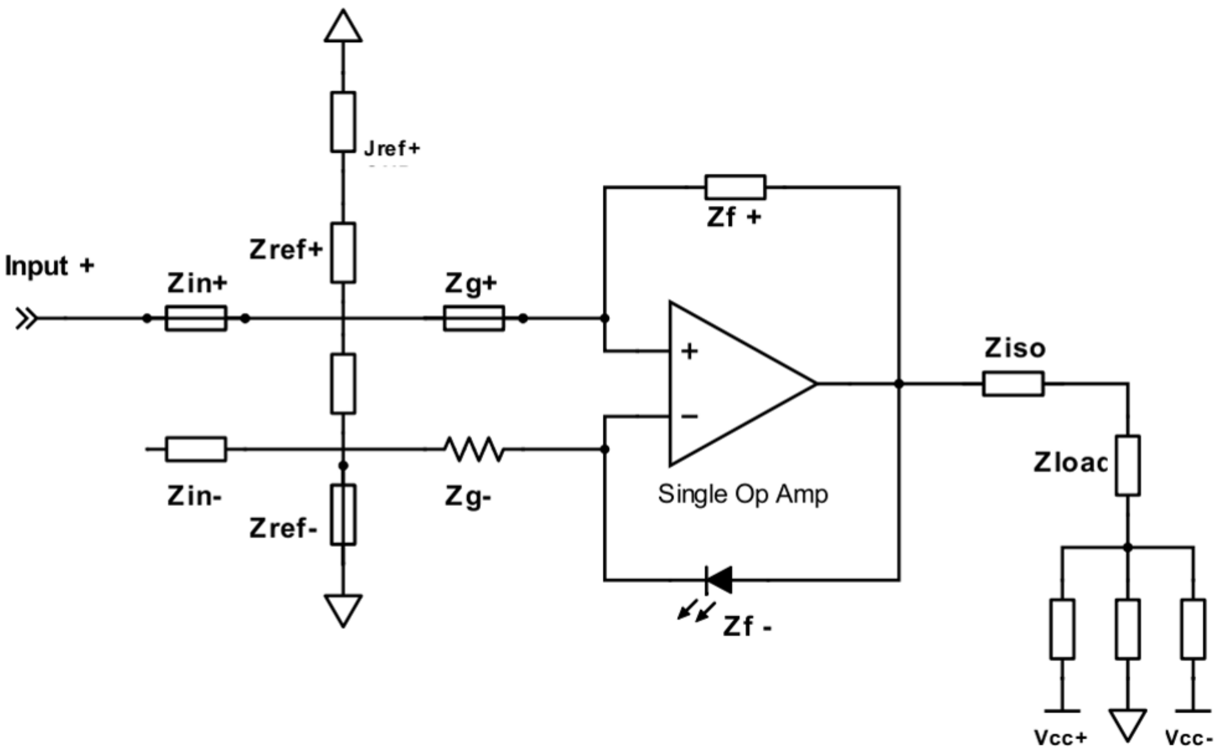


1.4.1.10 *LED driver*

You can easily use an op-amp as a current source, as a DC bias controls the current level.

$$I_{led} = \frac{V_{in+}}{R_{g-}}$$

Figure 17. **Connection schematic of the LED driver**



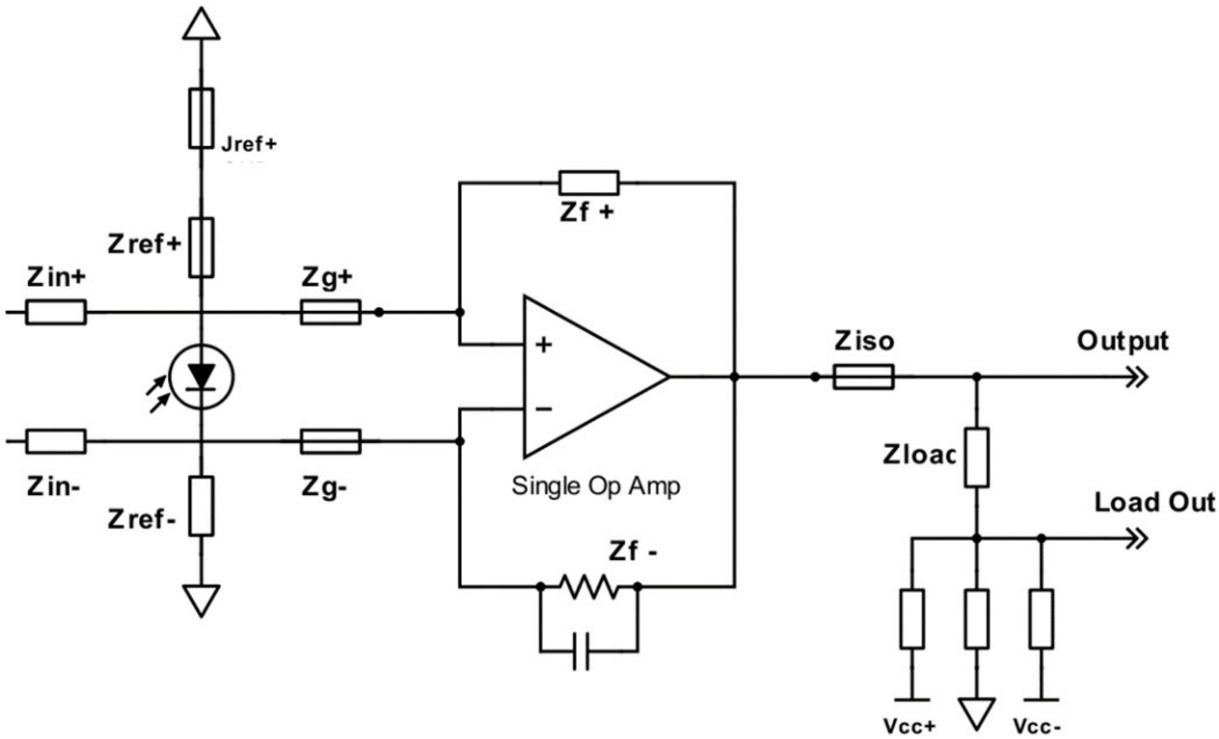
1.4.1.11 *Photodiode amplification*

In this schematic, the op-amp is used to convert the current that a photodiode generates into a voltage signal (transimpedance amplifier).

$$V_{Out} = I_{photodiode} \cdot R_{f-}$$

For further details on this application, see AN4451.

Figure 18. Connection schematic of the photodiode amplification



1.4.1.12 *Low side current sensing*

This is a very common application for op-amps. By interposing a low value resistor (shunt resistor) between the load and the ground, you can measure the current flowing through a load. This method allows you to convert the current into a voltage value. Then, you have to amplify this small voltage value.

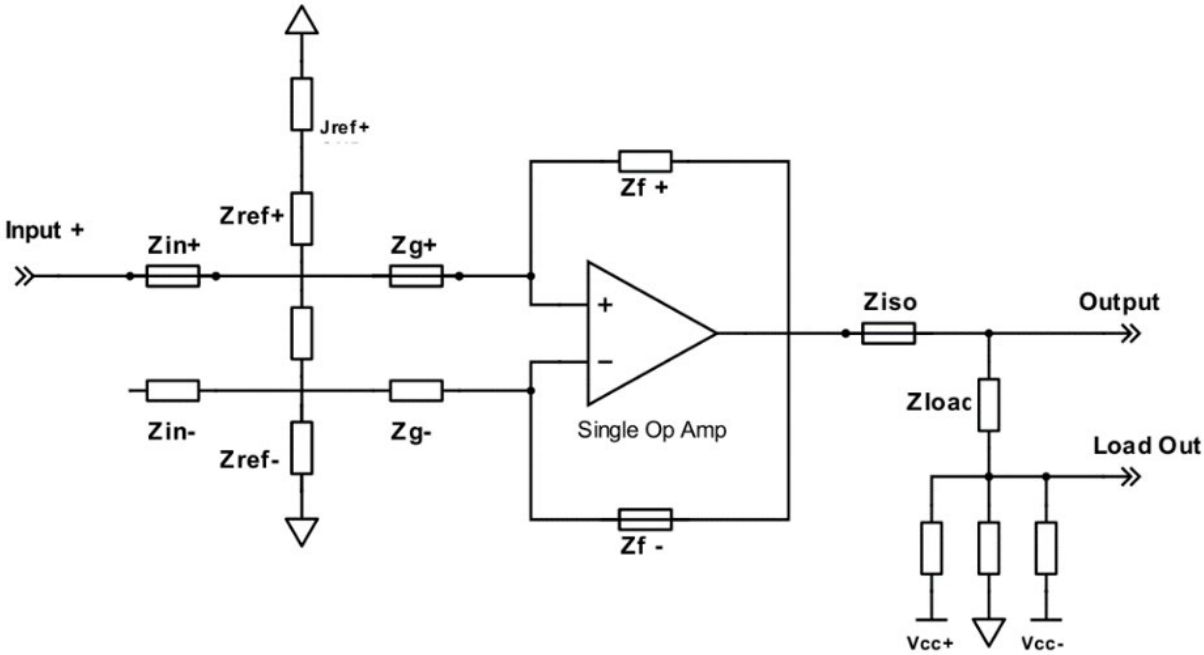
In this example schematic, the Input + is connected at the load low side. It converts the load current into a bias, as per the following equation:

$$V_{Shunt} = R_{Shunt} \cdot I_{Load}$$

The shunt voltage is then amplified, similarly to the non-inverting schematic:

$$V_{Out} = \left(1 + \frac{R_{f-}}{R_{g-}}\right) \cdot R_{Shunt} \cdot I_{Load}$$

Figure 19. Connection schematic of the low side current sensing



2 Schematic diagrams

Figure 20. STEVAL-CCA058A1 main board circuit schematic

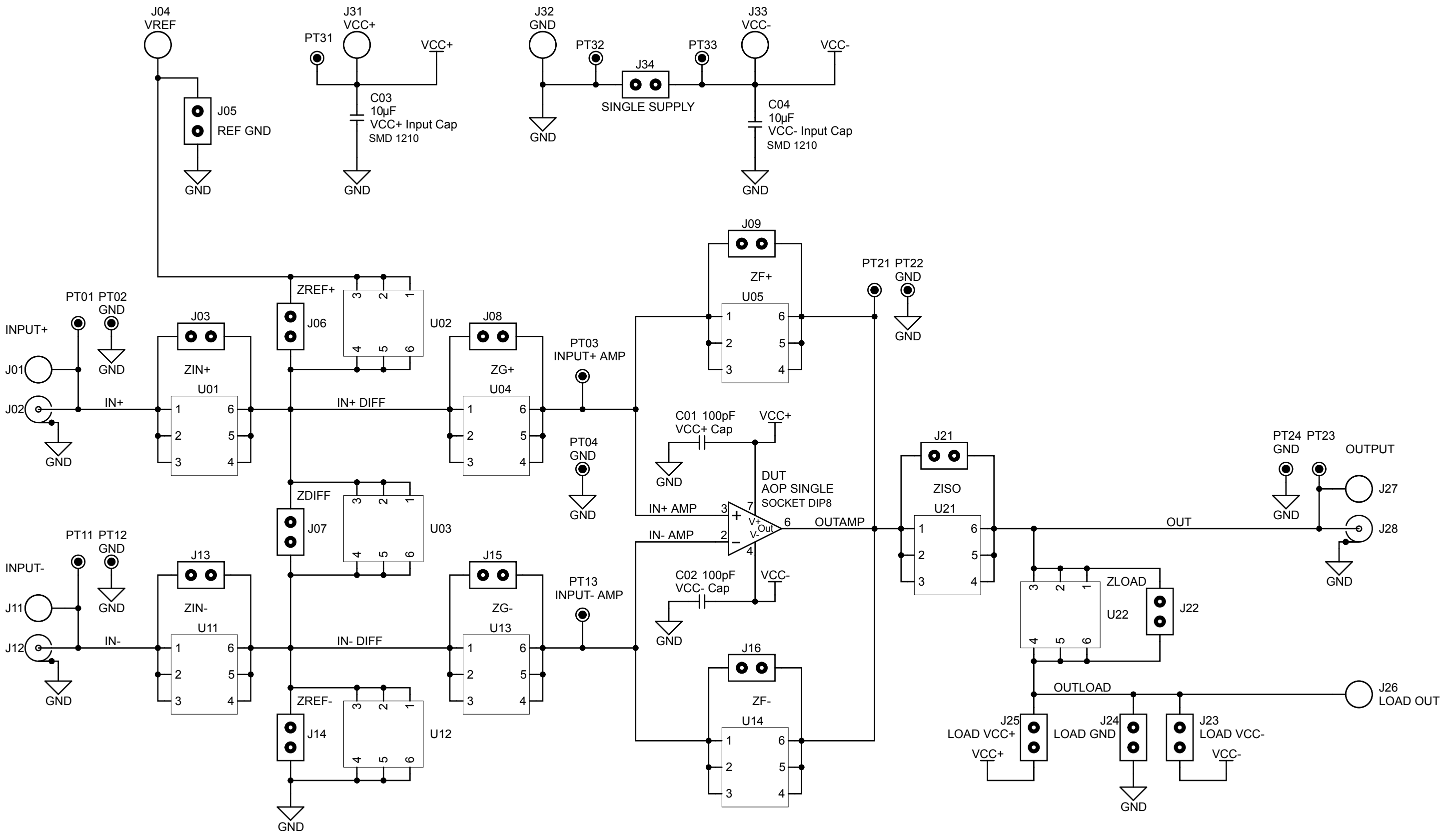
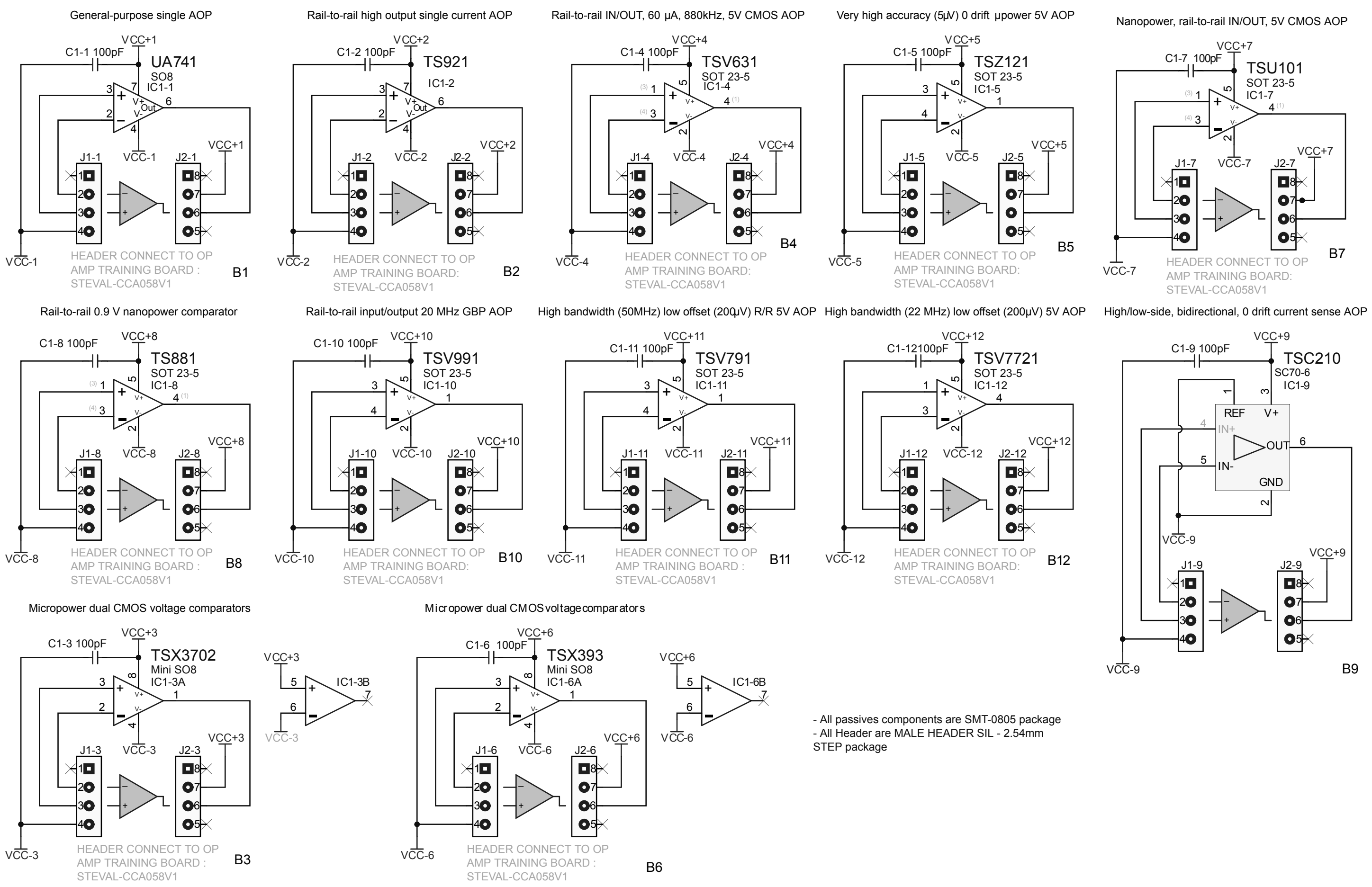


Figure 21. STEVAL-CCA058A1 op-amp adapter board circuit schematic



- All passives components are SMT-0805 package
- All Header are MALE HEADER SIL - 2.54mm STEP package

3 Bill of materials

Table 1. STEVAL-CCA058V1 bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	Table 2. STEVAL-CCA058A1	-	Main board	ST	Not available for separate sale
2	1	Table 3. STEVAL-CCA058B1	-	Op-amp adapter board	ST	Not available for separate sale

Table 2. Main board bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	2	C01, C02	100 pF, SMD 0805, 100 V, ±5%, C0G / NP0, WCAP-CSGP series, 55-125°C	Ceramic capacitors	Wurth Elektronik	885012007057
2	2	C03, C04	10 µF, SMD, 1210, 50 V, ±10%, X7R, C series, 55-125°C	Ceramic capacitors	TDK	C3225X7R1H106K250AC
3	3	J02, J12, J28	Straight, 500 V, 65-165°C	Coaxial connectors	RS PRO	R13-022-01-002611000
4	16	J03, J05, J06, J07, J08, J09, J13, J14, J15, J16, J21, J22, J23, J24, J25, J34	SIP 1X2 male, SIP 1X2, step 2.54 mm, 250 V, 3 A, WR-PHD series, -40-125°C	Connector headers	Wurth Elektronik	61300211121
5	16	Ju03, Ju05, Ju06, Ju07, Ju08, Ju09, Ju13, Ju14, Ju15, Ju16, Ju21, Ju22, Ju23, Ju24, Ju25, Ju34	Black, step 2.54 mm, 250 V, 3 A, WR-PHD series, -40-125°C	Jumpers	Wurth Elektronik	60900213421
6	5	M-02, M-04, M-06, M-08, M-09	6 mm, hole M3, WA-SCRW series, -30-85°C	Screws	Wurth Elektronik	97790603111
7	1	DUT	AOP single, DIP8, 5 A, -65-150°C	DIP8 socket	Winslow	W30508TTRC
8	11	U01, U02, U03, U04, U05, U11, U12, U13, U14, U21, U22	DIP6, 150 V, 1 A, -55-125°C, 110 series	DIP6 sockets	PRECI-DIP	110-87-306-41-001101
9	1	J31	Red, vertical, 4 mm, 60 V, 16 A, -25-85°C, BUG 10 series	Test jack	Hirschmann test and instrument	930175101
10	1	J32	Black, vertical, 4 mm, 60 V, 16 A, -25-85°C, BUG 10 series	Test jack	Hirschmann test and instrument	930175100

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
11	1	J33	Blue, vertical, 4 mm, 60 V, 16 A, -25-85°C, BUG 10 series	Test jack	Hirschmann test and instrument	930175102
12	2	J01, J11	Yellow, vertical, 4 mm, 60 V, 16 A, -25-85°C, BUG 10 series	Test jack	Hirschmann test and instrument	930175103
13	3	J04, J26, J27	Green, vertical, 4 mm, 60 V, 16 A, -25-85°C, BUG 10 series	Test jack	Hirschmann test and instrument	930175104
14	1	PT31	Red, 1.6 mm hole	Test point	Keystone	5010
15	1	PT33	Blue, 1.6 mm hole	Test point	Keystone	5127
16	6	PT01, PT03, PT11, PT13, PT21, PT23	White, 1.6 mm hole	Test points	Keystone	5012
17	6	PT02, PT04, PT12, PT22, PT24, PT32	Black, 1.6 mm hole	Test points	Keystone	5011
18	5	M-01, M-03, M-05, M-07, M-10	20 mm, M3 hole, WA-SPAII series, -30-110°C	Threaded spacers	Wurth Elektronik	970200365

Table 3. **Op-amp adapter board bill of materials**

Item	Quantity	Reference	Value	Description	Manufacturer	Part Number
1	12	C1-1, C1-2, C1-3, C1-4, C1-5, C1-6, C1-7, C1-8, C1-9, C1-10, C1-11, C1-12	100 pF, SMT - 0805, 100 V, -55-125°C, WCAP-CSGP series, C0G/NP0	Ceramic capacitors	Wurth Elektronik	885012007057
2	1	IC1-1	UA741CDT, SO-8	Wide application range high-performance monolithic operational amplifier	ST	UA741CDT
3	1	IC1-2	TS921IDT, SO-8	Rail-to-rail high output current op-amps	ST	TS921IDT
4	1	IC1-3	TSX3702IST, MiniSO-8	Micropower (5 µA) 16 V dual CMOS comparator with push-pull output	ST	TSX3702IST
5	1	IC1-4	TSV631ILT, SOT23-5L	Rail-to-rail input/ output 5 V CMOS op-amp	ST	TSV631ILT
6	1	IC1-5	TSZ121ILT, SOT23-5L	Very high accuracy (5 µV) zero drift 5 V CMOS op-amp	ST	TSZ121ILT

Item	Quantity	Reference	Value	Description	Manufacturer	Part Number
7	1	IC1-6	TSX393IST, MiniSO-8	Micropower (5 µA) 16 V CMOS dual comparator	ST	TSX393IST
8	1	IC1-7	TSU101ILT, SOT23-5L	Nano power (580 nA) rail-to-rail I/O 5 V CMOS op-amp	ST	TSU101ILT
9	1	IC1-8	TS881ILT, SOT23-5L	Rail-to-rail 0.9 V nanopower push-pull single comparator	ST	TS881ILT
10	1	IC1-9	TSC210ICT, SOT323-6L	Low/high side bidirectional, zero-drift, current sense amplifiers	ST	TSC210ICT
11	1	IC1-10	TSV991ILT, SOT23-5L	Wide-bandwidth (20 MHz) rail-to-rail input/output 5 V CMOS op-amp	ST	TSV991ILT
12	1	IC1-11	TSV791ILT, SOT23-5L	High bandwidth (50 MHz) low offset (200 µV) rail-to-rail 5 V op-amp	ST	TSV791ILT
13	1	IC1-12	TSV7721ILT, SOT23-5L	High bandwidth (22 MHz) low offset (200 µV) low-rail 5 V op-amp	ST	TSV7721ILT
14	24	J1-1, J1-2, J1-3, J1-4, J1-5, J1-6, J1-7, J1-8, J1-9, J1-10, J1-11, J1-12, J2-1, J2-2, J2-3, J2-4, J2-5, J2-6, J2-7, J2-8, J2-9, J2-10, J2-11, J2-12	SIL 1X4 male, SIP 1X3 step 2.54 mm, TS series, -55-105°C	Connector headers	Samtec	TS-104-T-A

4 Kit versions

Table 4. STEVAL-CCA058V1 kit versions

Finished good	Schematic diagrams	Bill of materials
STEVAL$CCA058V1A [1]	STEVAL$CCA058V1A schematic diagrams	STEVAL$CCA058V1A bill of materials

1. *This code identifies the STEVAL-CCA058V1 evaluation kit first version. The kit consist of the STEVAL-CCA058A1 main board, whose version is identified by the code STEVAL$CCA058A1A, and the STEVAL-CCA058B1 op-amp adapter board, whose version is identified by the code STEVAL$CCA058B1A.*

5 Regulatory compliance information

Formal Notice Required by the U.S. Federal Communications Commission

FCC NOTICE

This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine

whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

Formal Product Notice Required by Industry Canada Innovation, Science and Economic Development

Canada compliance:

For evaluation purposes only. This kit generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to Industry Canada (IC) rules.

À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Formal product notice required by EU

The STEVAL-CCA058V1 kit is in conformity with the essential requirements of the Directive 2015/863/EU (RoHS).

Revision history

Table 5. **Document revision history**

Date	Revision	Changes
01-Mar-2022	1	Initial release.

Contents

List of tables

List of figures