# How to use the evaluation board for the ADC120 8-channel analog to digital converter

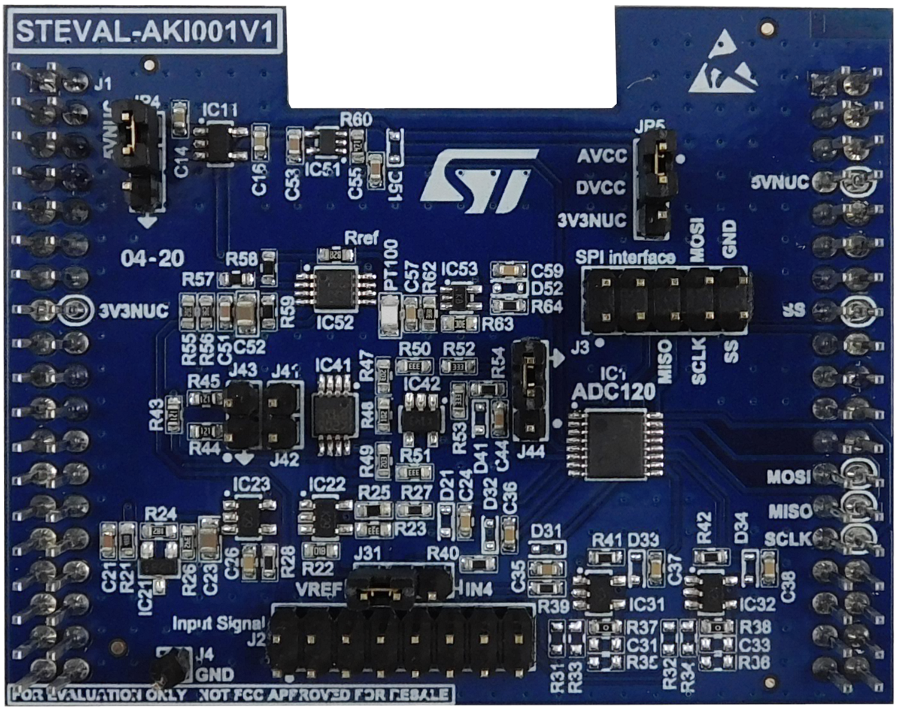
## Introduction

The STEVAL-AKI001V1 evaluation board allows the user to evaluate the conversion performance of the ADC120 8-channel analog-to-digital converter designed for 50 ksps to 1 Msps conversion.

The board has several on-board sources like temperature sensor and strain gauge signals, and can accept external signals to allow measurement and evaluation of the ADC120 conversion performance based on its successive approximation register (SAR) with internal track-and-hold cell.

The board is supplied ready-to-use in standalone mode, or it can be plugged onto a NUCLEO-L476RG board with SMT32 microcontroller, which enables further signal processing and PC communication.

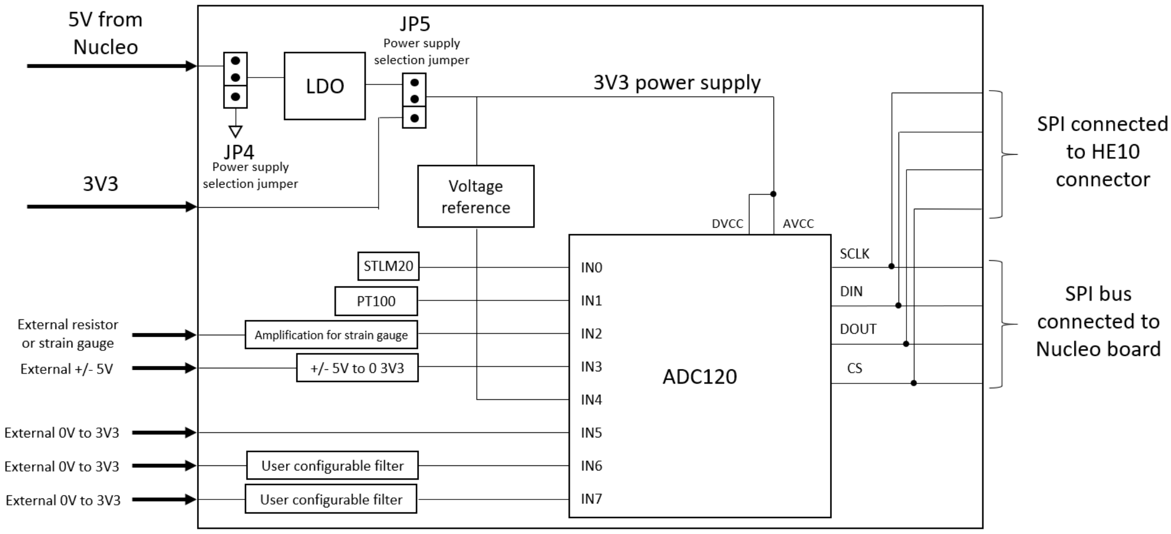
**Figure 1.** STEVAL-AKI001V1 evaluation board for the ADC120



# 1 Board overview

The board inputs are configured on the following J2 connector pins:
- Pin 8 (In3): input for ±5V signal
- PIN 10 (In4): input configurable to measure around 1.7 V reference voltage or external 0 to 3V3 voltage (selected using jumper J31)
- Pin 12 (In5): input for 0 to 3V3 signal (no filtering)
- Pin 14 (In6): input not directly connected, footprints are left to the user to allow amplification
- Pin 16 (In7): input not directly connected, footprints are left to the user to allow amplification

Figure 2. **STEVAL-AKI001V1 block diagram**




The STEVAL-AKI001V1 evaluation board includes the following hardware functionality:
- 2.54mm, 38cts double female connectors to be plugged to the STM32L476RG Nucleo development board (J1)
- 2.54mm, 10cts, double male connector to connect an SPI to UART communication module (J3)
- Several configuration jumpers to select power supply input
- 3V3 LDO for power supply (JP4 5V jumper and JP5 LDO 3V3)
- A TS3431 voltage reference
- An analog to digital converter ADC120 SAR, 12 bits, 8 inputs (IN0 to IN7)
- An STLM20 temperature sensor on IN0
- A PT100 resistance thermometer on IN1
- Acquisition of a ±5V signal on IN3
- Voltage reference sampling necessary for precise calculations
- Sampling of a 0 to 3V3 voltage input
- Acquisition of amplified inputs (not connected) configurable by the user on 2 channels (IN6 and IN7)
- Instrumentation amplifier for a strain gauge on IN2

The SPI communication lines are connected to the SPI communication lines of the STM32L476RG Nucleo development board and to the connector dedicated to the SPI to UART communication module. The jumpers are configured in the following way:
- JP4 - 5VNUC
- JP5 - AVCC

- J31 - VREF
- J44 - GND

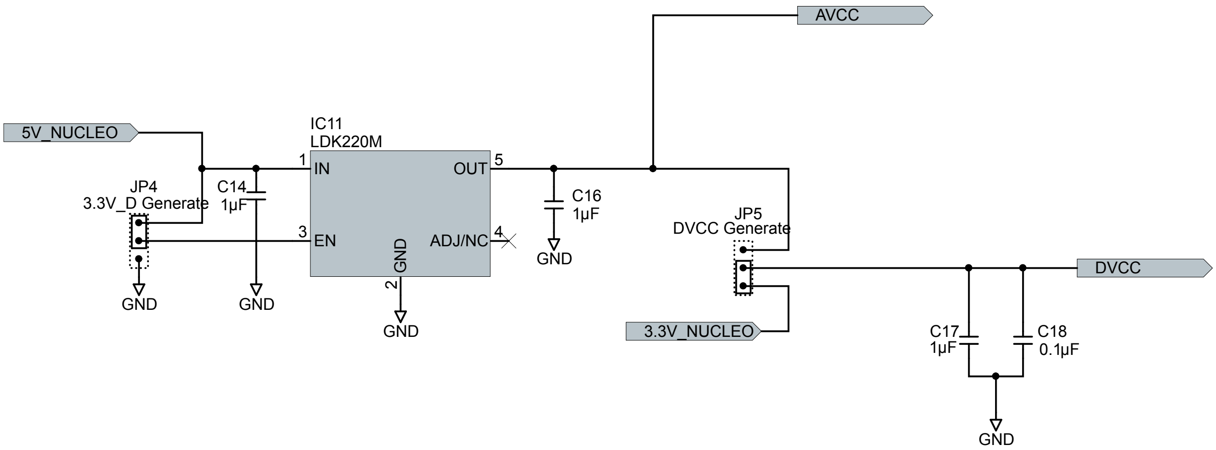
# 2 Board connection and operation

## 2.1 Power supply

The power supply input can be selected form the following sources:
- 5V from Nucleo board or external supply (if Nucleo is not used)
- 3V3 voltage from Nucleo development board.

JP4 enables the 3V3 LDO that converts the 5V into 3V3.
JP5 chooses between 3V3 vai the LDO and 3V3 from the Nucleo

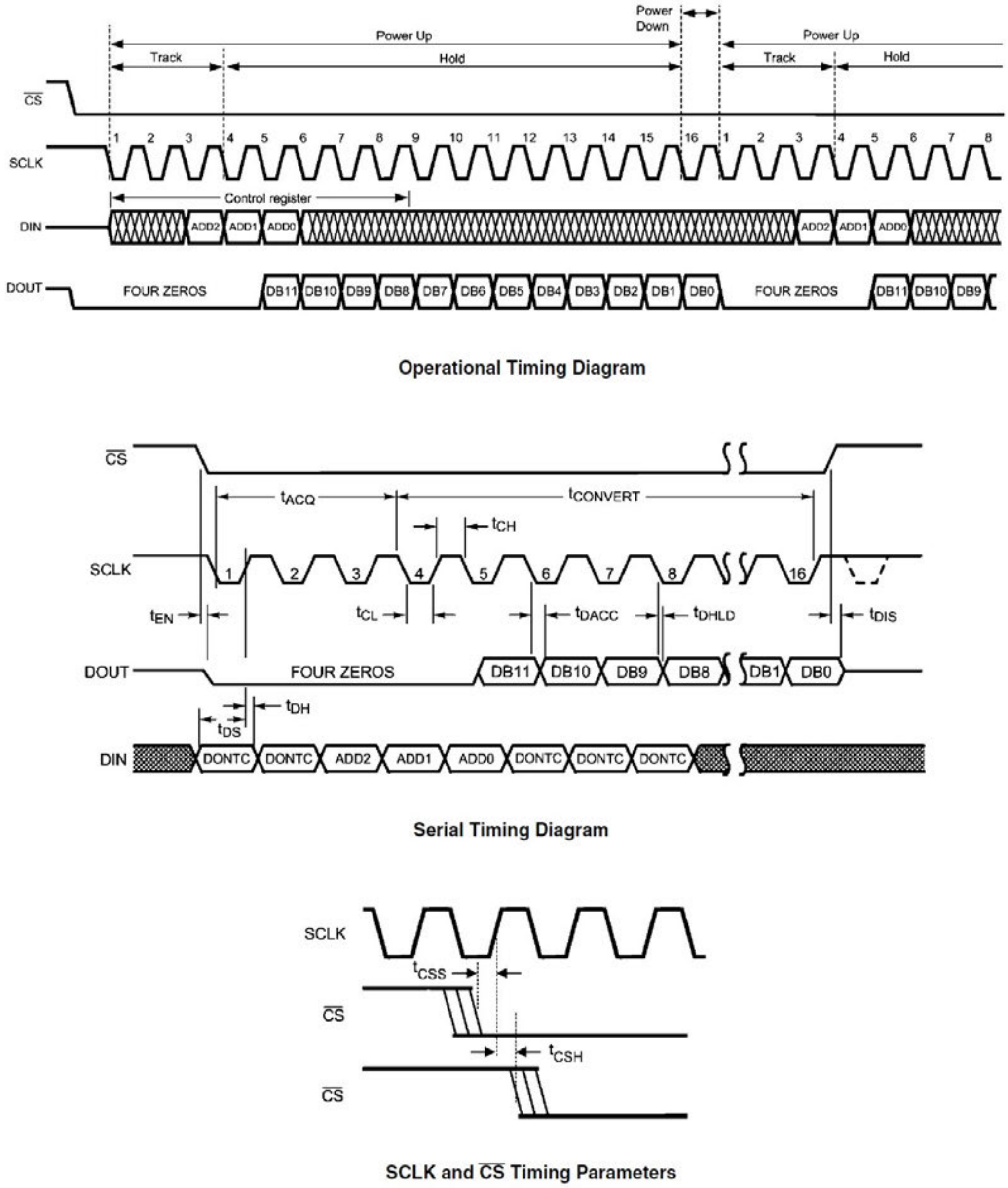
Figure 3. **Power supply selection jumpers**




## 2.2 SPI communication

The ADC120 has the following SPI communication inputs and oututs
- DIN line is MOSI (Master Output Slave Input)
- DOUT line is MISO (Master Input Slave Output)
- SCLK line is the clock
- CS line is Chip Select

Figure 4. **ADC120 SPI timing diagram**




## 2.3 Board operation

The ADC120 channel to be read can be selected by sending the proper code through the $D_{IN}$ (MOSI) line.

The reading on $D_{OUT}$ provides the converted raw data. A code running inside a microcontroller can calculate the proper value in volts or in degrees Celsius, depending on the analog sensor used.

**RELATED LINKS**

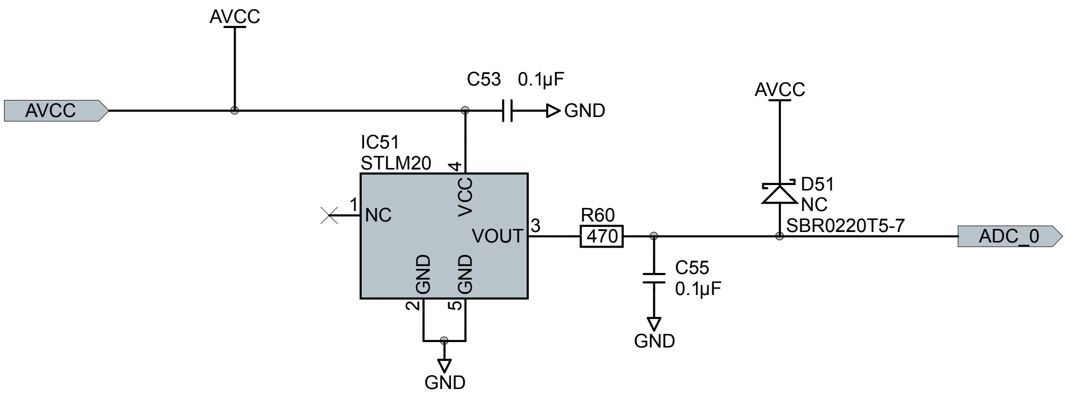
*Visit the ST website to download application note AN5454*

# 3 STEVAL-AKI001V1 ADC inputs

## 3.1 ADC channel 0: temperature measurement

The input channel 0 on the ADC120 receives the converted output from the STLM20 analog temperature sensor on the evaluation board.

**Figure 5.** **STEVAL-AKI001V1 schematic - temperature measurement with STLM20**




The voltage V (V) image of the temperature T (°C) is given by the following equation:

$$V_{ADC0} = \left(-3.88*10^{6}*T^{2}\right) + \left(-1.15*10^{-2}*T\right) + 1.8639 \quad (1)$$

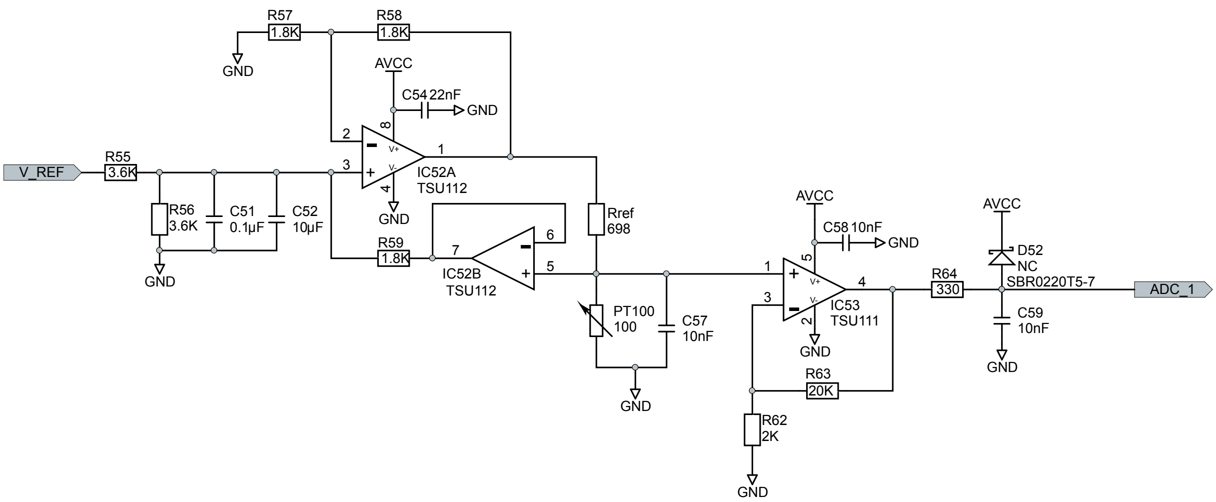
**RELATED LINKS**

*Visit the STLM20 product page on the ST website for more information regarding this device*

## 3.2 ADC channel 1: temperature measurement

The input channel 1 on the ADC120 receives the voltage image of the PT100 resistor on the evaluation board.

**Figure 6.** **STEVAL-AKI001V1 schematic - temperature measurement with PT100**




The resistance $R_{100}$ image of the temperature is given by the following equation:

$$R_{PT100} = \frac{V_{ADC1}*2*R_{ref}}{11*V_{ref}} \qquad (2)$$

And the temperature T is given by:

$$T = \frac{\frac{R_{PT100}}{R_0} - 1}{\alpha} \qquad (3)$$

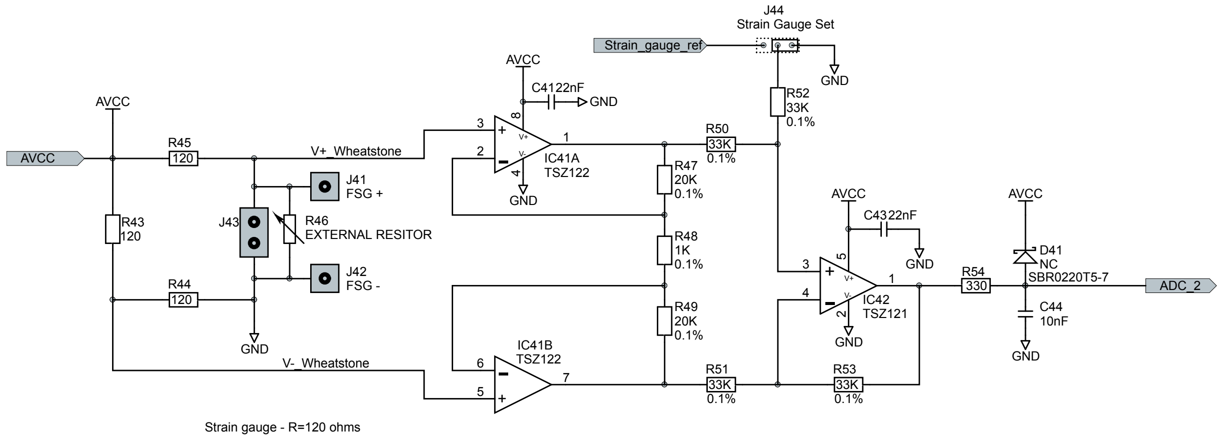
Where:

- $R_0 = 100\Omega$ is the resistance at 0 °C
- $\alpha = 0.00385\frac{\frac{\Omega}{\Omega}}{°C}$ is the temperature coefficient

## 3.3 ADC channel 2: input for strain gauge measurement

The ADC120 input channel 2 measures and amplifies the strain gauge variation via a Wheatstone bridge.

**Figure 7. STEVAL-AKI001V1 schematic - instrumentation amplifier for strain gauge measurement**




The ADC120 reads the voltage image of the amplified voltage variation.

If jumper J44 is connected to GND, the voltage image of the strain gauge voltage variation is given by the following equation:

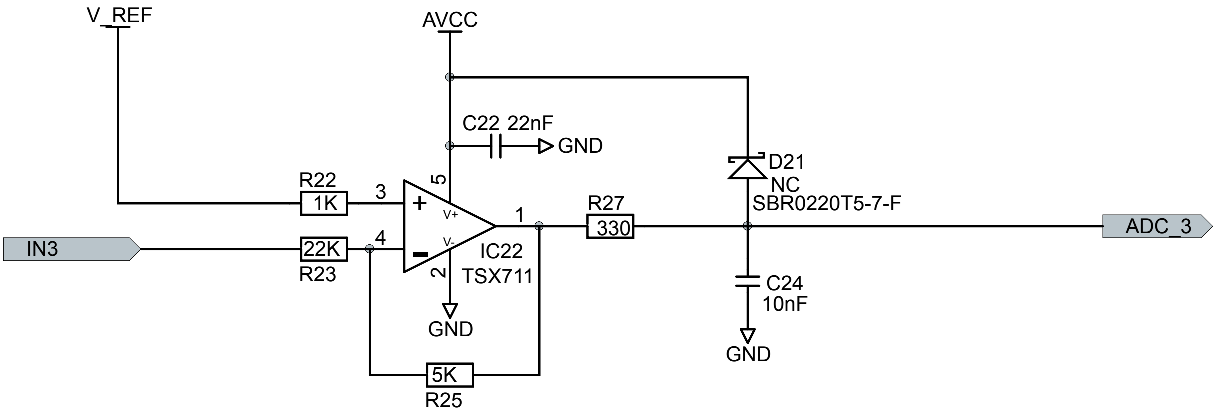
$$V_{ADC2} = \left(V^{-}_{Wheatsone} - V^{+}_{Wheatsone}\right)\left(\frac{1 + 2*R_{47}}{R_{48}}\right)\frac{R_{53}}{R_{51}} \qquad (4)$$

If jumper J44 is not connected to GND, an offset given by channel input 6 is implemented.

## 3.4 ADC channel 3: acquisition of a ±5 V signal on IN3

The ADC120 input channel 3 measures and converts a ±5V signal into a 0 to 3V3 signal through the rectifier shown in the figure below.

Figure 8. **STEVAL-AKI001V1 schematic - ±5 V to 0-3V3 voltage rectifier**



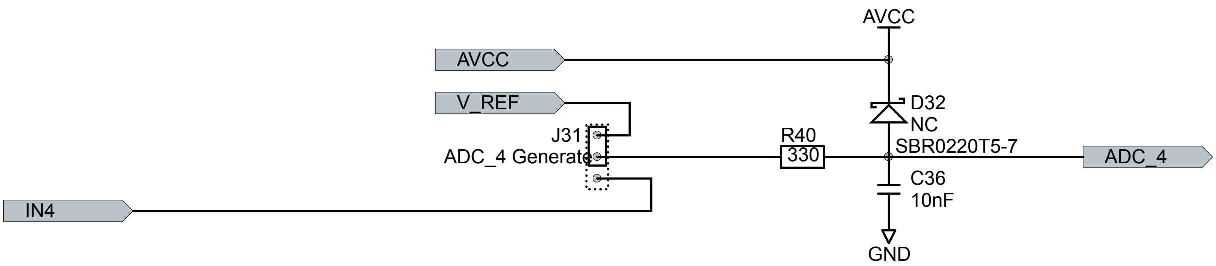

The ADC120 reads the positive voltage between 0 and 3V3. The rectified voltage is obtained from the equation:

$$V_{ADC3} = \frac{V_{ref} - In_3 * 0.1852}{0.8149} \quad (5)$$

## 3.5 ADC channel 4: reference voltage measurement

The ADC120 input channel 4 is used to measure the voltage of the inboard reference voltage provided by the TS3431.

Figure 9. **STEVAL-AKI001V1 schematic - reference voltage measurement**




ADC input 4 can be connected to the reference voltage or to another voltage on pin 10 of connector J2 by setting jumper J31 on the left (VREF) or on the right (In4), respectively.

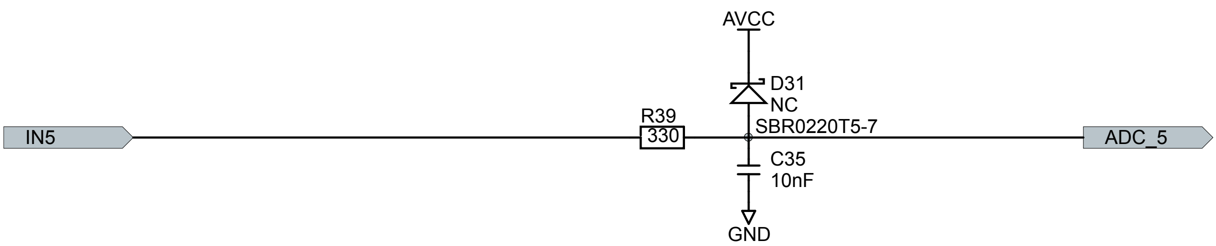
**RELATED LINKS**

*Visit the TS3431 product page on the ST website for more information regarding this device*

## 3.6 ADC channel 5: external 0-3V3 voltage measurement

Pin 12 on connector J2 can be used to connect a 0 to 3V3 voltage to test the conversion of the ADC120 on a custom level voltage. The ADC120 input channel 5 is designed to be operated by the user with any 0 to 3V3 voltage.

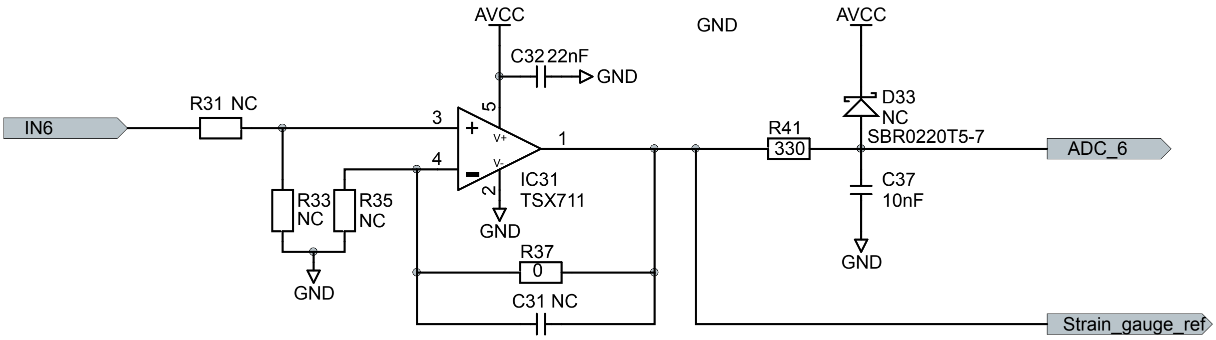
Figure 10. **STEVAL-AKI001V1 schematic - ADC input 5**



## 3.7 ADC channel 6: user configurable gain input

Pin 14 of connector J2 can be used to connect a voltage and configure the schematic as shown below to provide amplification, a divider, a filter, etc.

**Figure 11. STEVAL-AKI001V1 schematic - user configurable gain ADC channel 6**



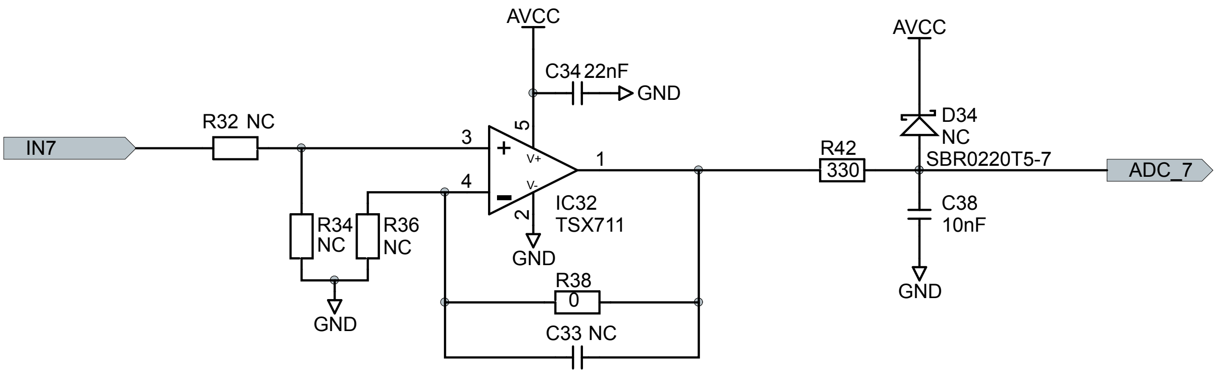

The ADC120 input channel 6 is designed for user configuration with any input voltage that does not surpass the 3V3 maximum input rating of the ADC120.

This channel 6 input voltage can also be used to provide the offset for the instrumentation amplifier on ADC channel 2 by setting the jumper J44 on strain gauge ref.

## 3.8 ADC channel 7: user configurable gain input

Pin 16 of connector J2 can be used to connect a voltage and configure the schematic as shown below to provide amplification, a divider, a filter, etc.

**Figure 12. STEVAL-AKI001V1 schematic - user configurable gain ADC channel 7**




The ADC120 input channel 7 is designed for user configuration with any input voltage that does not surpass the 3V3 maximum input rating of the ADC120.

# 4 Schematic diagrams



Figure 13. STEVAL-AKI001V1 schematic diagram - functional blocks

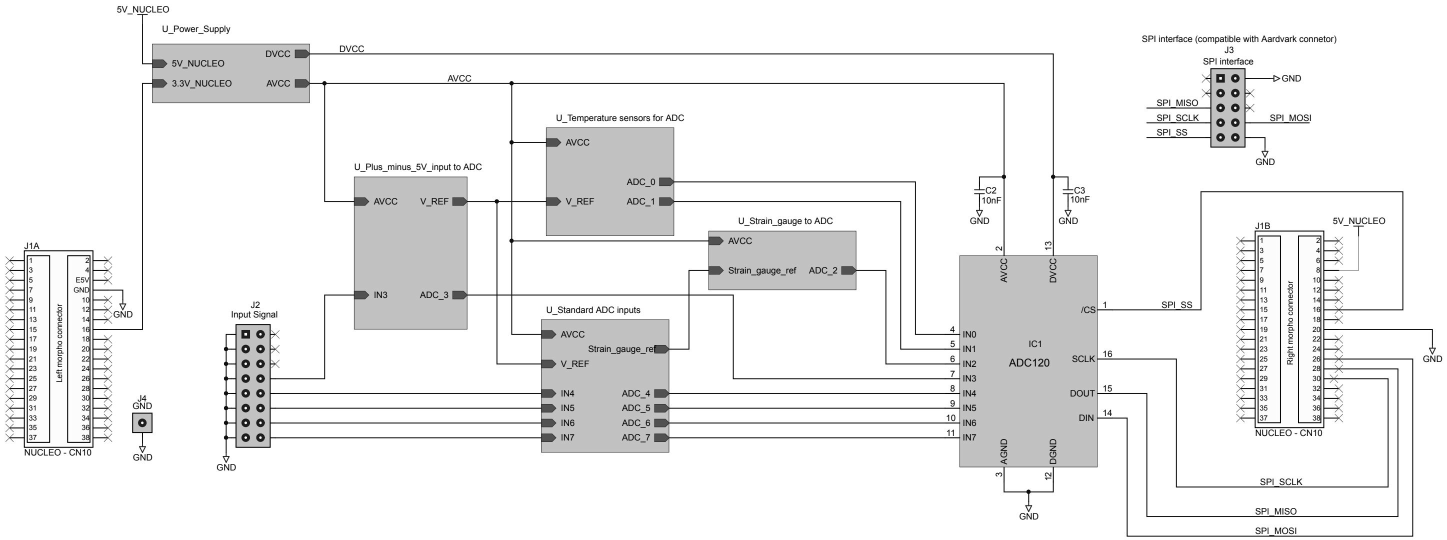



Figure 14. STEVAL-AKI001V1 schematic diagram - power supply 3V3

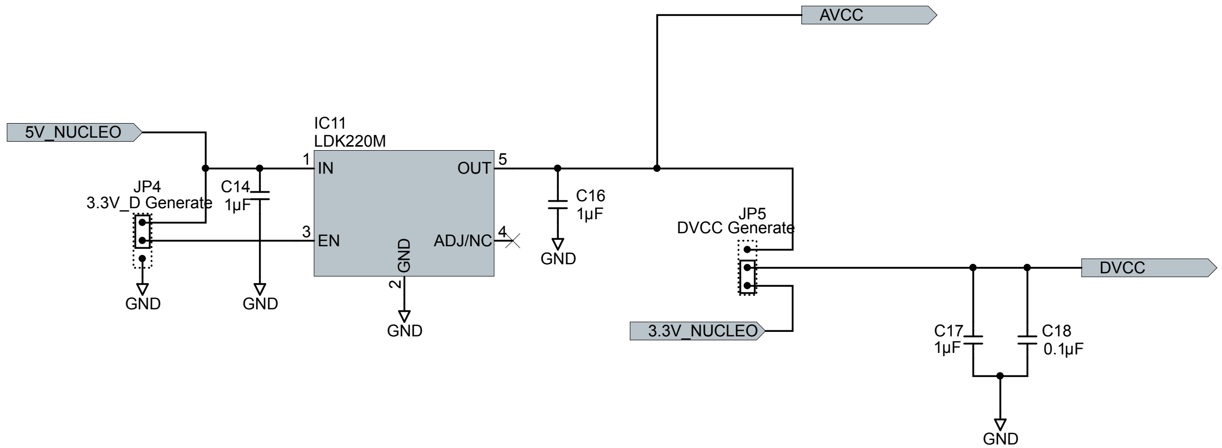
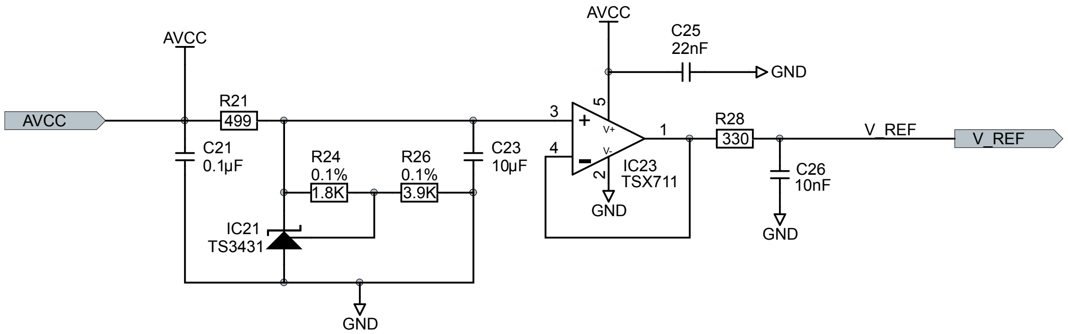


**Figure 15. STEVAL-AKI001V1 schematic diagram - reference voltage**




±5V input to 0-3V ADC

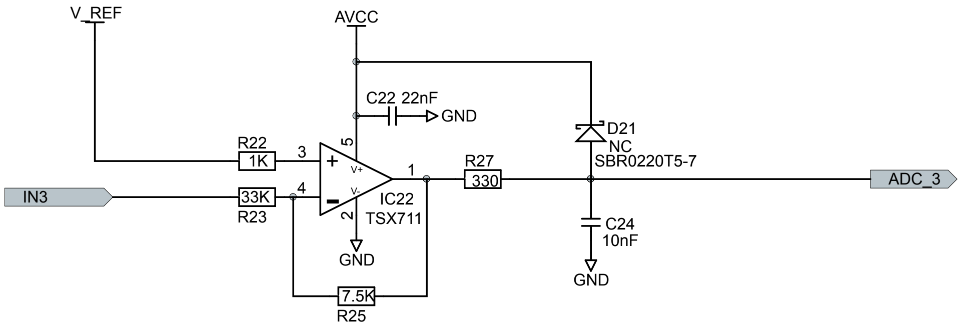


**Figure 16. STEVAL-AKI001V1 schematic diagram - ADC inputs**

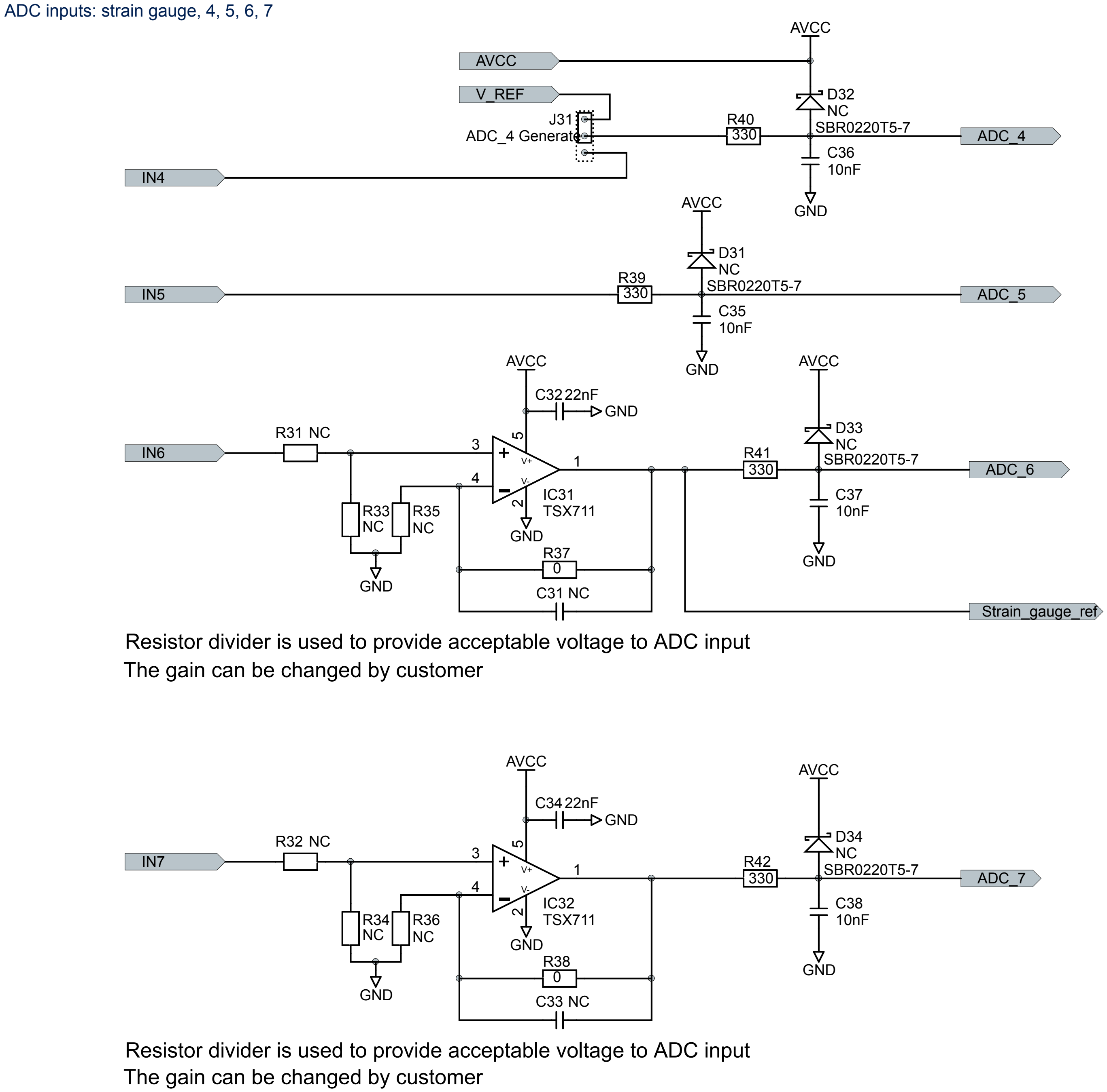


**Figure 17. STEVAL-AKI001V1 schematic diagram - Instrumentation amplifier for strain gauge**

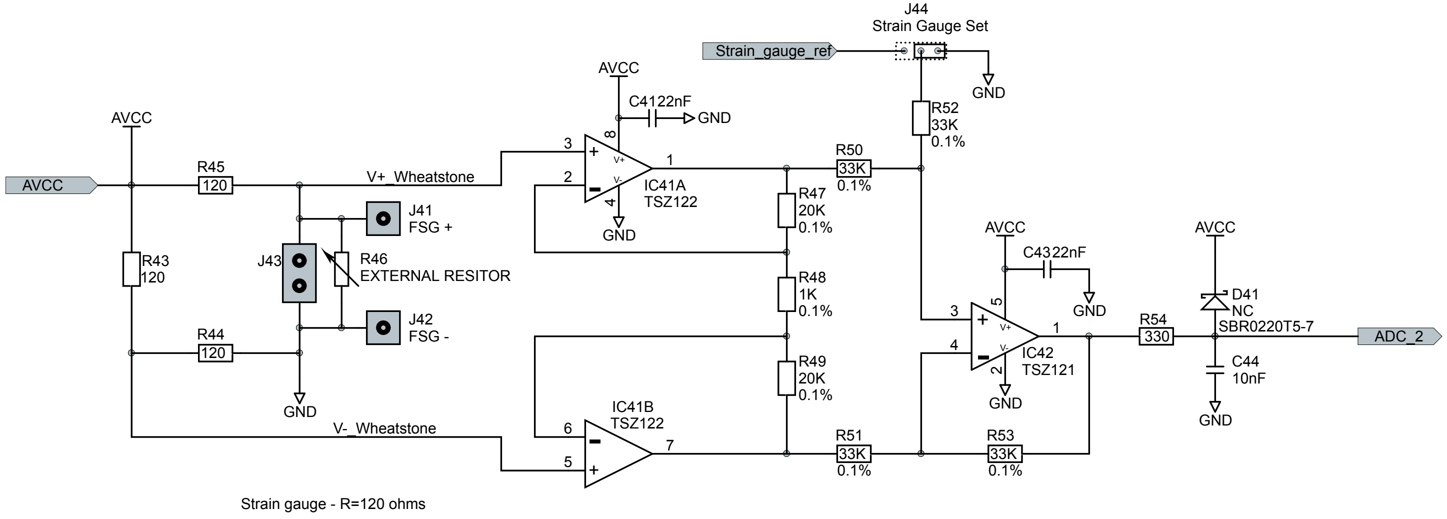
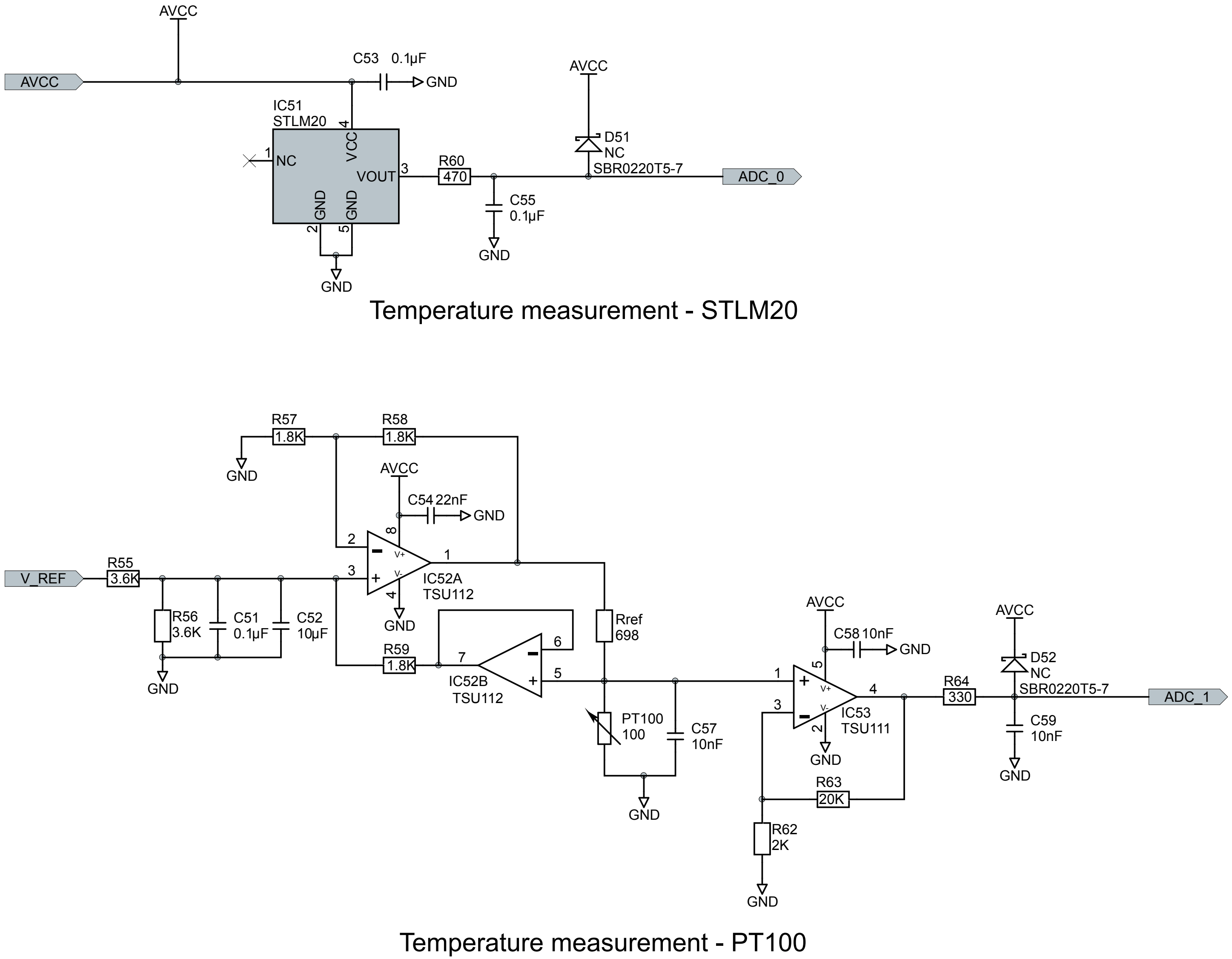


**Figure 18. STEVAL-AKI001V1 schematic diagram - temperature measurement**



# 5 Bill of materials

Table 1. **STEVAL-AKI001V1 bill of materials**

| Item | Q.ty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 1 | 12 | C2, C3, C24, C26, C35, C36, C37, C38, C44, C57, C58, C59 | 10nF, SMT 0603, 25V minV | CAPACITOR - CERAMIC | - | - |
| 2 | 3 | C14, C16, C17 | 1µF, SMT 0603, 25V minV | CAPACITOR - CERAMIC | - | - |
| 3 | 5 | C18, C21, C51, C53, C55 | 0.1µF, SMT 0603, 25V minV | CAPACITOR - CERAMIC | - | - |
| 4 | 7 | C22, C25, C32, C34, C41, C43, C54 | 22nF, SMT 0603, 25V minV | CAPACITOR - CERAMIC | - | - |
| 5 | 1 | C23 | 10µF, SMT 0603, 25V minV | CAPACITOR - CERAMIC | - | - |
| 6 | 0 | C31, C33 | NC, SMT 0603, 25V minV | CAPACITOR - CERAMIC | - | - |
| 7 | 1 | C52 | 10µF, SMT 0805, 25V minV, ±10% | CAPACITOR - CERAMIC, X5R, -55°C TO +85°C, GRM | MURATA | GRM21BR61E106KA73L |
| 8 | 0 | D21, D31, D32, D33, D34, D41, D51, D52 | NC, SOD523, 20V, 5A | DIODES & RECTIFIERS SCHOTTKY, -65°C TO 150°C, SBR0220T5 | Diodes Incorporated | SBR0220T5-7 |
| 9 | 1 | IC1 | TSSOP 16, 3.3 V | A/D CONVERTER, -40°C TO 125°C | ST | ADC120 |
| 10 | 1 | IC11 | SOT 323-5L, 13.2 V, 200mA, 2% | LDO VOLTAGE REGULATORS, -40°C TO 125°C | ST | LDK220M33R |
| 11 | 1 | IC21 | SOT 23-3, 25V | VOLTAGE REFERENCES, -40°C TO 105°C | ST | TS3431CILT |
| 12 | 4 | IC22, IC23, IC31, IC32 | SOT 23-5, 16V | OPERATIONAL AMPLIFIERS, -40°C TO 125°C | ST | TSX711ILT |
| 13 | 1 | IC41 | MSO 8, 5.5V | OPERATIONAL AMPLIFIERS, -40°C TO 125°C, TSZ12X | ST | TSZ122IST |
| 14 | 1 | IC42 | SOT 23-5, 5.5V | OPERATIONAL AMPLIFIERS, -40°C TO 125°C, TSZ12X | ST | TSZ121ILT |
| 15 | 1 | IC51 | SOT 353, 5.5V | TEMPERATURE SENSORS, -50°C TO 130°C, STLM20 | ST | STLM20W87F |
| 16 | 1 | IC52 | MSO 8, 5.5V | OPERATIONAL AMPLIFIERS, -40°C TO 85°C, TSU11X | ST | TSU112IST |

| Item | Q.ty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 17 | 1 | IC53 | SC 70-5, 5.5V | OPERATIONAL AMPLIFIERS, -55°C TO 130°C, TSU11X | ST | TSU111ICT |
| 18 | 1 | J1 | NUCLEO - CN10, SIP 19x2 - STEP 2.54MM, 655VDCV, 6.3A | CONNECTOR - HEADER, -55°C TO 125°C, SSQ | SAMTEC | SSQ-119-03-G-D |
| 19 | 1 | J2 | Input Signal, SIP 8x2 - STEP 2.54MM, 250V, 3A | CONNECTOR - HEADER, -40°C TO 125°C, WR-PHD | WURTH ELEKTRONIK | 61301621121 |
| 20 | 1 | J3 | SPI interface, SIP 5x2 - STEP 2.54MM, 250V, 3A | CONNECTOR - HEADER, -40°C TO 125°C, WR-PHD | WURTH ELEKTRONIK | 61301021121 |
| 21 | 3 | J4, J41, J42 | HEADER 1CT, SIP 1, 250V, 3A | CONNECTOR - HEADER, -40°C TO 125°C, WR-PHD | WURTH ELEKTRONIK | 61300111121 |
| 22 | 4 | J31, J44, JP4, JP5 | HEADER 3CTS, SIP 3 - STEP 2.54MM, 250V, 3A | CONNECTOR - HEADER, -40°C TO 125°C, WR-PHD | WURTH ELEKTRONIK | 61300311121 |
| 23 | 1 | J43 | Connect Foil Strain Gauges, SIP 2 - STEP 2.54MM, 250V, 3A | CONNECTOR - HEADER, -40°C TO 125°C, WR-PHD | WURTH ELEKTRONIK | 61300211121 |
| 24 | 4 | Ja31, Ja44, JPa4, JPa5 | JUMPER 2.54MM, 250V, 3A | JUMPER, -40°C TO 125°C, WR-PHD | WURTH ELEKTRONIK | 60900213421 |
| 25 | 1 | PT100 | 100, SMT 0805 | PLATINUM SENSOR, -50°C TO 150°C, SMD | IST INNOVATIVE SENSOR TECHNOLOGY | P0K1.0805.2P.B |
| 26 | 1 | R21 | 499, SMT 0603, ±1% | RESISTOR | - | - |
| 27 | 1 | R22 | 1K, SMT 0603, ±1% | RESISTOR | - | - |
| 28 | 1 | R23 | 33K, SMT 0603, ±1% | RESISTOR | - | - |
| 29 | 1 | R24 | 1.8K, SMT 0603, ±0.1% | RESISTOR | - | - |
| 30 | 1 | R25 | 7.5K, SMT 0603, ±1% | RESISTOR | - | - |
| 31 | 1 | R26 | 3.9K, SMT 0603, ±0.1% | RESISTOR | - | - |
| 32 | 8 | R27, R28, R39, R40, R41, R42, R54, R64 | 330, SMT 0603, ±1% | RESISTOR | - | - |
| 33 | 0 | R31, R32, R33, R34, R35, R36 | NC, SMT 0603, ±1% | RESISTOR | - | - |

| Item | Q.ty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 34 | 2 | R37, R38 | 0, SMT 0603, ±1% | RESISTOR | - | - |
| 35 | 3 | R43, R44, R45 | 120, SMT 0603, ±0.1% | RESISTOR | - | - |
| 36 | 2 | R47, R49 | 20K, SMT 0603, ±0.1% | RESISTOR | - | - |
| 37 | 1 | R48 | 1K, SMT 0603, ±0.1% | RESISTOR | - | - |
| 38 | 4 | R50, R51, R52, R53 | 33K, SMT 0603, ±0.1% | RESISTOR | - | - |
| 39 | 2 | R55, R56 | 3.6K, SMT 0603, ±1% | RESISTOR | - | - |
| 40 | 3 | R57, R58, R59 | 1.8K, SMT 0603, ±1% | RESISTOR | - | - |
| 41 | 1 | R60 | 470, SMT 0603, ±1% | RESISTOR | - | - |
| 42 | 1 | R62 | 2K, SMT 0603, ±1% | RESISTOR | - | - |
| 43 | 1 | R63 | 20K, SMT 0603, ±1% | RESISTOR | - | - |
| 44 | 1 | Rref | 698, SMT 0603, ±0.1% | RESISTOR | - | - |

# 6 Board layout

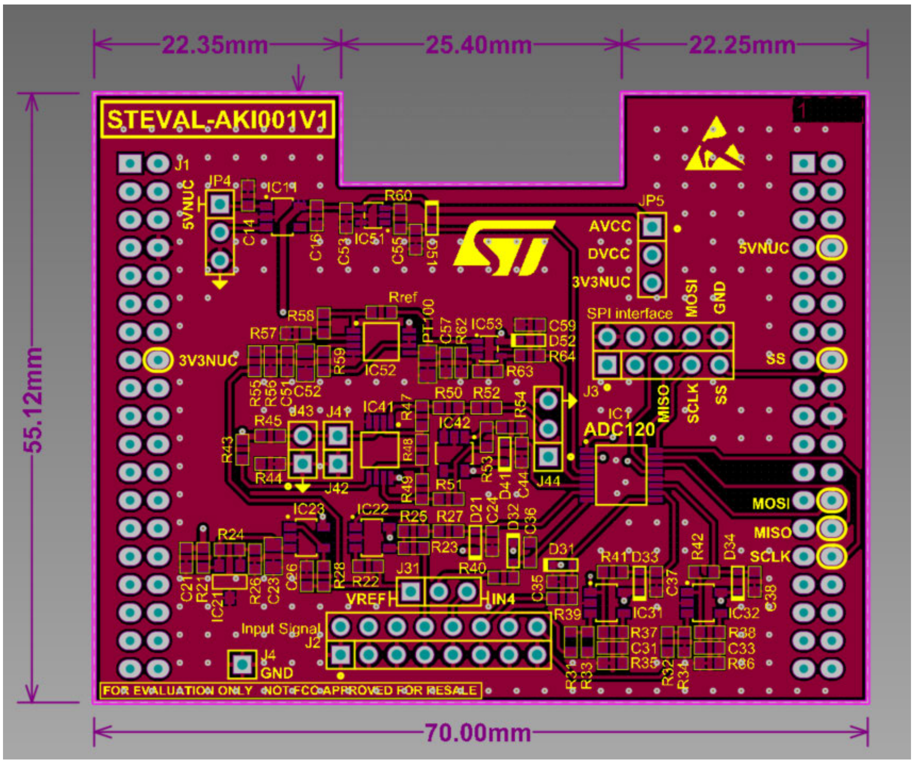



Figure 19. STEVAL-AKI001V1 board dimensions

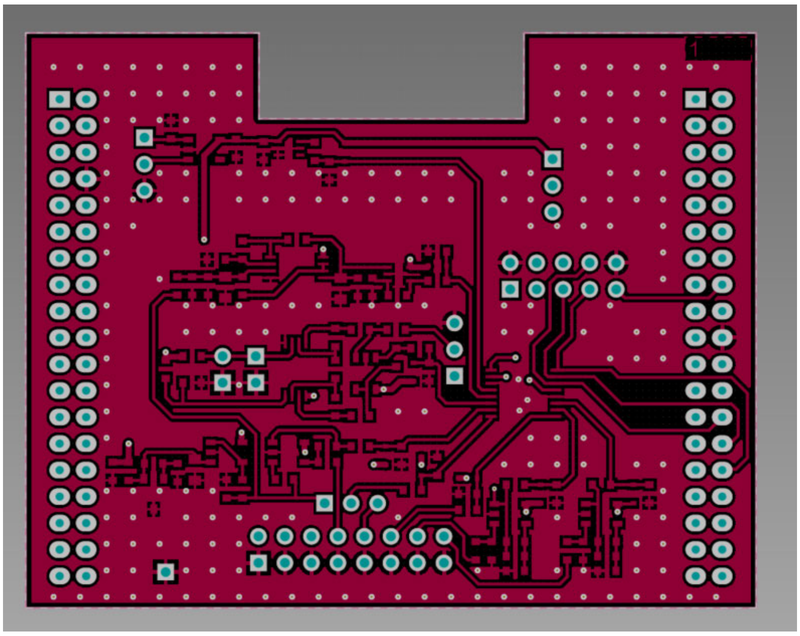


Figure 20. STEVAL-AKI001V1 board top layer

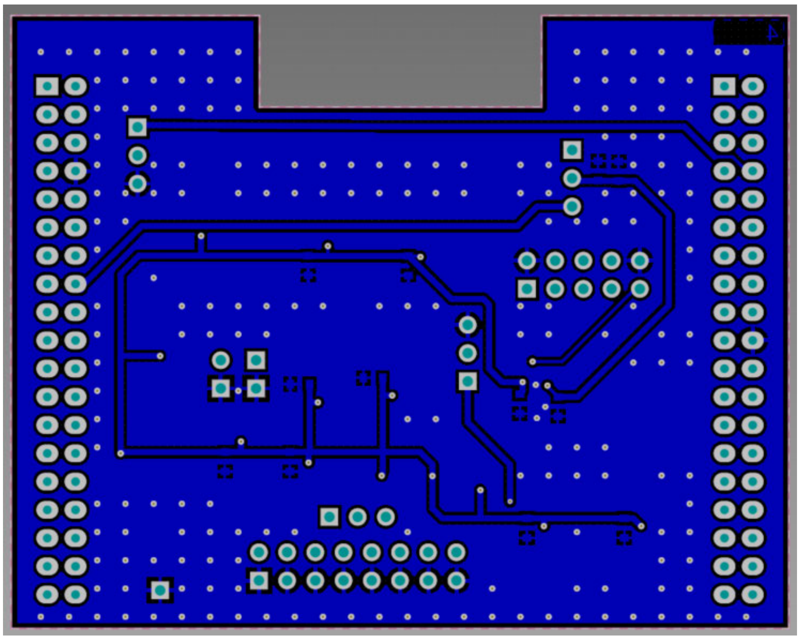


**Figure 21.** STEVAL-AKI001V1 board bottom layer

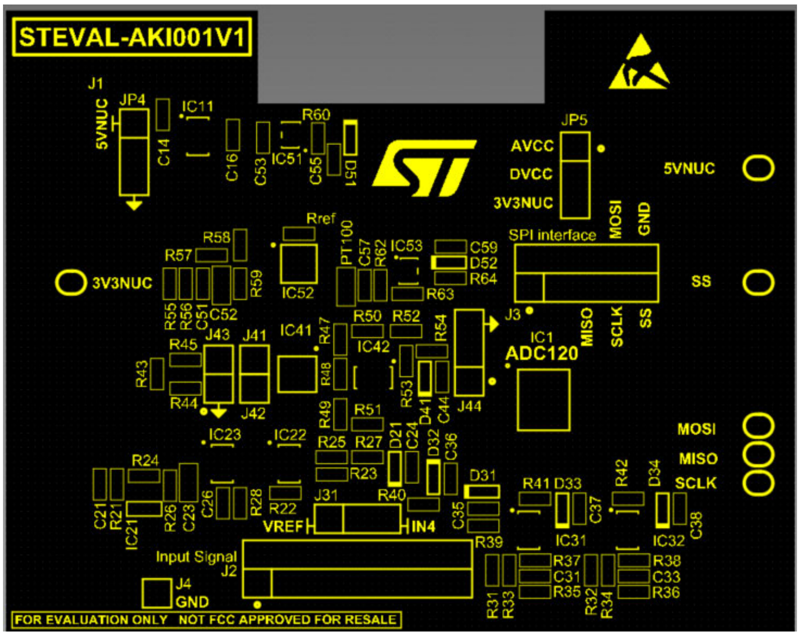



**Figure 22.** STEVAL-AKI001V1 board top silkscreen

Figure 23. STEVAL-AKI001V1 board bottom silkscreen

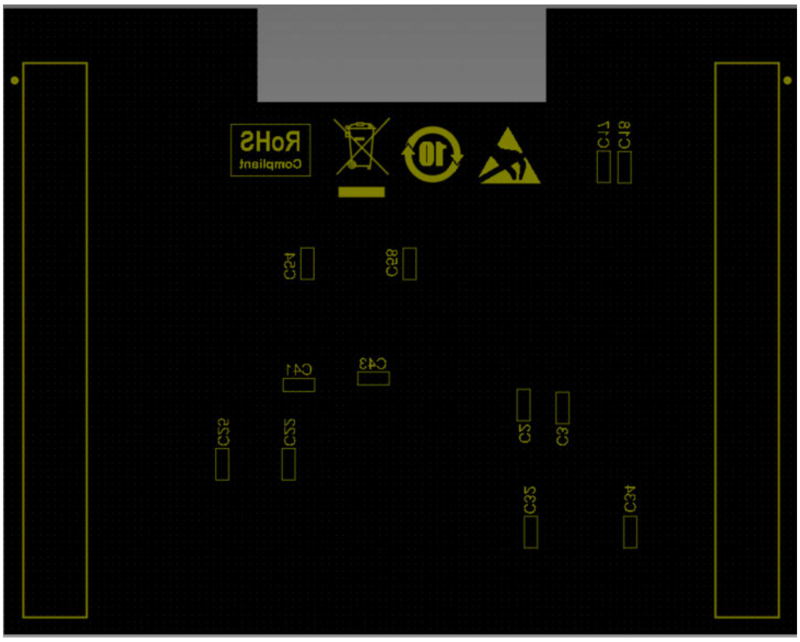


Figure 24. STEVAL-AKI001V1 board top solder

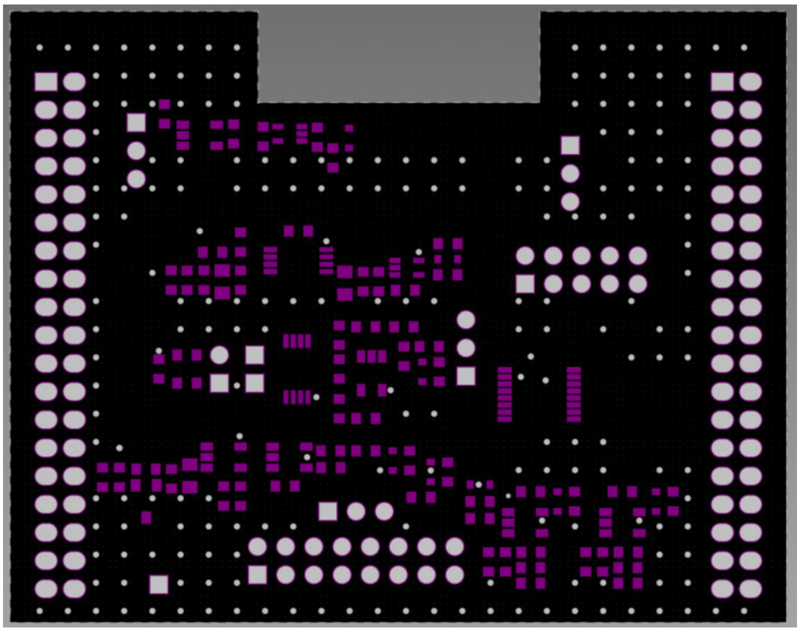


Figure 25. STEVAL-AKI001V1 board bottom solder

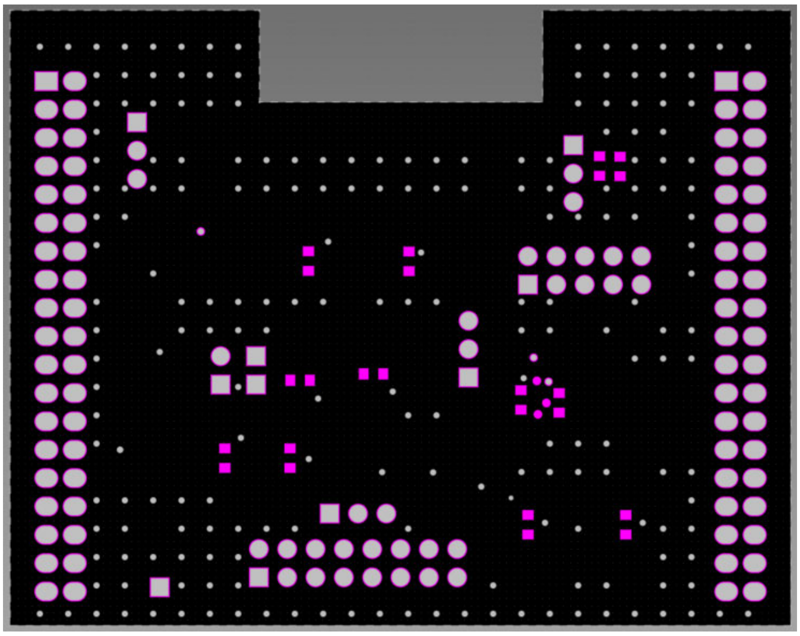


Figure 26. STEVAL-AKI001V1 board top assembly

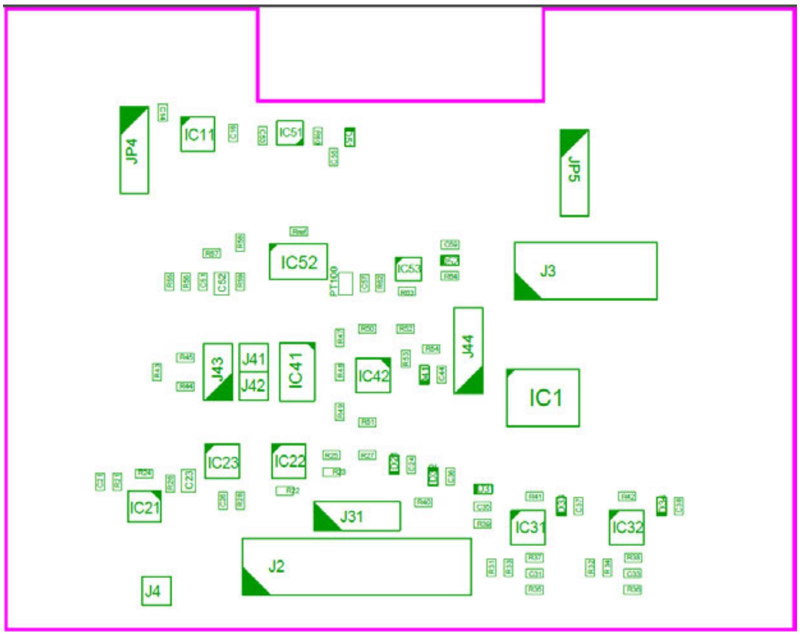
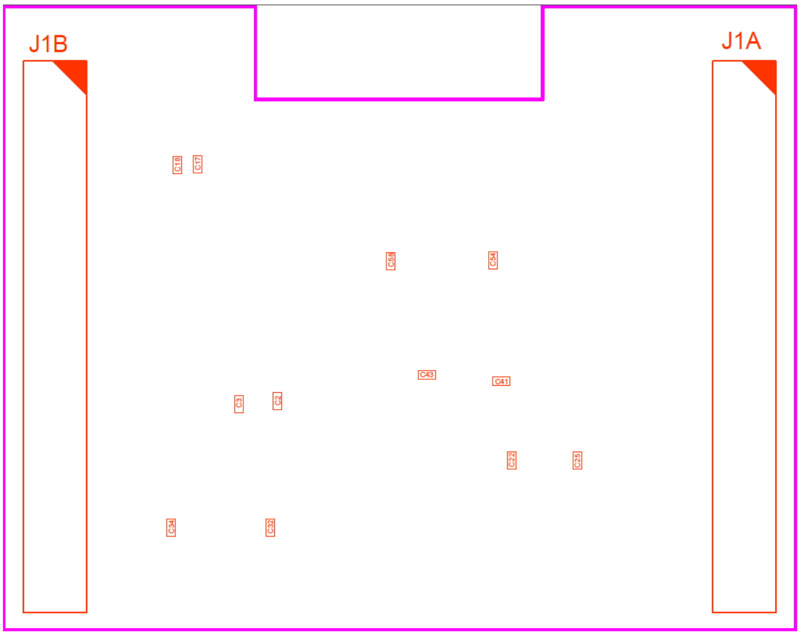


**Figure 27.** STEVAL-AKI001V1 board bottom assembly



## Revision history

**Table 2. Document revision history**

| Date | Version | Changes |
|---|---|---|
| 08-Apr-2020 | 1 | Initial release. |
| 23-Sep-2020 | 2 | Updated Section 1 Board overview, Section 3.4 ADC channel 3: acquisition of a ±5 V signal on IN3 and Section 4 Schematic diagrams. |

# Contents

# List of figures

# List of tables