Isolated Voltage Sensor

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1. Introduction

1.1 BACKGROUND

In power electronics, it is often necessary to galvanically isolate the power circuits from the control circuits. This is due to the high voltages in the power circuits, which, if connected by wires, can fry digital circuits, which run on much lower voltages. However, galvanic isolation barriers prevent direct connections to the power circuit, making direct measurement impossible.

This issue is right now of vital importance to the electronic industry, due to the unavailability of new components that lack of resources and political events have created. Also, environmentally it is indispensable to reduce the consumption of components by reusing the electronic components.

1.2 OBJECTIVE

Our project aims to solve this power electronics problem by creating an isolated voltage sensor implemented on a small electrical board which is then used on a bigger board from which we want to measure. This small electrical board crosses the galvanic barrier, with one end that steps down the sheer voltages in the power circuit and the other transmitting digital information to a computer interface.

Other isolated voltage sensors are on the market, but these already manufactured sensors are too expensive. Our design utilizes low-cost components that will make it affordable, this is one of our main concerns as the galvanic isolated sensor is a safety feature that can prevent a personal injury or a fire so it will help if everyone could afford it.

Being affordable is one of our concerns, but there are other main issues. Our project is to make a sensor so it is vital that we have a certain accuracy on the measurement. Also, this sensor will send the measurement to an interface so the user can read the value, this means that the measurement will be oscillating with time, the goal is to create a high enough sample rate so there is no lag between the voltage value and the actual display.

1.3 PHYSICAL DESIGN

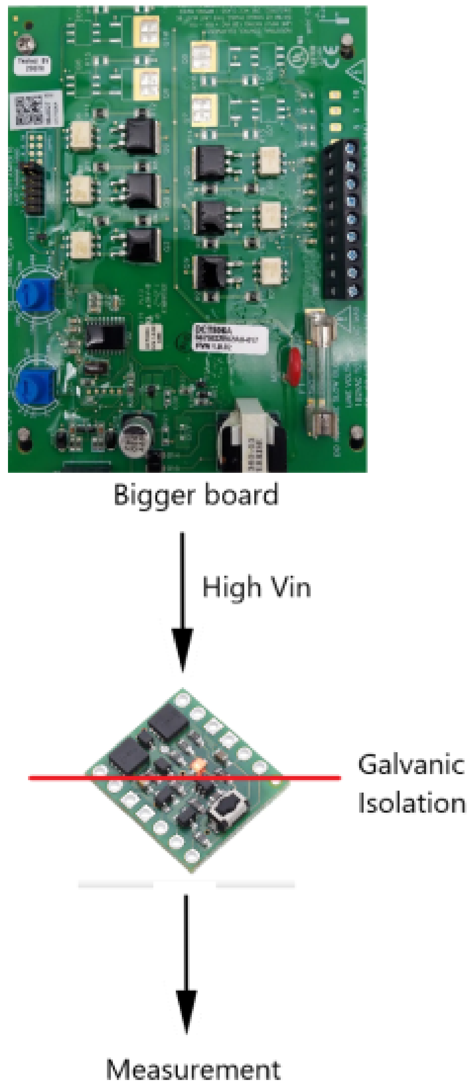


Figure 1: Visual

1.4 HIGH-LEVEL REQUIREMENT LIST

- Voltage: The isolated voltage sensor should be able to measure voltages up to ±100 volts, with a tolerance of 100 millivolts, 0.1% error from value to actual reading.

- Impedance: To not affect the power circuits that much, input impedance should at least be 10 megaohms.

- Sampling Rate: To provide an accurate measurement at any particular time, the sensor needs to sample at at least 10 kilosamples per second.

2. Design

2.1 BLOCK DIAGRAM

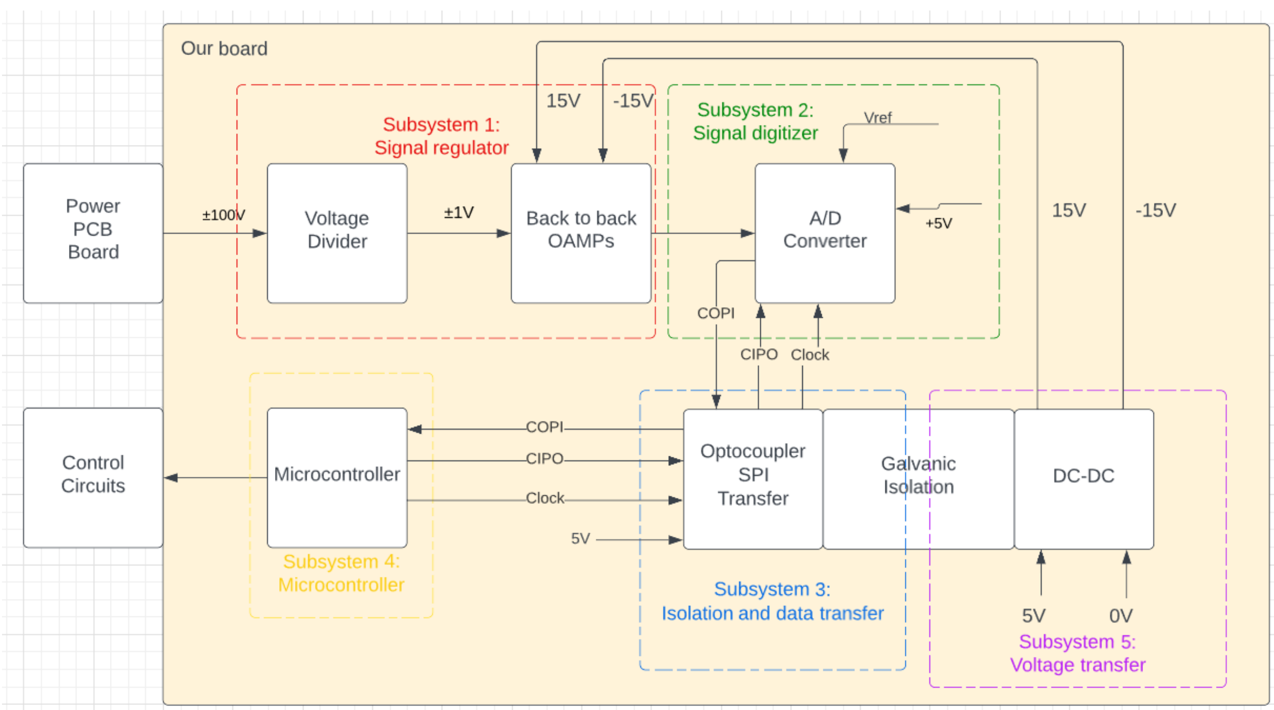


Figure 2: Block Diagram

2.1.1 Signal Regulator

Voltage divider:

The input voltage is way too high for normal electronic components so the input voltage is reduced using a simple voltage divider. Our objective is to divide it by at least one hundred making this the ratio between the resistors used.

We will buy an existing voltage divider that meets the specifications, the selected component will need to have an Input impedance should at least be 10 megaohms to minimize the loading effect of the circuit.

Requirement: Able to step down the voltage from ±100 V to ±1 V and the input impedance should at least be 10 megaohms.

Back-to-back OP-AMPs:

The OP-AMPs regulate the input signal so it can be read by the Analog to Digital Converter. If the input from the power PCB board is -100 volts, for example, the back-to-back OP-AMPs input voltage will be -1 V. The objective of this block is to output a voltage that goes from 0 to the Vref of the A/D converter. In the -1 Volt case the output voltage should be 0 as it is going to be the minimum input voltage

Table 1: Signal Regulator Subsystem – Requirements and Verification

Requirements	Verification
• Regulate the input voltage from ±100 V to 0-5V.	• Connect a voltmeter to the output of the signal regulator and adjust the input voltage while measuring the output. Check that for all the ±100 V spectrum the output moves in the 0-5V.
• The impedance of the combined subsystem should be at least 10 megaohms	• Connect an ohmmeter to the input and ground and check the input impedance

2.1.2 Signal digitizer

Analog to Digital Converter:

The A/D converter will take the input signal and transform it into a digital one, using the Vref and the Ground as its references to output zeros and ones. This signal will then be transferred to the UART device.

Table 2: Signal digitizer – Requirements and Verification.

Requirements	Verification
• From an accepted input of 0 - 5 volts, output a digital sequence of bits into the COPI that corresponds to that measurement	• Connect the input of the signal digitizer to a voltage supply. Then, select ten roughly evenly-spaced values within the range 0 - 5 volts as test values. Record the values. • Connect the output to a signal analyzer, take a snapshot that covers at least 20 cycles, and check if the binary cycle displayed has any correspondence with the actual input value

2.1.3 Isolation and data transfer

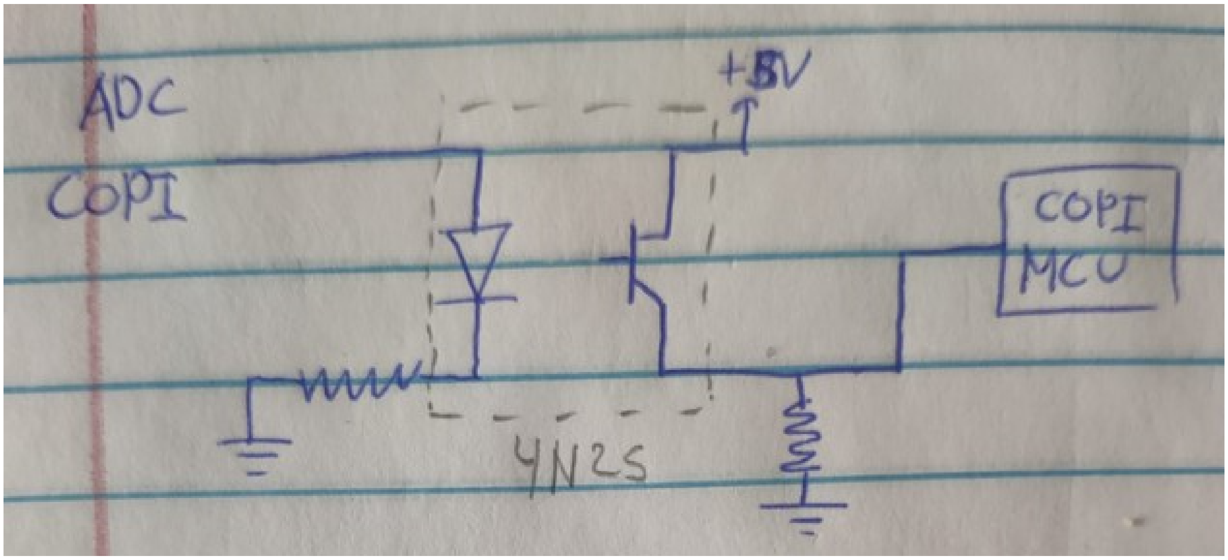
Data Transfer:

This device will take the data that the A-to-D converter outputs and it will make it readable for the microcontroller. It will have 4 channels of information: The Chip In Converter Out CIPO, the Chip Out Converter In COPI, the Clock and the CS. This will make information transfer between the converter and the microcontroller.

Galvanic Isolation:

This is the most important part of the project as the whole objective of the project is based on this isolation. In order to do this a 4N25 chip will be used, it consists of a photovoltaic diode and a transistor that will turn on or off depending on the signal input.

Requirement: Take into account the specifications of the diode and transistor



+5V
ADC
COPI
COPI
MCU
4N25

Table 3: Isolation and Data transfer Requirements and Verification.

Requirements	Verification
• Transfer the data with a certain velocity(to be discused). • Good galvanic isolation of the circuit	• Check the resistance: Use an ohmmeter to check the resistance between the two isolated circuits. There should be a high resistance reading, indicating that there is no electrical continuity between the two circuits.

2.1.4 Microcontroller

Microcontroller

The microcontroller will get the inputs from the Push-Pull device and it will make the calculations needed in order to have a readable measurement. The right microcontroller will be chosen when we advance more into the project but it will have to take into account the sample rate requirement.

Requirement: To provide an accurate measurement at any particular time, the sensor needs to sample at at least 10 kilosamples per second.

Table 4: Microcontroller Requirements and Verification.

Requirements	Verification
• The microcontroller shall convert the analog voltage level into a digital signal that can be displayed on the output display for the user to read the measured value. • To provide an accurate measurement at any particular time, the sensor needs to sample at least 10 kilosamples per second.	• When changing the voltage input checking that the output changes within a reasonable time and doesn't have a lag to it.

2.1.5 Voltage transfer

DC-DC converter

The DC-DC converter will take an input voltage from the controller side of the isolation barrier, VCC (5 volts) and ground, and without breaching the isolation barrier output two voltage signals usable by the components on the power side of the isolation barrier

Requirement: To provide an accurate measurement at any particular time, the sensor needs to sample at at least 10 kilosamples per second.

Table 5: Voltage Transfer Requirements and Verification.

Requirements	Verification
• Supply the 15 and -15 Volts to the OP-AMPSs when connected to VCC and ground.	• Connect the controller-side inputs as normal, but disconnect the power side and instead measure both the 15 volt and -15 volt end with a voltmeter

2.2. RISK ANALYSIS

The microcontroller is the block that poses the greatest difficulty to implement. It must take the data from the analog to digital converter and then it has to be programmed to calculate the actual value of the input voltage. Also, we will have to connect it to an UART system so it can display the data for the user to read it. We will also have to be very careful with the sample rate so we need the right microcontroller.

3. Ethics and Safety

3.1 ETHICS

Regarding ethics, we will have to show integrity with ourselves and with the university. Section 7.6 of the IEEE Code of Ethics I.5 states, “to seek, accept, and offer honest criticism of technical work…and to credit properly the contributions of others” [1]. The project is a challenge but one that we have sought so we look forward to using any constructive criticism that comes up through the process. As our project is not the first isolated voltage sensor, we ensure to credit any sources from previous projects and credit any resources we build upon.

3.2 SAFETY CONCERNS

While developing the isolated voltage sensor we will come across some safety issues like soldering our parts to the board, it is vital to follow the safety training for our own well-being and the people working in the laboratory with us.

But it’s not only our safety that is worrying, our sensor will also hopefully be used by other people and the goal is to isolate a circuit, with the objective of not burning any electronic components. This is a safety feature that may prevent the user from getting electroshocked by a far too high voltage or a fire from burning down the electronic board, a laboratory, or a building. I.1; “to hold paramount, the safety, health, and welfare of the public…and to protect the privacy of others” [1].

3.3 TEAM SAFETY

Finally, our team will ensure to follow Lab Safety guidelines in testing our circuits and sensors.

4. References

[1] "IEEE code of ethics," IEEE, Jun-2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 10-Feb-2022].