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Single-Pixel Evaluation Kit by trinamiX

User guide

Key features

- For trinamiX PbS and PbSe detectors
- Supplied by USB power
- Two channels for detectors
- Standalone measurement software
- Plug and Play

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Release Date: March 11th, 2020
PCB V2.04
ver. 1.4

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1. Introduction

The Single-Pixel Evaluation Kit is designed for measurement and testing with trinamiX PbS and PbSe detectors. It offers two sockets for PbS and PbSe Detector Developer Boards in simultaneous operation. These are available for bonded bare chip detectors as well as TO5 package. The Evaluation Kit is designed for USB operation. Using this connection, the board transfers recorded data to a computer. Furthermore, the whole board is supplied by USB power and enables operating without any additional external power supply. With the delivered software, users can monitor and measure the signal of up to two detectors. While operating, the detectors can simply be swapped. There is no requirement of additional hardware or software.

The board consists of an USB protocol controller unit with integrated analog-to-digital-converters and a voltage converting unit as shown in *Figure 1*. A micro USB cable has to be used for connection with a computer. From the voltage delivered by USB the voltage converting unit generates the supply voltages for the amplifiers on the detector boards as well as stabilized bias voltage for the detectors themselves. Analog output signals from the amplifiers will be digitalized and transmitted by the USB unit.

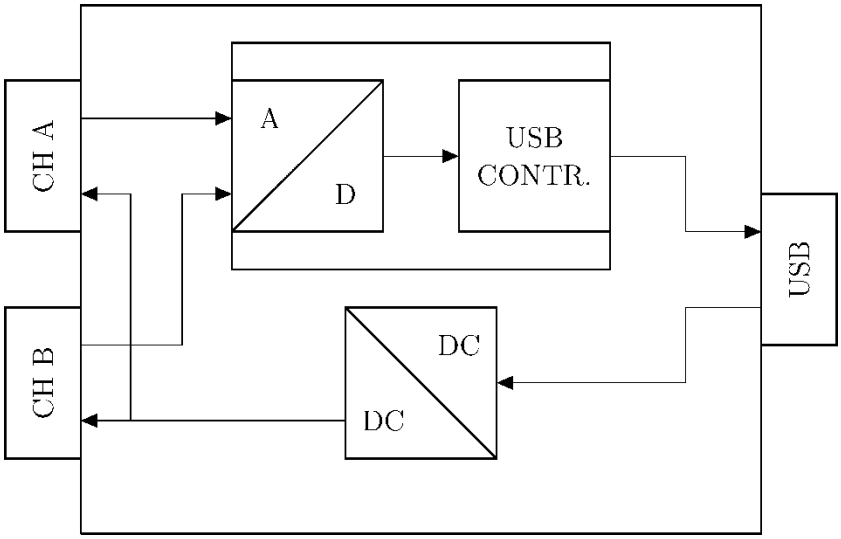


Figure 1. Functional block diagram.

This guide provides information about general specifications (section 2), how to setup the hardware and delivered software (section 3) as well as two application examples to demonstrate how the Evaluation Kit can be used (section 4).

2. Specifications

The Evaluation Kit software is designed to run at operation system Windows. An explanation guide for the software can be found in section 3.2.

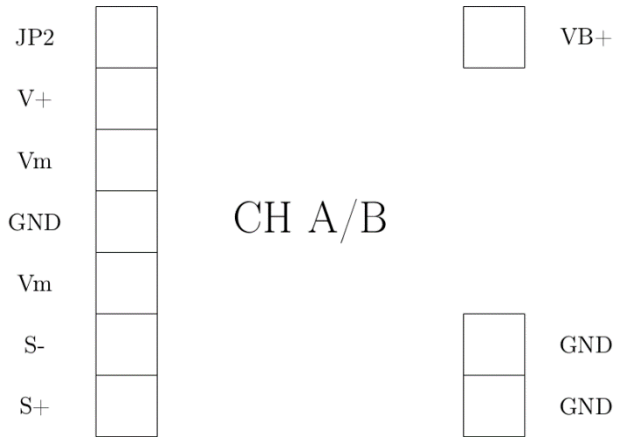
Important electrical specifications of the Evaluation Kit are written in *Table 1*. Characteristics of the analog inputs are listed in *Table* 2. In *Figure 2* the output pinning of the detector PCB socket is shown, including the applied voltages.

Table 1. Electrical characteristics.

Parameter		Description	Typ.	Unit
V_{IN}	Input voltage (USB)		5	V
I_{IN}	Input current (USB)	No detectors connected	58	mA
		1 detector plugged	62	mA
		2 detectors plugged	66	mA
V_{BIAS}	Detector bias voltage		10	V

Table 2. Analog to digital converter characteristics.

Parameter		Typ.	Unit
$V_{IN,max}$	Maximum input voltage	±1	V
f_S	Sampling frequency	8 – 48	kHz
Δf	Frequency resolution	0.1 – 60	Hz
BW	Bandwidth range	0.1 – 10	kHz



PIN	Description	V
JP2	Voltage divider output	n.c.
V+	Positive supply voltage	10.8
Vm	Amplifier voltage reference	5
GND		GND
Vm	Amplifier voltage reference	5
S-	Signal output (-)	5
S+	Signal output (+)	signal
VB+	Detector bias voltage	10
GND	Detector shield	GND
GND		GND

Figure 2. Detector PCB socket pinning.

Caution!

Do **NOT** use the bridge **R4** (shorting VB- and GND_1) on **Detector Developer Boards**. Powering a trinamiX Evaluation Kit with connected Developer Board that has assembled bridge R4 will short the 5V voltage source and damage the Evaluation Kit!

3. Setup

A picture of the whole default setup is shown in *Figure 3*. The Evaluation Kit is connected to the computer via USB cable. trinamiX Developer Boards with bare chip detectors are directly plugged into the Evaluation Kit. Signals of both detectors can simultaneously be monitored with the delivered software running on the computer. The hardware setup steps and an explanation guide, how to use the measurement tool, are described in the following sections.

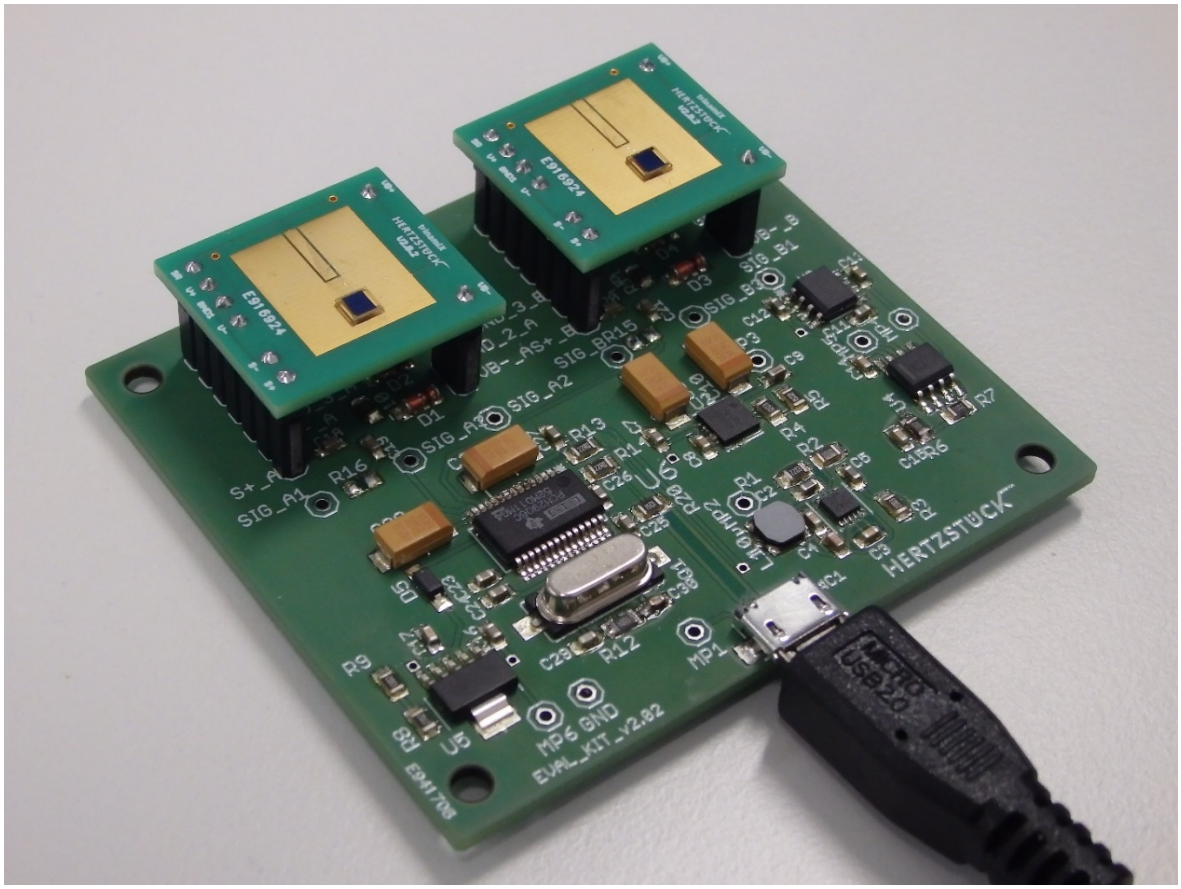
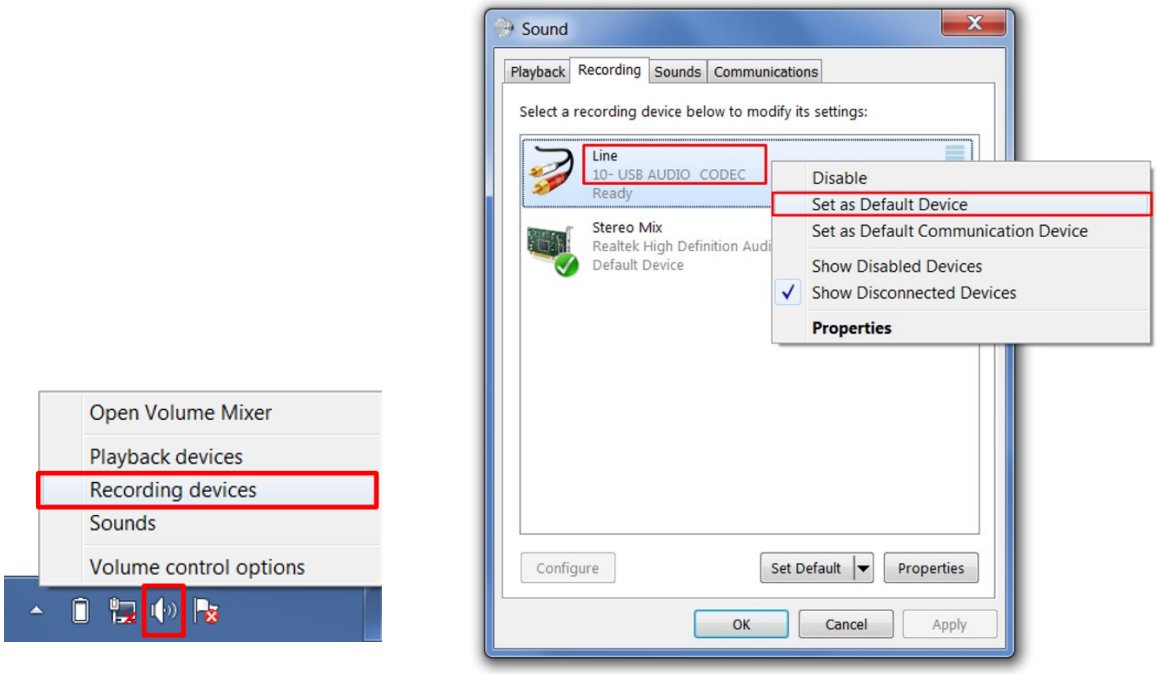


Figure 3. Picture of the Evaluation Kit connected with two trinamiX bare chip detectors.

3.1. Hardware

First, the Evaluation Kit must be connected to a computer with the USB cable, where the smaller micro USB connecter is plugged into Evaluation Kit and larger one into the computer. At the first time the device is connected windows will automatically install required drivers. As soon as this installation process finished a window will pop up in the information center.



(a) (b)

Figure 4. Opening the 'Recording devices' menu (a) and selecting the Evaluation Kit as 'Default Device' (b).

This Evaluation Kit is working as audio device to the computer. To check its successful registration, click right on the speaker symbol in the task bar and choose 'Recording devices' (*Figure 4a*). In the appearing window a list of all recording devices is displayed. The Evaluation Kit will be named as 'Line, X- USB AUDIO CODEC', where 'X' is a system depending integer ('10' in the picture). If there are any other recording devices, the Evaluation Kit needs to be 'Set as Default Device' with a right click on itself (*Figure 4b*). If these steps are successfully done, the hardware setup is finished and the measurement tool can be used.

3.2. Software

At first run the Setup Wizard and follow its steps for installation. Two programs will be installed:

- Evaluation Kit: Program for measurement with the Evaluation Kit
- National Instruments products: Required runtime for the Evaluation Kit since it is a LabView-based software.

After the installation is successfully done, the trinamiX Evaluation Kit software can be started by clicking onto the created shortcut. Measurement is automatically in progress once the software is started and can be stopped and restarted by user. 'Stop'- and 'Run'-button are in the upper left-hand side of the user interface. Using the 'Stop'-button (*Figure 5a*) will stop the program without losing any so far recorded data. Continuation of the measurement can then be done at any time by use of the 'Run'-button (*Figure 5b*).

(a) (b)

Figure 5. 'Stop'- (a) and 'Run'- button (b).

The tool is divided into two tabs 'Signal / FFT' and 'Analysis' (screenshots in *Figure 6* and *Figure 7*). The current signals and the corresponding spectra are displayed in 'Signal / FFT'. Observing of specific frequency can be done in the second tab 'Analysis'.

In the following subsections, each component of a tab is explained. The last subsection describes how recorded data are exported and saved for further analysis.

Tab: Signal / FFT

In this tab, the general measurement settings are defined and there are two graphs to observe input signals, which are described in the next paragraphs. The containing parts are shown in *Figure 6.*

Bandwidth, sampling frequency and gain

The bandwidth (**A**) represents the frequency resolution in the amplitude – frequency plot, according to the distance between two observable discrete frequencies (default 1 Hz). A small bandwidth results in a long measurement time T since it is depending with

$$T = \frac{1}{\Delta f}$$

on the bandwidth Δf. Thus, a suitable value for a given application must be found, depending on if a smaller bandwidth is worth a longer measurement time.

Default sampling frequency (**A**) is 48 kHz. It is the highest possible value, limited by hardware, and does not need to be changed in a standard use case.

Scaling of a given gain (**A**) of the signals is possible. This can be necessary if the elimination of any previous analog amplification of the signals is required. The gain is for each channel separately selectable (default: 1). This gain feature is used for calibration of the Evaluation Kit as well.

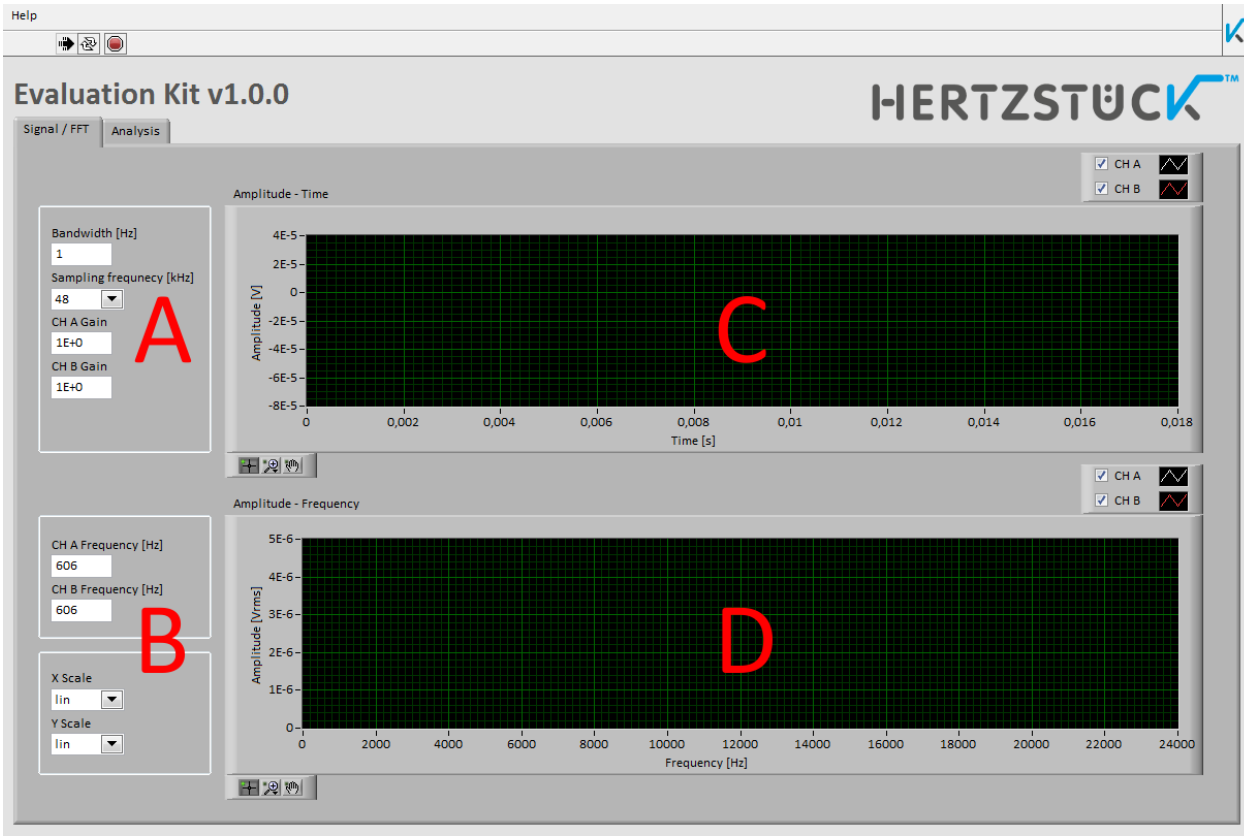


Figure 6. Tab Signal / FFT.

Amplitude – time plot

The displaying diagram of the actual recorded signal waveform is marked with **C** in *Figure 6*. In the upper right-hand side of the interface are two checkboxes to define which of the channels A and B are shown or hidden. Zoom function can be used to get a better view in both, time and amplitude direction. These are accessible in the bottom left-hand side of each diagram.

Amplitude – frequency plot

The FFT-calculation-based frequency spectra of the signals are observable in this diagram (**D**). Like in the amplitude – time plot, the user can decide if both channels are displayed. Zoom functions are available as well. In addition, it is possible to choose between linear and logarithmic scalar (**B**) in frequency and amplitude. This can be helpful if observing in a wide dynamic range is required.

Frequency tracking

The frequency that shall be observed has to be separately chosen for each channel in a text box (**B**). Default value is 606 Hz each.

Tab: Analysis

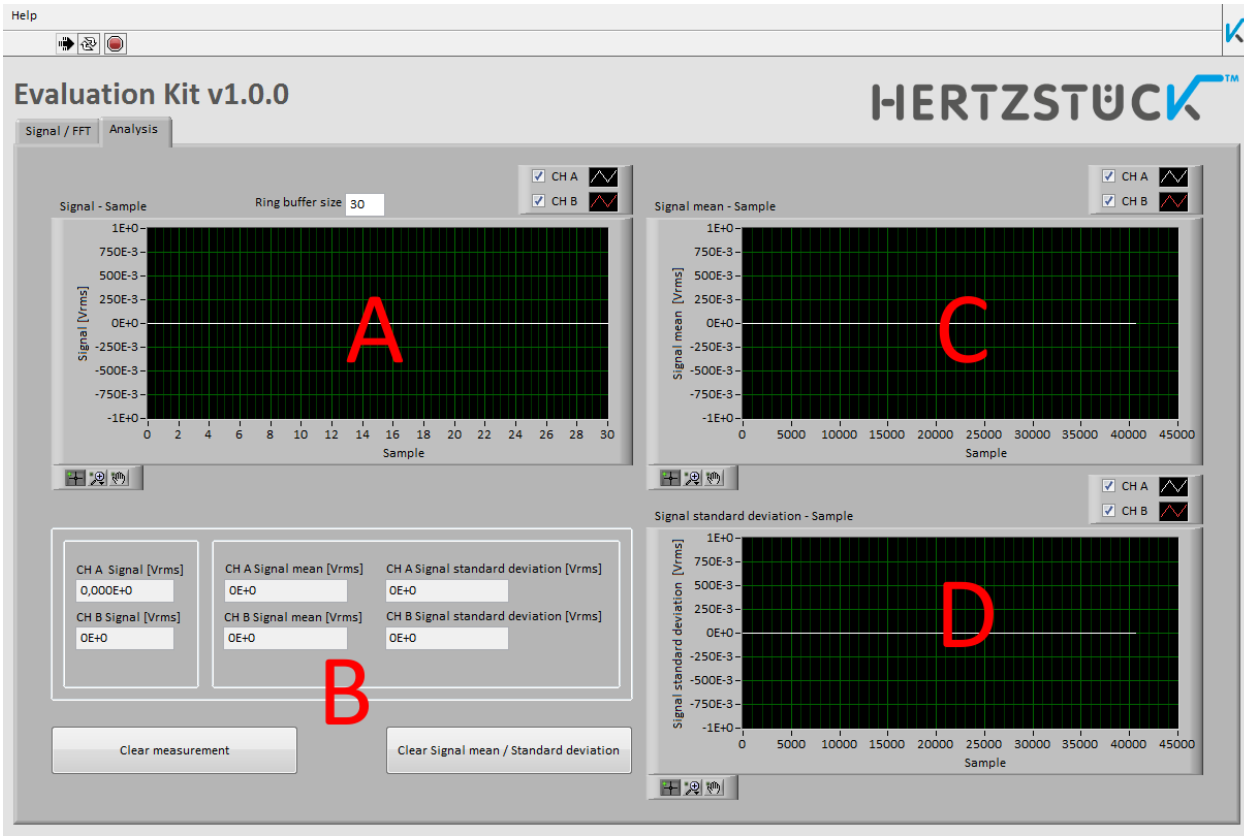


Figure 7. Tab Analysis.

Signal ring buffer

One key feature is observing the signals at a discrete frequency. From a signal ring buffer with selectable size mean and standard deviation are calculated and displayed (*Figure 7*). Current values in the buffer are plotted in graph **A**. The size of the signal ring buffer is controlled by an extra changeable value (default 30).

The newest amplitudes, the actual calculated mean and standard deviation for both channels are displayed in the fields at **B**.

Mean and standard deviation

The calculation of those values starts as soon as the signal ring buffer is filled up. Mean (**C**) as well as standard deviation (**D**) are plotted in separated diagrams. Thus, it is possible to monitor the behavior of a system over a long-time distance.

The 'Clear measurement'-button (**B**) can be used to reset the data that have been recorded yet. This is the recommended way of starting a new measurement session. Pressing the button 'Clear Signal mean / Standard deviation' will discharge the 'Signal mean – Sample' as wells as the 'Signal standard deviation – Sample' plot, leaving all data points currently stored in the ring buffer.

Saving data

Data displayed in any graph can be exported and saved in a same way. At first, the measurement should be interrupted by pressing the 'Stop'-button (*Figure 5*). Next, right-click into the graph and choose 'Export Data To Clipboard" in 'Export' (*Figure 8*). This step stores all data in the graph to clipboard. Please note, that this process could take some seconds depending on the number of data points.

To save the data in a file, create a text-file and paste the recently stored data. In case of a table processing program, there will be an own row for each data series (e.g. time, amplitude).

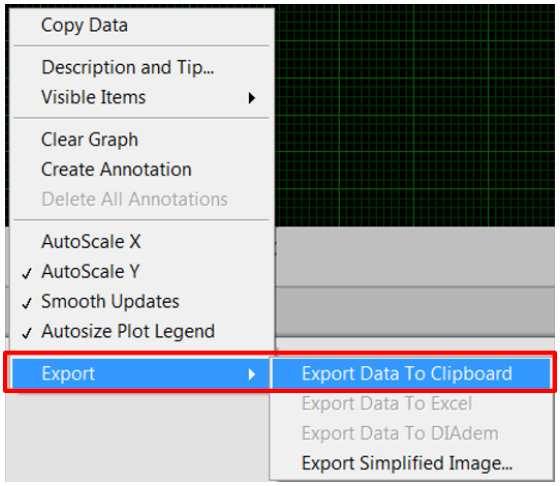


Figure 8. Exporting and copying data of a graph to clipboard.

3.3. Testing

To verify if the trinamiX Evaluation Kit is correctly operating, checking and comparing of the voltages at measurement points (MP) could be helpful. A digital multimeter (DMM) can be used to measure those values. Connect the ground pin of the DMM to the 'GND' measurement point and the positive pole to one of the MP. The following *Table 3* shows voltages that should be measured at the corresponding points:

Table 3. Voltages at the measurement points.

Measurement point	Typ.	Unit
MP1 (V_{IN})	5	V
MP2	11.6	V
MP3	10.8	V
MP4	5	V
MP5 (V_{BIAS})	10	V
MP6	4	V

If the voltage at MP1 equals zero, there might be a connection issue between Evaluation Kit and computer, since MP1 is the supply voltage from USB. Check the USB connection! If the 10 V at MP5 are not traceable, a problem within the voltage preparation could be the cause. Checking MP2, MP3 and MP4 can help to find the incorrectly working component. The 4 V at MP6 are only measurable when the USB connection is stable and the Kit has start measurements at channels A and B.

3.4. Calibration

The voltage measured by the Evaluation Kit is caused by an individual linear error. Thus, for accurate voltage measurement a calibration is recommended. The simplest way of calibration is applying a 1 kHz sinusoidal voltage signal (e.g. by a function generator) with a known amplitude to the analog inputs of channel A and B on the Evaluation Kit. With help of the amplitude measured by the Evaluation Kit and the applied signal the error can be determined with the equation:

$$\text{error} = \frac{\text{signal amplitude applied}}{\text{signal amplitude measured}}$$

Entering these factors into the CH A and CH B gain fields in the software will eliminating the measurement errors.

4. Application example

This section describes two measurement application examples the Evaluation Kit can be used for. The first one shows the difference between the signals of two PbS detectors due to uneven illumination. An experiment on how to determine the responsivity of a detector is demonstrated afterwards.

In both measurements, the following trinamiX products are used:

- 1x Evaluation Kit
- 2x Developer Board with bonded bare chip PbS detector and these specifications:

Active area [mm x mm]	2 x 2	
Dark resistance [MΩ]	0.3 to 3.0	
Peak responsivity [V/W]	$4 \cdot 10^5$	(at: 2.2 µm, 22 µW/cm , 50 V/mm)
Peak detectivity [cm$\sqrt{\text{Hz}}$/W]	$5 \cdot 10^{11}$	

4.1. Example 1: Illumination comparison

In this application example, the Evaluation Kit is used in an office. The plugged-in detectors are exposed to the office lights. Since the detectors should have equal characteristics, are located next to each other and are illuminated by the same lights the measured signals are almost identical. Next, one of the detectors will be slightly covered by a sheet of paper. Thus, the measured signal intensity of this detector should decrease due to lower illumination than before. *Figure 9* shows how these signals are looking like in the Evaluation Kit software for this example. The signal at channel A (white curve) corresponds to the uncovered detector. Channel B (red curve) has a lower intensity compared to channel A because of the covering by the paper.

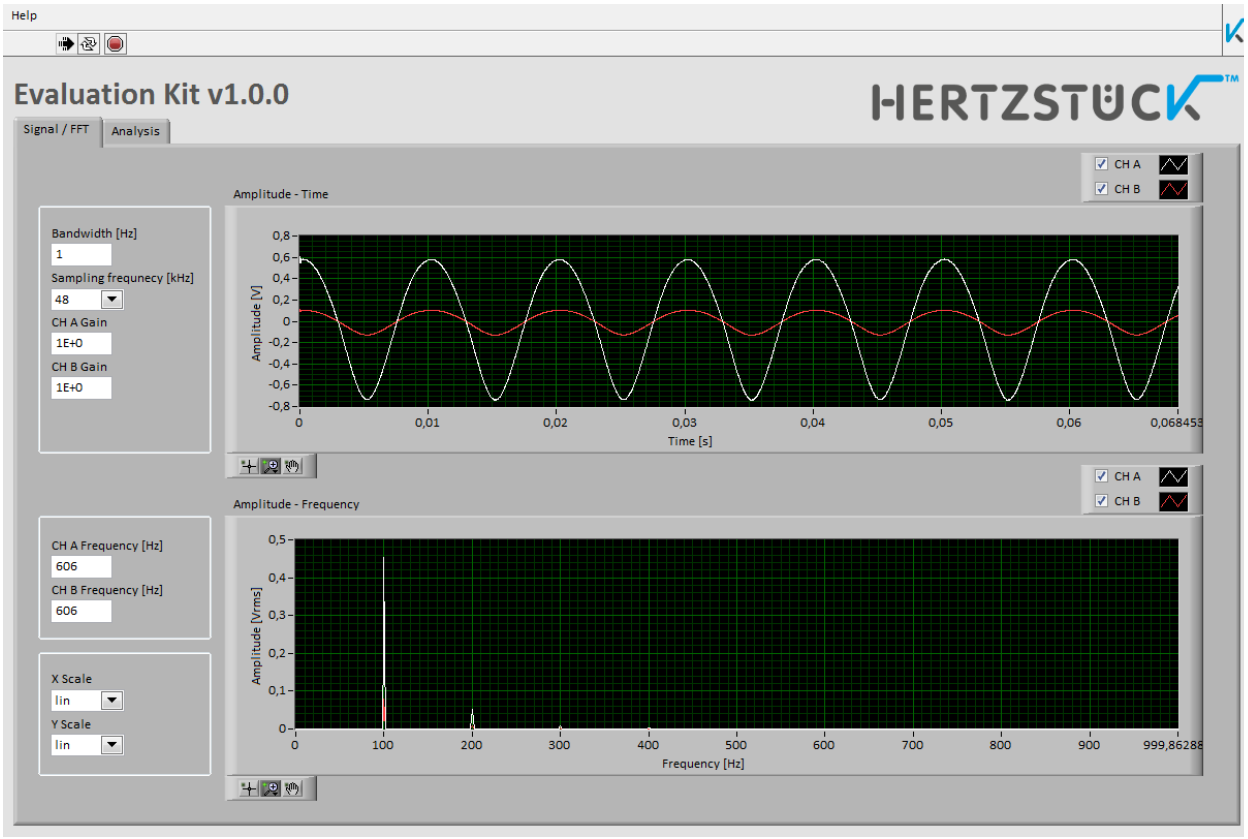


Figure 9. Signal / FFT tab in illumination comparison example.

In the lower graph, spectral information of the signals are displayed. At both channels the main peak is located at 100 Hertz and there are some lower peaks at multiples of this frequency as well. 100 Hertz is a standard frequency used for modulation of fluorescence tubes. This kind of lights are used in the office where this application example was done.

4.2. Example 2: Responsivity determination

For the determination of the responsivity a more complex measurement setup is required. A light source (a modulated $1550\ \mathrm{nm}$ LED) is placed on the optical axis, which is the reference to align the Evaluation Kit. It is placed in a way, that both detectors are in the same distance to the optical axis. This is the condition to provide an equal illumination for both detectors. The inhomogeneity of the light distribution can be neglected for a sufficient distance between light source and detector plane. Setup and alignment of light source and Evaluation Kit are schematically shown in *Figure 10*.

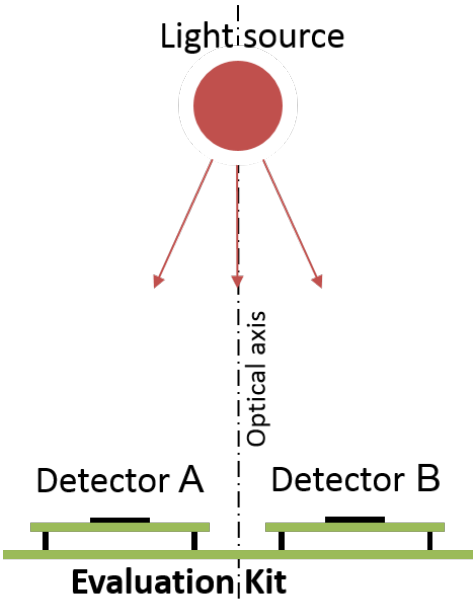


Figure 10. Schematic of the Evaluation Kit setup in the responsivity determination example.

At first, we take a closer look at the two-wire bonded on printed circuit board PbS-detectors that are under examination. They are operating in a voltage divider circuit. The resistance of the detectors have an amount of $851\ \mathrm{k\Omega}$ and $862\ \mathrm{k\Omega}$. A value of $1\ \mathrm{M\Omega}$ was chosen for load resistors. The following op-amp circuit is set to an amplification of eleven. Both bonded bare chip detectors boards are directly plugged into Evaluation Kit channels A and B. Since the operating voltages for the detector boards are provided by the Evaluation Kit itself, the voltage dividers are biased by a value of $10\ \mathrm{V}$.

The responsivity R of a detector can be calculated with the equation

$$R\ [\mathrm{V/W}] = \frac{S\ [\mathrm{V}]}{P\ [\mathrm{W/cm^2}] \cdot A\ [\mathrm{cm^2}]}$$

where S is the signal output voltage, P the incident power and A the active area of the detector. The detectors active area is known as described before. Values of incident power and signal voltage now have to be determined.

The incident power, emitted by the LED, is measured with a power meter. Measurement is done in the detector plane at the optical axis, where the received power has an amount of $16\,\mu W/cm^2$. Because of the illuminating distribution of the LED and its sufficient distance to the detector plane, the assumption of a homogeneous power distribution in this plane becomes valid. Thus, the measured value of $16\,\mu W/cm^2$ is used as the incident power at the detectors active area.

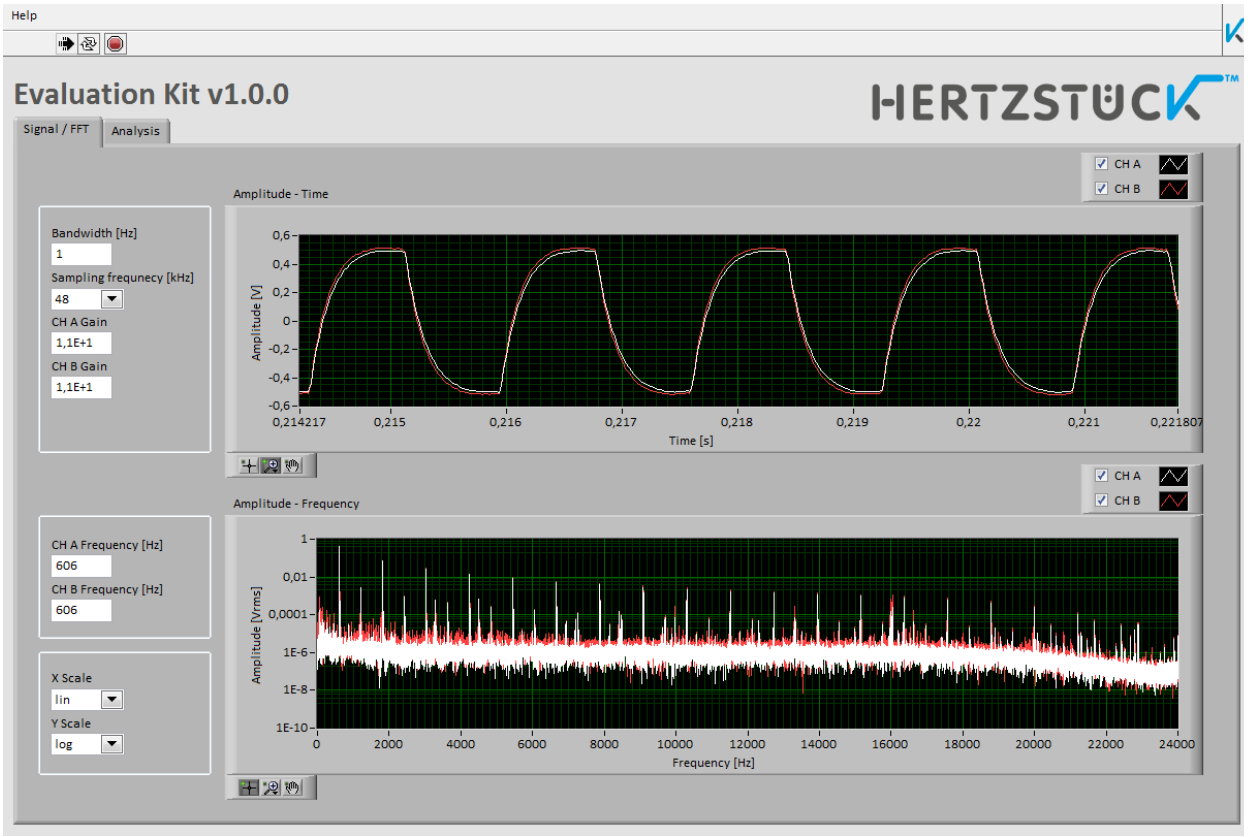


Figure 11. Signal / FFT tab in responsivity determination example.

For the measurement, a sampling frequency of $48\,kHz$ is chosen to get a spectrum as wide as possible. The frequency resolution is set to $1\,Hz$. The used $1550\,nm$ LED is square modulated by a frequency of $606\,Hz$. In the software (*Figure 11*), the signal in the amplitude-time graph is remindful of the charge- and discharge curve of an RC-circuit, due to parasitic capacitance of the detectors. However, in the amplitude-time graph the maximum amplitude is gained at the $606\,Hz$ modulation frequency and decreasing values at multiples of this frequency. Another noticeable point is that both channels have almost the same signal form as well as amplitude values.

Because of the amplification of the op-amp circuit after the detector, the amplification factor of eleven is typed in at channel A and B gain. Thus, the determined values in the analysis tab are directly corresponding to the voltage at the voltage divider output. The frequency of interest is the modulation frequency of 606 Hz and is set for both channels.

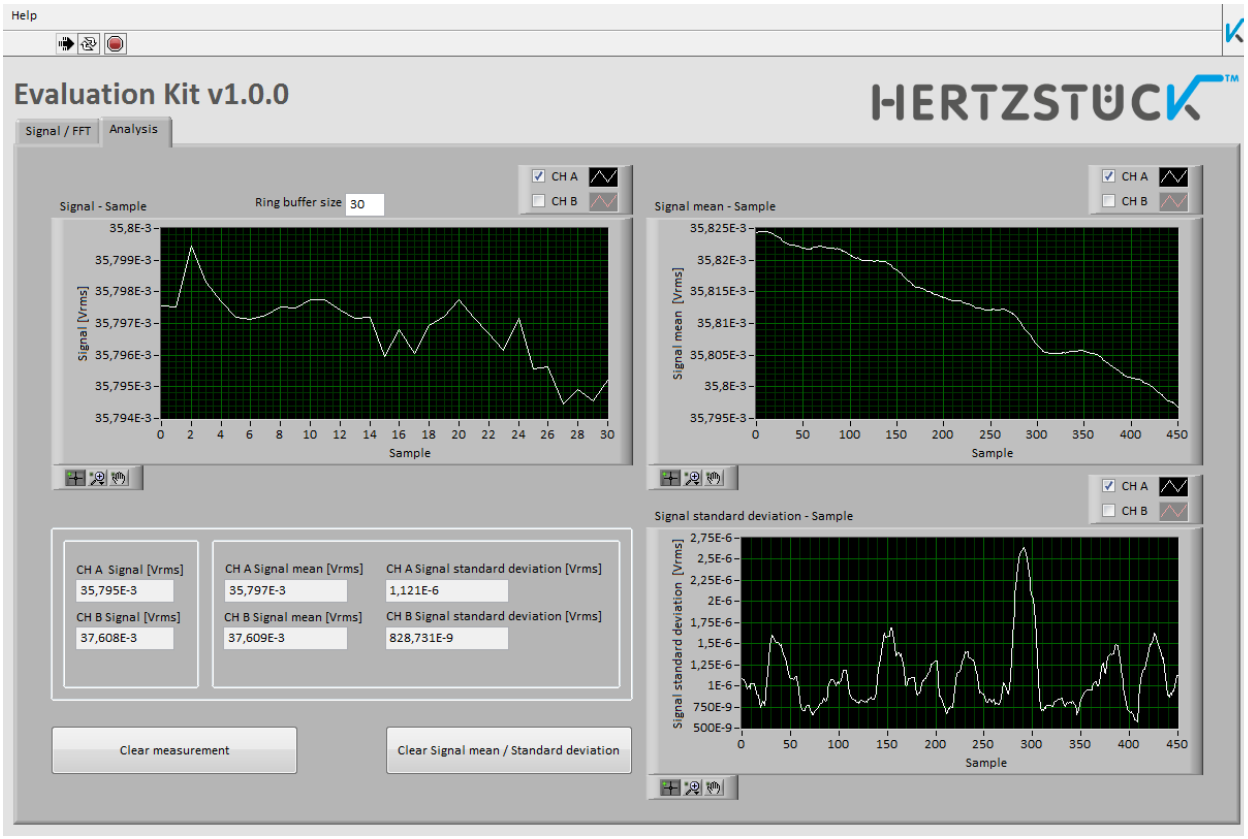


Figure 12. Analysis tab in responsivity determination example.

The voltage amplitudes at 606 Hz for channel A in the ring buffer are around 35.8 mV (*Figure 12*). The exact amount of the last measured sample can be read below with a value of 31.797 mV. To get a representative value for the responsivity, the last signal mean is used for its calculation. Thus, a responsivity of

$$R = \frac{35.8\ \text{mV}}{16\ \mu\text{W/cm}^2 \cdot 0.2\ \text{cm} \cdot 0.2\ \text{cm}} = 5.59 \cdot 10^4\ \text{V/W} \quad (at\ 5\,\text{V/mm}, 1550\ \text{nm})$$

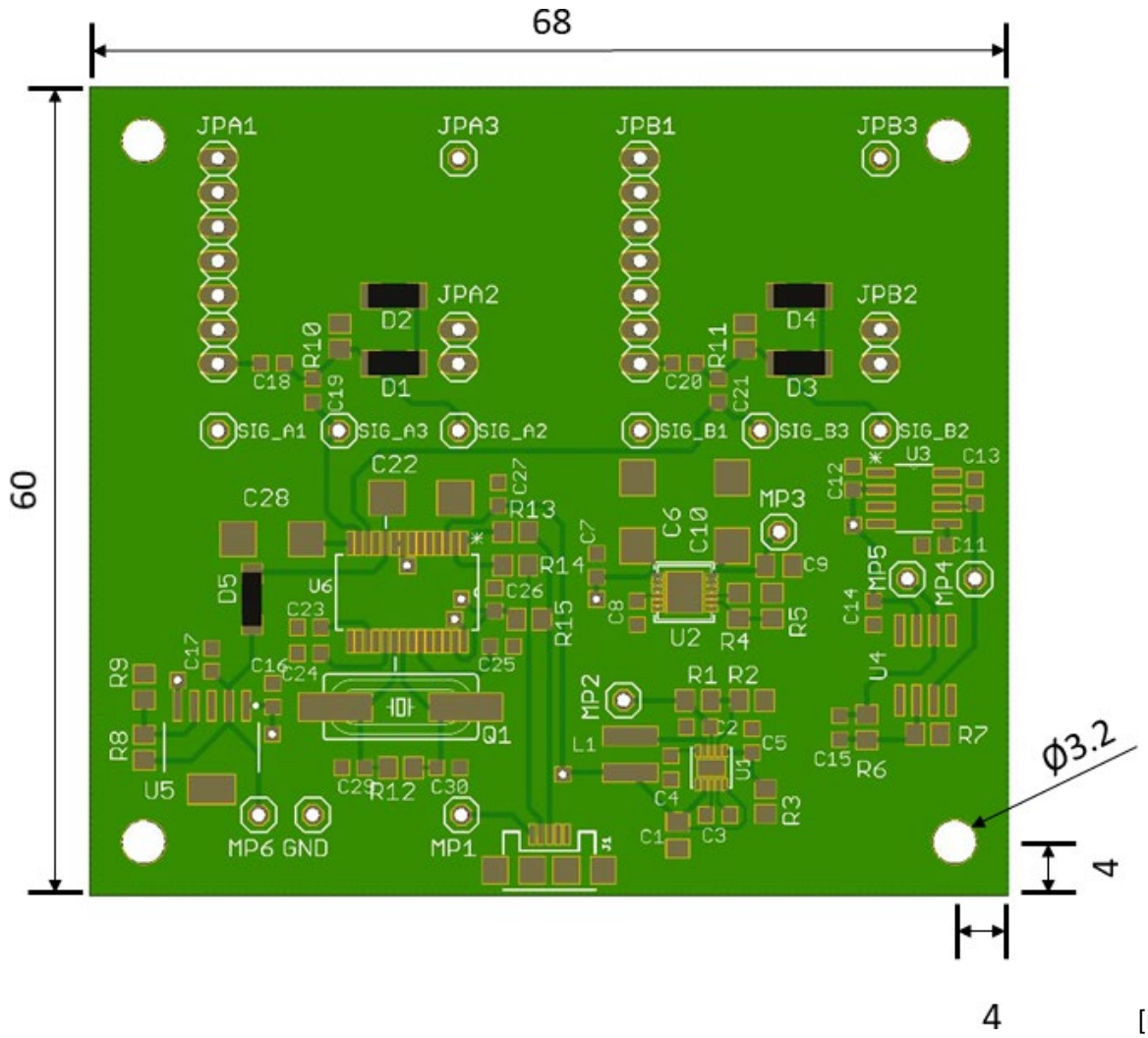
has been archived at channel A with this Evaluation Kit measurement setup ($5.89 \cdot 10^4$ V/W at channel B).

From the Analysis tab the overall measurement time can be calculated. In the signal mean-sample graph are almost 450 samples stored. Since the chosen bandwidth of 1 Hz results in a measurement time of one second, the setup provides one sample per second. Thus, the overall measurement took nearly eight minutes.

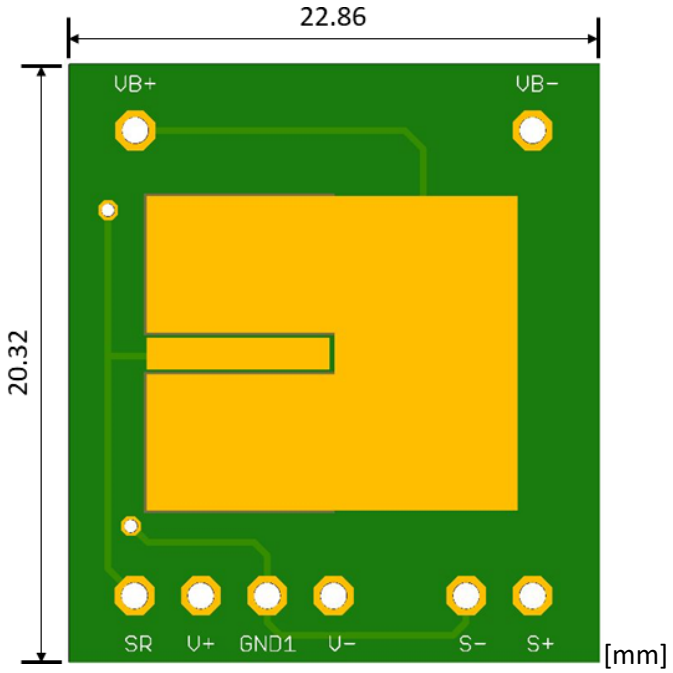
5. Appendix

5.1. Technical drawings

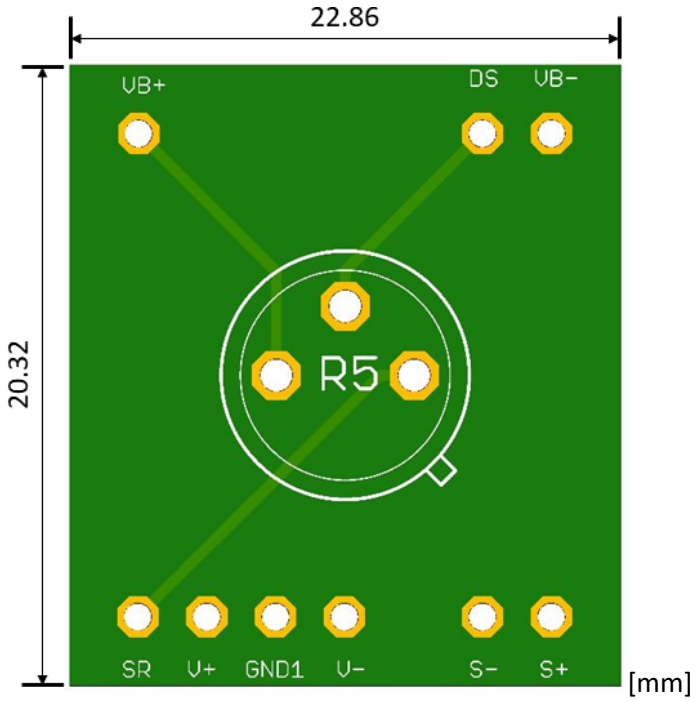
5.1.1. Main board



5.1.2. Detector Developer Board bare chip

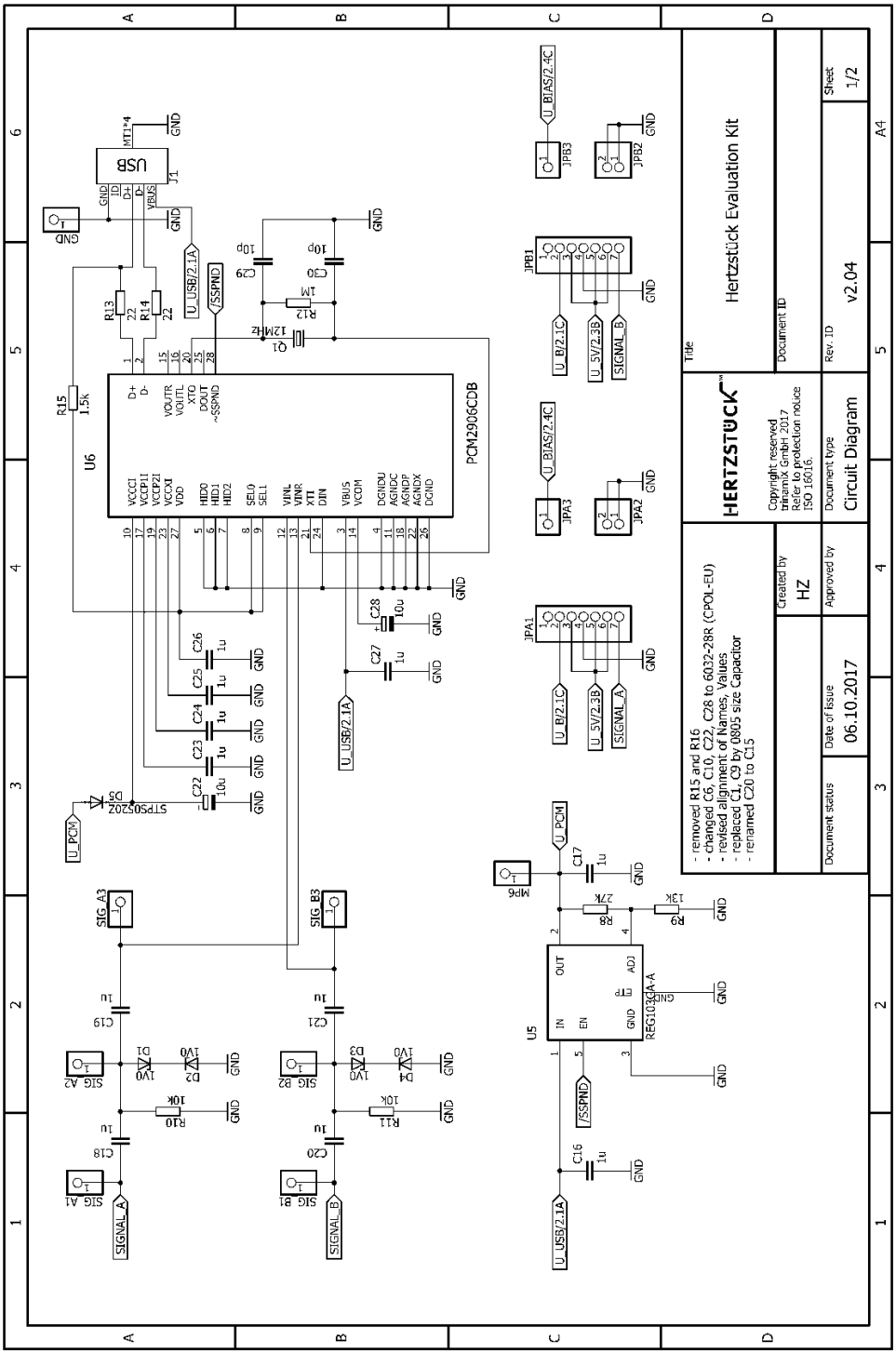


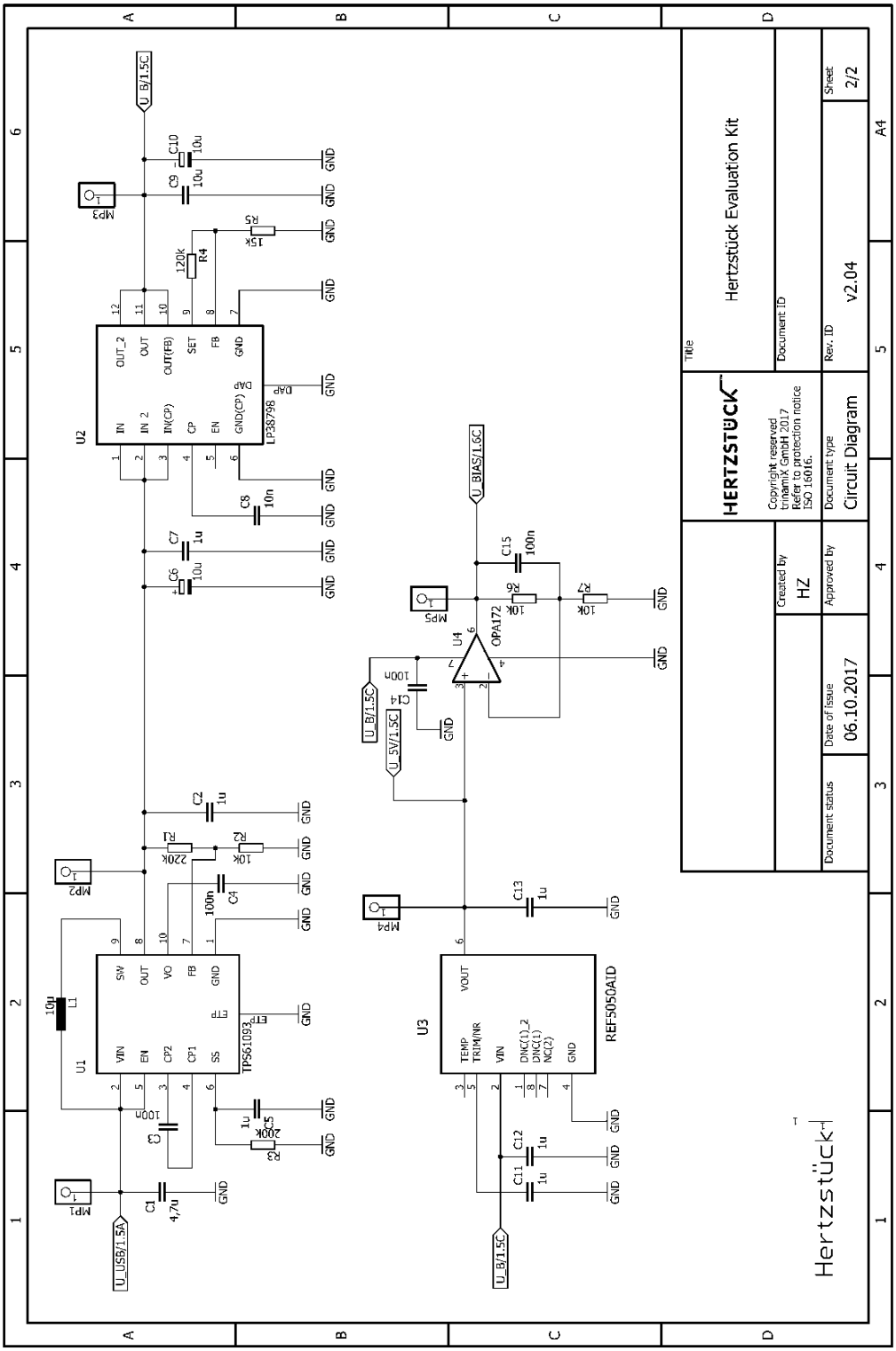
5.1.3. Detector Developer Board TO5 package



5.2. Circuit schematics

5.2.1. Main board





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Release Date: March 11th, 2020
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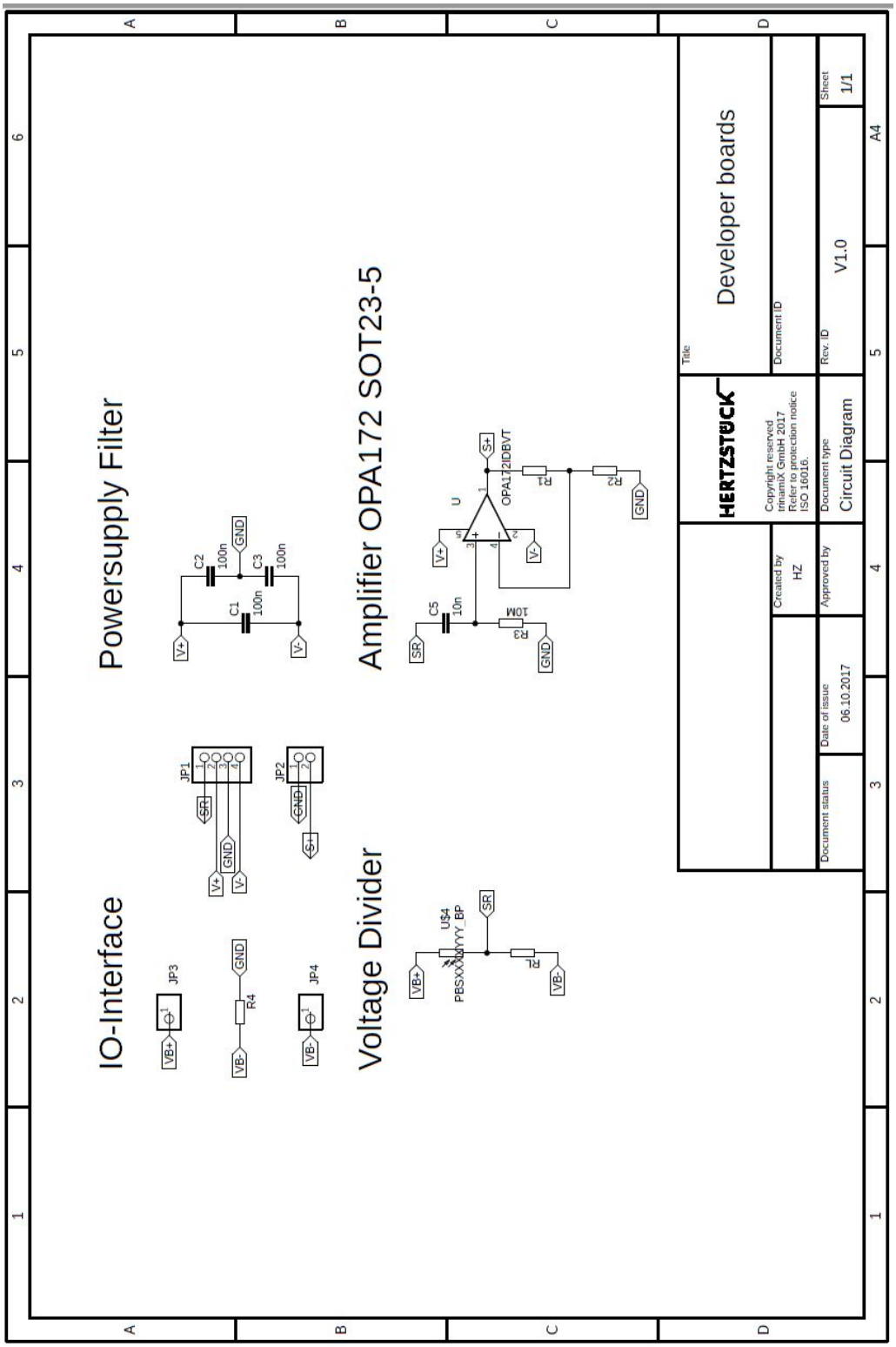
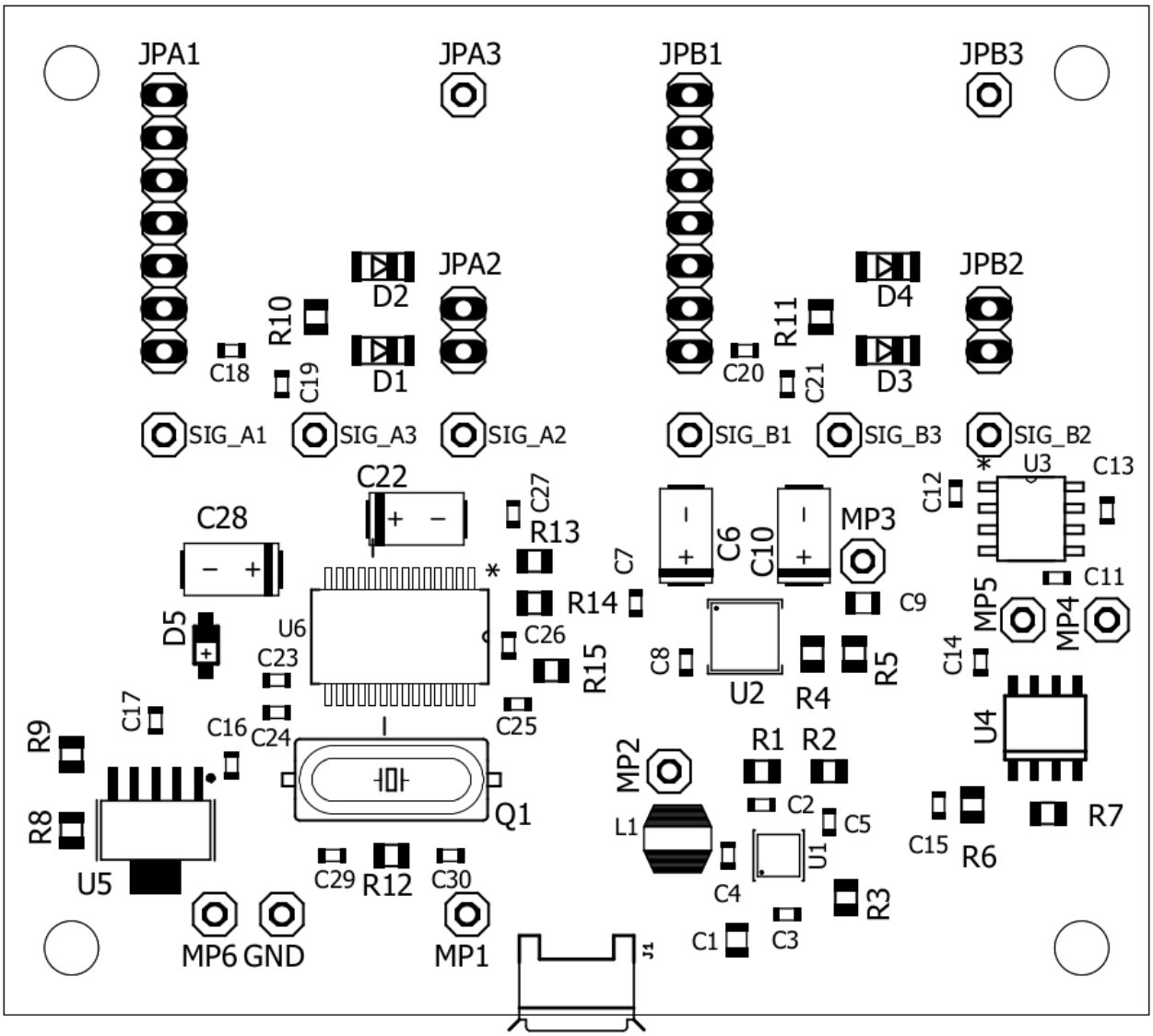
5.2.2. Detector Developer boards



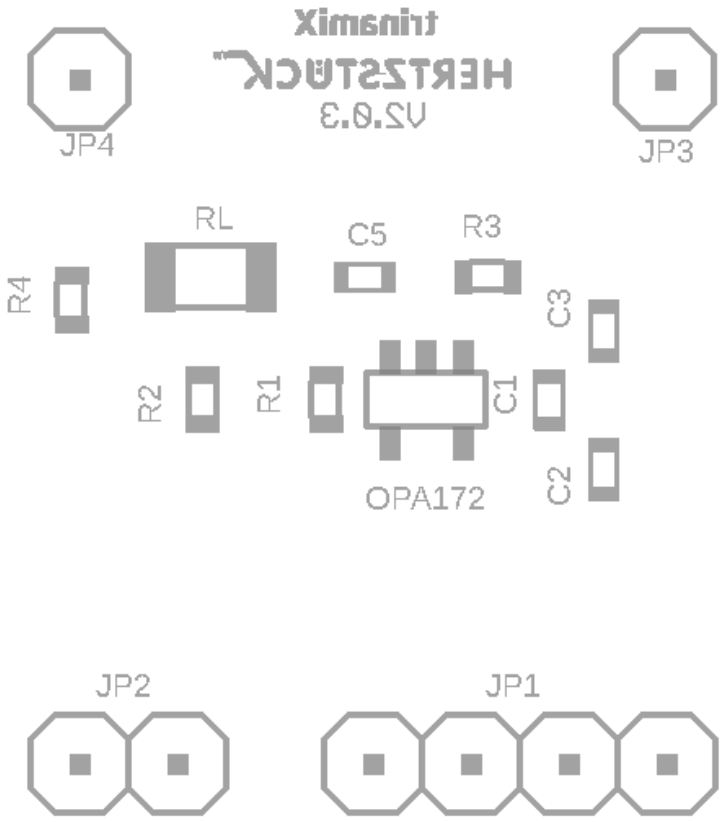
5.3. Bill of materials

5.3.1. Main board



Designator	Value	Description
C1	4.7µF	Capacitor, 0805, X5R, 25V, ±10%
C2, C5, C7, C11, C12, C13, C16, C17, C18, C19, C20, C21, C23, C24, C25, C26, C27	1uF	Capacitor, 0603, X5R, 16V, ±10%
C3, C4, C14, C15	100nF	Capacitor, 0603, X7R, 50V, ±10%
C6, C10, C22, C28	10µF	Capacitor, 6032, Tantalum, 25V,
C8	10nF	Capacitor, 0603, X7R, 50V, ±10%
C9	10µF	Capacitor, 0805, X5R, 16V, ±10%
C29, C30	10pF	Capacitor, 0603, C0G, 50V, ±10%
D1, D2, D3, D4	1V0	Diode, Zener, SOD-80-2, ±5%
D5	STPS0520Z	Diode, Schottky, SOD-123, 500mA
J1		Connector, Mirco-USB Type B
JPA1, JPB1		Connector, Board-to-Board, 7 Pins
JPA2, JPB2		Connector, Board-to-Board, 2 Pins
JPA3, JPB3		Connector, Board-to-Board, 1 Pins
L1	10µH	Inductance, 1.33A, 990mA, 0.228Ω
Q1	12MHz	Crystal, 16pF, ±30ppm
R1	220kΩ	Resistor, 0805, ±1%
R2, R6, R7, R10, R11	10kΩ	Resistor, 0805, ±1%
R3	200kΩ	Resistor, 0805, ±1%
R4	120kΩ	Resistor, 0805, ±1%
R5	15kΩ	Resistor, 0805, ±1%
R8	27kΩ	Resistor, 0805, ±1%
R9	13kΩ	Resistor, 0805, ±1%
R12	1MΩ	Resistor, 0805, ±1%
R13, R14	22Ω	Resistor, 0805, ±1%
R15	1.5kΩ	Resistor, 0805, ±1%
U1	TPS61093	Boost Converter, WSON-10
U2	LP38798	Regulator, WSON-12
U3	REF5050AID	Reference, SOIC-8, 5V, ±0.05%
U4	OPA172	OPA172, OP-Amp, SOIC-8
U5	REG103GA-A	REG103GA-A, Regulator, SOT-223-5
U6	PCM2906CDB	PCM2906CDB, Audio-Codec, USB Interface

5.3.2. Detector Developer Boards



5.4. Bill of materials – Detector Developer boards

Designator	Value	Description
JP1		Pin header 1x4
JP2		Pin header 1x2
JP3, JP4		Pin header 1x1
R1	3 MΩ	Resistor, 0603, ±1%
R2	1 MΩ	Resistor, 0603, ±1%
R3	10 MΩ	Resistor, 0603, ±1%
R4	Not equipped	Resistor, 0603, ±1%
C1, C2, C3	100 nF	Capacitor, 0603, ±10%
R3	10 MΩ	Resistor, 0603, ±1%
C5	10 nF	Capacitor, 0603, ±10%
OPA172	OPA172	OP-Amp, SOT23-5
U$4	0.3 – 3 MΩ / 0.1 – 3 MΩ	PbS detector / PbSe detector
RL	Matched to U$4	Load resistor

5.5. Disclaimer

Single-Pixel Evaluation Kit (EK) by trinamiX

WARNINGS, RESTRICTIONS AND DISCLAIMERS

This EK with electrical accessories is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by trinamiX to be a finished end product fit for general consumer use. Persons handling the EK must have electronics training and observe good engineering practice standards. As such, the EK being provided is not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards.

This EK does not fall within the scope of the European Union directives regarding restricted substances (RoHS), recycling (WEEE), FCC, or UL, and therefore may not meet the technical requirements of these directives or other related directives. It should not be used at all or be part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EK for evaluation, testing and other purposes.

2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EK. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EK and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.

3. You will employ reasonable safeguards to ensure that your use of the EK will not result in any property damage, injury or death, even if the EK should fail to perform as described or expected.

4. You will take care of proper disposal and recycling of the EK's electronic components and packing materials. Exceeding the specified EK ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings, please contact a trinamiX field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EK and/or interface electronics. If there is uncertainty as to the load specification, please contact a trinamiX field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EK schematic located in the EK User's Guide. When placing measurement probes near this device during normal operation, please be aware that this device may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use this EK.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold trinamiX, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EK that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EK fails to perform as described or expected.

FCC NOTICE: This EK is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the EK 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 EK 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 EK not cause harmful interference to licensed radio stations and that this EK accept harmful interference. Unless the assembled EK is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the EK must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

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