UM3408

User manual

Getting started with the STEVAL-AETKT4V1 evaluation kit for high precision bidirectional and high voltage current sense amplifiers

Introduction

TSC202x family is a current sense amplifier specially designed to accurately measure current by amplifying the voltage across a shunt resistor connected to its input. It is a zero-drift topology allowing to reach a high CMRR level of 100dB min and high level of input offset voltage of 200μV at 12V common mode voltage and over temperature.

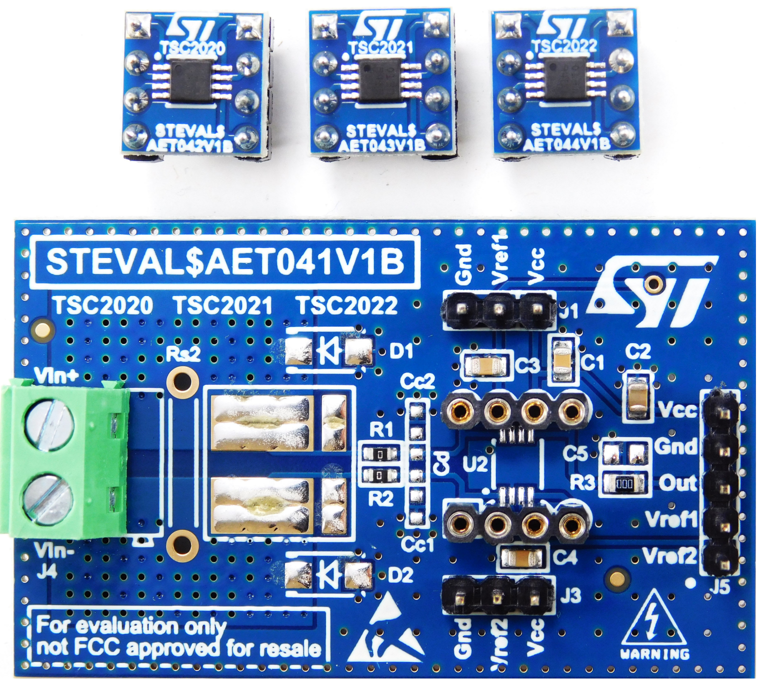
Multiple fixed gain versions are available (x20, x50, x100) for design optimization. Thanks to the use of thin film resistor, TSC202x offers an extremely precise gain and very high CMRR performance even in high frequency range. Moreover, there is the possibility to fix the output common mode voltage allowing the TSC202x to be either used as unidirectional or bidirectional current sensing amplifier.

TSC202x provides an extended input common range from -4V below negative supply voltage, and up to 100V allowing either low side or high side current sensing, while the TSC202x devices can operate from 2.7 to 5.5 V.

TSC202x embedded a system to optimize the PWM rejection, allowing to reduce the effect of fast input common mode voltage variation, on the output signal.

The parameters are very stable in the full Vcc range, and several characterization curves show the TSC2020 device characteristics at 2.7V and 5.0 V. Additionally, the main specifications are guaranteed in extended temperature ranges from -40 to 125 °C.

Figure 1. **STEVAL-AETK4TV1 evaluation kit**



Notice: *For dedicated assistance, submit a request through our online support portal at **www.st.com/support**.*

1 Overview

- Wide common-mode voltage: -4 to 100 V
- High common-mode rejection CMR: 100 dB min.
- Offset voltage: ±150 µV max.
- Offset drift: 0.5 µV/°C max.
- Enhanced PWM rejection
- 2.7 to 5.5 V supply voltage
- Gain from 20 to 100
- Gain error: 0.3% max.
- Temperature range -40 to 125°C
- RoHS compliant

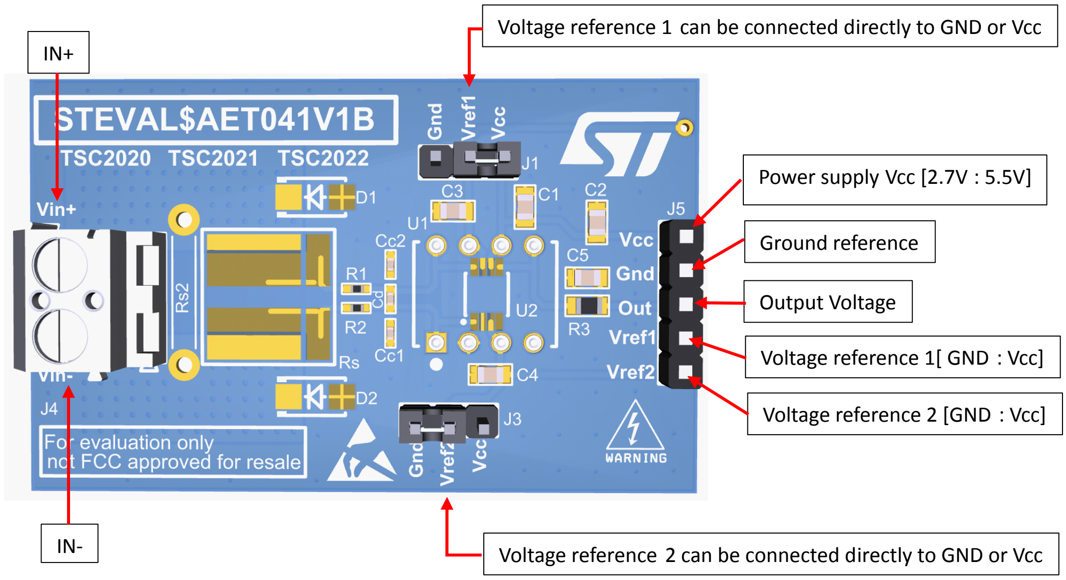
2 Setting

The connector J5 (5 pins) on the right of the board allows you to set up the power supply voltage, output common mode voltage, and read the current sense output voltage.

The connector J1 and J3 allow a quick setup of the output common mode voltage.

The connector J4, on the left of the board is used to set the inputs of the TSC202x current sensing.

Figure 2. Board presentation



3 Unidirectional/bidirectional operation

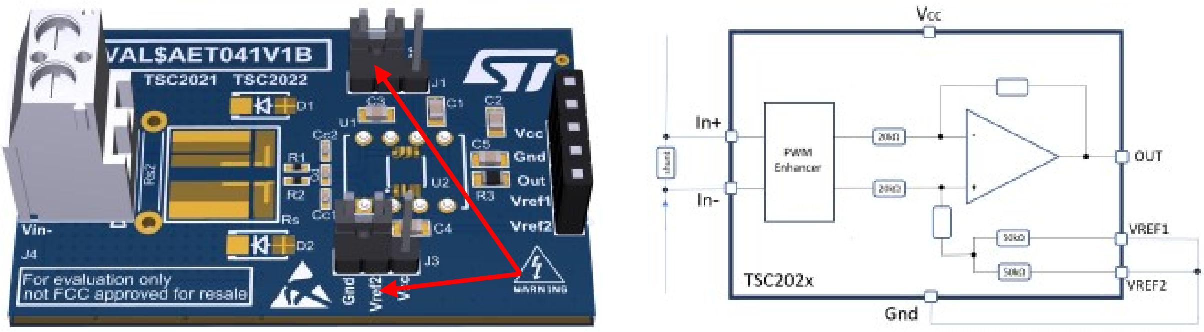
The TSC202x output common mode voltage level can be set thanks to voltages applied on the Vref1 and Vref2 pins. These two pins allow to set the device either in bidirectional or in unidirectional operation. The voltage applied on those pins must not exceed the Vcc range. There is no difference between both reference pins, the voltage can be applied either to one pin or to the other without distinction.

3.1 Unidirectional operation

Unidirectional mode of operation allows the device to measure the current through a shunt resistor in one direction only. The output reference can be Ground or Vcc and can be set by using Vref1 and Vref2 pins for adjustment.

3.1.1 Ground referenced

Figure 3. Output referenced to ground



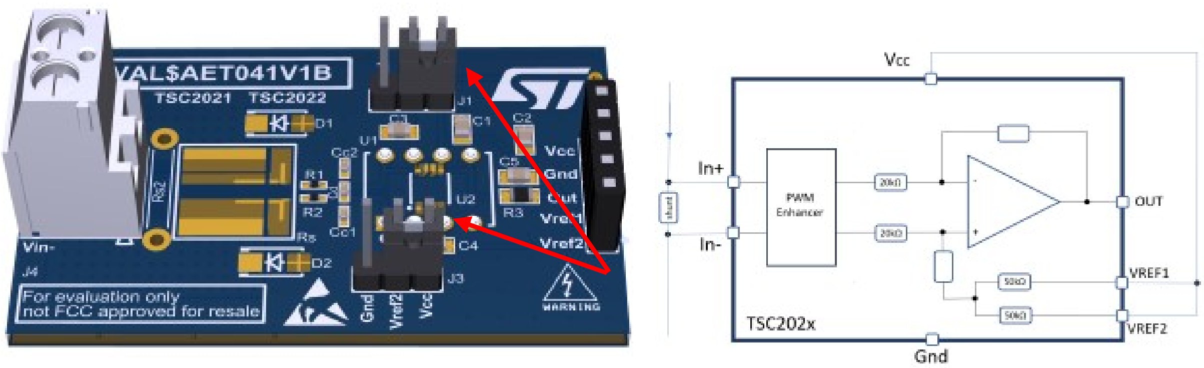
In the configuration described in Figure 3, both Vref1 pin and Vref2 pin are connected to the ground. The output common mode voltage is then automatically set to GND and the general the output voltage can be express as equation (1):

$$Vout = (IN_+ - IN_-)*Gain \quad (1)$$

This configuration allows the full-scale output in unidirectional mode. It allows to measure a current flowing into the shunt from IN- to IN+.

3.1.2 Vcc referenced

Figure 4. Output referenced to Vcc



In the configuration described Figure 4, Vref1 pin and Vref2 pin are connected to the Vcc power supply. The output common mode voltage is then automatically set to Vcc voltage and the general the output put voltage can be express as equation (2):

$$Vout = (IN_+ - IN_-)^*Gain + Vcc \quad (2)$$

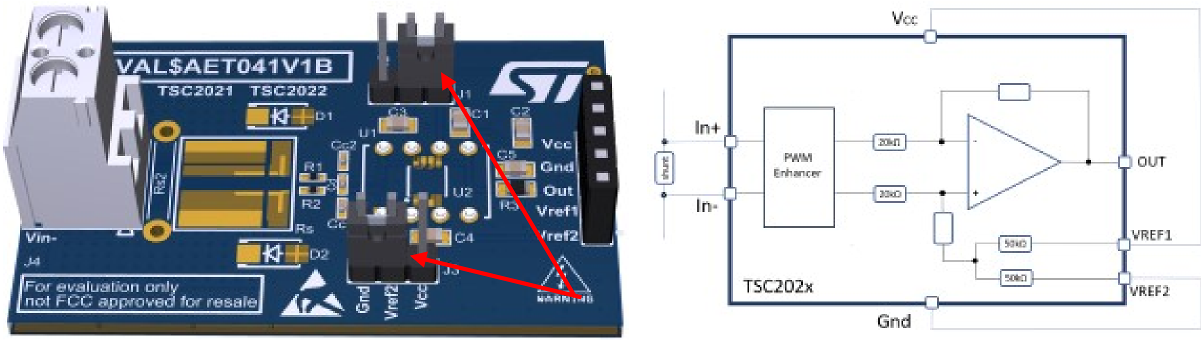
This configuration allows the full-scale output in unidirectional mode to measure a current flowing into the shunt from IN+ to IN-.

3.2 Bidirectional operation

Bidirectional mode of operation allows the device to measure currents through a shunt resistor in two directions. The output reference can be set anywhere within the power supply range. If the output common mode voltage is set at mid-range, the full-scale current measurement range will be equal in both directions. This is achieved by connecting one Vref pin to Vcc and the other Vref pin to Gnd as described by Figure 5. Split supply.

3.2.1 Split supply

Figure 5. **Split supply**

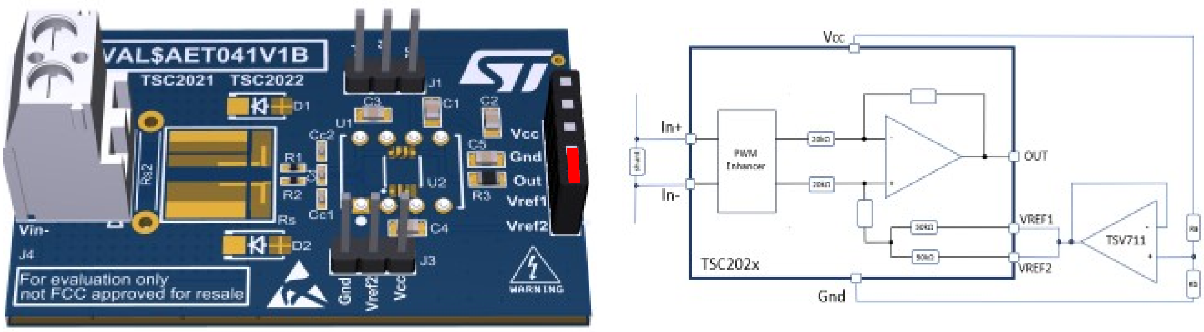


The great advantage of this configuration is that the TSC202x can be used in bidirectional mode with an output common mode voltage set at the middle of scale, with an accuracy of 0.2%, without any added external component or power supply. This configuration allows to create a midscale offset ratiometric to the power supply. The output voltage can be expressed as equation (3):

$$Vout = (IN_+ - IN_-)^*Gain + \frac{Vref1 + Vref2}{2} \quad (3)$$

3.2.2 External reference voltage

Figure 6. **External supply**



It can be done by connecting both Vref pins to a voltage reference as described by Figure 6. External supply. Users can set the output in a non-symmetrical configuration, adjusting Vref the way user needs.

If this solution is required, it is recommended to buffer the resistor divider as depicted on Figure 6. External supply thanks to a precise Opamp as the TSV711.

The output voltage can be expressed as equation (4):

$$Vout = (IN_+ - IN_-)^*Gain + Vcc^*\frac{Ra}{Ra + Rb} \quad (4)$$

When the output common mode voltage is supplied by an external power supply, to improve the output voltage measurement, it is recommended to measure the Vout differentially with respect to Vref voltage. It will provide the best CMRR measurement, the best noise immunity and a more accurate Vout voltage. A decoupling capacitance of 1nF minimum can be also added to better filter the power supply

4 Shunt resistance

The STEVAL-AETKT4V1 offers the possibility to solder shunt resistance directly on the PCB. Two footprints have been defined.

A two-wire connection shunt as described in Figure 7 and a four-wire connection shunt as described in Figure 8.

It is up to the user to choose the most appropriate shunt for its application. If the chosen shunt is not compatible with both footprints, it should be connected outside this eval board.

Figure 7. Shunt 2 wires connections

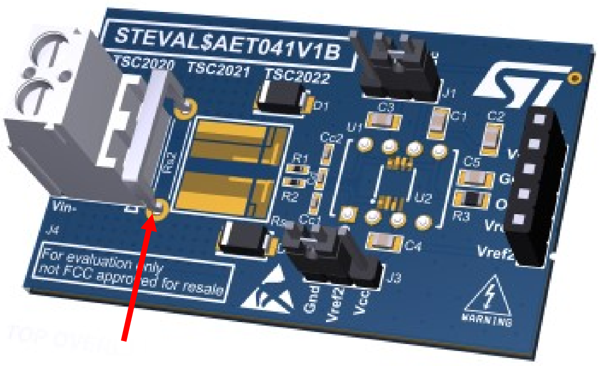
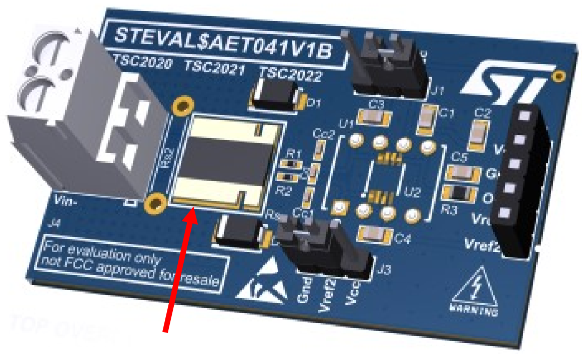


Figure 8. Shunt 4 wires connections



The selection of the shunt resistor is a tradeoff between dynamic range and power dissipation.

Generally, in high current sensing application, the focus is to reduce as much as possible the power dissipation (RI^2) by choosing the smallest value of shunt as $Rsense \leq \frac{Pmax}{Imax^2}$.

In low current application the Rsense value could be higher, to minimize the impact of the offset voltage of the circuit on accuracy measurement.

The tradeoff is mainly when a dynamic range of current to measure is large, meaning ability to measure with the same shunt value low current to high current. Generally, the current full scale (Imax-Imin) will define the shunt value thanks to the full output voltage range and the TSC202x gain. The TSC202x offer the possibility to work with full scale ΔVout = 100mV to Vcc-100mV with maximum gain accuracy of Eg=0.3%.

At first order the full current range to measure through Rsense can be defined by the equation (5), just by taking the gain error and input offset voltage as inaccuracy parameters:

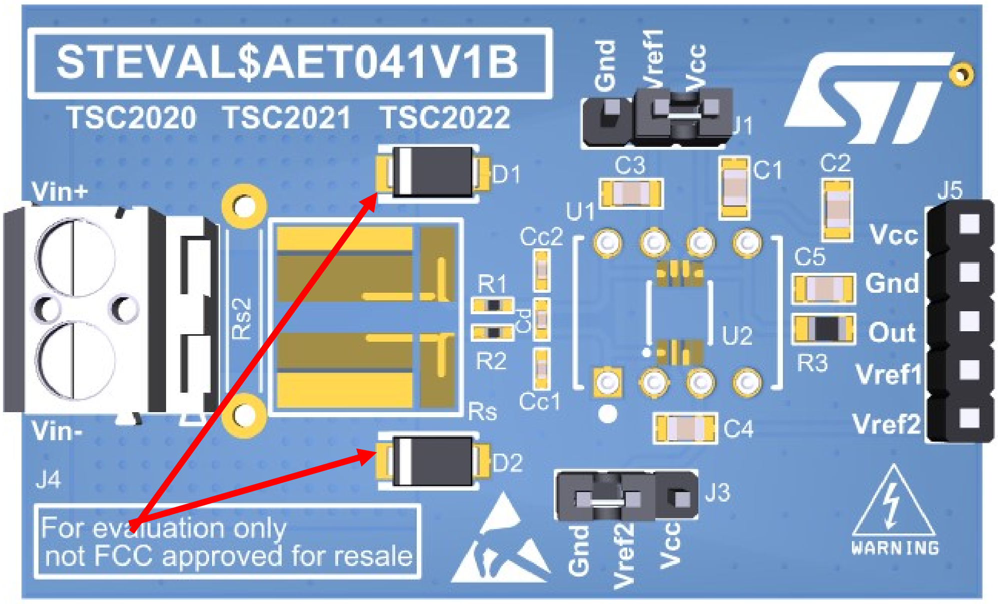
$$Isense\_full\_scale*Rsense = \frac{Vcc - 200mV}{TSC\_Gain(1 + Eg)} - \left|Vio\right| \quad (5)$$

5 TVS protection diode

While the high side current sensing TSC2020 is naturally well immunized against ESD in a controlled environment such as laboratory or production site, thanks to its good CDM and HBM immunity level, it must be protected when it is used in uncontrolled environment. To ensure the best ESD immunity it is advice to use fast transient diode TVS in unidirectional or bidirectional mode depending on the application where the TSC2020 is used.

The STEVAL-AET041V1 mother board allows to add protection TVS as for example the SMAJ70A for Industrial domain or SM4T82AY for automotive application. These TVS allow the TSC2020 practically on its full input common mode range, with a Vicm from -0.7V up to 82V. TVS diode are not mounted.

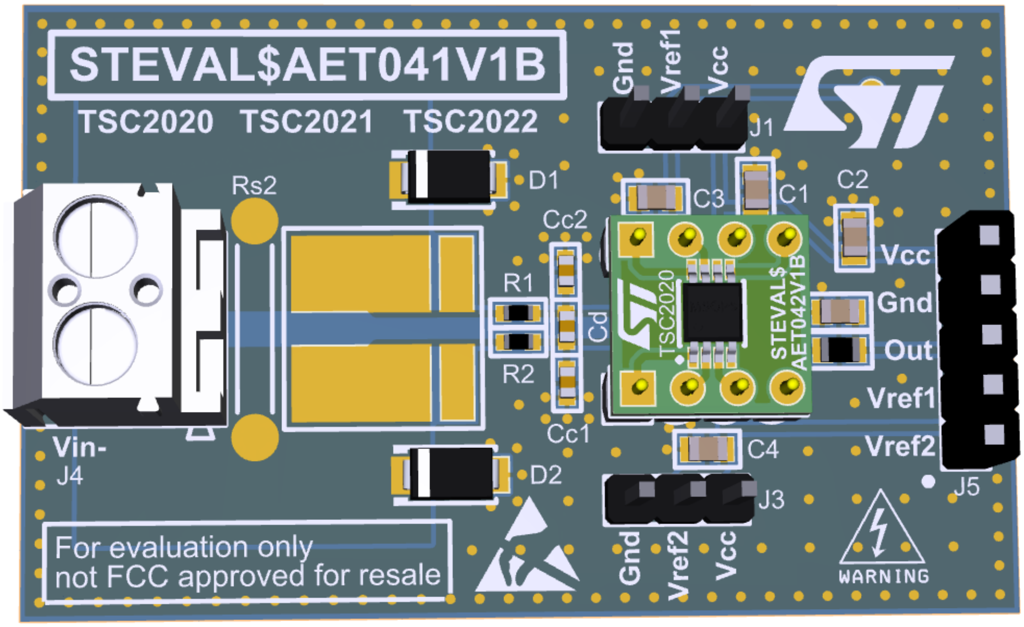
Figure 9. TVS diode footprint



6 Daughter board connection

The STEVAL-AETKT4V1 evaluation kit allows you to use 3 different current sense amplifiers, and each of them can be connected on the mother board STEVAL-AET041V1 as suggested by figure 10.

Figure 10. **Daughter board connection**



7 Schematic diagrams

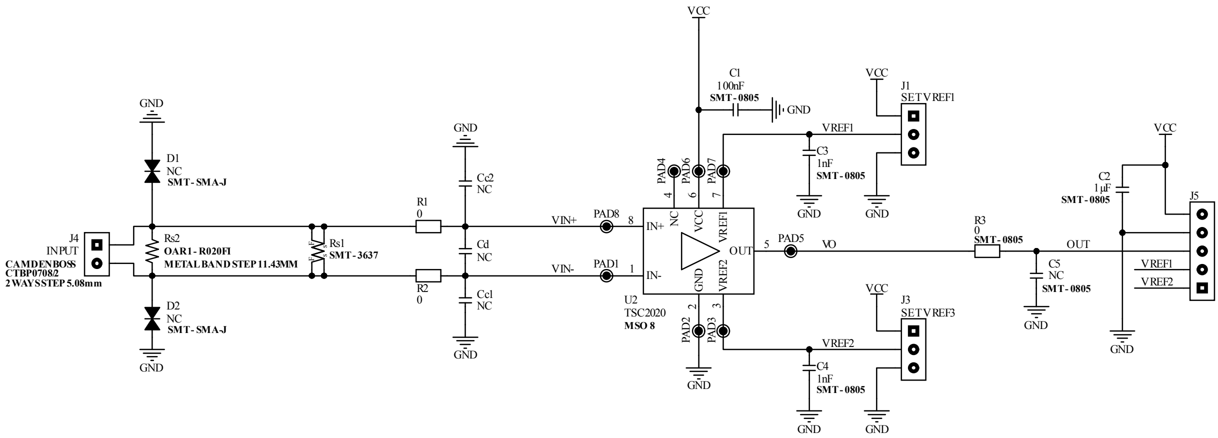


Figure 11. **STEVAL-AET041V1B circuit schematic**

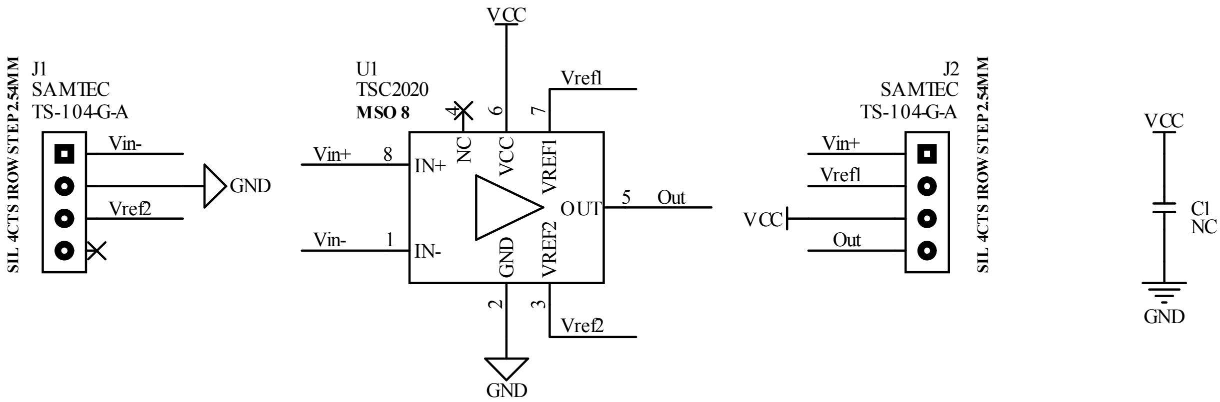


Figure 12. **STEVAL-AET042V1B circuit schematic**

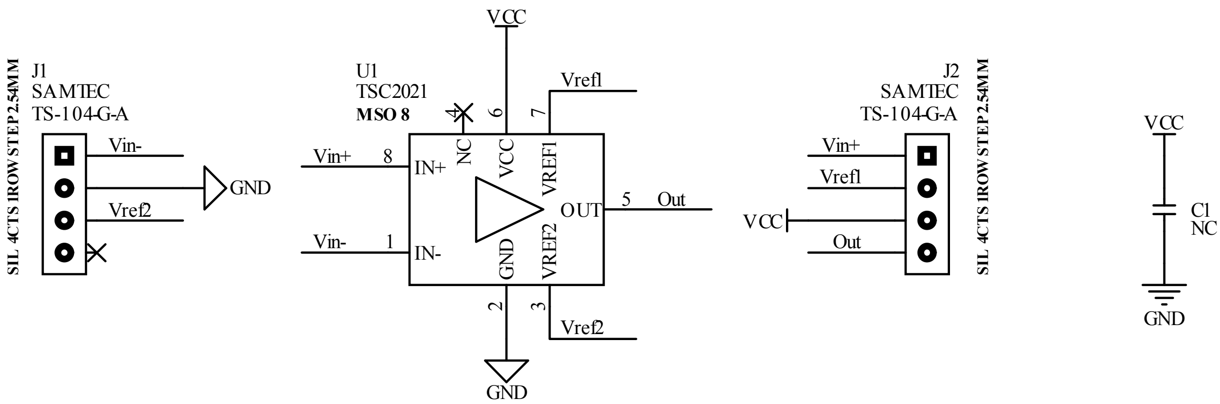
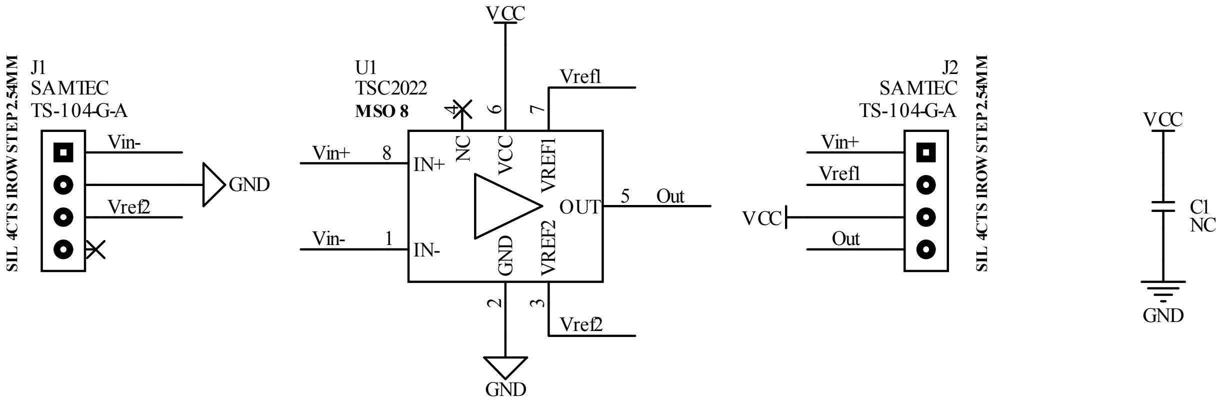


Figure 13. **STEVAL-AET043V1B circuit schematic**

Figure 14. **STEVAL-AET044V1B circuit schematic**



8 Bill of materials

Table 1. STEVAL-AETKT4V1 bill of materials

Item	Qty	Ref.	Part/value	Description
1	1	Table 2		Main Board
2	1	Table 3		Daughter Board Gain20
3	1	Table 4		Daughter Board Gain50
4	1	Table 5		Daughter Board Gain100

Table 2. STEVAL-AET041V1B bill of materials

Item	Qty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	C1	100nF	CAPACITOR CERAMIC, X7R, -55°C to 125°C	WURTH ELEKTRONIK	885012207128
2	1	C2	1µF	CAPACITOR CERAMIC, X7R, -55°C to 125°C	KYOCERA AVX	08051C105K4T2A
3	2	C3, C4	1nF	CAPACITOR CERAMIC, X7R, -55°C to 125°C	WURTH ELEKTRONIK	885012207116
4	4	C5, Cc1, Cc2, Cd	NC	CAPACITOR CERAMIC	Any	
5	2	D1, D2	NC	DIODE - TVS-SMAJ70A	Any	
6	2	J1, J3	SIP 1x3 MALE	CONNECTOR - HEADER, -40°C to 125°C	WURTH ELEKTRONIK	61300311121
7	1	J4	TERMINAL BLOCK	CONNECTOR - TERMINAL BLOCK	CAMDENBOSS	CTBP0708/2
8	1	J5	SIP 1X5 MALE	CONNECTOR - HEADER, -40°C to 125°C	WURTH ELEKTRONIK	61300511121
9	4	M-01, M-02, M-03, M-04	8MM	ANTI SLIP PAD, -34°C to 65°C	M3	SJ5076
10	8	PAD1, PAD2, PAD3, PAD4, PAD5, PAD6, PAD7, PAD8	-	MINI SOCKET, -65°C to 125°C	TE CONNECTIVITY	5050935-2
11	2	R1, R2	0	RESISTOR, -55°C to 175°C	PANASONIC	ERJH3G0R00V
12	1	R3	0	RESISTOR	WALSIN	MR08X000PTL
13	1	Rs1	TBD	RESISTOR - SHUNT		
14	1	Rs2	TBD	RESISTOR - SHUNT		OAR1 - R020FI
15	1	U2	TSC2020, MSO 8	IC - High Voltage, Precision, Bidirectional Current-sense amplifier MSO8	ST	TSC2020

Note: The STEVAL-AET041V1B board is supplied with the kit and is not available for separate sale.

Table 3. STEVAL-AET042V1B bill of materials

Item	Qty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	C1	NC	CAPACITOR	Any	
2	2	J1, J2	4CTS	CI CONNECTOR - BREAKABLE MALE-MALE BARS, -55°C TO 125°C	SAMTEC	TS-104-G-A
3	1	U1	TSC2020, MSO 8	IC - High Voltage, Precision, Bidirectional Current-sense amplifier Gain x20r	ST	TSC2020

Note: The STEVAL-AET042V1B board is supplied with the kit and is not available for separate sale.

Table 4. STEVAL-AET043V1B bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	C1	NC	CAPACITOR	Any	
2	2	J1, J2	4CTS	CI CONNECTOR - BREAKABLE MALE-MALE BARS, -55°C TO 125°C	SAMTEC	TS-104-G-A
3	1	U1	TSC2021, MSO 8	IC - High Voltage, Precision, Bidirectional Current-sense amplifier Gain x50r	ST	TSC2021

Note: The STEVAL-AET043V1B board is supplied with the kit and is not available for separate sale.

Table 5. STEVAL-AET044V1B bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	C1	NC	CAPACITOR	Any	
2	2	J1, J2	4CTS	CI CONNECTOR - BREAKABLE MALE-MALE BARS, -55°C TO 125°C	SAMTEC	TS-104-G-A
3	1	U1	TSC2022, MSO 8	IC - High Voltage, Precision, Bidirectional Current-sense amplifier Gain x100r	ST	TSC2022

Note: The STEVAL-AET044V1B board is supplied with the kit and is not available for separate sale.

9 Kit versions

Table 6. STEVAL-AETKT4V1 versions

Finished good	Schematic diagrams	Bill of materials
STEVAL$AETKT4V1A [1]	STEVAL$AETKT4V1A schematic diagrams	STEVAL$AETKT4V1A bill of materials

1. *This code identifies the STEVAL-AETKT4V1 evaluation kit first version. The kit consists of a STEVAL-AET041V1B whose version is identified by the code STEVAL$AET041V1B, a STEVAL-AET042V1B whose version is identified by the code STEVAL$AET042V1B, a STEVAL-AET043V1B whose version is identified by the code STEVAL$AET043V1B and a STEVAL-AET044V1B whose version is identified by the code STEVAL$AET044V1B.*

10 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale

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.

Notice for Innovation, Science and Economic Development Canada (ISED)

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).

Notice for the European Union

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2015/863/EU (RoHS).

Notice for the United Kingdom

This device is in compliance with the UK Electromagnetic Compatibility Regulations 2016 (UK S.I. 2016 No. 1091) and with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK S.I. 2012 No. 3032).

Revision history

Table 7. **Document revision history**

Date	Revision	Changes
03-Oct-2024	1	Initial release.
14-Oct-2024	2	Updated Section 8: Bill of materials.

Contents

List of tables

List of figures

IMPORTANT NOTICE – READ CAREFULLY

STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST's terms and conditions of sale in place at the time of order acknowledgment.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of purchasers' products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. For additional information about ST trademarks, refer to www.st.com/trademarks. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2024 STMicroelectronics – All rights reserved